SMART GRID TECHNOLOGY TRAINING PROGRAM
Program Design Guide
for
SMART GRID TECHNOLOGY

University of Hawaii Community Colleges System

Project Award Number:
DE-OE0000430

July 2013
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PART I

PROJECT OVERVIEW
EXECUTIVE SUMMARY

Modernizing the country’s power infrastructure and preparing for the deployment of an advanced intelligent energy system commonly referred to as “Smart Grid” are imperative as the nation struggles with an aging and inefficient power grid. Central to the success of this new technology is a skilled and informed workforce. The U.S. Power and Energy Engineering Workforce Collaborative estimated in 2009 that “45% of power system engineers will be eligible for retirement by 2014 and approximately 21,000 – 24,000 professional engineers may be needed to meet the new system needs.”

The role of the university system is to continue enhancing education curricula and teaching techniques to insure an adequate supply of well qualified job candidates can be successful in the energy jobs of the future. Additionally, a properly trained workforce will be needed to select, install, and maintain these leading-edge technologies. Examples of initiatives include reliability assurance, cybersecurity, transmission, and distribution capability upgrades, Smart Grid systems, integration of distributed generation, alternative energy systems, and energy efficiency. A balance of engineering professionals coupled with highly trained operators and technicians make up the vast majority of the workforce managing day-to-day operations and keeping electricity flowing across the nation.

To address these needs, the U.S. Department of Energy’s Office of Electric Delivery and Energy Reliability (OE) has funded 51 organizations to participate in the Workforce Training in the Electric Power Sector Program. The goal of this initiative is to train professionals at all levels of the utility hierarchy to implement future innovations, including demand response, distributed generation, energy utilization/optimization, and cost simulations based on multiple rate structures.

The University of Hawaii Community College System, in cooperation with the Pacific Center for Advanced Technology Training and Leeward Community College Office of Continuing Education and Workforce Development, developed curriculum paths designed to train technicians to deploy and maintain electric power systems that employ intelligent energy system technologies.

This project provides a curriculum capable of being adapted to accommodate several educational pathways. These include traditional undergraduate associate degrees, certificate programs that address multiple specialized pathways, and incumbent workforce development training.

The curriculum is designed with an open architecture; the arc of training may be easily tailored to meet specific requirements of colleges, public utilities, and private employers. The technician-level course material blends theoretical principles with practical problem-solving skills for technicians, system planners, reliability coordinators, control room operators, and control system administrators. Key to the curriculum is a modular approach to organize the content and enable trainers to repackage courses and content for stackable and specialized certifications or credentials.

The program design guide provides for multiple training pathway possibilities with stackable options including an Associate of Science Degree, Associate of Applied Science Degree, Certificate of Completion, and Certificate of Achievement. Additionally, workforce development trainers will find it easy to adapt the materials to develop short-term workforce training in areas such as information technology, advanced metering infrastructure, power transmission and distribution, or intelligent energy management systems.

PROGRAM FUNDING

This project is supported in part by a grant from the U.S Department of Energy under the American Recovery and Reinvestment Act Workforce Training for the Electric Power Sector.

Department of Energy Grant DE-DE0000430 was awarded to the University of Hawaii System Community Colleges. University of Hawaii’s Pacific Center for Advanced Technical Training (PCATT), Honolulu, Hawaii, was charged with overall project execution.

ACKNOWLEDGEMENTS

The development of this program has been made possible through the dedication of numerous faculty, staff, and administrators of the University of Hawaii, subject matter experts, and industry partners who tirelessly devoted their time and expertise to this effort.

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Hampden Engineering Corporation
Schneider Electric
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Automation Direct
Simtronics Corporation
Arc Informatique
Emerson Corporation
Paladin Corporation
Power Analytics Corporation
Milsoft Utility Solutions
OPTO 22 Corporation
INTELLECTUAL PROPERTY

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SAFETY NOTICE

The Smart Grid Technology Program Design Guides contain information on equipment, processes, and procedures commonly encountered in the power industry. Specific procedures vary depending upon equipment, installation, configuration, and local requirements. Before adopting any procedure, verify electronic and mechanical compatibility. All procedures involving electrical connection to primary power, energizing, and performing tests on energized equipment must be performed by or under the supervision of a qualified person.

In order to ensure compliance with all safety and health regulations before performing a procedure, refer to the proper authority having jurisdiction. Additionally, refer to specific manufacturer recommendations, installation manuals, and equipment procedures. The material contained in this manual is intended to be an educational resource for the user.

PROGRAM GUIDE TERMINOLOGY

The following terminology will be used throughout this guide as well as individual course design guides and laboratory exercises. The terms may have common meaning; in the context of this material the terms carry specific meaning:

Assessment Rubric: An assessment rubric is a guideline for rating student performance. The rubric provides those conducting an assessment with exactly the characteristics for each level of performance on which they should base their judgment. The rubric also provides those assessed with clear information about how well they performed, as well as a clear indication of what they need to accomplish in the future to better their performance.

Bibliography: A list of books and reference materials used to develop the course design guide.

Blooms Taxonomy: A method of classification of learning objectives within education that divides educational objectives into three domains: Cognitive, Affective, and Psychomotor. Within the domains, learning at the higher levels is dependent on having attained prerequisite knowledge and skills at lower levels.

Co-requisite: Courses, knowledge, or skills that may be gained in conjunction with the subject course.

Course Design Guide: This is the document that is designed to be used as a framework to develop specific course material for delivery to students.

Course Number: This is a statement that describes the level of learning or complexity of the course material being presented. In post-secondary education courses at the 100-and 200-level are normally foundations for an Associate’s or Bachelor’s degree. 100-level courses may not have any prerequisite requirements, while 200-level courses will have a requirement for some prior achievement.

Course Objectives: Objectives describe what learners will be able to do at the end of instruction. The description delineates the intended result of instruction rather than the process of instruction itself.

Course Title: The suggested title of a course as related to the content.

Course Topics: The main organizing principles of a specific course provide a focus which governs the subject matter.
Credits: Number of hours for which a student is given credit for completing a course. Typically a college level course is 45 contact hours and awards 3 credits.

Curriculum: Group of courses making up area of specialization.

Lab Exercise: Lab or laboratory exercises describe the actual use of equipment, simulation software, or other demonstration methods. Lab exercises are used as both a learning tool and a means of assessment for performance objectives. Included in the category of lab exercises are tabletop or paper exercises that involve the development of procedural performance measures.

Lecture: This method of teaching is classroom instruction where the instructor and the students engage in a dialog, traditionally a one-way transfer of critical information. In the context of this program the term lecture encompasses a variety of classroom instruction methods that include group discussion, facilitated learning team exercises, or other adult learning methods and practices appropriate to the material being presented.

Prerequisite: Specific courses, knowledge, or skills that are required to gain entry into a subject course.

Student Learning Outcomes: Phrases that describe the knowledge, skills, and abilities that a student will have attained as a result of involvement in a particular set of educational experiences.

Student Text and Other Reading Materials: A list of suggested text books, articles, white papers, or other scholarly works that would be of value to the student for primary research and study during the course.
HOW TO USE THIS GUIDE

PROGRAM DEVELOPMENT

Each of the degree and certificate programs represents an “arc of training” that the student follows, beginning with foundational abilities and understandings, leading to theoretical and practical knowledge of the various technical disciplines. The programs culminate by synthesizing knowledge, skills, and abilities that will enable the student to apply leading edge technology to solve real world problems.

The degree and certificate programs, as well as each of the individual courses, have been designed to provide the student with an opportunity to learn, adopt, and gain proficiency in the generally accepted academic skill standards of Critical Thinking, Technology and Information Literacy, Oral and Written Communication, and Quantitative Reasoning. Additionally, the course materials are intended to reinforce the values of Citizenship, Community, Culture, and Sustainability.

COURSE DESIGN GUIDE DEVELOPMENT

The course design guides are intended to be the standard resource from which an institution will develop and customize course materials to meet individual campus degree requirements. The guides provide a logical, topical outline of knowledge and skills that encompass the subject matter. Each Course Design Guide is divided into three sections:

- Course Information
- Learning Outcomes and Rubric
- Topical Outline

COURSE INFORMATION

The course information section provides a standard template where developers and instructors will find basic information on the course: naming conventions, delivery format, suggested instructor background, standards, and references to help guide the creation of instructional materials.

STUDENT LEARNING OUTCOMES

Each course was developed and designed using student learning outcomes based on Bloom’s Taxonomy of Educational Learning Objectives, which categorizes cognitive learning into one of six distinct levels:

Knowledge — Comprehension — Application — Analysis — Synthesis — Evaluation

Each level of Bloom’s Taxonomy uses verbs to describe and evaluate students’ mastery of an objective. Each student learning outcome has a scale of mastery, formatted in a rubric, that will act as a guide to assess the achievement of the stated outcome.
TOPICAL OUTLINE
The topical outline is divided into logical sections that provide an increasing amount of detail of the course material. The sections are “Units,” “Topics,” and “Objectives,” presenting the reader with an increasing order of detail on subject information. Units provide the broadest area of study for the course; topics are arranged in a logical sequence supporting each unit. Each of the topics has an associated list of objectives assigned. Some courses provide both learning objectives and performance objectives; the performance objectives will have an accompanying laboratory exercise design sheet following the topical outline. Each topic lists a suggested time frame for completion. The time indicated includes the lectures, in class worksheets, and appropriate assessment.

EQUIPMENT AND SUPPLIES
The laboratory exercises and activities were designed to be adapted to a variety of training equipment, software suites, and laboratory configurations. Each course and lab provides suggestions on equipment and configurations intended to minimize the initial investment costs where possible. As programs mature, and more robust laboratory equipment is desired, this guide provides a full spectrum of configurations.

COURSE DEVELOPMENT GUIDELINES
Beyond the course design guides, the next logical step is for an instructor to develop specific course materials appropriate to the institution, degree or certificate program requirements, and industry input. The checklist below is intended to be a guide in the development of specific course materials.

DEVELOPMENT CHECKLIST
• Review course design guide
• Select student text/workbook
• Determine pre-requisites and/or co-requisites required for student entry at the college
• Determine the learning level and appropriate course number
• Develop a course schedule that incorporates each topic and provides ample time for the introduction of the topic, student activities, and assessment
• Develop lesson plans for each topic, dividing lessons into time units appropriate to the course schedule
• Develop assessment rubrics for each unit and topic
• Develop assessment materials that effectively measure student achievement
• Develop student worksheets for each topic
• Develop lab exercises, as appropriate, for each performance objective
• Develop a syllabus
• Develop training aids that are appropriate to the topics
• Submit course approval according to the institution’s rules and guidelines
PART II

DEGREE AND CERTIFICATE PROGRAMS
DEGREE AND CERTIFICATE PROGRAMS

PROGRAM MISSION

The mission of the Smart Grid Technology program is to develop and enhance a career pathway for technicians who will deploy and maintain electric power transmission and distribution through the application of smart grid technologies.

PROGRAM OBJECTIVES

The Objective of the Smart Grid Technology program is to provide a fundamental and theoretical understanding of power transmission and distribution as well as develop practical problem-solving skills. The program will provide participants with a theoretical foundation in electricity and electronics, coupled with a working knowledge of power generation, transmission, and distribution of alternating current, and the inter-relationships that bind them into a coordinated power system. The program covers areas of specialization that include networking communications, advanced metering infrastructure, and control systems.

The emerging field of intelligent energy systems, often referred to as Smart Grid, is a blending of the traditional grid technology with that of instrumentation, control, and communications. Each of the programs have been designed to specifically address the convergence of these diverse technical specialties and provide a solid foundation so that participants are prepared for employment in a variety of positions in the rapidly changing field of energy management.

PROGRAM STUDENT LEARNING OUTCOMES

Upon successful completion of the degree and certificate programs in Intelligent Energy Systems the graduate will be able to:

- Apply the principles of mathematics, electricity, and control systems to identify, analyze, troubleshoot, and solve routine technical problems related to intelligent energy systems used in the power generation, transmission, distribution of energy
- Exhibit and practice appropriate safety, health, personal protection, and equipment safety procedures applicable to workplaces related to the power industry
- Accomplish power industry job responsibilities in accordance with relevant law, policies, procedures, standards, regulations, and ethical principles
- Demonstrate understanding of the structure and operation of intelligent energy systems and their relationship to power generation, transmission, and distribution systems and their impact on society and environment
- Operate, calibrate, and maintain test equipment, instrumentation, and control systems related to the power utility industry
- Analyze grid systems power flow, including distributed generation sources and loads, and apply power flow analysis results to solve simple planning problems related to the implementation of intelligent energy systems

The programs listed above are a recommendation to institutions considering degree or certificate pathways. Institutions are expected to modify the program to meet campus specific general education or core course requirements.
ASSOCIATE OF SCIENCE DEGREE
INTELLIGENT ENERGY SYSTEMS

The Associate of Science degree program is a vocational engineering technology pathway. The outline includes all introductory and technical course material as well as course material designed to satisfy typical general education requirements.

The rationale for the Associate of Science Degree is to provide a pathway for students who are likely to continue their education and pursue a bachelor’s degree. The nominal pathway is intended as a guide that may be tailored to school specific requirements.

The general education courses provide a student the ability to apply and integrate technical or specialized training into a broader perspective. The general education courses provide students with critical thinking and problem solving skills, written and oral communication skills, and a broader perspective of citizenship, community, and culture.

<table>
<thead>
<tr>
<th>Semester</th>
<th>Course Name</th>
<th>Credits</th>
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<tr>
<td>First</td>
<td>English Composition</td>
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<tr>
<td></td>
<td>College Algebra/Pre-calculus</td>
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<tr>
<td></td>
<td>Fundamentals of Electricity and Electronics</td>
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<tr>
<td></td>
<td>Fundamentals of Database Information Systems</td>
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<td>Safety Health and Environment</td>
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<td>Power Generation, Transmission, and Distribution</td>
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<td>Intelligent Energy Systems - Fundamentals</td>
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</tr>
<tr>
<td></td>
<td>SCADA - Industrial Control Systems</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Computer Networking I</td>
<td>4</td>
</tr>
<tr>
<td>Third</td>
<td>SCADA - Industrial Control Equipment</td>
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<tr>
<td></td>
<td>Computer Networking II</td>
<td>3</td>
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<td>Intelligent Energy Systems - Architecture</td>
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<tr>
<td></td>
<td>Geography and the Natural Environment</td>
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<tr>
<td></td>
<td>History Elective</td>
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<tr>
<td>Fourth</td>
<td>Advanced Metering Infrastructure</td>
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<tr>
<td></td>
<td>Fundamentals of Industrial and Utility Security</td>
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<td>Intelligent Energy Systems - Interoperability</td>
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Minimum credits required to obtain an Associate of Science - Intelligent Energy Systems 65

The courses listed above are a recommendation to institutions considering degree or certificate pathways. Institutions are expected to modify the courses listed to meet campus specific general education or core course requirements.
ASSOCIATE OF APPLIED SCIENCE DEGREE
INTELLIGENT ENERGY SYSTEMS

The Associate of Applied Science Degree Program is a career technical education pathway. The outline includes all introductory and technical course material as well as course material designed to satisfy typical general education requirements for an applied science degree.

The rationale for the Associate of Applied Science Degree is to provide a pathway for students who are likely to obtain this as a terminal degree. The nominal pathway is intended as a guide that may be tailored to school specific requirements.

The general education courses provide a student the ability to apply and integrate technical or specialized training into a broader perspective. The general education courses provide students with critical thinking and problem solving skills, written and oral communication skills, and a broader perspective of citizenship, community, and culture.

<table>
<thead>
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<th>Semester</th>
<th>Course Name</th>
<th>Credits</th>
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<td>First</td>
<td>English Composition or Technical Writing</td>
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<td>College Algebra or Applied Mathematics</td>
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<td>Fundamentals of Electricity and Electronics</td>
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<td>Second</td>
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<td>SCADA – Industrial Control Systems</td>
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<td>Third</td>
<td>SCADA – Industrial Control Equipment</td>
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<td>Geography and the Natural Environment</td>
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<td>Fundamentals of Industrial and Utility Security</td>
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<td>Social Science/Arts/Humanities/Literature Elective</td>
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</table>

Minimum credits required to obtain an Associate of Applied Science - Intelligent Energy management Systems 62

The courses listed above are a recommendation to institutions considering degree or certificate pathways. Institutions are expected to modify the courses listed to meet campus specific general education or core course requirements.
## CERTIFICATE OF ACHIEVEMENT
### POWER TRANSMISSION DISTRIBUTION AND CONTROL SYSTEMS

The Certificate of Achievement in Power Transmission Distribution and Control Systems is a career technical education pathway. The outline includes introductory and technical course material necessary to gain proficiency in the technical specialty of power and control systems. Students electing to follow this pathway could apply all coursework if they elect to continue their education and pursue an associate degree.

The rationale for the Certificate of Achievement is to provide a pathway for students who are interested in gaining essential skills to enter the workforce. The nominal pathway is intended as a guide that may be tailored to school specific requirements.

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Credits</th>
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<td>Introduction to Smart Grid</td>
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<td>Safety Health and Environment</td>
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<td>SCADA – Industrial Control Equipment</td>
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Minimum credits required to obtain a certificate of Achievement - Intelligent Energy Systems (Power Distribution and Control Systems) 34

The courses listed above are a recommendation to institutions considering degree or certificate pathways. Institutions are expected to modify the courses listed to meet campus specific general education or core course requirements.
CERTIFICATE OF ACHIEVEMENT  
NETWORKING AND ADVANCED METERING INFRASTRUCTURE

The Certificate of Achievement in Networking and Advanced Metering Infrastructure is a career technical education pathway. The outline includes introductory and technical course material necessary to gain proficiency in the technical specialty of Networking and Advanced Metering Infrastructure. Students electing to follow this pathway could apply all coursework if they elect to continue their education and pursue an associate degree.

The rationale for the Certificate of Achievement is to provide a pathway for students who are interested in gaining essential skills to enter the workforce. Students completing this certificate may be eligible to take the CCNA exam. The nominal pathway is intended as a guide that may be tailored to school specific requirements.

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<th>Course Name</th>
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<td>3</td>
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</tbody>
</table>

Minimum credits required to obtain a certificate of Achievement - Intelligent Energy Systems (Networking and Advanced Metering Infrastructure) 34

The courses listed above are a recommendation to institutions considering degree or certificate pathways. Institutions are expected to modify the courses listed to meet campus specific general education or core course requirements.
CERTIFICATE OF COMPLETION
INTELLIGENT ENERGY SYSTEMS

The Certificate of Completion is a intermediate credential that is intended to prepare students to continue education in either a certificate or degree program. The outline includes introductory and technical course material necessary to gain a basic understanding of the field of study as well as foundational material in sustainable technology. Students electing to follow this pathway could apply all coursework if they elect to continue their education. The rationale for the Certificate of Completion is to provide a pathway for students who are exploring possible career paths while completing core or developmental courses. The nominal pathway is intended as a guide that may be tailored to school specific requirements.

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical Writing</td>
<td>3</td>
</tr>
<tr>
<td>Applied Mathematics</td>
<td>4</td>
</tr>
<tr>
<td>Fundamentals of Electricity and Electronics</td>
<td>4</td>
</tr>
<tr>
<td>Introduction to Smart Grid</td>
<td>1</td>
</tr>
<tr>
<td>Safety Health and Environment</td>
<td>3</td>
</tr>
<tr>
<td>Power Generation, Transmission, and Distribution</td>
<td>4</td>
</tr>
<tr>
<td>Intelligent Energy Systems - Fundamentals</td>
<td>3</td>
</tr>
</tbody>
</table>

Minimum credits required to obtain a certificate of Completion - Intelligent Energy Systems 22

The courses listed above are a recommendation to institutions considering degree or certificate pathways. Institutions are expected to modify the courses listed to meet campus specific general education or core course requirements.
PART III
COURSE DESIGN GUIDES
FUNDAMENTALS OF DATABASE INFORMATION SYSTEMS COURSE DESIGN GUIDE

COURSE TITLE
Fundamentals of Database Information Systems

CATALOG DESCRIPTION
This course provides a foundation of database information systems and introduces the fundamental concepts of data collection and query languages, including topics on terminology, data formats, naming conventions, query structure, and reporting structure. Students will also learn basic database management systems programming skills and scripting languages.

CREDITS
3.0 credits, 48 hours

COURSE FORMAT
This is a lecture-format course with opportunity for students to complete project based assignments to gain proficiency in database systems.

COURSE NUMBER
Material for this course is presented to meet the requirements for a 100-level course.

PREREQUISITES
Basic English Comprehension

INSTRUCTOR INFORMATION
Recommended Qualifications: Master’s Degree in electronics, information systems, or related field. Experience in systems management and a working knowledge in the subject/topic area. Experience teaching post-secondary/adult students.

TEACHING METHODS AND ASSIGNMENTS FOR ACHIEVING LEARNING OUTCOMES
The course material is presented in a lecture format that achieves the course learning objectives. Each topic lists suggested time allocation. The course is divided into eight units; each unit addresses specific topics of database management and development. Each topic has a recommended length (topic hours) assigned. Hours are a guideline for instruction intended to be adapted to the individual instructors teaching style.

Students are expected to spend additional study/practice outside of the class time. The generally accepted ratio of class to study time is 3:1 for this course. Total time allocated includes an hour course introduction, a 2-hour review, and a 2-hour written exam.

STUDENT TEXTS, READING AND OTHER MATERIALS
- *Database Concepts* by David Kroenke and David J. Auer
- *Database Systems Design, Implementation, and Management* by Carlos Coronel, Steven Morris, and Peter Rob
BIBLIOGRAPHY


STUDENT LEARNING OUTCOMES

Upon successful completion the student will have the ability to:

- Explain the history and purpose of data collection and the differences between conceptual concepts, and logical and physical data design
- Identify and analyze a problem, and define the requirements appropriate to its solution
- Gather information from a variety of sources, use information in an appropriate manner to address issues, and take action
- Understand the processes that support the development, deployment, and management of information systems within an application environment
- Explain the concepts of different database models
- Explain different database models and types, and the difference between them
- Identify SQL queries for data manipulations, data definition, scripting, and reporting
- Identify relational databases and normalization
<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>EXEMPLARY 4</th>
<th>SATISFACTORY 3</th>
<th>DEVELOPING 2</th>
<th>BEGINNING 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data collection history concepts, logical and physical data design</td>
<td>Exhibits clear understanding of concepts, and logical and physical data design</td>
<td>Demonstrates average understanding of concepts, and logical and physical data design</td>
<td>Exhibits basic understanding of concepts, and logical and physical data design</td>
<td>Does not exhibit clear understanding of concepts, and logical and physical data design</td>
</tr>
<tr>
<td>Identification of a problem and a solution based on appropriate requirements</td>
<td>States problem clearly and provides excellent solution based on appropriate requirements</td>
<td>Demonstrates good understanding of the problem statement and provides adequate solution based on requirements</td>
<td>Exhibits basic understanding of the problem and provides low-level solution based on the requirements</td>
<td>Exhibits limited understanding of the problem statement and provides limited solution based on the requirements</td>
</tr>
<tr>
<td>Information gathering from a variety of sources and appropriate use of the information in addressing issues and taking action</td>
<td>Demonstrates excellent understanding of information gathering from a variety of sources and makes use of the information in an appropriate manner to address issues and take action</td>
<td>Demonstrates good understanding of information gathering from a variety of sources and makes adequate use of the information to address issues and take action</td>
<td>Demonstrates basic understanding of information gathering from a variety of sources to address issues and take action</td>
<td>Demonstrates limited understanding of information collection from a variety of sources to address issues and take action</td>
</tr>
<tr>
<td>Processes of development, deployment, and management of information systems within an application environment</td>
<td>Demonstrates clear understanding of the processes that support the development, deployment, and management of information systems within an application environment</td>
<td>Demonstrates adequate understanding of the processes that support the development, deployment, and management of information systems within an application environment</td>
<td>Demonstrates basic understanding of the processes that support the development, deployment, and management of information systems within an application environment</td>
<td>Demonstrates limited understanding of the processes that support the development, deployment, and management of information systems within an application environment</td>
</tr>
<tr>
<td>Concepts of different database models</td>
<td>Demonstrates clear understanding of the concepts of different database models</td>
<td>Demonstrates adequate understanding of the concepts of different database models</td>
<td>Demonstrates basic understanding of the concepts of different database models</td>
<td>Demonstrates limited understanding of the concepts of different database models</td>
</tr>
<tr>
<td>Identification of the difference between database models and types</td>
<td>Demonstrates clear understanding of the difference between database models and types</td>
<td>Demonstrates adequate understanding of the difference between database models and types</td>
<td>Demonstrates basic understanding of the difference between database models and types</td>
<td>Demonstrates limited understanding of the difference between database models and types</td>
</tr>
<tr>
<td>SQL queries for data manipulations, data definitions, scripting, and reporting</td>
<td>Demonstrates clear understanding of SQL queries for data manipulation, definitions, scripting, and reporting</td>
<td>Demonstrates adequate understanding of SQL queries for data manipulation, definitions, scripting, and reporting</td>
<td>Demonstrates basic understanding of SQL queries for data manipulation, definitions, scripting, and reporting</td>
<td>Demonstrates limited understanding of SQL queries for data manipulation, definitions, scripting, and reporting</td>
</tr>
<tr>
<td>Relational databases and normalization</td>
<td>Demonstrates clear understanding of relational databases and normalization</td>
<td>Demonstrates adequate understanding of relational databases and normalization</td>
<td>Demonstrates basic understanding of relational databases and normalization</td>
<td>Demonstrates limited understanding of relational databases and normalization</td>
</tr>
</tbody>
</table>
## UNIT 1: DATA COLLECTION AND DATABASE MODELS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 History/Purpose of Data Collection</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Explain the history of data collection</td>
</tr>
<tr>
<td></td>
<td>• Explain arrays/single flat file and collections</td>
</tr>
<tr>
<td></td>
<td>• Explain the purpose and the relation between data collections and their application</td>
</tr>
<tr>
<td></td>
<td>• Explain the interaction of data and how this impacts the data collection</td>
</tr>
<tr>
<td>1.2 Data Collection Process</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Define the conceptual, logical, and physical data collection process</td>
</tr>
<tr>
<td></td>
<td>• Define differences between conceptual, logical, and physical data collection processes</td>
</tr>
<tr>
<td>1.3 Conceptual, Logical, and Physical Database Design Processes</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td>• Define various levels of design abstraction</td>
</tr>
<tr>
<td></td>
<td>• Define conceptual, logical, and physical database design processes</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 2: DATA, CRITERIA, PROBLEM STATEMENT, AND SOLUTION

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2.1 Problem Statement Definition Based on a Set of Criteria</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Explain how the data points are collected in order to form a set of criteria</td>
</tr>
<tr>
<td></td>
<td>• Explain how a problem statement is formed based on a set of given criteria</td>
</tr>
<tr>
<td><strong>2.2 Logical Solution Process</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Define a logical process from a set of criteria to form the problem statement</td>
</tr>
<tr>
<td></td>
<td>• Define logical set of indicators in order to find the solution to a problem</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 3: MULTIPLE DATA SOURCES

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3.1 Data Collection From Multiple Sources</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Explain how the data points are collected in order to form a set of criteria</td>
</tr>
<tr>
<td></td>
<td>• Explain how a problem statement is formed based on a set of given criteria</td>
</tr>
<tr>
<td><strong>Lecture - 2 hrs.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>3.2 Appropriate Collection of Data From Multiple Sources and the Impact on a Database to Accurately Provide Accurate Information</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Explain the concept of appropriate data collection</td>
</tr>
<tr>
<td></td>
<td>• Explain appropriate collection of data from multiple sources</td>
</tr>
<tr>
<td></td>
<td>• Explain how appropriate data addresses a set of issues</td>
</tr>
<tr>
<td></td>
<td>• Show understanding of the need to translate data from multiple sources into a common format</td>
</tr>
<tr>
<td><strong>Lecture - 2 hrs.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>3.3 Appropriate Information Provided by Data Addresses Specific Collection Requirements</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Define appropriate collection of data for a given problem or issue</td>
</tr>
<tr>
<td></td>
<td>• Define how information collected from data can be used to address issues and take action</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate recognition of sources and determining appropriate collection requirements from</td>
</tr>
<tr>
<td><strong>Lecture - 2 hrs.</strong></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
# Unit 4: Development, Deployment, and Management of Information Systems

<table>
<thead>
<tr>
<th>Topics</th>
<th>Objectives</th>
</tr>
</thead>
</table>
| 4.1 Data Collection From Single Entity and Multiple Sources | The student will be able to:  
  - Show how the data points are collected from single or multiple sources in order to form a set of criteria  
  - Explain how a problem statement is formed based on a set of given criteria |
| Lecture - 2 hrs.                             |                                                                             |
| 4.2 Appropriate Collection of Data From Multiple Sources and its Impact to Address Issues | The student will be able to:  
  - Explain appropriate collection of data from multiple sources  
  - Define how appropriate data addresses a set of issues |
| Lecture - 1 hr.                              |                                                                             |
| 4.3 Appropriate Information Provided by Data Helps to Address Issues and Take Action | The student will be able to:  
  - Explain what is an appropriate collection of data  
  - Define how information collected from data can be used to address issues and take action |
| Lecture - 1 hr.                              |                                                                             |

Notes:

FUNDAMENTALS OF DATABASE INFORMATION SYSTEMS
# UNIT 5: DATABASE TYPES AND MODELS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1 Define Types of Databases</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td>• Define analytical databases</td>
</tr>
<tr>
<td></td>
<td>• Define operational databases</td>
</tr>
<tr>
<td>5.2 Define Database Models</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 3 hrs.</td>
<td>• Demonstrate understanding of the architecture of a database</td>
</tr>
<tr>
<td></td>
<td>• Explain the common features of multiple database models</td>
</tr>
<tr>
<td></td>
<td>• Define flat database model</td>
</tr>
<tr>
<td></td>
<td>• Define Hierarchical Database model</td>
</tr>
<tr>
<td></td>
<td>• Define Network Database model</td>
</tr>
<tr>
<td></td>
<td>• Define Object Orientated Database model</td>
</tr>
<tr>
<td></td>
<td>• Define Relational Databases model</td>
</tr>
<tr>
<td></td>
<td>• Show recognition of the appropriate database model for</td>
</tr>
<tr>
<td>5.3 Explain the Difference Between</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Database Designs</td>
<td>• Explain pros and cons of each database model from flat to relational</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td>• Provide an example for each database model</td>
</tr>
<tr>
<td>5.4 Explain Which Database Design</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Best Fits a Set of Data</td>
<td>• Explain what is an appropriate database model and why it is chosen</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td>• Show understanding that each database model fits a given data set</td>
</tr>
</tbody>
</table>

Notes:
<table>
<thead>
<tr>
<th>UNIT 6: DATABASE DESIGN MODELS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOPICS</strong></td>
</tr>
<tr>
<td>6.1 Database Design Models</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>6.2 Database Models</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>6.3 Entity Relational Data Model, Object Oriented Data Model, and Functional Data Model</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Notes:
# UNIT 7: QUERIES AND DATABASES

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>7.1 Database Queries, Scripts, and Reporting</strong>&lt;br&gt;Lecture - 2 hrs.</td>
<td>The student will be able to:&lt;br&gt;• Build a database query&lt;br&gt;• Write scripts such as VBscript&lt;br&gt;• Create reports</td>
</tr>
<tr>
<td><strong>7.2 Query Types</strong>&lt;br&gt;Lecture - 2 hrs.</td>
<td>The student will be able to:&lt;br&gt;• Define select queries&lt;br&gt;• Define parameter queries&lt;br&gt;• Define cross-tab queries&lt;br&gt;• Define action queries&lt;br&gt;• Define SQL queries</td>
</tr>
<tr>
<td><strong>7.3 SQL - Structured Query Language</strong>&lt;br&gt;Lecture - 2 hrs.</td>
<td>The student will be able to:&lt;br&gt;• Explain what is an appropriate collection of data&lt;br&gt;• Define how information collected in the database can be used to write query scripts such as VB scripts for creating reports and addressing issues and taking action</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 8: ENTITY RELATIONAL DATABASES

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>8.1 Understanding What Makes a Database “Relational”</strong>&lt;br&gt; Lecture - 2 hrs.</td>
<td>The student will be able to:&lt;br&gt; • Define relational databases&lt;br&gt; • Explain why and when to choose a relational database</td>
</tr>
<tr>
<td><strong>8.2 Relational Database Entity Integrity</strong>&lt;br&gt; Lecture - 2 hrs.</td>
<td>The student will be able to:&lt;br&gt; • Explain appropriate collection of data from multiple sources&lt;br&gt; • Define how appropriate data addresses a set of issues</td>
</tr>
<tr>
<td><strong>8.3 Relational Database and Normalization</strong>&lt;br&gt; Lecture - 2 hrs.</td>
<td>The student will be able to:&lt;br&gt; • Apply relational database structure to a problem&lt;br&gt; • Define the rules of normalization&lt;br&gt; • Define advantages of normalized relational databases&lt;br&gt; • Develop a normalized relational database</td>
</tr>
</tbody>
</table>

Notes:
COMPUTER NETWORKING I
COURSE DESIGN GUIDE

COURSE TITLE
Computer Networking I

CATALOG DESCRIPTION
This course introduces the OSI and TCP/IP models, industry standards, commonly used network topologies, IP addressing using subnet masks and variable length subnet masks, basic network copper cabling, routing concepts, and the configuration and use of routers.

CREDITS
4.0 credits, 96 hours

COURSE FORMAT
This course is intended as a lecture-lab format to accommodate exercises that demonstrate the theoretical concepts and topics.

COURSE NUMBER
Material for this course is presented to meet the requirements for a 100-level course.

PREREQUISITES
Fundamentals of Database Information Systems, Math

INSTRUCTOR INFORMATION
Recommended Qualifications: A Master’s Degree or higher in Computer Science, Computer Networking, or related field, OR certified CCNA/CCNP. Three to five years experience working for private company/contractor, government, power utility, or related entries. Working knowledge and background in subject/topic area. Experience teaching secondary or post-secondary/adult students.

TEACHING METHODS AND ASSIGNMENTS FOR ACHIEVING LEARNING OUTCOMES
The teaching methods most commonly used in this course focus on in-class lectures and demonstrations of necessary topics and content areas. Group scenarios are useful in creating a collaborative working environment that is focused and centered on strategic problem solving issues. Further knowledge and application of subject matter will be taught and explored in lab sessions. Online teaching tools may be used to substitute for lab sessions. Individual and group exercises will simulate real-world working environments that build upon leadership and communication with groups/teams.
STUDENT TEXTS, READING AND OTHER MATERIALS

- Dye, Mar, Rick McDonald, and Antoon Ruﬁ. Network Fundamentals, CCNA Exploration Companion Guide. Indianapolis: Cisco Press, 2008. Print. This is a hard copy version of the material for the ﬁrst half of the course.


BIBLIOGRAPHY


STUDENT LEARNING OUTCOMES

Upon successful completion the student will have the ability to:

- Correctly name and describe the functions performed at each layer of the OSI and TCP/IP reference models
- Compare the OSI and TCP/IP networking models
- Use a protocol analyzer to examine network trafﬁc and the details of TCP/IP packets
- Design IP networks according to specifications, including creating appropriate subnet designs and assigning IP addresses
- Describe WAN standards and protocols
- Explain the functions of routing and network layer protocols
- Describe distance vector routing protocols
- Identify commonly used distance vector routing protocols such as RIP version 1
- Describe EIGRP features as an advanced distance vector routing protocol
- Describe link state routing protocols
- Identify commonly used link state routing protocols such as OSPF
- Perform basic router conﬁgurations including hostnames, passwords, Ethernet interfaces, serial interfaces
- Conﬁgure static routing and dynamic routing protocols including RIP version 1, RIP version 2, EIGRP, and OSPF
- Design, set up, and conﬁgure a network using at least two routers, including speciﬁed routing protocols
## ASSESSMENT RUBRIC

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>EXEMPLARY 4</th>
<th>SATISFACTORY 3</th>
<th>DEVELOPING 2</th>
<th>BEGINNING 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name, describe, compare OSI and TCP/IP reference and networking models</td>
<td>Exhibits superior knowledge of networking and reference models</td>
<td>Exhibits adequate knowledge of networking and reference models</td>
<td>Exhibits essential knowledge of networking and reference models</td>
<td>Exhibits limited knowledge of networking and reference models</td>
</tr>
<tr>
<td>Use of protocol analyzer, design IP networks to specifications</td>
<td>Demonstrates clear use of protocol analyzer, mastery of IP network design and application</td>
<td>Demonstrates competent use of protocol analyzer, acceptable knowledge of IP network design and application</td>
<td>Demonstrates low-level use of protocol analyzer, basic knowledge of IP network design and application</td>
<td>Demonstrates incomplete use of protocol analyzer, incomplete knowledge of IP network design and application</td>
</tr>
<tr>
<td>WAN standards/protocols, functions of routing/network layer protocols, distance vector protocols</td>
<td>Shows exceptional knowledge and understanding of standards, protocols and functions of WAN, routing/network layers, and vector protocols</td>
<td>Shows sufficient knowledge and understanding of standards, protocols and functions of WAN, routing/network layers, and vector protocols</td>
<td>Shows basic knowledge and understanding of standards, protocols and functions of WAN, routing/network layers, and vector protocols</td>
<td>Shows rudimentary knowledge and understanding of standards, protocols and functions of WAN, routing/network layers, and vector protocols</td>
</tr>
<tr>
<td>Distance Vector Routing protocols (RIP, IGRP, EIGRP)</td>
<td>Shows complete knowledge and understanding of various routing protocols and their applications</td>
<td>Shows sound knowledge and understanding of various routing protocols and their applications</td>
<td>Shows limited knowledge and understanding of various routing protocols and their applications</td>
<td>Shows little to no knowledge and understanding of various routing protocols and their applications</td>
</tr>
<tr>
<td>Link State Routing protocols (OSPF, IS-IS)</td>
<td>Shows complete knowledge and understanding of various link state routing protocols and their applications</td>
<td>Shows sound knowledge and understanding of various link state routing protocols and their applications</td>
<td>Shows limited knowledge and understanding of various link state routing protocols and their applications</td>
<td>Shows little to no knowledge and understanding of various link state routing protocols and their applications</td>
</tr>
<tr>
<td>Basic router configuration, static and dynamic routing protocols</td>
<td>Demonstrates thorough knowledge of router configuration and dynamic routing protocols</td>
<td>Demonstrates ample knowledge of router configuration and dynamic routing protocols</td>
<td>Demonstrates essential knowledge of router configuration and dynamic routing protocols</td>
<td>Demonstrates fundamental knowledge of router configuration and dynamic routing protocols</td>
</tr>
<tr>
<td>Design, setup, and configure networks</td>
<td>Illustrates excellent knowledge, understanding, and application of network design, setup, and configuration</td>
<td>Illustrates average knowledge, understanding, and application of network design, setup, and configuration</td>
<td>Illustrates low-level knowledge, understanding, and application of network design, setup, and configuration</td>
<td>Illustrates limited knowledge, understanding, and application of network design, setup, and configuration</td>
</tr>
</tbody>
</table>
## UNIT 1: NETWORKING BASICS AND OSI MODEL

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
</table>
| **1.1 Data Network Components: Characteristics of Network Architecture** | **The student will be able to:**  
  - Identify key components of any data network  
  - Describe characteristics of network architectures: fault tolerance, scalability, QoS, and security |
| Lecture - 2 hrs. | |
| **1.2 Network Structure and Communications: OSI and TCP/IP Models** | **The student will be able to:**  
  - Explain the functions of protocols in network communications  
  - Explain the advantages of using a layered model in networking  
  - Describe the role of each layer in the OSI model and TCP/IP models  
  **Performance Objectives, the student will:**  
  - Connect network components with the correct cables  
  - Configure IP addresses and verify basic connectivity  
  - Observe and test network settings with basic utilities (ping, tracert, arp, ipconfig)  
  - Capture network traffic using Wireshark  
  - Lab Exercise: 1.2-1 Building Small Networks and Wireshark |
| Lecture - 1 hr.  
  Lab - 3 hrs. | |
| **1.3 Application Layer Functions and Protocols: Network Analysis Tools** | **The student will be able to:**  
  - Describe the function of well-known TCP/IP applications and related services, including HTTP, DNS, DHCP, SMTP/POP/IMAP, and Telnet  
  - Use network analysis tools to examine how common user applications work |
| Lecture - 1 hr. | |
| **1.4 Transport Layer, TCP and UDP Protocols** | **The student will be able to:**  
  - Identify the role of the Transport layer in end-to-end transfer of data between applications  
  - Describe the roles of the Transport layer protocols: TCP and UDP  
  - Explain the key functions of the Transport layer, including reliability, port addressing, and segmentation  
  **Performance Objectives, the student will:**  
  - Set up a switched network that connects to the Internet  
  - Configure two hosts for connection to the Internet  
  - Start and restart a web server application  
  - Capture and analyze HTTP traffic using network analyzer  
  - Demonstrate common netstat command parameters and outputs  
  - Use netstat to examine protocol information on a host computer  
  - Start a TFTP server and perform TFTP file transfer between network devices  
  - Identify TCP header fields and operations using network analyzer  
  - Identify UDP header fields and operations using network analyzer  
  - Lab Exercise: 1.4-1 Application and Transport Layer Protocols |
| Lecture - 2 hrs.  
  Lab - 3 hrs. | |
| **1.5 OSI Network Layer, IP** | **The student will be able to:**  
  - Identify the role of the Network layer in providing communication from source device to destination device  
  - Examine the Internet Protocol (IP) and its features for providing connectionless and best-effort service  
  - Explain the hierarchical addressing of devices  
  - Explain the fundamentals of routes, next-hop addresses, and packet forwarding |
| Lecture - 2 hrs. | |
## COMPUTER NETWORKING I

### UNIT 1: NETWORKING BASICS AND OSI MODEL

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.6 Network Addressing – IPv4</strong>&lt;br&gt;Lecture - 5 hrs.&lt;br&gt;Lab - 1 hr.</td>
<td><strong>The student will be able to:</strong>&lt;br&gt;• Explain the classful structure of IPv4 addressing&lt;br&gt;• Given an IPv4 address, classify by type, and describe how it is used in the network&lt;br&gt;• Explain how addresses are assigned within networks by administrators&lt;br&gt;• Determine the network portion of the host address and explain the role of the subnet mask&lt;br&gt;• Calculate the addressing ranges required for a given network design criteria&lt;br&gt;• Verify and test network connectivity and operational status of the IP protocol stack on a host&lt;br&gt;&lt;br&gt;<strong>Performance Objectives, the student will:</strong>&lt;br&gt;• Convert decimal to binary&lt;br&gt;• Convert binary to decimal&lt;br&gt;• Name the five different classes of IP addresses&lt;br&gt;• Describe the characteristics and use of the different IP address classes&lt;br&gt;• Identify the class of an IP address based on the network number&lt;br&gt;• Determine which byte, or octet of an IP address is the network address (ID) and which part is the host ID&lt;br&gt;• Identify valid and invalid IP host addresses based on the rules of IP addressing&lt;br&gt;• Define the range of addresses and default subnet mask for each class&lt;br&gt;- Lab Exercise: 1.6-1 IPv4 Addressing</td>
</tr>
<tr>
<td><strong>1.7 CIDR, VLSM, IPv6</strong>&lt;br&gt;Lecture - 2 hrs.</td>
<td><strong>The student will be able to:</strong>&lt;br&gt;• Explain classless IPv4 addressing&lt;br&gt;• Design classless IPv4 addressing schemes&lt;br&gt;• Describe the benefits of IPv6 over IPv4&lt;br&gt;• Implement and verify network connectivity with classless addressing</td>
</tr>
<tr>
<td><strong>1.8 OSI Data Link Layer, MAC Address, Media Access Control</strong>&lt;br&gt;Lecture - 2 hrs.</td>
<td><strong>The student will be able to:</strong>&lt;br&gt;• Explain the role of Data Link layer protocols in data transmission&lt;br&gt;• Describe how the Data Link layer prepares data for transmission on network media&lt;br&gt;• Describe the different types of media access control methods&lt;br&gt;• Describe the Layer 2 frame structure and identify generic fields</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 1: NETWORKING BASICS AND OSI MODEL

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.9 OSI Physical Layer, Media and Cabling, Types of Cables – Straight-Through, Crossover, Rollover</strong>&lt;br&gt;Lecture - 1 hr.</td>
<td>The student will be able to:&lt;br&gt;• Explain the role of Physical layer protocols and services&lt;br&gt;• Identify the basic characteristics of copper, fiber, and wireless network media&lt;br&gt;• Describe common uses of copper, fiber, and wireless network media</td>
</tr>
<tr>
<td><strong>1.10 Ethernet Operation, Ethernet Frame, Media Access, ARP</strong>&lt;br&gt;Lecture - 2 hrs.&lt;br&gt;Lab - 3 hrs.</td>
<td>The student will be able to:&lt;br&gt;• Explain the fields of the Ethernet frame&lt;br&gt;• Describe the function and characteristics of the media access control method used by Ethernet&lt;br&gt;• Describe the features of Ethernet&lt;br&gt;• Compare and contrast Ethernet hubs and switches&lt;br&gt;• Explain the function of ARP&lt;br&gt;&lt;br&gt;<strong>Performance Objectives, the student will:</strong>&lt;br&gt;• Set up a switched network that connects to the Internet&lt;br&gt;• Configure two hosts for connection to the Internet&lt;br&gt;• Examine and manage the host computer’s ARP table using Window’s ARP command&lt;br&gt;• Analyze ARP exchanges and header information using Wireshark&lt;br&gt;• Upload a configuration to a switch&lt;br&gt;• Examine the switch’s MAC address table&lt;br&gt;- Lab Exercise: 1.10-1 ARP and MAC Switching Table</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 2: INTRODUCTION TO ROUTING

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
</table>
| **2.1 Planning and Cabling Networks, Basic Router Configuration, Configuring Interfaces, Configuring RIP** | The student will be able to:  
- Identify the types of connections for intermediate and end device connections in a LAN  
- Identify the pin configurations for straight-through and crossover cables  
- Design an addressing scheme for an internetwork and assign ranges for hosts, network devices, and the router interface  

**Performance Objectives, the student will:**  
- Perform basic router configuration  
- Configure IP addresses, subnet masks, and default gateways on workstations  
- Upload router configuration file  
- Perform basic configuration on a router, including hostname and interface addresses  
- Test connectivity in a network  
- Observe various information on a router including configuration, routing table, and interface status  
  - Lab Exercise: 2.1-1 Basic Two Router Lab with Configuration Upload |
| **2.2 Configuring and Testing Network, Logging, Backing Up the Router Configuration, Network Utilities: Ping, Traceroute** | The student will be able to:  
- Identify the IOS modes of operation  
- Identify the basic IOS commands  
- Compare and contrast the basic show commands |
| **2.3 Introduction to Routing and Packet Forwarding** | The student will be able to:  
- Explain the function of the router  
- Identify the main components of a router  
- Describe the structure of a routing table  
- Describe how a router determines a path and switches packets  

**Performance Objectives, the student will:**  
- Perform basic router configuration tasks, including password for privileged mode, telnet operation, and router interfaces  
- Test and verify connectivity in the network  
- Telnet to the router, and observe the telnet operation in Wireshark  
  - Lab Exercise: 2.3-1 Basic Router Configuration |
| **2.4 Static Routing** | The student will be able to:  
- Define the general role of the router in networks  
- Describe the directly connected networks and the different router interfaces  
- Examine directly connected networks in the routing table  
- Identify static routes with exit interfaces in the routing table  
- Describe summary and default routes  

**Performance Objectives, the student will:**  
- Set up and verify static routing  
- Configure simple dynamic routing using RIP  
  - Lab Exercise: 2.4-1 Static vs Dynamic Routing |
# UNIT 2: INTRODUCTION TO ROUTING

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5 Introduction to Dynamic Routing Protocols</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Describe the role of dynamic routing protocols</td>
</tr>
<tr>
<td></td>
<td>• Describe and identify metrics used by dynamic routing protocols</td>
</tr>
<tr>
<td></td>
<td>• Explain the use of administrative distance of a route</td>
</tr>
<tr>
<td></td>
<td>• Identify different elements in the routing table</td>
</tr>
<tr>
<td></td>
<td>• Design and apply subnetting schemes</td>
</tr>
<tr>
<td>2.6 Distance Vector Routing Protocols</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Identify the characteristics of distance vector routing protocols</td>
</tr>
<tr>
<td></td>
<td>• Describe how distance vector routing protocols maintain routing tables</td>
</tr>
<tr>
<td></td>
<td>• Identify common distance vector routing protocols</td>
</tr>
<tr>
<td>2.7 RIP Version 1</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Describe the properties and operation of RIPv1</td>
</tr>
<tr>
<td>Lab - 3 hrs.</td>
<td>• Configure RIPv1 and verify its operation</td>
</tr>
<tr>
<td></td>
<td>• Describe automatic summarization in RIPv1</td>
</tr>
<tr>
<td></td>
<td>• Configure and verify default routes in RIPv1</td>
</tr>
<tr>
<td>Performance Objectives, the student will:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Configure and verify dynamic routing using RIP</td>
</tr>
<tr>
<td></td>
<td>• Configure default route and propagate it using RIP</td>
</tr>
<tr>
<td></td>
<td>• Investigate RIP timer values and contents of RIP updates</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 2.7-1 RIPv1 Configuration</td>
</tr>
</tbody>
</table>

Notes:
<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 VLSM &amp; CIDR</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Compare classful and classless IP addressing</td>
</tr>
<tr>
<td></td>
<td>• Explain benefits of classless IP addressing</td>
</tr>
<tr>
<td></td>
<td>• Describe the role of CIDR in making efficient use of IPv4 addresses</td>
</tr>
<tr>
<td></td>
<td>Performance Objectives, the student will:</td>
</tr>
<tr>
<td></td>
<td>• Configure RIPv1 as the routing protocol in your VLSM subnetted network</td>
</tr>
<tr>
<td></td>
<td>• Configure default route and propagate it using RIPv1</td>
</tr>
<tr>
<td></td>
<td>• Investigate operation and correct routing errors arising from use of RIPv1 in a VLSM subnetted network</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 3.1-1 RIPv1 and VLSM</td>
</tr>
<tr>
<td>3.2 RIPv2</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Describe the properties and operation of RIPv2</td>
</tr>
<tr>
<td></td>
<td>• Examine RIPv2 classless routing updates</td>
</tr>
<tr>
<td></td>
<td>• Configure and verify RIPv2</td>
</tr>
<tr>
<td></td>
<td>Performance Objectives, the student will:</td>
</tr>
<tr>
<td></td>
<td>• Design and implement a VLSM network addressing scheme</td>
</tr>
<tr>
<td></td>
<td>• Configure and verify RIPv2 operation in a network using VLSM addressing</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 3.2-1 RIPv2 and VLSM</td>
</tr>
<tr>
<td>3.3 EIGRP</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Describe features and operation of EIGRP</td>
</tr>
<tr>
<td></td>
<td>• Configure and verify EIGRP</td>
</tr>
<tr>
<td></td>
<td>• Describe the concepts and operation of DUAL</td>
</tr>
<tr>
<td></td>
<td>Performance Objectives, the student will:</td>
</tr>
<tr>
<td></td>
<td>• Configure RIPv2 as the routing protocol</td>
</tr>
<tr>
<td></td>
<td>• Observe the auto-summarization of RIP</td>
</tr>
<tr>
<td></td>
<td>• Configure EIGRP as the routing protocol</td>
</tr>
<tr>
<td></td>
<td>• Observe the effect of running both RIP and EIGRP in your network</td>
</tr>
<tr>
<td></td>
<td>• Observe properties and operation of EIGRP</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 3.3-1 RIPv2 and EIGRP</td>
</tr>
<tr>
<td>3.4 Routing Table</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Describe the types of routes found in the routing table</td>
</tr>
<tr>
<td></td>
<td>• Describe the route lookup process</td>
</tr>
<tr>
<td></td>
<td>• Describe the routing behavior in routed networks</td>
</tr>
<tr>
<td></td>
<td>Performance Objectives, the student will:</td>
</tr>
<tr>
<td></td>
<td>• Determine the subnetting used in a network from examining routing tables</td>
</tr>
<tr>
<td></td>
<td>• Determine directly connected networks from examining routing tables</td>
</tr>
<tr>
<td></td>
<td>• Determine routing protocols used for dynamic routing</td>
</tr>
<tr>
<td></td>
<td>• Map the network by examining routing tables</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 3.4-1 Routing Table Interpretation</td>
</tr>
</tbody>
</table>
## UNIT 3: ROUTING TABLES AND LINK-STATE ROUTING

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
</table>
| 3.5 Link State Routing Protocol | **The student will be able to:**  
  - Describe the basic features and concepts of link-state routing protocols  
  - Explain the benefits of link-state routing protocols  
  **Performance Objectives, the student will:**  
  - Configure and verify operation of OSPF as the routing protocol  
  - Observe the OSPF neighbors and the topological database in the OSPF network  
  - Observe and understand the DR/BDR election process  
  - Configure and propagate a default route in OSPF  
  - Lab Exercise: 3.5-1 OSPF in Multi-Access Network |
| 3.6 OSPF                | **The student will be able to:**  
  - Describe the basic features of OSPF  
  - Describe the Designated Router/Backup Designated Router (DR/BDR) election process  
  - Configure and propagate a default route in OSPF  
  - Configure and verify OSPF  
  **Performance Objectives, the student will:**  
  - Configure and verify OSPF as routing protocol for the single-area network  
  - Lab Exercise: 3.6-1 Single-Area OSPF Network |

Notes:
COMPUTER NETWORKING I
LAB 1.2-1 BUILDING SMALL NETWORKS AND WIRESHARK

PERFORMANCE OBJECTIVE

- Connect network components with the correct cables.
- Configure IP addresses and verify basic connectivity.
- Observe and test network settings with basic utilities (Ping, Tracert, ARP, ipconfig).
- Capture network traffic using Wireshark.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

None

BACKGROUND

Initial setup of a network involves use of proper cables to connect devices. It is important to have a clear understanding of which cables to use for network connections, whether straight-through or crossover. Cabling is part of the Physical layer (Layer 1) of the OSI model.

To communicate over the network, devices need an address. The IP or logical address is defined at the Network layer (Layer 3) of the OSI model.

Various utilities are available to observe and test the operation of the network. A network sniffer such as Wireshark can be used to observe data flow in the network. Connectivity can be verified by the Ping and Tracert (Traceroute on the Cisco routers) utilities.

SAFETY REQUIREMENTS

None

TEST EQUIPMENT

None

MATERIALS NEEDED

- 2 Windows workstations with Internet access
- Cables – straight-through and crossovers (2 each)
- 1 switch or hub
CRITICAL TASKS STUDENTS MUST COMPLETE

- Cable peer-to-peer and simple switched network.
- Configure workstation with IP address and subnet mask.
- Verify network settings and operation using ipconfig, traceroute, and ping.
- Obtain network traffic information such as ARP and TCP 3-way handshake using network sniffer such as WireShark.

FINDINGS

- There are two types of Ethernet cables used in networking: straight-through and crossover cables. Crossover cables are used to connect two end devices in a LAN, such as workstation to workstation, or workstation to router, or router Ethernet interface to another router Ethernet interface. This is needed so the transmit lines of one is ‘crossed over’ to the receive lines of the other. A switch will do the crossover, so a straight-through cable is required to connect workstation to switch or router to switch.

- To communicate within a LAN two addresses are needed: IP address and MAC or hardware address. The ARP operation is used to determine the MAC address for a known IP address. This information is stored in RAM in the ARP table or ARP cache.

- The TCP protocol uses a 3-way handshake to establish (synchronize) a communication link. Applications using TCP will exchange three signals (SYN, SYN-ACK, and ACK) to establish the link.

- Network testing may use a number of utilities including: ipconfig, Tracert, Ping, ARP. ipconfig is used on a Windows workstation to check the network settings, including IP address, subnet mask, default gateway, etc. Tracert is used to determine the path taken by a packet to reach the destination (Note: Tracert is the command in Windows, Traceroute on Cisco routers). Ping is used to test end-to-end connectivity. ARP is used to check IP address and MAC address mapping, or to add or delete such entries in the ARP cache.

ADDITIONAL INFORMATION

None
COMPUTER NETWORKING I
LAB 1.4-1 APPLICATION AND TRANSPORT LAYER PROTOCOLS AND INVESTIGATING UDP PROTOCOL WITH WIRESHARK

PERFORMANCE OBJECTIVE

- Set up a switched network that connects to the Internet.
- Configure two hosts for connection to the Internet.
- Start and restart a web server application.
- Capture and analyze HTTP traffic using network analyzer.
- Demonstrate common Netstat command parameters and outputs.
- Use Netstat to examine protocol information on a host computer.
- Start a TFTP server and perform TFTP file transfer between network devices.
- Identify TCP header fields and operations using network analyzer.
- Identify UDP header fields and operations using network analyzer.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

Instructor needs to ensure the students have administrative privileges on the workstations to run server software, change addressing parameters, etc. It would facilitate the lab if the Apache web server and a TFTP server software were already downloaded and installed for students to use in lab. (Note: this can be done as part of the lab by the students if they have sufficient privileges on the workstations.) If lab policies preclude students from having administrative privileges on the computers, a desktop virtualization environment, such as Virtual PC, can be used to provide students their own virtual computers.

BACKGROUND

Web browsers are used on a daily basis by many Internet users. Web browsers implement the Hyper-Text Transfer Protocol (HTTP), which is an application layer protocol. The HTTP protocol also relies on the TCP transport layer protocol for reliably transporting data across the Internet. In this lab, you will use Wireshark to examine the content of HTTP traffic, including the application layer data and the TCP header for the transport layer.

Netstat is an abbreviation for the network statistics utility, and is available on both Windows and Unix/Linux computers. Optional parameters for the Netstat command will change the displayed output. Netstat displays both incoming and outgoing network connections for TCP and UDP, routing table information for the host computer, and interface statistics. In this lab you will use the Netstat command on a host computer, and adjust Netstat output options to analyze and understand the status of TCP/IP Transport Layer protocols.

The two protocols in the Transport Layer of the TCP/IP protocol stack are the Transmission Control Protocol (TCP), defined in RFC 761, January 1980, and User Datagram Protocol (UDP), defined in RFC 768, August 1980. Both protocols support upper-layer protocol communication. For example, TCP is used to provide Transport Layer support for the HTTP and FTP protocols, among others. UDP provides Transport Layer support for the Domain Name Service (DNS) and Trivial File Transfer protocol (TFTP), among others.
SAFETY REQUIREMENTS
None

TEST EQUIPMENT
None

MATERIALS NEEDED
- One network switch
- Straight-through cables
- Two host computers
- Apache web server software
- TFTP server software

CRITICAL TASKS STUDENTS MUST COMPLETE
- Download, install, configure, and verify the Apache web server (if not already installed).
- Capture and analyze HTTP traffic with network analyzer.
- Observe TCP and UDP protocol information using Netstat.
- Identify TCP header fields and operation using network analyzer.
- Identify UDP header fields and operation using network analyzer.

FINDINGS
- This lab provided the opportunity to analyze TCP and UDP protocol operations from captured FTP and TFTP sessions. TCP manages communication much differently from UDP, but reliability and guaranteed delivery requires additional control over the communication channel. UDP has less overhead and control, and the upper-layer protocol must provide some type of acknowledgement control. Both protocols, however, transport data between clients and servers using Application Layer protocols and are appropriate for the upper-layer protocol each supports.

- Since neither FTP nor TFTP are secure protocols, all data transferred is sent in clear text. This includes any user ids, passwords, or clear text file contents. Analyzing the upper-layer FTP session will quickly identify the user id, password, and configuration file passwords. Upper-layer TFTP data examination is a bit more complicated, but the data field can be examined and configuration of user id and password information extracted.

ADDITIONAL INFORMATION
None
COMPUTER NETWORKING I
LAB 1.6-1 IPV4 ADDRESSING

PERFORMANCE OBJECTIVE

• Convert decimal to binary.
• Convert binary to decimal.
• Name the five different classes of IP addresses.
• Describe the characteristics and use of the different IP address classes.
• Identify the class of an IP address based on the network number.
• Determine which byte, or octet, of an IP address is the network address (ID) and which part is the host ID.
• Identify valid and invalid IP host addresses based on the rules of IP addressing.
• Define the range of addresses and default subnet mask for each class.

LAB TYPE
Individual

TIME REQUIRED
3 hours

INSTRUCTOR PREPARATION
None

BACKGROUND

Decimal to Binary Conversion
Knowing how to convert decimal values to binary values is valuable when converting human readable IP addresses in dotted decimal format to machine-readable binary format. This is normally done for calculation of subnet masks and other tasks. The following is an example of an IP address in 32-bit binary form and dotted decimal form.

Binary IP Address: 11000000 . 10101000 . 00101101 . 01111001

Decimal IP Address: 192.168.45.121

A tool that makes the conversion of decimal values to binary values simple is the following binary place values table. The top row represents the powers of 2 associated with each bit position shown in the second row. The second row is created by counting right to left from one to eight, for the basic eight bit positions. The third row gives the decimal value for each bit position. The table will work for any size binary value. The value row starts with one and is multiplied by 2, for each position to the left.

<table>
<thead>
<tr>
<th>Power of 2</th>
<th>27</th>
<th>26</th>
<th>25</th>
<th>24</th>
<th>23</th>
<th>22</th>
<th>21</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position</td>
<td>8</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Place Value</td>
<td>128</td>
<td>64</td>
<td>32</td>
<td>16</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
Binary to Decimal Conversion
A byte, 8 bits, can range from 00000000 to 11111111 creating 256 combinations with decimal values ranging from 0 to 255. IP addressing uses 4 bytes, or 32 bits, to identify both the network and specific device.

IPv4 Addressing and Subnetting
IPv4 addresses are expressed in dotted decimal. There are two main parts to the address: network part and the host part. The network part identifies the network where the host resides, while the host part identifies the specific host on the network. Networks can be broken down into smaller subnets by borrowing bits from the host part to form a subnet part of the address. Each subnet would be its own broadcast domain, and routing makes use of both the network and subnet parts of the address.

SAFETY REQUIREMENTS
None

TEST EQUIPMENT
None

MATERIALS NEEDED
None

CRITICAL TASKS STUDENTS MUST COMPLETE
- Convert decimal to binary and binary to decimal.
- Express IPv4 addresses in binary and dotted decimal formats.
- Identify the structure of classful IPv4 addressing.
- Determine the subnet mask for classful IPv4 addressing.
- Determine usable address range for an IPv4 network.

FINDINGS
- IPv4 is a 32-bit address typically expressed in dotted decimal format. Originally IPv4 was designed with a classful structure, with each class address defined with a network part and a host part. A network can be divided into smaller subnets, and a subnet mask is used to identify which part is network and subnet (used for routing) and which part is the host (to identify the specific interface).

ADDITIONAL INFORMATION
None
LAB 1.10-1 ARP AND MAC SWITCHING TABLES

PERFORMANCE OBJECTIVE

• Set up a switched network that connects to the Internet.
• Configure 2 hosts for connection to the Internet.
• Examine and manage the host computer’s ARP table using Window’s ARP command.
• Analyze ARP exchanges and header information using Wireshark.
• Upload a configuration to a switch.
• Examine the switch’s MAC address tables.

LAB TYPE
Team

TIME REQUIRED
3 hours

INSTRUCTOR PREPARATION

Ensure students have sufficient privilege to be able to clear the ARP cache on their host computer. If using Windows Vista or Windows 7, this means they will need to be able to open a command window using the “Run as administrator” option.

Prepare a basic switch configuration for students to upload to the switch in the last part of the lab.

Windows XP is the recommended operating system for this lab, as Windows XP includes the HyperTerminal communication application by default. Windows Vista and Windows 7 do not include HyperTerminal by default, so it is necessary either to install HyperTerminal for students to use, or to install another terminal communications program, such as PuTTY or TeraTerm.

BACKGROUND

ARP is used by the TCP/IP protocol stack to map a Layer 3 IP address to a Layer 2 MAC address. A frame must have a destination MAC address. The originating host sends a broadcast ARP request to dynamically discover the MAC address associated with the destination IP address. The device with that destination IP address responds with its MAC address, which is recorded in ARP cache of the originating host.

Every device on the LAN maintains its own ARP cache in RAM. ARP entries that have not been used for a certain period of time will be removed from the ARP cache. The period of time will vary depending on the operating system, e.g. some Windows operating systems store ARP cache entries for 2 minutes. If the entry is used again during that time, the ARP timer for that entry is extended to 10 minutes.

ARP is an excellent example in performance tradeoff. With no cache, ARP must continually request address translations each time a frame is to be sent. This adds latency (delay) to the communication and could congest the LAN. Conversely, unlimited hold times for entries in the ARP cache could cause errors with devices that leave the network or change their Layer 3 address.

ARP is a protocol that enables network devices to communicate with the TCP/IP protocol. Without ARP, there is no efficient method to build the datagram’s Layer 2 destination address.
ARP is a potential security risk. ARP spoofing, or ARP poisoning, is a technique used by an attacker to inject a false MAC address into a network. An attacker can falsely use (forge) the MAC address of a legitimate network device, and frames will subsequently be sent to the wrong destination device. This type of spoofing can be prevented by using static MAC address to IP address mappings, or by configuring an authorized list of MAC addresses to restrict network access to only valid devices.

SAFETY REQUIREMENTS
None

TEST EQUIPMENT
None

MATERIALS NEEDED
- One network switch for each lab group
- Ethernet straight-through cables for connecting host computers to switch
- Host computers for each student in lab group

CRITICAL TASKS STUDENTS MUST COMPLETE
- Set up switched network.
- Use the Window’s ARP command to observe the ARP table, add ARP entries, remove ARP entries.
- Examine the ARP operation using Wireshark.
- Examine the MAC address table on a switch.

FINDINGS
- MAC addresses are needed for delivering frames within the local network. The Address Resolution Protocol (ARP) enables a host computer to learn the MAC address of a destination device when the Layer 3 IP address of the destination device is known. ARP maps Layer 3 IP addresses to Layer 2 MAC addresses.

- If a packet must leave the local network to reach a destination device, the packet is encapsulated in a data link layer (frame) header with the destination MAC address set to the MAC address of the default gateway. Local Area Networks, such as Ethernet, specify the use of the MAC address for the data link (Layer 2) addressing. Other types of networks, such as Wide Area Networks (WANs) have different requirements for Layer 2 addressing and do not use MAC addresses for that purpose.

- The ARP cache stores ARP address mappings of all directly connected network devices, including host computers as well as routers and switches. Entries in the ARP cache can be learned dynamically or may be statically configured.

ADDITIONAL INFORMATION
None
COMPUTER NETWORKING I
LAB 2.1-1 BASIC TWO-ROUTER LAB WITH CONFIGURATION UPLOAD

PERFORMANCE OBJECTIVE

• Create a WAN (wide-area network) consisting of two workstations and two routers.
• Identify the proper cables to directly connect workstation to router.
• Identify the proper cables to connect two routers to form a WAN link.
• Configure workstation IP address information.
• Create a console connection from a workstation to a router using a rollover (console) cable.
• Configure PuTTY or HyperTerminal on the workstation.
• Use PuTTY or HyperTerminal on the workstation to observe the router user interface.
• Upload a configuration to the router using a floppy disk or USB flash device.
• Manually enter a basic configuration to a router using PuTTY or HyperTerminal.
• Test connectivity using the Ping command.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

• If the computer lab policies preclude students from having administrative privileges on the computers, a desktop virtualization environment, such as Virtual PC, can be used to provide students their own virtual computers.
• Students will need to have sufficient privilege to be able to change network settings on their host computer.
• Prepare a basic router configuration that students can use for uploading a router configuration.
• Windows XP is the recommended operating system for this lab, as Windows XP includes the HyperTerminal communication application by default. Windows Vista and Windows 7 do not include HyperTerminal by default, so it is necessary either to install Hyperterminal for students to use, or to install another terminal communications program, such as PuTTY or TeraTerm.

BACKGROUND

This lab gives an introduction to the operating system (OS) of the router. From the OS, basic configuration of the router can be done. It is also possible to upload a configuration file. In this lab, the student will cable the lab topology, upload a configuration to one of the routers, then configure the other router to provide network connectivity between directly connected devices.

A WAN connection is a serial connection between two routers. A router is a networking device that can be used to interconnect LANs. Routers forward packets between different networks using Layer 3 IP addressing. Routers are the networking devices used to connect the Internet.
To communicate, the routers and workstations must have connections at the physical layer, the data link layer, and the network layer of the OSI model. The physical layer connection is provided by connecting the devices with the correct cables (physical media) for the type of network being set up. The data link layer connection is obtained by the use of clock signals and data link layer addressing, which occurs transparently to the user. The network layer connection is achieved by configuring the routers and workstations with the correct IP network settings (Layer 3). Ethernet crossover patch cables are used to connect workstations directly to their (gateway) routers. V.35 serial cables create the simulated WAN link between the routers.

**SAFETY REQUIREMENTS**

None

**TEST EQUIPMENT**

None

**MATERIALS NEEDED**

- Two host computers with an Ethernet 10/100 NIC
- Two routers with FastEthernet ports and serial interface, and serial cable to connect the routers
- Appropriate network cables to connect workstations to the routers
- One floppy diskette or USB flash device containing the configuration files for the routers

**CRITICAL TASKS STUDENTS MUST COMPLETE**

- Connect the devices in the given network topology.
- Configure workstations with IP address, subnet mask, and default gateway.
- Upload a configuration file to a router.
- Configure the hostname on a router.
- Configure and enable interfaces on a router.
- Test and verify connectivity in a network.
- Observe the routing table, status of interfaces, and configuration on a router.
FINDINGS

• The technology for Ethernet networks is classified as Local Area Network (LAN) technology. LANs are designed to operate at high speeds in relatively small geographic areas. Wide Area Networks are different technologies designed to operate over much longer distances, but usually at much slower speeds than LANs. One example of WAN technology is synchronous serial communication that requires the use of serial cables and a clock signal to establish a connection between two connected devices. Students created a simple wide-area network (WAN) that connected the LANs between two PCs and their local gateway routers.

• WANs use different cables than LANs. In this lab, crossover Ethernet cables were used to connect a PC directly to the Ethernet port of the gateway router, and V.35 serial cables were used to connect the two routers via a WAN link.

• To perform initial configuration of a router, students first created a console connection from a PC to a router using a rollover (console) cable and configured terminal emulation software such as PuTTY or HyperTerminal to view the router’s user interface. In this lab students configured one router by uploading a configuration from a floppy disk or USB flash device, and configured the second router by entering the configuration commands directly into the router’s command line user interface.

• Once the network has been set up and configured, students verified that everything was working correctly by testing the end-to-end connectivity using the Ping command.

ADDITIONAL INFORMATION

None
COMPUTER NETWORKING I
LAB 2.3-1 BASIC ROUTER CONFIGURATION

PERFORMANCE OBJECTIVE

• Design addressing for a basic subnet network.
• Cable a given network topology.
• Perform basic router configuration tasks, including password for privileged mode, telnet operation, and router interfaces.
• Observe the output of the debug IP routing command.
• Configure static routes.
• Test and verify connectivity in the network.

LAB TYPE
Team

TIME REQUIRED
3 hours

INSTRUCTOR PREPARATION
None

BACKGROUND
Configuration and testing of routers are an important skill in networking. When a router’s interfaces are configured with addresses on different networks or subnets, the router can then route between those networks or subnets. Initially a router only knows directly connected networks. To learn remote destinations (networks that are not directly connected), routes can be statically configured or learned dynamically from a routing protocol. In this lab we will configure static routes to provide connectivity within the network.

SAFETY REQUIREMENTS
None

TEST EQUIPMENT
None

MATERIALS NEEDED
• Three routers and serial cables to connect them
• Three workstations
• Appropriate network cables to connect workstations to routers
CRITICAL TASKS STUDENTS MUST COMPLETE

- Design a basic subnetting scheme for a given network.
- Cable a given network topology.
- Perform basic configuration of the router, including IP addresses and subnet mask on interfaces, passwords, etc.
- Implement the subnetting scheme in the network.
- Configure summary static and default routes.
- Test and verify connectivity between directly connected neighbors.
- Observe status and conditions on the router, including interface status, routing table, configuration, etc.

FINDINGS

- The initial routing table of the router contains routes (networks) that are directly connected. One way for a router to learn remote networks is to have them configured manually (static routing). For large networks it would be an administrative burden to configure and maintain routes using only static routing. Later in the course we will streamline the router operation by using routing protocols to learn routes dynamically.

- Smaller routing tables give more efficient router operation. Summary routes and default routes can be used to minimize the size of the routing table.

- Particularly important in this lab are the commands to configure a static route and a default route. Static routes can be configured by specifying either the next-hop address or the exit interface. These entries appear differently in the routing table. For serial links, it is advantageous to specify the exit interface, while on multi-access interfaces (such as FastEthernet) it is better to specify the next-hop address.

ADDITIONAL INFORMATION

None
COMPUTER NETWORKING I
LAB 2.4-1 STATIC VS. DYNAMIC ROUTING

PERFORMANCE OBJECTIVE

- Design and implement an IP addressing scheme for a network.
- Perform basic router configuration.
- Set up and verify static routing.
- Configure simple dynamic routing using RIP.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

None

BACKGROUND

Routes can be added to the routing table statically (entered manually) or dynamically (learned via a routing protocol). To configure a static route, students must specify the network and subnet mask, and either the next hop or the exit interface. RIP version 1 is a simple classful routing protocol, that is often used in small networks.

SAFETY REQUIREMENTS

None

TEST EQUIPMENT

None

MATERIALS NEEDED

- Three routers with serial cables
- Three workstations
- Appropriate network cables to connect workstations to routers

CRITICAL TASKS STUDENTS MUST COMPLETE

- Design subnetting for IPv4 addressing of a network.
- Perform basic router configuration.
- Configure static routes.
- Verify connectivity in network using static routing.
- Configure and test simple dynamic routing using RIP.
FINDINGS

- Routes can be added to the routing table manually—providing static routing. Routes can also be learned dynamically from routing protocols. Maintaining static routing in large networks can be labor intensive. Dynamic routing allows routes to be learned automatically. As network changes or new networks are added, these routes are automatically learned and updated in the routing tables.

ADDITIONAL INFORMATION

None
COMPUTER NETWORKING I
LAB 2.7-1 RIPV1 CONFIGURATION

PERFORMANCE OBJECTIVE

- Configure and verify dynamic routing using RIP.
- Configure default route and propagate it using RIP.
- Investigate RIP timer values and contents of RIP updates.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

None

BACKGROUND

RIP version 1 is a classful distance vector routing protocol, allowing only a single subnet mask for subnetting. RIP v1 sends updates to directly connected neighbor routers in the form of broadcasts to the 255.255.255.255 address. RIP sends updates every 30 seconds by default, and has other timers to determine when routes are invalid, and when they should be flushed from the routing table. RIP ver1 does not support CIDR or VLSM, nor does it provide for authentication between routers.

SAFETY REQUIREMENTS

None

TEST EQUIPMENT

None

MATERIALS NEEDED

- Three routers with serial cables
- Three workstations.
- Appropriate network cables to connect workstations to routers

CRITICAL TASKS STUDENTS MUST COMPLETE

- Design an IP addressing scheme for a network.
- Configure IP addresses on router interfaces.
- Configure and verify dynamic routing using RIP.
- Configure default route and propagate it using RIP.
- Investigate RIP timer values and contents of RIP updates.

FINDINGS
- RIPv1 is a simple, distance vector routing protocol, which sends copies of its routing table as broadcasts to directly connected RIP routers. RIPv1 enables routes by specifying the classful network address (not subnets). RIP will propagate a default route if configured with the default-information originate command. RIP default timer values include 30 seconds for updates, 180 seconds for invalid, 240 seconds for flush.

**ADDITIONAL INFORMATION**

None
COMPUTER NETWORKING I
LAB 3.1-1 RIPV1 AND VLSM

PERFORMANCE OBJECTIVE

• Design an IP addressing scheme using VLSM.
• Configure RIPv1 as the routing protocol in VLSM subnet network.
• Configure default route and propagate it using RIP.
• Investigate operation of RIPv1 in a VLSM subnet network.
• Correct routing errors arising from use of RIPv1 in a VLSM subnet network.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

None

BACKGROUND

RIP version 1 is a classful routing protocol, allowing only a single subnet mask for subnetting. RIPv1 does not support CIDR or VLSM. Loss of routing will occur when RIPv1 is used in a VLSM subnet network. Static routes can be used to provide any missing routes.

SAFETY REQUIREMENTS

None

TEST EQUIPMENT

None

MATERIALS NEEDED

• Three routers with serial cables
• Three workstations
• Appropriate network cables to connect workstations to routers
CRITICAL TASKS STUDENTS MUST COMPLETE

• Design a subnetting IP addressing scheme using VLSM.
• Implement the VLSM subnetting scheme in the network.
• Configure default route and propagate it using RIP.
• Configure RIPv1 as the routing protocol in the VLSM subnet network.
• Diagnose routing errors in the operation of RIPv1 in a VLSM subnet network.
• Correct routing errors arising from use of RIPv1 in a VLSM subnet network by adding appropriate static routes.

FINDINGS

• RIPv1 does not support CIDR or VLSM, and will ignore routes with subnetting different from the subnetting configured on the interface, resulting in routing errors. These errors can be corrected by use of static routes (manually adding the missing routes).

ADDITIONAL INFORMATION

None
COMPUTER NETWORKING I
LAB 3.2-1 RIPV2 AND VLSM

PERFORMANCE OBJECTIVE

• Design a VLSM network addressing scheme.
• Implement a VLSM network addressing scheme.
• Configure and verify RIPv2 operation in a network using VLSM addressing.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

None

BACKGROUND

In the previous lab, we noted problems with RIPv1 and VLSM, i.e. RIPv1 does not support VLSM. In a VLSM subnet network, routing errors occur with RIPv1 as some routes are ignored by RIP. RIPv2 provides support for VLSM. In addition, RIPv2 provides for authentication, and does not use broadcasts for updates. It sends updates as multicasts, to a group of all RIP routers.

SAFETY REQUIREMENTS

None

TEST EQUIPMENT

None

MATERIALS NEEDED

• Three routers with serial cables
• Three workstations
• Appropriate network cables to connect workstations to routers

CRITICAL TASKS STUDENTS MUST COMPLETE

• Design a VLSM addressing scheme to meet requirements for a network.
• Implement a VLSM addressing scheme.
• Configure RIPv2 as the routing protocol.
• Verify successful operation of RIPv2 in a VLSM subnet network.
• Configure and propagate a default route in RIP.
• Observe contents of RIPv2 updates.
FINDINGS

- VLSM allows each subnet to be configured individually to meet requirements for number of hosts. RIPv2 configuration is similar to RIPv2, with the additional version 2 command. RIPv2 supports VLSM. RIPv2 sends updates as multicasts instead of broadcasts. New features in RIPv2 include authentication for added security.

ADDITIONAL INFORMATION

None
COMPUTER NETWORKING I
LAB 3.3-1 RIPV2 AND EIGRP

PERFORMANCE OBJECTIVE

• Design a VLSM addressing scheme for a given network.
• Configure the routers to implement your addressing scheme design.
• Configure RIPv2 as the routing protocol.
• Observe the auto-summarization of RIPv2.
• Configure EIGRP as the routing protocol.
• Observe the effect of running both RIPv2 and EIGRP in your network.
• Observe properties and operation of EIGRP.
• Test and verify connectivity in your network.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

None

BACKGROUND

EIGRP is an enhanced distance vector, which uses a composite route metrics of bandwidth, delay, load, and reliability (uses only bandwidth and delay by default). Its admin distance for internal routes is 90, which is smaller than RIPv2’s 120. EIGRP uses DUAL as its route computation engine. One feature of EIGRP is the topology table, where all EIGRP learned routes are stored, while only the best route is stored in the routing table. The topology table helps EIGRP converge quicker than RIPv2, as in some cases when the best route goes down, a replacement route can be found without additional computation.

SAFETY REQUIREMENTS

None

TEST EQUIPMENT

None

MATERIALS NEEDED

None
CRITICAL TASKS STUDENTS MUST COMPLETE

- Design a VLSM addressing scheme for a given network.
- Configure the routers to implement your addressing scheme design.
- Configure RIPv2 as the routing protocol.
- Observe the auto-summarization of RIP.
- Configure EIGRP as the routing protocol.
- Observe the effect of EIGRP in replacing RIP routes with EIGRP routes.
- Observe the effect of bandwidth on the route metric of EIGRP.
- Observe the routing table and topology table of EIGRP.
- Test and verify connectivity in your network.

FINDINGS

- EIGRP like RIPv2 supports VLSM. Internal EIGRP routes have lower admin distance than RIP routes and will therefore replace them. Admin distance is used in selecting the best route when routes are learned from different routing protocols or sources.

- The primary metric used by EIGRP is bandwidth, and route metrics can be changed by configuring different bandwidth values for the different links.

- EIGRP use DUAL as its route computation engine, and incorporates many features of link state routing protocols. One feature is the use of a topology table, which stores all routes (not only the best route) learned by EIGRP.

ADDITIONAL INFORMATION

None
COMPUTER NETWORKING I
LAB 3.4-1 ROUTING TABLE INTERPRETATION

PERFORMANCE OBJECTIVE

- Determine subnetting used in a network from examining routing tables.
- Determine directly connected networks from examining routing tables.
- Determine routing protocols used for dynamic routing.
- Map the network by examining routing tables.

LAB TYPE
Team

TIME REQUIRED
3 hours

INSTRUCTOR PREPARATION
None

BACKGROUND
Information in the routing table provides all best routes known by a router, as well as metrics, subnetting, and properties of the routes. This information can be used to create a map of the network, showing how the routers are connected, and what network each router is connected to.

SAFETY REQUIREMENTS
None

TEST EQUIPMENT
None

MATERIALS NEEDED
None

CRITICAL TASKS STUDENTS MUST COMPLETE
- Determine subnetting used in a network from examining routing tables.
- Determine default route information from examining routing tables.
- Determine directly connected networks from the routing table.
- Determine routing protocols used in dynamic routing.
- Determine interfaces addresses from the routing tables.
- Map the network from information in the routing tables.
FINDINGS

• The complete network topology map—how all routers are connected can be determined from information found in the routing tables.

• Metric values and admin values for routes as well as next hop address to use in forwarding packets—found in the routing tables.

• The routing table also contains the neighbor router’s interface IP address.

ADDITIONAL INFORMATION

None
LAB 3.5-1 OSPF IN MULTI-ACCESS NETWORK

PERFORMANCE OBJECTIVE

• Cable a given network topology.
• Configure and activate the router interfaces.
• Verify connectivity between all routers.
• Configure OSPF as the routing protocol.
• Observe the OSPF neighbors and the topological database in the OSPF network.
• Observe properties of OSPF processes for an interface.
• Configure OSPF timer values and priorities.
• Observe and understand the DR/BDR election process.
• Configure and propagate a default route in OSPF.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

None

BACKGROUND

OSPF is a link-state routing protocol. It shares routing information with all OSPF routers within an area so each router can generate a map of the entire OSPF network. OSPF makes use of three tables: neighbor table, topological database, and routing table. When an OSPF router first comes on line, there is a flood of traffic as route information is shared with the router. However, once the network reaches a steady-state, there is minimal routing information as routing updates are event-triggered (occurs only when there is a change in the network topology). OSPF will elect a DR (Designated Router) and a BDR (Backup Designated Router) in a multi-access network to minimize the flooding of routing information. The DR acts as a focal point for all routing updates.

SAFETY REQUIREMENTS

None

TEST EQUIPMENT

None

MATERIALS NEEDED

• One switch
• Three routers
• Appropriate network cables to connect routers to switch
CRITICAL TASKS STUDENTS MUST COMPLETE

- Perform basic router configuration to activate the router interfaces.
- Verify connectivity between all routers.
- Configure OSPF as the routing protocol for the single-area, multi-access network.
- Display the OSPF neighbors’ tables.
- Display the OSPF topological database.
- Observe properties of OSPF processes for an interface.
- Observe the metric used by OSPF.
- Configure OSPF timer values and observe their effect on the OSPF process.
- Configure priorities and observe their effect on the DR/BDR election.
- Observe and understand the DR/BDR election process.
- Configure and propagate a default route in OSPF.

FINDINGS

- OSPF is a link-state routing protocol, which makes use of three tables: neighbor table, topological database, and routing table. Each router receives link-state information for all other OSPF routers in its area, then creates its own map of the network. In a multi-access network, a DR and BDR are elected to minimize flooding of routing information within the OSPF area. While start times will have an effect on the election, typically the router with the highest priority will be elected DR (if priorities are the same, the router with the highest router ID is elected DR).

- OSPF uses cost as it metric, where cost is calculated from the link bandwidth (the faster the link, the lower the cost).

- OSPF uses various timers for sending hellos and determining whether an OSPF neighbor is active or not. Timer values must match for OSPF routers to form adjacencies.

ADDITIONAL INFORMATION

None
COMPUTER NETWORKING I
LAB 3.6-1 SINGLE-AREA OSPF NETWORK

PERFORMANCE OBJECTIVE

- Design a VLSM addressing scheme to meet requirements of a network.
- Perform basic router configuration including hostname and passwords for logging into user mode, privileged mode, and Telnet sessions.
- Configure and enable router interfaces to implement your VLSM addressing scheme.
- Configure network settings on your workstations.
- Verify connectivity between directly connected network devices.
- Configure OSPF as a routing protocol for the single-area network.
- Verify connectivity throughout the network.

LAB TYPE
Team

TIME REQUIRED
3 hours

INSTRUCTOR PREPARATION
None

BACKGROUND

OSPF is a link-state routing protocol. It shares routing information with all OSPF routers within an area so each router can generate a map of the entire OSPF network. OSPF makes use of three tables: neighbor table, topological database, and routing table. When an OSPF router first comes on line, there is a flood of traffic as route information is shared with the router. However, once the network reaches a steady-state, there is minimal routing information as routing updates are event-triggered (occurs only when there is a change in the network topology).

OSPF is a classless routing protocol that requires configuration of network, wildcard mask, and area.

OSPF supports CIDR and VLSM.

OSPF uses cost as its route metric.

SAFETY REQUIREMENTS
None

TEST EQUIPMENT
None
MATERIALS NEEDED

- Three routers with serial cables to connect them together
- Three workstations
- Appropriate cables to connect workstations to routers

CRITICAL TASKS STUDENTS MUST COMPLETE

- Design a VLSM addressing scheme to meet requirements of the network.
- Configure the router hostname.
- Configure router passwords for logging into user mode, privileged mode, and Telnet sessions.
- Configure workstations and routers to implement the VLSM addressing scheme.
- Configure OSPF as the routing protocol for the single-area network.
- Configure and propagate a default route in OSPF.
- Observe OSPF metric value for a link.
- Observe OSPF routes, admin distance, and metrics in the routing table.
- Verify connectivity throughout the network.

FINDINGS

- OSPF is a classless link-state routing protocol that supports both CIDR and VLSM.
- Configuration of OSPF first requires enabling OSPF and a process-id. For the network command, the network, wildcard mask, and area must be specified.
- OSPF uses cost as the route metric. Cost is determined from the link bandwidth.
- OSPF routes have an admin distance of 110.
- A default route propagated in OSPF is considered an external OSPF route. There are two types of external routes in OSPF (Type 1 and Type 2). Depending on the type, the cost metric is determined differently.

ADDITIONAL INFORMATION

None
COMPUTER NETWORKING II
COURSE DESIGN GUIDE

COURSE TITLE
Computer Networking II

CATALOG DESCRIPTION
This course covers the basics of local area network (LAN) switching, wireless communications, and accessing wide area networks (WANs). Concepts in hierarchical LAN design, virtual LANs, basic wireless configurations form the basis of the network. Included are advanced topics in WAN converged applications, quality of service (QoS), and point-to-point (PPP) protocols.

CREDITS
3.0 credits, 48 hours

COURSE FORMAT
This is a lecture format course.

COURSE NUMBER
Material for this course is presented to meet the requirements for a 200-level undergraduate course in Applied Science or the Career Technical Education program.

PREREQUISITES
Completion of Computer Networking I or equivalent.

INSTRUCTOR INFORMATION
Recommended Qualifications: A Master’s Degree or higher in Computer Science, Computer Networking, or related field, with CCNA/CCNP certification. Three to five years work experience in a related field. Working knowledge and background in utility industry networking. Experience teaching post-secondary/adult students.

TEACHING METHODS AND ASSIGNMENTS FOR ACHIEVING LEARNING OUTCOMES
The course material is presented in a lecture format that achieves the course learning objectives. Each topic lists suggested time allocation. Total time allocated includes a course introduction, midterm exams, final exam review, and final exam.

STUDENT TEXTS, READING AND OTHER MATERIALS

- Dye, Mark, Rick McDonald, and Anton Rufi. *Network Fundamentals, CCNA Exploration Companion Guide*. Indianapolis: Cisco Press, 2008. Print. This is a hard copy version of the material for the first half of the course.


BIBLIOGRAPHY


  (also online www.chipkin.com)


  <www.petri.co.il/csc_setup_a_vlan_on_a_cisco_switch.htm>.

STUDENT LEARNING OUTCOMES

Upon successful completion the student will have the ability to:

• Explain elements of hierarchical LAN design
• Explain the functions of switching in a LAN
• Describe virtual LANs (VLANs)
• Describe wireless operation in a LAN
• Describe key WAN technology concepts
• Describe the role, benefits, and features of DNP3
• Describe the fundamental concepts and message structure of DNP3
• Explain the purpose of access control lists (ACLs)
• Describe operation of VPNs
• Explain features of DHCP and NAT
## ASSESSMENT RUBRIC

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<tr>
<td>Wireless operations in a LAN</td>
<td>Shows complete knowledge and understanding of wireless operations in a LAN</td>
<td>Shows sound knowledge and understanding of wireless operations in a LAN</td>
<td>Shows limited knowledge and understanding of wireless operations in a LAN</td>
<td>Shows little to no knowledge and understanding of wireless operations in a LAN</td>
</tr>
<tr>
<td>DNP3 (Distributed Network Protocol version 3)</td>
<td>Shows complete knowledge and understanding of DNP3</td>
<td>Shows sound knowledge and understanding of DNP3</td>
<td>Shows limited knowledge and understanding of DNP3</td>
<td></td>
</tr>
<tr>
<td>ACLs (Access Control Lists)</td>
<td>Demonstrates thorough knowledge of ACLs</td>
<td>Demonstrates ample knowledge of ACLs</td>
<td>Demonstrates essential knowledge of ACLs</td>
<td>Demonstrates fundamental knowledge of ACLs</td>
</tr>
<tr>
<td>VPNs (Virtual Private Networks)</td>
<td>Exhibits superior knowledge of VPNs</td>
<td>Exhibits adequate knowledge of VPNs</td>
<td>Exhibits essential knowledge of VPNs</td>
<td>Exhibits limited knowledge of VPNs</td>
</tr>
<tr>
<td>DHCP and NAT</td>
<td>Illustrates excellent knowledge, understanding, and application of DHCP and NAT</td>
<td>Illustrates average knowledge, understanding, and application of DHCP and NAT</td>
<td>Illustrates low-level knowledge, understanding, and application of DHCP and NAT</td>
<td>Illustrates limited knowledge, understanding, and application of DHCP and NAT</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 1: SWITCHING

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.1 LAN Design; Hierarchical Core-Distribution-Access Layer Model</strong>&lt;br&gt;Lecture - 2 hrs.</td>
<td>The student will be able to:&lt;br&gt;• Describe the functions of each of the three levels in the hierarchical LAN design&lt;br&gt;• Describe how a hierarchical network supports the concept of a converged network</td>
</tr>
<tr>
<td><strong>1.2 Basic Switch Concepts</strong>&lt;br&gt;Lecture - 3 hrs.</td>
<td>The student will be able to:&lt;br&gt;• Describe switch forwarding methods&lt;br&gt;• Describe the difference between symmetric and asymmetric switching&lt;br&gt;• Explain the use of memory buffering in switch operation&lt;br&gt;• Explain the difference in operations of Layer 2 and Layer 3 switches</td>
</tr>
<tr>
<td><strong>1.3 Virtual LANs (VLANs)</strong>&lt;br&gt;Lecture - 4 hrs.</td>
<td>The student will be able to:&lt;br&gt;• Describe the role of VLANs in the network&lt;br&gt;• Describe types of VLANs used in modern switched networks, including default VLAN, user/data VLANs, native VLANs, management VLAN, and voice VLANs&lt;br&gt;• Describe the function of &quot;trunking&quot; VLANs</td>
</tr>
<tr>
<td><strong>1.4 Spanning Tree Protocol (STP) (IEEE 802.1d)</strong>&lt;br&gt;Rapid Spanning Tree Protocol (RSTP) (IEEE 802.1w)&lt;br&gt;Lecture - 1 hr.</td>
<td>The student will be able to:&lt;br&gt;• Explain the role of redundancy in a network&lt;br&gt;• Explain how Spanning Tree Protocol allows use of redundant physical links in a switched LAN</td>
</tr>
<tr>
<td><strong>1.5 Inter-VLAN Routing:</strong>&lt;br&gt;Traditional Inter-VLAN Routing&lt;br&gt;Router-On-A-Stick Inter-VLAN Routing&lt;br&gt;Lecture - 3 hrs.</td>
<td>The student will be able to:&lt;br&gt;• Describe traditional methods for routing traffic between different VLANs&lt;br&gt;• Describe router-on-a-stick</td>
</tr>
<tr>
<td><strong>1.6 Basic Wireless Concepts</strong>&lt;br&gt;Lecture - 3 hrs.</td>
<td>The student will be able to:&lt;br&gt;• Describe Wireless LAN standards&lt;br&gt;• Describe the components and basic operation of a wireless network&lt;br&gt;• Explain the security considerations for disabling SSID broadcasts, MAC filtering, WPA2&lt;br&gt;• Explain the operation of 802.1X authentication</td>
</tr>
</tbody>
</table>

Notes:
### UNIT 2: WAN AND SCADA PROTOCOLS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2.1 Introduction to WANs</strong>&lt;br&gt;Lecture - 1 hr.</td>
<td>The student will be able to:&lt;br&gt;- Describe key WAN technology concepts&lt;br&gt;- Select the appropriate WAN technology to meet different enterprise business requirements</td>
</tr>
<tr>
<td><strong>2.2 PPP</strong>&lt;br&gt;Lecture - 2 hrs.</td>
<td>The student will be able to:&lt;br&gt;- Describe the fundamental concepts of point-to-point serial communication&lt;br&gt;- Describe important PPP concepts&lt;br&gt;- Explain the difference between PAP and CHAP authentication</td>
</tr>
<tr>
<td><strong>2.3 SCADA Protocols: DNP3 (Distributed Network Protocol)</strong>&lt;br&gt;Lecture - 7 hrs.</td>
<td>The student will be able to:&lt;br&gt;- Describe the role, benefits and features of DNP3&lt;br&gt;- Describe DNP3 fundamental concepts and message structure&lt;br&gt;- Describe features of DNP3 Physical layer&lt;br&gt;- Describe features of DNP3 Data Link layer&lt;br&gt;- Describe features of DNP3 Transport layer&lt;br&gt;- Describe DNP3 Application layer message handling and functions</td>
</tr>
<tr>
<td><strong>2.4 SCADA Protocols: IEC 60870-5</strong>&lt;br&gt;Lecture - 6 hrs.</td>
<td>The student will be able to:&lt;br&gt;- Describe IEC 60870-5 standards and system topology&lt;br&gt;- Describe the message structure and addressing of IEC 60870-5&lt;br&gt;- Describe IEC 60870-5 application data objects and interoperability&lt;br&gt;- Describe IEC 60870-5 protocol architecture&lt;br&gt;- Describe features of the IEC 60870-5 physical layer&lt;br&gt;- Describe features of the IEC 60870-5 data link layer&lt;br&gt;- Describe features of the IEC 60870-5 application layer&lt;br&gt;- Describe IEC 60870-5 information elements</td>
</tr>
</tbody>
</table>

Notes:
<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3.1 Network Security</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 3 hrs.</td>
<td>• Identify security threats to enterprise networks</td>
</tr>
<tr>
<td></td>
<td>• Describe methods to mitigate security threats</td>
</tr>
<tr>
<td><strong>3.2 Access Control Lists</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 4 hrs.</td>
<td>• Explain how ACLs are used to control access</td>
</tr>
<tr>
<td></td>
<td>• Explain packet filtering</td>
</tr>
<tr>
<td></td>
<td>• Explain the purpose of ACLs</td>
</tr>
<tr>
<td><strong>3.3 IP Addressing Services – DHCP</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td>• Explain DHCP features and benefits</td>
</tr>
<tr>
<td></td>
<td>• Describe DHCP operation</td>
</tr>
<tr>
<td><strong>3.4 NAT</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Explain key features and operation of NAT</td>
</tr>
<tr>
<td></td>
<td>• Explain the difference between NAT and NAT Overload</td>
</tr>
<tr>
<td></td>
<td>• Explain advantages and disadvantages of NAT</td>
</tr>
<tr>
<td><strong>3.5 IP Addressing Services - IPv6</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Explain how IPv6 solves problems of IP address deletion</td>
</tr>
<tr>
<td></td>
<td>• Explain how IPv6 addresses are assigned</td>
</tr>
<tr>
<td></td>
<td>• Describe transition strategies for implementing IPv6</td>
</tr>
<tr>
<td><strong>3.6 Teleworker Services</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 4 hrs.</td>
<td>• Describe enterprise requirements for providing teleworker services in both</td>
</tr>
<tr>
<td></td>
<td>• Describe teleworker requirements and recommended architecture for providing</td>
</tr>
<tr>
<td></td>
<td>• Explain how enterprise networks are extended by broadband services such as</td>
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<td></td>
<td>• Describe properties of a VPN</td>
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<tr>
<td></td>
<td>• Explain the benefits of VPN technology</td>
</tr>
<tr>
<td></td>
<td>• Describe how VPN technology can be used to provide secure teleworker services</td>
</tr>
<tr>
<td></td>
<td>to an enterprise network</td>
</tr>
</tbody>
</table>

Notes:
FUNDAMENTALS OF INDUSTRIAL AND UTILITY SECURITY
COURSE DESIGN GUIDE

COURSE TITLE
Fundamentals of Industrial and Utility Security

CATALOG DESCRIPTION
This course will provide the student with an overview of security policies and protocols that are common to the utility industry. Students will learn the concepts of risk and threat management as they are presented on the physical, personnel, asset, information, and cyber layers within a utility infrastructure. This course introduces integrated solutions that will meet present and future security challenges of power utilities with an emphasis placed on control systems. Course topics include relevant case studies that are available through NIST and EPRI documentation. Application of protocols and procedures will be facilitated through a course final project that focuses on developing a comprehensive security framework to satisfy proposed security threats that are identified through case studies.

CREDITS
3.0 credits, 48 hours

COURSE FORMAT
This course is a lecture format, and reading and writing intensive, with a project-based final assessment.

COURSE NUMBER
Material for this course is presented to meet the requirements for a 200-level course.

PREREQUISITES
Intelligent Energy Systems Architecture, Computer Networking I and II.

INSTRUCTOR INFORMATION
Recommended Qualifications: A Master’s Degree or higher in Computer Information Systems, ICS, or a related field. Security+ certification recommended. Three to five years work experience in security related field. Working knowledge and background in utility security. Experience teaching post-secondary/adult students.

TEACHING METHODS AND ASSIGNMENTS FOR ACHIEVING LEARNING OUTCOMES
This course is divided and organized according to topic units and the recommended hourly time allotment for each unit. Instructor lecturers, class discussions, and student research/independent learning methods are the main teaching methods. Problem-based (case studies) group scenarios can be incorporated and assigned to greater facilitate a professional working environment in order to achieve the student learning outcomes. An individual student “end-to-end” final project is recommended as a tool to assess student learning and application of the course curriculum.
STUDENT TEXTS, READING AND OTHER MATERIALS


BIBLIOGRAPHY


STUDENT LEARNING OUTCOMES

Upon successful completion of this course students will be able to:

- Explain deterrent and mitigation techniques that are applied to various types of security attacks on industrial control systems
- Determine, and explain appropriate security awareness, training, and incident response procedures as they relate to risk/threat management and business continuity
- Examine and discuss the design of networks to establish the security protocols necessary to cyber network technologies
- Assess and explain security issues related to Industrial Control Systems, SCADA, and smart grid cyber security
- Evaluate and discuss cryptographic tools, products, and security services as they relate to authentication, account management, and public key infrastructure
## ASSESSMENT RUBRIC

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>EXEMPLARY 4</th>
<th>SATISFACTORY 3</th>
<th>DEVELOPING 2</th>
<th>BEGINNING 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Various security attacks, applicable deterrents and mitigation techniques</td>
<td>Exhibits superior understanding and application of deterrent and mitigation techniques towards security attacks</td>
<td>Exhibits average understanding and application of deterrent and mitigation techniques towards security attacks</td>
<td>Exhibits essential understanding and application of deterrent and mitigation techniques towards security attacks</td>
<td>Exhibits limited or no understanding and application of deterrent and mitigation techniques towards security attacks</td>
</tr>
<tr>
<td>Security awareness, training, and incident response procedures for risk/threat management</td>
<td>Demonstrates exceptional knowledge and background in security awareness, training, and incident response</td>
<td>Demonstrates acceptable knowledge and background in security awareness, training, and incident response</td>
<td>Demonstrates low level knowledge and background in security awareness, training, and incident response</td>
<td>Demonstrates foundational knowledge and background in security awareness, training, and incident response</td>
</tr>
<tr>
<td>Network design, security protocols, and cyber network technologies</td>
<td>Illustrates clear understanding of network design, security protocols, and cyber network technologies</td>
<td>Illustrates competent understanding of network design, security protocols, and cyber network technologies</td>
<td>Illustrates primary understanding of network design, security protocols, and cyber network technologies</td>
<td>Illustrates fundamental understanding of network design, security protocols, and cyber network technologies</td>
</tr>
<tr>
<td>Security issues: industrial control systems, SCADA, smart grid</td>
<td>Shows excellent knowledge and understanding of security issues related to industrial controls, SCADA, and smart grid systems</td>
<td>Shows sound knowledge and understanding of security issues related to industrial controls, SCADA, and smart grid systems</td>
<td>Shows formative knowledge and understanding of security issues related to industrial controls, SCADA, and smart grid systems</td>
<td>Shows limited or no knowledge and understanding of security issues related to industrial controls, SCADA, and smart grid systems</td>
</tr>
<tr>
<td>Cryptography, security services, authentication, account management, and public key infrastructure</td>
<td>Demonstrates superior knowledge and application of cryptography towards authentication, account management, and public key infrastructure</td>
<td>Demonstrates strong knowledge and application of cryptography towards authentication, account management, and public key infrastructure</td>
<td>Demonstrates essential knowledge and low level application of cryptography towards authentication, account management, and public key infrastructure</td>
<td>Demonstrates limited knowledge and limited application of cryptography towards authentication, account management, and public key infrastructure</td>
</tr>
</tbody>
</table>

Notes:
### UNIT 1: INDUSTRIAL CONTROL SYSTEMS SECURITY

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
</table>
| 1.1 Risk Management | The student will be able to:  
  - Describe the fundamental concepts of security  
  - Explain concepts in risk management as related to Industrial Control Systems  
  - Describe the importance of policies in risk management  
  - Describe vulnerabilities and threats |
| Lecture - 4 hrs. | |
| 1.2 Control Types | The student will be able to:  
  - Describe security control classes (management, technical, operational and physical)  
  - Describe security control baselines  
  - Describe common security control types  
  - Describe security controls in external environments  
  - Describe security control assurance |
| Lecture - 4 hrs. | |
| 1.3 Control System Architecture | The student will be able to:  
  - Describe a typical contemporary Industrial Control System Architecture  
  - Describe the security challenges within Industrial Control Systems  
  - Describe Defense-in-Depth strategies for isolating and protecting assets  
  - Describe security controls (countermeasures) for Industrial Control Systems |
| Lecture - 4 hrs. | |
| 1.4 SCADA Security | The student will be able to:  
  - Describe a typical SCADA network architecture  
  - Describe connections into a SCADA network  
  - Apply SCADA specific security administration  
  - Describe a SCADA security policy framework  
  - Incorporate security controls (countermeasures) for a SCADA System |
| Lecture - 4 hrs. | |
| 1.5 Fundamentals of Industrial and Utility Security | The student will be able to:  
  - Describe the logical architecture and the interfaces of a smart grid environment  
  - Explain the high-level security requirements for securing a smart grid infrastructure  
  - Describe security controls (countermeasures) for a smart grid system  
  - Describe smart grid cryptography and key management issues  
  - Describe smart grid privacy issues  
  - Describe vulnerability classes and a security analysis of a smart grid system |
| Lecture - 4 hrs. | |
| 1.6 Case Study Analysis and Recommended Security Measures | The student will be able to:  
  - Develop a systematic approach to solving a problem  
  - Research information from technical documents related to Industrial Control Systems  
  - Prepare a document according to technical standards |
| Lecture - 4 hrs. | |

Notes:
## UNIT 2: NETWORK SECURITY

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2.1 Network Security</strong></td>
<td>The student will be able to:                                                                                       • Explain the security function and purposes of network devices and technologies</td>
</tr>
<tr>
<td><strong>Lecture - 6 hrs.</strong></td>
<td>• Describe secure network administration principles</td>
</tr>
<tr>
<td></td>
<td>• Distinguish and differentiate network design elements and compounds</td>
</tr>
<tr>
<td></td>
<td>• Describe the usage of common networking protocols</td>
</tr>
<tr>
<td></td>
<td>• Identify commonly used default network ports</td>
</tr>
<tr>
<td></td>
<td>• Describe solutions for securing a wireless deployment</td>
</tr>
<tr>
<td><strong>2.2 Cryptography</strong></td>
<td>The student will be able to:                                                                                       • Explain general cryptography concepts as they apply to security</td>
</tr>
<tr>
<td><strong>Lecture - 3 hrs.</strong></td>
<td>• Describe the usage of appropriate cryptographic tools and products</td>
</tr>
<tr>
<td></td>
<td>• Explain the core concepts of the public key infrastructure</td>
</tr>
<tr>
<td><strong>2.3 Compliance and Operational Security</strong></td>
<td>The student will be able to:                                                                                       • Describe appropriate incident response procedures</td>
</tr>
<tr>
<td><strong>Lecture - 5 hrs.</strong></td>
<td>• Explain the importance of security related awareness and training</td>
</tr>
<tr>
<td></td>
<td>• Compare and contrast aspects of business continuity</td>
</tr>
<tr>
<td></td>
<td>• Explain the impact and proper use of environmental controls</td>
</tr>
<tr>
<td></td>
<td>• Describe disaster recovery plans and procedures</td>
</tr>
<tr>
<td><strong>2.4 Threats and Vulnerabilities</strong></td>
<td>The student will be able to:                                                                                       • Analyze and differentiate among types of attacks</td>
</tr>
<tr>
<td><strong>Lecture - 5 hrs.</strong></td>
<td>• Analyze and differentiate among types of mitigation and deterrent techniques</td>
</tr>
<tr>
<td></td>
<td>• Describe assessment tools and techniques used to discover security threats</td>
</tr>
<tr>
<td></td>
<td>• Describe the process and proper use of penetration testing</td>
</tr>
<tr>
<td><strong>2.5 Application, Data, and Host Security</strong></td>
<td>The student will be able to:                                                                                       • Explain the concept and importance of application security</td>
</tr>
<tr>
<td><strong>Lecture - 3 hrs.</strong></td>
<td>• Describe appropriate procedures to establish host security</td>
</tr>
<tr>
<td></td>
<td>• Explain the importance of data security</td>
</tr>
<tr>
<td><strong>2.6 Access Control and Identity Management</strong></td>
<td>The student will be able to:                                                                                       • Explain the function of authentication services</td>
</tr>
<tr>
<td><strong>Lecture - 2 hrs.</strong></td>
<td>• Explain the concept and best practices as related to authentication,</td>
</tr>
<tr>
<td></td>
<td>authorization and access control</td>
</tr>
</tbody>
</table>

Notes:
FUNDAMENTALS OF SAFETY, HEALTH, AND ENVIRONMENT
COURSE DESIGN GUIDE

COURSE TITLE
Fundamentals of Safety, Health, and Environment

CATALOG DESCRIPTION
The Fundamentals of Safety, Health, and Environment course emphasizes the knowledge and skills to reinforce attitudes and behaviors required for safe and environmentally sound work habits. Coursework, demonstrations, and exercises highlight the importance of regulatory compliance issues to be addressed in the performance of all job tasks. Course topics are to be reinforced by scenarios performed at the campus as well as industrial sites as available.

CREDITS
3.0 credits, 48 hours

COURSE FORMAT
This course is a lecture format that incorporates in-class demonstrations and activities.

COURSE NUMBER
Material for this course is presented to meet the requirements for a 200-level course.

PREREQUISITES
The recommended prerequisite for this course is the successful completion of a college level reading and writing course such as a 100-level Technical/Professional Writing or English Composition.

INSTRUCTOR INFORMATION
Recommended Qualifications: A Master’s Degree in Occupational Safety and three to five years experience teaching post-secondary industrial safety, occupational safety, or equivalent. Working knowledge of content, curriculum, methods, materials, and equipment in the career technical specialty of the course: Process Technology, Energy Technology, Advanced Manufacturing.

TEACHING METHODS AND ASSIGNMENTS FOR ACHIEVING LEARNING OUTCOMES
The course is divided into five learning units; each learning unit addresses a specific safety concept as well as topics with direct application to industry or technology. Each topic has a recommended length (topic hours) assigned. Topic hours are a guideline for instruction that can be adapted to the individual instructor’s teaching style. Included in the instructional materials are example worksheets, homework assignments, and quizzes. Students are expected to spend additional study/practice time outside of the class time. The generally accepted ratio of class to study time is 3:1 for this course.

The course material is presented in a lecture format to achieve the course learning objectives. Each topic lists suggested time allocation. Total time allocated includes an hour course introduction, a 2-hour review, and a 2-hour written exam.

STUDENT TEXTS, READING AND OTHER MATERIALS


**ADDITIONAL REFERENCES**

• Code of Federal Regulations (CFR) TITLE 29-Labor, Part 1910- Occupational Safety and Health Standards

• Subpart R-Special Industries §1910.269 & Subpart S-Electrical §1910.301-399

• ANSI/ASSE Z244.1–2003 Control of Hazardous Energy Lockout/Tagout and Alternative Methods


**STUDENT LEARNING OUTCOMES**

Upon successful completion the student will have the ability to:

• Anticipate, recognize, and evaluate potential hazards to people, property, and the environment with respect to risk and regulatory requirements

• Control potential and existing hazards to people, property, and the environment to achieve acceptable levels of risk or meet regulatory requirements

• Manage and communicate safety, health, and environmental information to peers and stakeholders

• Function as a member of the safety professional community, with a commitment to continuing professional growth

• Acknowledge the standards of professional conduct that are published by professional safety organizations and/or certification bodies
# ASSESSMENT RUBRIC

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>EXEMPLARY 4</th>
<th>SATISFACTORY 3</th>
<th>DEVELOPING 2</th>
<th>BEGINNING 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anticipate recognize, and evaluate potential hazards</strong></td>
<td>Actively looks for, recognizes, and suggests solutions to potential safety hazards</td>
<td>Refines solutions suggested by others</td>
<td>Does not suggest or refine solutions, but is willing to try out solutions suggested by others</td>
<td>Does not try to solve problems or help others solve problems, letting others do the work</td>
</tr>
<tr>
<td><strong>Control potential and existing hazards</strong></td>
<td>Consistently stays focused on the task and what needs to be done, and is self-directed</td>
<td>Focuses on the task and what needs to be done most of the time, and other group members can count on this person</td>
<td>Focuses on the task and what needs to be done some of the time, and other group members must sometimes nag, prod, and remind this person to keep on-task</td>
<td>Rarely focuses on the task and what needs to be done, letting others do the work</td>
</tr>
<tr>
<td><strong>Safety Communications</strong></td>
<td>Routinely provides useful ideas when participating in the group and in classroom discussion, and is a definite leader who contributes a lot of effort</td>
<td>Usually provides useful ideas when participating in the group and in classroom discussion, and is a strong group member who tries hard</td>
<td>Sometimes provides useful ideas when participating in the group and in classroom discussion, and is a satisfactory group member who does what is required</td>
<td>Rarely provides useful ideas when participating in the group and in classroom discussion, and may refuse to participate</td>
</tr>
<tr>
<td><strong>Team Approach</strong></td>
<td>Almost always listens to, shares with, and supports the efforts of others, and tries to keep people working well together</td>
<td>Usually listens to, shares with, and supports the efforts of others, and does not cause &quot;waves&quot; in the group</td>
<td>Often listens to, shares with, and supports the efforts of others, but sometimes is not a good team member</td>
<td>Rarely listens to, shares with, and supports the efforts of others, but often is not a good team player</td>
</tr>
<tr>
<td><strong>Ability to understand and adhere to published standards of conduct</strong></td>
<td>Provides work of the highest quality and always meets the published standards</td>
<td>Provides high quality work and mostly meets the published standards</td>
<td>Provides work that occasionally needs to be checked/redone by other group members to ensure quality</td>
<td>Provides work that usually needs to be checked/redone by others to ensure quality</td>
</tr>
</tbody>
</table>

Assessment: Assignments, testing and student participation should be taken into consideration when instructors develop individual grading policies. The above assessment rubric specifically addresses the learning outcomes of the course. This is intended to be a tool to assess and assign a value to the achievement of the stated learning outcomes.

Notes:
## UNIT 1: SAFETY REGULATIONS AND THE INDUSTRIAL ENVIRONMENT

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Regulatory Awareness</td>
<td>The student will be able to:</td>
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<tr>
<td></td>
<td>• Explain how electric shock, and other industrial incidents have impacted safety, health, and the environment regulation in industry</td>
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<td></td>
<td>• Explain the necessity of occupational safety regulations</td>
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<tr>
<td></td>
<td>• Describe governmental agencies and regulations that address safety, health, and environmental issues including:</td>
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<tr>
<td></td>
<td>• OSHA</td>
</tr>
<tr>
<td></td>
<td>• Environmental Protection Agency</td>
</tr>
<tr>
<td></td>
<td>• Department of Transportation</td>
</tr>
<tr>
<td></td>
<td>• Nuclear Regulatory Commission</td>
</tr>
<tr>
<td></td>
<td>• United Nations Standard</td>
</tr>
<tr>
<td></td>
<td>• Describe Industry group and voluntary standards for safety, health, and environmental issues</td>
</tr>
<tr>
<td></td>
<td>• Describe the overall effect on the worker and impact that regulation has on the work environment</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 2: HAZARDS AND THEIR EFFECTS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Hazards and Effects</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td>• Identify the various chemical hazards (gases, liquids, and particulates)</td>
</tr>
<tr>
<td></td>
<td>found in the various industries and discuss potential effects such</td>
</tr>
<tr>
<td></td>
<td>chemicals have on safety, health, and the environment</td>
</tr>
<tr>
<td></td>
<td>• Identify specific categories of hazardous chemicals used in various</td>
</tr>
<tr>
<td></td>
<td>industries and describe the potential health and environmental hazards</td>
</tr>
<tr>
<td></td>
<td>posed by each</td>
</tr>
<tr>
<td></td>
<td>• Explain the purpose and function of hazardous material labeling systems</td>
</tr>
<tr>
<td></td>
<td>• Show understanding of the purpose and components of an MSDS</td>
</tr>
<tr>
<td></td>
<td>• Describe the primary governmental regulations relating to chemical</td>
</tr>
<tr>
<td></td>
<td>hazards</td>
</tr>
<tr>
<td>2.2 Recognize Chemical Hazards</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td>• Identify the various chemical hazards (gases, liquids, and particulates)</td>
</tr>
<tr>
<td></td>
<td>and discuss potential effects they have on the work environment</td>
</tr>
<tr>
<td></td>
<td>• Identify specific categories of hazardous chemicals and describe the</td>
</tr>
<tr>
<td></td>
<td>potential health, and environmental hazards posed by each</td>
</tr>
<tr>
<td>2.3 Recognize Biological Hazards</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Identify potential biological hazards and discuss their potential</td>
</tr>
<tr>
<td></td>
<td>effects on safety, health, and the environment</td>
</tr>
<tr>
<td></td>
<td>• Identify and understand how blood-borne pathogens can affect the human</td>
</tr>
<tr>
<td></td>
<td>body</td>
</tr>
<tr>
<td></td>
<td>• Describe governmental regulations and industry guidelines that address</td>
</tr>
<tr>
<td></td>
<td>biological hazards</td>
</tr>
</tbody>
</table>

Notes:
# UNIT 2: HAZARDS AND THEIR EFFECTS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2.4 Recognize Equipment and Energy Hazards</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Discuss the equipment and energy hazards posed by certain activities performed in an industrial environment, including</td>
</tr>
<tr>
<td></td>
<td>- Working with moving or rotating equipment</td>
</tr>
<tr>
<td></td>
<td>- Working with equipment that is pressurized, has elevated temperatures, or emits radiation</td>
</tr>
<tr>
<td></td>
<td>- Working with energized equipment (powered by electricity or other power sources)</td>
</tr>
<tr>
<td><strong>2.5 Fire and Explosion Hazards</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Recognize specific physical hazards present in an industrial environment and explain the potential Fundamentals of Safety, Health, and Environmental hazards posed by fire, explosion, and detonation</td>
</tr>
<tr>
<td></td>
<td>• Explain the characteristics of fire using the fire triangle, fire tetrahedron, the chain reaction, and role of free radicals in combustion</td>
</tr>
<tr>
<td></td>
<td>• Identify specific sources of fuel, heat, and oxygen that are present in an industrial environment</td>
</tr>
<tr>
<td></td>
<td>• Identify various sources of heat transfer</td>
</tr>
<tr>
<td></td>
<td>• Identify and understand the classes of fire and the methods used to extinguish fires of different classes</td>
</tr>
<tr>
<td><strong>2.6 Atmospheric Hazards</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Identify pressure temperature and radiation hazards</td>
</tr>
<tr>
<td></td>
<td>• Identify respiration hazards</td>
</tr>
<tr>
<td></td>
<td>• Discuss height hazards and fall protection</td>
</tr>
</tbody>
</table>

Notes:
### UNIT 3: CONTROL OF HAZARDS IN AN INDUSTRIAL ENVIRONMENT

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
</table>
| **3.1 Engineering and Administrative Controls**  
Lecture - 5 hrs. | The student will be able to:  
- Discuss various administrative control program elements that are both voluntary and mandatory  
- Describe common administrative hazard-control activities in industrial organizations  
- Identify various engineering controls, specifically alarm and indication systems used in an industrial environment to minimize threats including Fire Alarms/Detection Systems and Toxic Gas Alarms/Detection Systems  
- Identify and understand the purpose and requirements for Redundant Alarm and Shutdown Devices, Automatic Shutdown Devices, and Interlocks  
- Explain typical actions required by personnel when alarms occur  
- Explain the main types of alarm systems and how they operate  
- Recognize various engineering controls, specifically process containment and control systems used in an industrial environment to minimize and/or eliminate threats to health and safety  
- Describe various engineering controls, specifically process upset control systems used in an industrial environment to minimize and/or eliminate threats to health and safety  
- Describe the function and purpose of permitting systems  
- Conduct a job safety analysis and complete a safe work permit to ensure the work environment is safe prior allowing workers to work in a specific area  
- Use locks, tags, and blinds to isolate a piece of equipment  
- List the six steps used when locking out/tagging out an electrical circuit |
| **3.2 Personal Protective Equipment (PPE)**  
Lecture - 4 hrs. | The student will be able to:  
- Discuss the function and purpose of Personal Protective Equipment (PPE) used in an industrial environment  
- Describe the levels of protection for the listed PPE  
- Demonstrate the ability to determine the proper PPE for a specific level of protection  
- Demonstrate the use and care of listed PPE  
  - Respiratory protection  
  - Eye protection  
  - Hearing protection  
  - Head protection  
  - Hand protection  
  - Foot protection  
  - Skin protection |
| **3.3 Monitoring Equipment**  
Lecture - 1 hr. | The student will be able to:  
- Explain the function and purpose of testing equipment used in an industrial environment  
  - LEL/O2 meters  
  - Gas detection equipment  
  - Personal monitoring devices  
  - Detector tubes  
- Demonstrate use of an LEL/O2 meter to test a confined space prior to entry |
## UNIT 4: ELECTRICAL SAFETY

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4.1 Electrical Safety Regulations</strong> Lecture - 6 hrs.</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Understand the role of the Occupational Safety and Health Administration (OSHA) and National Fire Protection Association (NFPA) in Electrical Safety Standards</td>
</tr>
<tr>
<td></td>
<td>• Understand the purpose and function of the National Electrical Code® (NEC®) and how it is applied at both national and state level</td>
</tr>
<tr>
<td></td>
<td>• Describe the designation of a “Qualified Person” and the roles and responsibilities of a person with the designation</td>
</tr>
<tr>
<td></td>
<td>• Describe Safety Labels and how they are utilized to indicate degrees of danger to personnel, including signal words, colors, shapes, and symbols</td>
</tr>
<tr>
<td></td>
<td>• Describe the International Electro-technical Commission (IEC) 1010 Safety Standard</td>
</tr>
<tr>
<td><strong>4.2 Electrical Shock</strong> Lecture - 3 hrs.</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Explain the reasons for and methods of electric shock</td>
</tr>
<tr>
<td></td>
<td>• State the effects on the body of receiving different levels of shock current</td>
</tr>
<tr>
<td><strong>4.3 Grounding</strong> Lecture - 3 hrs.</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• State the reason for grounding and how grounding is used to prevent or minimize electric shock</td>
</tr>
<tr>
<td></td>
<td>• State what the correct reading should be when using a DMM to make sure an electrical system is properly grounded</td>
</tr>
<tr>
<td><strong>4.4 Arc Flash Safety</strong> Lecture - 6 hrs.</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Describe Ground Fault Circuit Interrupters (GFCI)</td>
</tr>
<tr>
<td></td>
<td>• Draw schematic diagrams of the three most common GFCI circuit configurations</td>
</tr>
<tr>
<td></td>
<td>• Understand voltage surge, transient voltage, and overvoltage</td>
</tr>
<tr>
<td></td>
<td>• Understand why power distribution systems are divided into different categories of overvoltage</td>
</tr>
<tr>
<td></td>
<td>• Interpret the IEC 1010 CAT I, CAT II, CAT III, and CAT IV overvoltage installation ratings and the use of DMM &amp; PEE for each category</td>
</tr>
<tr>
<td></td>
<td>• List the type of personal protective equipment (PPE) required to safely work in proximity to electrical circuits, including protective clothing, Arc blast protection, head protection, eye protection, ear protection, and hand protection</td>
</tr>
<tr>
<td></td>
<td>• Interpret arc flash and flame resistant protective equipment boundary charts and select the appropriate protective equipment</td>
</tr>
</tbody>
</table>

Notes:
FUNDAMENTALS OF ELECTRICITY AND ELECTRONICS

COURSE DESIGN GUIDE

COURSE TITLE
Fundamentals of Electricity and Electronics

CATALOG DESCRIPTION
This course introduces students to alternating and direct current electrical theory and the basic laws and formulas used to represent electrical concepts. The course includes circuit configurations, source, and load types, as well as the wiring configurations of common electrical devices. In context with the theoretical concepts are practical exercises on the proper use of tools and test equipment.

CREDITS
4.0 credits, 96 hours

COURSE FORMAT
This course is a lecture/lab format that incorporates related lab exercises and activities during in-class, instructor-supervised lab exercises.

COURSE NUMBER
Material for this course is presented to meet the requirements for a 100-level course. Additional mathematical concepts and formula derivation may be included to meet the requirements of 200-level courses.

PREREQUISITES
Applied Math, college Algebra, or equivalent.

COREQUISITE
Course may be taken concurrently with Applied Mathematics/College Algebra.

INSTRUCTOR INFORMATION
Recommended Qualifications: A Master’s Degree in Engineering, Mathematics, or Physics and three to five years experience teaching secondary or post-secondary mathematics. Instructors must have in-depth knowledge of the subject matter and the teaching skills to efficiently and effectively convey this knowledge to learners. Teaching skills involve using several instructional methods and resources to effectively transfer knowledge and skills from experience. The course will use working knowledge of content, curriculum, methods, materials, and equipment in the career technical specialty, such as Process Technology, Energy Technology, and Advanced Manufacturing. Experience and ability to plan and implement lessons based on objectives for career technical programs.

TEACHING METHODS AND ASSIGNMENTS FOR ACHIEVING LEARNING OUTCOMES:
The course is divided into six learning units; each learning unit addresses a specific topic with direct application to the fundamentals of electrical principles. Each topic has a recommended length (topic hours) assigned. Topic hours are a guideline for instruction that is intended to be adapted to the individual instructor’s teaching style. The ratio of lecture to lab is 1:3. Students are expected to spend additional study/practice time outside of the class time. The recommended ratio of class to study time is 1:4 for this course. Each topic lists suggested time allocation. Total time allocated includes an hour course introduction, a 2-hour review, and a 2-hour written exam.
STUDENT TEXTS, READING AND OTHER MATERIALS


BIBLIOGRAPHY


STUDENT LEARNING OUTCOMES

Upon successful completion of this course students will be able to:

- Analyze and apply the nature of electricity, and the quantities, units, and measurements associated with it
- Demonstrate the identification of the abbreviations, acronyms, and symbols of electrical components in an electrical circuit and the function of each one
- Manipulate equations and solve problems by the application of Ohm’s law
- Design appropriate process for making a measurement, demonstrating the safe work practices and proper use of digital and analog multimeters in making ohms, voltage, and current measurements
- Calculate the voltage, resistance, and current for series, parallel, and series/parallel circuits for DC circuits
- Apply the understanding of resistance, inductance, and capacitance to AC circuits, and its application to power loads
<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>EXEMPLARY 4</th>
<th>SATISFACTORY 3</th>
<th>DEVELOPING 2</th>
<th>BEGINNING 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyze and apply the nature of electricity and the quantities, units, and measurements associated with it</td>
<td>Explanation shows complete understanding of the electricity fundamentals used to solve the problem(s)</td>
<td>Explanation shows substantial understanding of the electricity fundamentals used to solve the problem(s)</td>
<td>Explanation shows some understanding of the electricity fundamentals needed to solve the problem(s)</td>
<td>Explanation shows very limited understanding of the underlying concepts needed to solve the problem(s)</td>
</tr>
<tr>
<td>Demonstrate the identification of the abbreviations, acronyms, and symbols of electrical components in an electrical circuit and the function of each one</td>
<td>Correct terminology and notation are always used, making it easy to understand what was done</td>
<td>Correct terminology and notation are usually used, making it fairly easy to understand what was done</td>
<td>Correct terminology and notation are used, but it is sometimes not easy to understand what was done</td>
<td>Little use, or inappropriate use, of terminology and notation</td>
</tr>
<tr>
<td>Manipulate equations and solve problems by the application of Ohm's law</td>
<td>Typically uses an efficient and effective strategy to solve the problem(s) that utilize Ohm's law</td>
<td>Typically uses an effective but not efficient strategy to solve the problem(s) that utilize Ohm's law</td>
<td>Sometimes uses an effective strategy to solve problems that utilize Ohm's law but not consistently</td>
<td>Rarely uses an effective strategy to solve problems that utilize Ohm's law</td>
</tr>
<tr>
<td>Design appropriate process for making a measurement, demonstrating safe work practices and proper use of digital and analog multimeters in making ohms, voltage and current measurements</td>
<td>Clear evidence of troubleshooting, testing, and refinements based on data or scientific principles; lab is carried out with full attention to relevant safety procedures; the set-up, experiment, and tear-down posed no safety threat to any individual</td>
<td>Clear evidence of troubleshooting, testing and refinements; lab is generally carried out with attention to relevant safety procedures; the set-up, experiment, and tear-down posed no safety threat to any individual, but one safety procedure needs to be reviewed</td>
<td>Some evidence of troubleshooting, testing and refinements; lab is carried out with some attention to relevant safety procedures; the set-up, experiment, and tear-down posed no safety threat to any individual, but several safety procedures need to be reviewed</td>
<td>Little evidence of troubleshooting, testing or refinement; safety procedures were ignored and/or some aspect of the experiment posed a threat to the safety of the student or others</td>
</tr>
<tr>
<td>Calculate the voltage, resistance, and current for series, parallel, and series/parallel circuits for DC circuits</td>
<td>Shows complete understanding of electrical principles used to solve multiple circuits (series, parallel, series/parallel)</td>
<td>Shows substantial understanding of the electrical principles used to solve multiple circuits (series, parallel, series/parallel)</td>
<td>Shows some understanding of the electrical principles needed to solve multiple circuits (series, parallel, series/parallel)</td>
<td>Shows very limited understanding of the underlying concepts needed to solve the multiple circuits (series, parallel, series/parallel)</td>
</tr>
<tr>
<td>Apply the understanding of resistance, inductance, and capacitance to AC circuits, and its application to power loads</td>
<td>Shows complete understanding of power loads</td>
<td>Shows substantial understanding of power loads</td>
<td>Shows some understanding of power loads</td>
<td>Shows very limited understanding of power loads</td>
</tr>
</tbody>
</table>
### UNIT 1: ELECTRICITY PRINCIPLES

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Electricity Principles</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 3 hrs.</td>
<td>• List and describe common forms of electricity</td>
</tr>
<tr>
<td></td>
<td>• Describe the fundamental properties of matter and atomic structure</td>
</tr>
<tr>
<td></td>
<td>• Describe the properties of conductors, insulators, and semiconductors</td>
</tr>
<tr>
<td></td>
<td>• Identify chemical elements that have special interest to the electrical field</td>
</tr>
<tr>
<td></td>
<td>• Identify applications where the electrical properties of compounds are important</td>
</tr>
<tr>
<td></td>
<td>• Describe the law of electric charges and common theories of current flow</td>
</tr>
<tr>
<td></td>
<td>• Describe common methods of electricity production</td>
</tr>
<tr>
<td>1.2 Basic Quantities</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 3 hrs.</td>
<td>• Describe the fundamental properties of energy</td>
</tr>
<tr>
<td></td>
<td>• List and describe common types of voltage</td>
</tr>
<tr>
<td></td>
<td>• Calculate common types of AC voltage values</td>
</tr>
<tr>
<td></td>
<td>• List and describe common types of current and current flow</td>
</tr>
<tr>
<td></td>
<td>• List and describe common types of power</td>
</tr>
<tr>
<td></td>
<td>• List and describe common types of circuit</td>
</tr>
<tr>
<td></td>
<td>• Calculate power factor</td>
</tr>
<tr>
<td></td>
<td>• Explain the function of resistance, conductors, and insulators in an electrical circuit</td>
</tr>
<tr>
<td></td>
<td>• Describe the properties of heat and heat measurement</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 2: SYMBOLS AND PRINT READING

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
</table>
| 2.1 Symbols     | **The student will be able to:**  
  - Demonstrate the proper identification and function of the abbreviations, acronyms, and symbols used to represent electrical components in an electrical circuit:  
    - Describe the characteristics and function of power sources, disconnects, and OCPDs (over-current protection devices)  
    - Describe the characteristics and function of contacts and control switches  
    - Describe the characteristics and function of relays and timers  
    - Describe the characteristics and function of contractors and motor starters  
    - Describe the characteristics and function of solenoids, resistors, thermistors, capacitors, and diodes  
    - Describe the characteristics and function of common electric switching devices  
    - Describe the characteristics and function of digital logic gates  
    - Describe the characteristics and function of coils and transformers  
    - Describe the characteristics and function of common types of motors  
    - Describe the characteristics and function of lights, alarms, meters, and general wiring  
  - Describe the function of symbols in process control and instrumentation drawings  
  - Define and describe the use of symbols on plans and drawings  

| 2.2 Print Reading | **The student will be able to:**  
  - Apply understanding of symbols and plans to determine the function of systems represented on prints  |

Notes:
### UNIT 3: OHM’S LAW AND POWER FUNCTIONS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Ohm’s Law and the Power Formula</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Calculate voltage, current, and resistance using Ohm’s law</td>
</tr>
<tr>
<td></td>
<td>• Explain the voltage/current relationship and the current/resistance relationship according to Ohm’s law</td>
</tr>
<tr>
<td></td>
<td>• Describe common applications of Ohm’s law to designing or trouble shooting circuits</td>
</tr>
<tr>
<td></td>
<td>• Calculate power, voltage, and current using the power formula</td>
</tr>
<tr>
<td></td>
<td>• Explain the power/current relationship according to the power formula</td>
</tr>
<tr>
<td></td>
<td>• Describe common applications of the power formula</td>
</tr>
<tr>
<td></td>
<td>• Explain how Ohm’s law and the power formula can be combined to create additional formulas</td>
</tr>
<tr>
<td></td>
<td>Performance Objectives, the student will:</td>
</tr>
<tr>
<td></td>
<td>• Examine electrical resistance R through a metal conductor</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 3.1-1 Ohm’s Law</td>
</tr>
</tbody>
</table>

Notes:
### UNIT 4: METERING AND MEASURING

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4.1 Metering</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Identify common types of meters</td>
</tr>
<tr>
<td></td>
<td>• Describe the function of meter abbreviations, symbols, and terminology</td>
</tr>
<tr>
<td></td>
<td>• List common considerations for reading analog displays</td>
</tr>
<tr>
<td></td>
<td>• List common considerations for reading digital displays</td>
</tr>
<tr>
<td><strong>4.2 Taking Standard Measurements</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Identify common measurement principles</td>
</tr>
<tr>
<td>Lab - 6 hrs.</td>
<td>• Describe common procedures for taking voltage measurements</td>
</tr>
<tr>
<td></td>
<td>• Describe common procedures for taking current measurements</td>
</tr>
<tr>
<td></td>
<td>• Describe common procedures for taking resistance measurements</td>
</tr>
<tr>
<td></td>
<td>• Describe common procedures for taking temperature measurements</td>
</tr>
<tr>
<td></td>
<td>• List and describe common types of scopes and their operation</td>
</tr>
<tr>
<td></td>
<td>• Describe common applications of scopes</td>
</tr>
<tr>
<td></td>
<td>• Describe the operation and common applications of digital logic probes</td>
</tr>
<tr>
<td><strong>Performance Objectives, the student will:</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Operate, read, and use information from various meters including voltmeters,</td>
</tr>
<tr>
<td></td>
<td>in-line ammeters, clamp-on ammeters, ohmmeters, megohmmeters, and thermometers</td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 4.2-1 Meter Measurements</td>
</tr>
<tr>
<td><strong>4.3 Basic Oscilloscope Theory and Operation</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 4 hrs.</td>
<td>• List the key sections of the oscilloscope</td>
</tr>
<tr>
<td>Lab - 6 hrs.</td>
<td>• List precautions when using scopes</td>
</tr>
<tr>
<td></td>
<td>• Measure voltage with a scope</td>
</tr>
<tr>
<td></td>
<td>• Identify common waveforms (square, sine, etc.)</td>
</tr>
<tr>
<td></td>
<td>• Display and interpret various waveforms</td>
</tr>
<tr>
<td></td>
<td>• Determine the phase of various waveforms</td>
</tr>
<tr>
<td></td>
<td>• Check the frequency of a wave using the oscilloscope</td>
</tr>
<tr>
<td></td>
<td>• Understand how to solve circuit problems utilizing a computer and oscilloscope</td>
</tr>
<tr>
<td><strong>Performance Objectives, the student will:</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Operate, read, and use information generated from an oscilloscope</td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 4.3-1 Oscilloscope Lab</td>
</tr>
</tbody>
</table>

**Notes:**

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**FUNDAMENTALS OF ELECTRICITY AND ELECTRONICS**
# UNIT 5: DC CIRCUITS

<table>
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<th>TOPICS</th>
<th>OBJECTIVES</th>
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| **5.1 Series Circuits** | **The student will be able to:**  
• Describe a series connection  
• Explain polarity in a series circuit  
• Describe the operation and function of switches in a series circuit  
• Calculate resistance, voltage, current, and power in a series circuit  
• Describe a common application of a series circuit  
• Calculate equivalent capacitance and inductance  
• Describe the function various power sources (batteries, cells, solar cells, etc.) in a series circuit |
| Lecture - 2 hrs.        |                                                                                                                                                                                                           |
|                         | **5.2 Parallel Circuits**  
Lecture - 2 hrs.  
Lab - 6 hrs.                                   | **The student will be able to:**  
• Describe a parallel connection  
• Explain polarity in a parallel circuit  
• Describe the operation and function of switches in a parallel circuit  
• Calculate resistance, voltage, current, and power in a parallel circuit  
• Describe a common application of a parallel circuit  
• Calculate equivalent capacitance and inductance  
• Describe the function various power sources (batteries, cells, solar cells, etc.) in a parallel circuit |
|                         | **Performance Objectives, the student will:**  
- Lab Exercise: 5.2-1 Series Circuits and Parallel Circuits                                                                                                                                               |
| **5.3 Series/Parallel Circuits** | **The student will be able to:**  
• Describe a series/parallel connection  
• Explain polarity in a series/parallel circuit  
• Describe the operation and function of switches in a series/parallel circuit  
• Calculate resistance, voltage, current, and power in a series/parallel circuit  
• Describe a common application of a series/parallel circuit  
• Calculate equivalent capacitance and inductance  
• Describe the function various power sources (batteries, cells, solar cells, etc.) in a series/parallel circuit |
| Lecture - 6 hrs.        | **Performance Objectives, the student will:**  
- Lab Exercise: 5.3-1 Combined Series/Parallel Circuits                                                                                                                                               |
<p>| Lab - 10 hrs.           | Notes:                                                                                                                                                                                                    |</p>
<table>
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| **6.1 Magnetism, Solenoids, and Transformers** | The student will be able to:  
| Lecture - 3 hrs.  
Lab - 3 hrs. |  
• Explain the principles of magnetism and electromagnetism  
• Describe the function and common applications of a solenoid  
• Describe the function and operation of a transformer  
• Describe how transformers are rated and explain power loss  
• List and describe common types of transformers  
• Describe transformer overloading and transformer cooling methods  
• List and describe common transformer connections  |
| **Performance Objectives, the student will:** |  
• Lab Exercise: 6.1-1 Transformer Power Supply  
• Lab Exercise: 6.1-2 Transformers |
| **6.2 Electrical Motors** | The student will be able to:  
| Lecture - 3 hrs.  
Lab - 3 hrs. |  
• Describe the function and operation of an electric motor  
• Explain work and torque in relation to electric motors  
• List and describe common motor torque classification  
• Describe the relationship between torque, horsepower, and motor speed  
• List and describe common types of 1 motor  
• List and describe common types of 3 motors  
• List and describe common types of DC motors  
• Describe the electrical, operating, environmental, and mechanical ratings listed on a motor nameplate  |
| **Performance Objectives, the student will:** |  
• Lab Exercise: 6.2-1 Motors |
| **6.3 Resistance, Inductance, and Capacitance** | The student will be able to:  
| Lecture - 3 hrs.  
Lab - 3 hrs. |  
• Describe the characteristics of a basic circuit  
• Describe the characteristics of a resistive circuit  
• Explain the principle of inductance  
• Use and describe the function and common types of inductors  
• List and describe common types of inductive reactance  
• List and describe the function and common types of capacitors  
• List and describe common types of capacitive reactance  
• Explain the principle of Impedance  |
| **Performance Objectives, the student will:** |  
• Lab Exercise: 6.3-1 Inductance and Capacitance |

Notes:
## UNIT 6: CIRCUITS (AC), POWER LOADS

### TOPICS

6.4 Power Loads

Lecture - 3 hrs.
Lab - 3 hrs.

### OBJECTIVES

The student will be able to:

- State the difference between potential energy and kinetic energy
- List six sources of voltage
- State the proper steps required when taking DC voltage, AC voltage, in-line current, clamp-on current, and resistance measurements
- State the difference between true power, reactive power, and apparent power, and state their abbreviations
- State the effect inductance and capacitance have on voltage and current phase relationships in an AC circuit
- Calculate the power factor given true power and apparent power
- Given any two electrical values, use Ohm’s law to calculate voltage, current, or resistance in a circuit
- Given any two electrical values, use the power formula to calculate voltage, current, or power in a circuit
- Calculate resistance, voltage, or power in a series-connected circuit
- Calculate resistance, voltage, or power in a parallel-connected circuit
- Calculate resistance, voltage, or power in a series/parallel-connected circuit

**Performance Objectives, the student will:**

- Lab Exercise: 6.4-1 Powerloads

### Notes:
FUNDAMENTALS OF ELECTRICITY AND ELECTRONICS
LAB 3.1-1 OHMS LAW

PERFORMANCE OBJECTIVE

• Examine electrical resistance through a metal conductor. By measuring the voltage and current through the conductor, demonstrate Ohm’s Law and the dependence of resistance on the length, cross-sectional area and electrical resistivity of a conductor.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

None

BACKGROUND

When a potential difference or voltage is applied along an electrical circuit, the resulting current flow is limited by the electrical resistance of the circuit. This is a fundamental concept of harnessing and using electrical energy for useful work in a circuit. This lab provides the student with a tangible example of the application of Ohm’s law.

SAFETY REQUIREMENTS

• Inspect wiring of equipment before each use. Replace damaged or frayed electrical cords immediately.
• Use safe work practices every time electrical equipment is used.
• Know the location and how to operate shut-off switches and/or circuit breaker panels. Use these devices to shut off equipment in the event of a fire or electrocution.
• Limit the use of extension cords. Use extension cords only for temporary operations and then only for short periods of time. In all other cases, request installation of a new electrical outlet.
• Multi-plug adapters must have circuit breakers or fuses.
• Place exposed electrical conductors (such as those sometimes used with electrophoresis devices) behind shields.
• Minimize the potential for water or chemical spills on or near electrical equipment.
TEST EQUIPMENT

- DC ammeter (0 - 1.0A)
- DC voltmeter
- DC low voltage power supply
- Digital multimeter
- Meter stick
- Micrometer
- Stopwatch
- Triple beam balance

MATERIALS NEEDED

- Resistors
- Connecting wires

CRITICAL TASKS STUDENTS MUST COMPLETE

- Use the ammeter to measure current through a resistor in a simple circuit.
- Vary the current at least five times and measure the resulting voltage.
- Measure and record the length and the diameter of each of the mounted wires using the meter stick and micrometer respectively. Calculate the radius r of each wire.
- Measure the resistance R of each wire directly with a digital multimeter.

FINDINGS

- Plot a graph of V (y axis) against I (x axis) using a spreadsheet. Calculate the slope of the graph for V/I.
- Compare the experimental value of R determined from the V/I slope with the accepted value measured using the digital multimeter by calculating the relative error and the percent relative error.
- Calculate the resistivity of a wire.
- Look up the resistivity values for the wires used.
- Compare the experimentally calculated resistivities with the resistivity values.
- Calculate the percent relative error for the resistivity of each wire.

ADDITIONAL INFORMATION

None
PERFORMANCE OBJECTIVE

- Operate, read, and use information from various meters including voltmeters, in-line ammeters, clamp-on ammeters, ohmmeters, megohmmeters, and thermometers.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

Set up the sample circuits that the students will be using to measure AC voltage, DC voltage, DC current, AC current, resistance.

BACKGROUND

The students have a basic understanding of all the probes and how to operate them safely. Have students consult the user manuals for the specific devices that they will be using in this lab. Make sure that they identify safety issues and any additional information specific to the meter being used.

SAFETY REQUIREMENTS

- Inspect wiring of equipment before each use. Replace damaged or frayed electrical cords immediately.
- Use safe work practices every time electrical equipment is used.
- Know the location and how to operate shut-off switches and/or circuit breaker panels. Use these devices to shut off equipment in the event of a fire or electrocution.
- Limit the use of extension cords. Use extension cords only for temporary operations and then only for short periods of time. In all other cases, request installation of a new electrical outlet.
- Multi-plug adapters must have circuit breakers or fuses.
- Place exposed electrical conductors (such as those sometimes used with electrophoresis devices) behind shields.
- Minimize the potential for water or chemical spills on or near electrical equipment.

TEST EQUIPMENT

- Voltmeter
- In-line Ammeter
- Clamp-on Ammeter
- Ohmmeter
- Megohmmeter
- Contact Thermometer (optional)
- Infrared Meter (optional)
MATERIALS NEEDED

• Simple circuit to test

CRITICAL TASKS STUDENTS MUST COMPLETE

• Measure AC voltage with a voltmeter.
  • Set the function switch to AC voltage.
  • Plug the black test lead into the common jack.
  • Plug the red test lead into the voltage jack.
  • Connect the meter test leads to the circuit.
  • Read the voltage displayed on the meter.
• Measure DC voltage with a voltmeter.
  • Set the function switch to DC voltage.
  • Plug the black test lead into the common jack.
  • Plug the red test lead into the voltage jack.
  • Connect the meter test leads to the circuit.
  • Read the voltage displayed on the meter.
• Measure DC current with an in-line ammeter.
  • Set the selector switch to DC.
  • Plug the black test lead into the common jack.
  • Plug the red test lead into the voltage jack.
  • Turn the power of the circuit or device under test OFF and discharge all capacitors if possible.
  • Open the circuit and connect the test leads to each side of the opening.
  • Turn the power to the circuit under test ON.
  • Read the current displayed on the meter.
  • Turn the power OFF and remove the meter from the circuit.
• Measure AC current with a clamp-on ammeter.
  • Set the function switch to AC.
  • Plug the current probe accessory into the meter when using a multimeter that requires a current probe.
  • Open the jaws by pressing against trigger.
  • Enclose one conductor in the jaws.
  • Read the current displayed on the meter.
• Measure resistance with an ohmmeter.
  • Ensure that all power is OFF in the circuit or component under test.
  • Disconnect the component from the circuit.
  • Set function switch to resistance position.
  • Plug the black test lead into the common jack.
  • Plug the red test lead into the voltage jack.
• Ensure that meter batteries are in good condition.
• Connect the meter leads across the component under test.
• Read the resistance displayed on the meter.
• Measure resistance with a megohmmeter.
• Ensure that all power is OFF in the circuit or component under test.
• Set the selector switch to the voltage at which the circuit is to be tested.
• Plug the black test lead into the negative (earth) jack.
• Plug the red test lead into the positive (line) jack.
• Ensure that meter batteries are in good condition.
• Connect the line leads to the conductor under test.
• Press the test button or turn the crank.
• Read the resistance displayed on the meter.
• Consult the equipment manufacturer or meter manufacturer for the minimum recommended resistance values.
• Measure temperature using a contact thermometer (optional).
• Select a temperature probe.
• Connect the temperature probe to the meter.
• Set the meter to the correct temperature range.
• Place the temperature probe tip on the object or in the area to be measured.
• Read the temperature displayed on the meter.
• Measure temperature using an infrared meter (optional).
• Aim the meter at the area to be measured using proper stand off distance, angle of attack, and multiple reading matrix.
• Take the temperature reading of any areas suspected to have temperatures above ambient temperature.
• Take the ambient temperature reading for reference, demonstrating proper techniques for assessing ambient temperature.

FINDINGS

• Students will record the measurements that they have taken.
• Students will use various software to calculate values using measurements taken.
• Given a scenario, students will determine if direct measurements match known input values of a given circuit.
• Students will list any specific safety issues encountered when using the meters.
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LAB 4.3-1 OSCILLOSCOPE LAB

PERFORMANCE OBJECTIVE

• Become familiar with operation of digital oscilloscope.
• If the instructor changes the oscilloscope settings and connections, the student will be able to bring it back into operation.
• Explain the difference between AC and DC coupling.
• Explain how triggering works.
• Explain what FFT is and demonstrate use of oscilloscope FFT (optional).
• Measure the time constant of the oscilloscope AC coupling.
• Obtain a value for the fall time with error bars.

LAB TYPE
Team

TIME REQUIRED
3 hours

INSTRUCTOR PREPARATION
Set up the sample circuits that the students will be using to measure AC voltage, DC voltage, DC current, AC current, resistance.

BACKGROUND
The students should have a basic understanding of the theory of the oscilloscope and how to operate it safely. Have students consult the user manuals for the specific devices that they will be using in this lab. Make sure that they identify safety issues and any additional information specific to the meter being used.

SAFETY REQUIREMENTS
• Inspect wiring of equipment before each use. Replace damaged or frayed electrical cords immediately.
• Use safe work practices every time electrical equipment is used.
• Know the location and how to operate shut-off switches and/or circuit breaker panels. Use these devices to shut off equipment in the event of a fire or electrocution.
• Limit the use of extension cords. Use extension cords only for temporary operations and then only for short periods of time. In all other cases, request installation of a new electrical outlet.
• Multi-plug adapters must have circuit breakers or fuses.
• Place exposed electrical conductors (such as those sometimes used with electrophoresis devices) behind shields.
• Minimize the potential for water or chemical spills on or near electrical equipment.
TEST EQUIPMENT

- Digital Oscilloscope

MATERIALS NEEDED

- Resistors
- Capacitors
- Breadboard

CRITICAL TASKS STUDENTS MUST COMPLETE

- Basic waveform measurement.
- Hook up the output of the function generator to the oscilloscope.
- Set the function generator to output a sine wave.
- Use BNC cables
- Decide to use a T-connector or a terminator.
- Change the oscilloscope settings so students can see the sine wave on the screen.
- Measure characteristics of a sine wave.
- Measure peak to peak voltage (amplitude) and measure the period (frequency).
- First, use the grid on the oscilloscope screen (“divisions” are the dotted lines).
- Next, use the cursors.
- Finally, use the “measure” functions.
- Trigger the signal on a rising edge.
- Set up AC coupling.
- Apply a large DC voltage to the oscilloscope input.
- Compare DC coupling with AC coupling.
- Use rising part of square wave to measure fall time.
- Measure the fall time of the AC coupling.
- Function generator: square wave; zero DC offset (amplitude about 8.6 V).
- Use cursors to measure fall time (peak to 10% value).
- Use “measure” function to measure fall time.
- FFT.
- Find the frequency of a sine wave using FFT “Math” function.
- Look at the harmonics in triangle and square wave.
- Change the XY mode to make a Lissajous curve.
- Build a low or high pass filter using resistors, capacitors, and breadboard.
FINDINGS

- Repeat the procedures for measuring basic waveforms for a few different waves: very large amplitude, very low amplitude, large DC offset.
- Determine if there are waveforms that the oscilloscope cannot measure properly.
- Discover what happens to the signal when different triggers are used.
- Observe when AC coupling which trigger is the best mode for viewing any “ripple” on the DC voltage.
- Learn what RC constant implies.
- Observe how this compares with the expected value for the oscilloscope.
- Compare what is shown on the oscilloscope using the FFT function with a Fourier series applet.
- Be able to explain what is going on with an FFT and when it may be useful.

ADDITIONAL INFORMATION

Recommended materials:
- Fourier series applet by Paul Falstad: http://www.falstad.com/fourier/
FUNDAMENTALS OF ELECTRICITY AND ELECTRONICS
LAB 5.2-1 SERIES CIRCUITS AND PARALLEL CIRCUITS

PERFORMANCE OBJECTIVE

• Students will be able to accurately explain and describe how series and parallel circuits operate.
• Students will identify the appropriate uses of series and parallel circuits.
• Through calculations, students will develop resistance, voltage, current, and power measurements for both series and parallel circuits.

LAB TYPE

Team

TIME REQUIRED

6 hours

INSTRUCTOR PREPARATION

None

BACKGROUND

An electrical circuit is a continuous path or array of paths through which an electrical current can flow. The two different ways in which components of a circuit can be connected are called “series” and “parallel.” In a series connection, components are connected one after another; therefore, the same current flows through all of them. In a parallel connection, the circuit components are connected side by side. That is the positive and negative sides of each component are respectively connected together; therefore, each has the same potential drop across. In this lab, we will explore measurements of current and potential differences in simple circuits. Also, we will attempt to verify the textbook expressions for the equivalent resistance of components connected in series and in parallel, and for the power dissipation in a resistive load.

SAFETY REQUIREMENTS

• Inspect wiring of equipment before each use. Replace damaged or frayed electrical cords immediately.
• Use safe work practices every time electrical equipment is used.
• Know the location and how to operate shut-off switches and/or circuit breaker panels. Use these devices to shut off equipment in the event of a fire or electrocution.
• Limit the use of extension cords. Use extension cords only for temporary operations and then only for short periods of time. In all other cases, request installation of a new electrical outlet.
• Multi-plug adapters must have circuit breakers or fuses.
• Place exposed electrical conductors (such as those sometimes used with electrophoresis devices) behind shields.
• Minimize the potential for water or chemical spills on or near electrical equipment.
TEST EQUIPMENT

- Breadboard with 3 resistor sockets
- Digital multimeter
- Ammeter
- Voltmeter
- Variable voltage supply set for 10 volts output

MATERIALS NEEDED

- Resistors
- Jumper cables
- Power source

CRITICAL TASKS STUDENTS MUST COMPLETE

- Be sure the students turn the power supply off when building a circuit until they are ready to take measurements.

- When connecting the digital multi-meters (DMM), set the instruments to their least sensitive scale.

- Students may switch to a more sensitive (smaller value) scale to get a more precise reading. The smallest scale possible on the meter will give the value with the most significant figures attainable with that instrument, therefore, making measurements more accurate.

- CAUTION: Do not connect a circuit with zero resistance (only wires between + and - on the supply) or the fuse on the power supply will be damaged and it will need to be replaced.

- NOTE: To measure current, the current must flow through the ammeter. Therefore, the ammeter must be connected in series with the current to be measured. It must be placed so that the current to be measured has no alternative but to flow through the ammeter. A voltmeter on the other hand needs only be connected in parallel with the voltage to be measured.

- Measurements on Series Circuits
  - Use a DMM set to measure resistance in Ohms (Ohms function switch setting) to obtain the individual resistance values for three resistors in a series circuit.
  - Read manufacturer color coded resistance values, and a Resistor Color Coding Chart, to determine the manufacturer specified resistance values of your resistors.
  - Assemble series circuit following the circuit diagram. Directly measure the equivalent resistance (Rs) of the resistors connected in series using a DMM.

- Assemble a parallel circuit and directly measure the equivalent resistance (Rp) of the resistors, connected in parallel.
  - It is important that you take your resistance measurements only when the power supply is not connected to the rest of your electrical circuit.

- Connect the power supply to your circuit as shown. Set the power supply to and measure the voltage drop across each resistor, the total voltage across all the resistors connected together, the current in the circuit, and the current through each resistor. Write down the results.

- Change the voltmeter and ammeter connections accordingly to make all these measurements. When measuring the voltage across a resistor while also measuring current, connect the voltmeter only across the resistor, not across the resistor and ammeter.
• Measurements on Parallel Circuits
  - Connect the three resistors in parallel and connect the three resistors to the power supply. Be attentive to
    the direction of current flow. Set the power supply to 5V and measure the voltage drop across each
    resistor, the total voltage drop across the positive and negative sides of the circuit, the current in the circuit,
    and the current through each resistor.
  - Change the voltmeter and ammeter connections accordingly to make all these measurements.
    When measuring the voltage across a resistor while also measuring current, connect the voltmeter only
    across the resistor, not across the resistor and ammeter.

FINDINGS
• Series Circuits
  - Calculate the theoretical values of your equivalent resistances Rs and Rp using the measured values
    for R1, R2, and R3.
  - Calculate the voltage for each resistor.
  - Compare the results and account for any differences.
  - Calculate the power dissipated in each.
• Parallel Circuits
  - Calculate the current for each resistor.
  - Calculate the total current of the three resistors.
  - Calculate the predicted current.
  - Compare the results from the preceding two items and account for any differences.

ADDITIONAL INFORMATION
None
LAB 5.3-1 COMBINED SERIES/PARALLEL CIRCUITS

PERFORMANCE OBJECTIVE

• Investigate the relationship between current and voltage in a combined series-parallel circuit.

LAB TYPE

Team

TIME REQUIRED

4 hours

INSTRUCTOR PREPARATION

In this lab students will work with a circuit combining series and parallel elements. Students will use six resistors to create a circuit with two parallel resistor pairs connected with two series resistors. They will then apply a DC voltage to the circuit and measure the current through and voltage across each resistor. These measurements will be used to verify Kirchhoff’s loop and junction rules.

BACKGROUND

An electrical circuit is a continuous path or array of paths through which an electrical current can flow. The two different ways in which components of a circuit can be connected are called “series” and “parallel.” In a series connection, components are connected one after another; therefore, the same current flows through all of them. In a parallel connection, the circuit components are connected side by side. That is the positive and negative sides of each component are respectively connected together; therefore, each has the same potential drop across. In this lab, we will explore measurements of current and potential differences in simple circuits. Also, we will attempt to verify the textbook expressions for the equivalent resistance of components connected in series and in parallel, and for the power dissipation in a resistive load.

SAFETY REQUIREMENTS

• Inspect wiring of equipment before each use. Replace damaged or frayed electrical cords immediately.
• Use safe work practices every time electrical equipment is used.
• Know the location and how to operate shut-off switches and/or circuit breaker panels. Use these devices to shut off equipment in the event of a fire or electrocution.
• Limit the use of extension cords. Use only extension cords for temporary operations and then only for short periods of time. In all other cases, request installation of a new electrical outlet.
• Multi-plug adapters must have circuit breakers or fuses.
• Place exposed electrical conductors (such as those sometimes used with electrophoresis devices) behind shields.
• Minimize the potential for water or chemical spills on or near electrical equipment.
TEST EQUIPMENT

- Breadboard with 3 resistor sockets
- Digital multimeters
  - Ammeter
  - Voltmeter
- Variable Voltage Supply set for output

MATERIALS NEEDED

- Resistors
- Jumper cables

CRITICAL TASKS STUDENTS MUST COMPLETE

- Construct a DC circuit that has both series and parallel resistance cub circuits, power supply, and in-line ammeter.
- Calculate the total theoretical equivalent resistance of the circuit.
- Measure current vs. potential.
  - Graph current vs. voltage on the same plot as the series graph and determine the total equivalent resistance of the circuit.
- Measure the total resistance of the circuit with the ohmmeter as before.
  - Be sure to disconnect the power supply from the circuit by pulling a banana-plug lead out of the power supply before measuring the resistance.
  - Reconnect the power supply after the student has measured the resistance.

FINDINGS

- Calculate the percent difference between the ohmmeter value (of the equivalent resistance) and the value obtained from the slope of the best-fit line.
- Determine the percentage difference between the best-fit line value and the ohmmeter value for this circuit. All three plots should be graphed on one graph.
- Determine why voltage drops (potential differences) across the resistors wired in parallel be the same.
- Determine whether circuits in houses are wired in parallel, series, or both. Be sure and consider the fuse box. Note the evidence for your answer.

ADDITIONAL INFORMATION

None
FUNDAMENTALS OF ELECTRICITY AND ELECTRONICS
LAB 6.1-1 TRANSFORMER POWER SUPPLY

PERFORMANCE OBJECTIVE

- Transformer voltage step-down behavior
- Purpose of tapped windings
- Safe wiring techniques for power cords

LAB TYPE

Team

TIME REQUIRED

1 hour

INSTRUCTOR PREPARATION

None

BACKGROUND

Power transformers may be obtained from old radios, which can usually be obtained from thrift stores for a few dollars. The radio should also provide the power cord and plug necessary for this project. Line cord switches may be obtained from a hardware store. If you want to be absolutely sure what kind of transformer you are getting, though, purchase one from an electronics supply store.

If you decide to equip your power supply with a fuse, be sure to get a slow-acting or slow-blow fuse. Transformers may draw high “surge” currents when initially connected to an AC source, and these transient currents will blow a fast-acting fuse. Determine the proper current rating of the fuse by dividing the transformer’s “VA” rating by 120 volts: in other words, calculate the full allowable primary winding current and size the fuse accordingly.

SAFETY REQUIREMENTS

- Warning! This project involves the use of dangerous voltages. Make sure all high-voltage (120 volt household power) conductors are safely insulated from accidental contact.
- No bare wires should be seen anywhere on the “primary” side of the transformer circuit.
- Be sure to solder all wire connections so that they are secure, and use real electrical tape (not duct tape, scotch tape, packing tape, or any other kind) to insulate your soldered connections.
- Inspect wiring of equipment before each use. Replace damaged or frayed electrical cords immediately.
- Use safe work practices every time electrical equipment is used.
- Know the location and how to operate shut-off switches and/or circuit breaker panels. Use these devices to shut off equipment in the event of a fire or electrocution.
- Limit the use of extension cords. Use them only for temporary operations and then only for short periods of time. In all other cases, request installation of a new electrical outlet.
- Multi-plug adapters must have circuit breakers or fuses.
- Place exposed electrical conductors (such as those sometimes used with electrophoresis devices) behind shields.
- Minimize the potential for water or chemical spills on or near electrical equipment.
TEST EQUIPMENT

- Low-voltage AC power supply

MATERIALS NEEDED

- Steel flatbar, 4 pieces
- 28 gauge “magnet” wire
- Miscellaneous bolts, nuts, washers

CRITICAL TASKS STUDENTS MUST COMPLETE

- Construct a switchable, fused circuit with a 120vac power source, step down transformer with a center tap and appropriate load.
- Enclose the transformer inside of a box. Use an electrical “junction” box. If the enclosure used is metal rather than plastic, a three-prong plug should be used with the “ground” prong (the longest one on the plug) connected directly to the metal case for maximum safety.
- Before plugging the plug into a wall socket, do a safety check with an ohmmeter. With the line switch in the “on” position, measure resistance between either plug prong and the transformer case. There should be infinite (maximum) resistance. If the meter registers continuity (some resistance value less than infinity), then you have a “short” between one of the power conductors and the case, which is dangerous!
- Next, check the transformer windings themselves for continuity. With the line switch in the “on” position, there should be a small amount of resistance between the two plug prongs. When the switch is turned “off,” the resistance indication should increase to infinity (open circuit – no continuity). Measure resistance between pairs of wires on the secondary side. These secondary windings should register much lower resistances than the primary.
- Plug the cord into a wall socket and turn the switch on. Measure AC voltage at the secondary side of the transformer, between pairs of terminals. Between two of these terminals should measure about 12 volts. Between either of these two terminals and the third terminal should measure half of that. This third wire is the “center-tap” wire of the secondary winding.

ADDITIONAL INFORMATION

Recommended materials:
- Lessons In Electric Circuits, Volume 2, chapter 1: “Basic AC Theory”
- Lessons In Electric Circuits, Volume 2, chapter 9: “Transformers”
FUNDAMENTALS OF ELECTRICITY AND ELECTRONICS
LAB 6.1-2 TRANSFORMERS

PERFORMANCE OBJECTIVE
• Effects of electromagnetism
• Effects of electromagnetic induction
• Effects of magnetic coupling on voltage regulation
• Effects of winding turns on “step” ratio

LAB TYPE
Team

TIME REQUIRED
2 hours

INSTRUCTOR PREPARATION
None

BACKGROUND
“Magnet wire” is small-gauge wire insulated with a thin enamel coating. It is intended to be used to make electromagnets, because many “turns” of wire may be wrapped in a relatively small-diameter coil. Any gauge of wire will work, but 28 gauge is recommended so as to make a coil with as many turns as possible in a small diameter.

• Calculating total voltage/coil turn relationship
  \[ \frac{N_p}{N_s} = \frac{E_p}{E_s} \]
  - where \( N_p \) = number of turns in primary coil
  - \( N_s \) = number of turns in secondary coil
  - \( E_p \) = voltage applied to primary coil (in V)
  - \( E_s \) = voltage induced in secondary coil (in V)

SAFETY REQUIREMENTS
• Inspect wiring of equipment before each use. Replace damaged or frayed electrical cords immediately.
• Use safe work practices every time electrical equipment is used.
• Know the location and how to operate shut-off switches and/or circuit breaker panels. Use these devices to shut off equipment in the event of a fire or electrocution.
• Limit the use of extension cords. Use them only for temporary operations and then only for short periods of time. In all other cases, request installation of a new electrical outlet.
• Multi-plug adapters must have circuit breakers or fuses.
• Place exposed electrical conductors (such as those sometimes used with electrophoresis devices) behind shields.
• Minimize the potential for water or chemical spills on or near electrical equipment.
TEST EQUIPMENT

- Low-voltage AC power supply

MATERIALS NEEDED

- Steel flatbar, 4 pieces
- 28 gauge “magnet” wire
- Miscellaneous bolts, nuts, washers

CRITICAL TASKS STUDENTS MUST COMPLETE

- Drill bolt holes through the bars before wire is wrapped around them.
- Wrap two equal-length bars of steel with a thin layer of electrically-insulating tape. Wrap several hundred turns of magnet wire around these two bars. These windings can be done with an equal or unequal number of turns, depending on whether or not the transformer needs to be able to “step” voltage up or down. To start, use equal turns. Then experiment later with coils of unequal turn count.
- Join those bars together in a rectangle with two other shorter bars of steel. Use bolts to secure the bars together.
- Once the wrappings and windings are complete, check for shorted windings (ohmmeter reading between wire ends and steel bar). There should be no continuity (infinite resistance) between the winding and the steel bar. Check for continuity between winding ends to ensure that the wire isn’t broken or open somewhere within the coil. If either resistance measurements indicate a problem, the winding must be re-done.
- Power the transformer with the low-voltage output of the “power supply.” Do not power the transformer directly from wall-socket voltage (120 volts), as home-made windings really aren’t rated for any significant voltage!
- Measure the output voltage (secondary winding) of the transformer with an AC voltmeter. Connect a load of some kind (light bulbs are good) to the secondary winding and re-measure voltage. Note the degree of voltage “sag” at the secondary winding as load current is increased.
- Loosen or remove the connecting bolts from one of the short bar pieces, thus increasing the reluctance (analogous to resistance) of the magnetic “circuit” that couples the two windings together. Note the effect on output voltage and voltage “sag” under the load.
- Make a transformer with unequal-turn windings and try it in step-up versus step-down mode, powering different AC loads.

FINDINGS

- Describe the calculated versus actual findings.

ADDITIONAL INFORMATION

Recommended materials:

- Lessons In Electric Circuits, Volume 2, chapter 9: “Transformers”
FUNDAMENTALS OF ELECTRICITY AND ELECTRONICS
LAB 6.2-1 MOTORS

PERFORMANCE OBJECTIVE

- Build a simple electric motor and modify the motor for maximum performance.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

- If the motor does not work, here are some common problems to consider:
  - Brushes not adjusted properly.
  - Armature not spinning freely. Check from rubbing on field magnet.
  - Poor electrical connections.
  - Insulation not removed completely on commutator. Scrape with knife blade.
  - Armature not wound properly. Switch with armature from a functioning motor to check.
  - A small cardboard box is recommended for holding the completed motors. They damage easily when transported. The box protects the motor from damage.

BACKGROUND

The electric motor is extremely common in our everyday lives. While often hidden from view, the electric motor is an essential component in many familiar devices. The electric motor is a device that converts electrical energy into mechanical energy. Electric motors are found in such diverse objects as blow-dryers, washing machines, fans, power drills, blenders, mixers, computer disk drives, tape players, VCRs, camcorders, CD players, computer CD ROM drives, sewing machines, dishwashers, copy machines, laser printers, car starter motors, elevators, escalators, refrigerators, and vacuum cleaners. To function in such range of devices, the basic motor design is adapted to meet the particular needs of the specific application. It is this versatility that helps to make the motor an essential element of our technological world.

SAFETY REQUIREMENTS

- Inspect wiring of equipment before each use. Replace damaged or frayed electrical cords immediately.
- Use safe work practices every time electrical equipment is used.
- Know the location and how to operate shut-off switches and/or circuit breaker panels. Use these devices to shut off equipment in the event of a fire or electrocution.
- Limit the use of extension cords. Use them only for temporary operations and then only for short periods of time. In all other cases, request installation of a new electrical outlet.
- Multi-plug adapters must have circuit breakers or fuses.
- Place exposed electrical conductors (such as those sometimes used with electrophoresis devices) behind shields.
- Minimize the potential for water or chemical spills on or near electrical equipment.
TEST EQUIPMENT

• None

MATERIALS NEEDED

• “D” cell battery
• Magnet
• Magnet wire (1 meter)
• Paper clips (2)
• Sand paper tape
• Rubber band

CRITICAL TASKS STUDENTS MUST COMPLETE

• Form a coil by wrapping the wire around an object about the size of a quarter. Leave about 4 cm of straight wire at each end.
• Use the sand paper to remove the insulation from each end of the wire.
• Bend the paper clips as shown and use tape or rubber band to fasten them to the end of the battery.
• Place the magnet on the battery as shown in the diagram.
• Set the wire coil on the clips as shown in the diagram. Be sure the bare copper wire is making contact with the paper clips.
• Give the loop a spin and it should start rotating on its own. Slight adjustments may need to be made to get the motor to function.

FINDINGS

• The current flowing through the wire creates an electromagnet. Explain how this works.
• One end of the coil is a north pole and the other end is a south pole. How does this cause the coil in this motor to spin?
• Can the coil spin in both directions? Explain why or why not.
• How could the motor be modified to make the coil spin faster?

ADDITIONAL INFORMATION

None
FUNDAMENTALS OF ELECTRICITY AND ELECTRONICS
LAB 6.3-1 INDUCTANCE AND CAPACITANCE

PERFORMANCE OBJECTIVE

- Explore transient behavior due to inductors and capacitors in DC circuits.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

Ensure that all students have appropriate supplies.

BACKGROUND

- Experimental Theory: The three common passive circuit elements are resistor, capacitor, and inductor.
  - Capacitor: A capacitor collects electrical charge. It is made of two or more conductors separated by insulators.
  - Applying DC voltage causes current (charge flow) to enter a capacitor. Charge accumulates on its surfaces like water in a reservoir.
  
- Inductor: An inductor is a coil of wire with the property of electrical inertia. An analogy is the inertia of mass. A large truck accelerates slowly due to its mass. At high speed, it is hard to stop for the same reason. Similarly, inductors resist increase or decrease in current.

- Capacitors and Inductors in a DC Circuit: Capacitors and inductors cause very brief non-linear effects when a DC voltage is applied or changed. Shortly after a DC voltage change, capacitor and inductor circuits reach “steady state.” These extremely brief effects are called transient behavior.
  
- Since current cannot start instantaneously in an inductor, the inductor voltage \( V_l = V \) when the switch is closed \( (I = 0, \text{ thus } iR = 0) \). As current increases \( V_l \) falls.

- RLC Circuit: A capacitor, inductor, and resistor circuit can oscillate.

- Calculating inductive reactance.

- Calculating inductive reactance with voltage and current.

- Calculating capacitive reactance.

- Calculating capacitive reactance with voltage and current.

SAFETY REQUIREMENTS

- Inspect wiring of equipment before each use. Replace damaged or frayed electrical cords immediately.

- Use safe work practices every time electrical equipment is used.

- Know the location and how to operate shut-off switches and/or circuit breaker panels. Use these devices to shut off equipment in the event of a fire or electrocution.

- Limit the use of extension cords. Use them only for temporary operations and then only for short periods of time. In all other cases, request installation of a new electrical outlet.

- Multi-plug adapters must have circuit breakers or fuses.
- Place exposed electrical conductors (such as those sometimes used with electrophoresis devices) behind shields.
- Minimize the potential for water or chemical spills on or near electrical equipment.

**TEST EQUIPMENT**
- Multimeter
- Signal Generator
- Oscilloscope
- RCL Meter
- Electronic Prototyping board

**MATERIALS NEEDED**
- Resistors
- Inductors
- Capacitors
- Oscilloscope probes

**CRITICAL TASKS STUDENTS MUST COMPLETE**
- Voltage across a capacitor in a series RC circuit.
- Inductor voltage in a series RL circuit.

**FINDINGS**
- Draw labeled diagrams for three circuits (see Fig. 15 for symbols).
- Using data collected in 5.1, plot capacitor voltage (amplitude versus time in μsec). Using the theoretical equation for vC(t), calculate amplitude at t = 1, 2, 3, 4, 5, 6, 8, and 10. Plot on the same chart for comparison and discuss the match, advancing an explanation for any discrepancies. (Excel makes it easy to plot these graphs together. Use some other tool if you wish.)
- For the RLC circuit in 5.3.5, calculate the frequency of oscillation from the period measured, for both capacitors.
- For the 51 Ω and 10 mH inductor used in 5.3.5, and using measured values for R, L, and C, calculate fd (= d /2) for that circuit using the formula in 3.4.5, for both capacitors. How do these compare to those measured?
- For the resistor values on either side of the calculated value of resistance at which resonance ends, did oscillation/non-oscillation occur as predicted?
- Did changing by using a different resistor reduce the transient behavior?
- If the transience was shortened, was the reduction about as calculated?

**ADDITIONAL INFORMATION**
None
FUNDAMENTALS OF ELECTRICITY AND ELECTRONICS
LAB 6.4-1 POWER LOADS

PERFORMANCE OBJECTIVE

• Investigate power loads and how to conduct load factor correction.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

None

BACKGROUND

Experimental determination of the power factor typically requires the measurement of the phase difference between voltage and current. Two properties of the function generator and oscilloscope make this measurement difficult.

• The reference (ground) leads on the oscilloscope and function generator are internally tied to ground making it imperative that they all be connected to the same point in the circuit.

• The difference between channels 1 and 2 (CH1-CH2) can only be displayed by itself on the oscilloscope.

• Carefully consider where to take measurements with the above constraints.

SAFETY REQUIREMENTS

• Inspect wiring of equipment before each use. Replace damaged or frayed electrical cords immediately.

• Use safe work practices every time electrical equipment is used.

• Know the location and how to operate shut-off switches and/or circuit breaker panels. Use these devices to shut off equipment in the event of a fire or electrocution.

• Limit the use of extension cords. Use them only for temporary operations and then only for short periods of time. In all other cases, request installation of a new electrical outlet.

• Multi-plug adapters must have circuit breakers or fuses.

• Place exposed electrical conductors (such as those sometimes used with electrophoresis devices) behind shields.

• Minimize the potential for water or chemical spills on or near electrical equipment.
CRITICAL TASKS STUDENTS MUST COMPLETE

- Investigate inductive load
  - An inductor is a coil of wire and wire has resistance. Measure the resistance of your 0.47mH inductor. If this resistance is significant include it in calculations.
  - Experimentally determine the load impedance ZL, power factor angle, power factor PF, and complex power using voltage and current measurements. Compare these to predicted values found in the prelab.

- Load power factor correction
  - Add a capacitor of the value determined to be in parallel with the original load as shown in figure 2. Note the value of the capacitor may need to be updated based upon the resistance of the inductor.
  - Verify that your power factor correction is working. Because of the measurement constraints described above, it might be easier to verify the power factor correction by comparing the load voltage to the source voltage. What should this relationship be and how does it compare to the experimental results?
  - Normally, it isn’t a good idea to change a circuit with input and power applied, but carefully insert and remove the capacitor while watching the source and load voltages to easily see the effect of the compensation.

FINDINGS

- Does the load compensation work at other frequencies other than 10kHz? Investigate this both mathematically and experimentally. Is there a difference in the load as frequency is increased versus decreased?
FUNDAMENTALS OF POWER GENERATION, TRANSMISSION, AND DISTRIBUTION SYSTEMS

COURSE DESIGN GUIDE

COURSE TITLE
Power Generation, Transmission, and Distribution Systems

CATALOG DESCRIPTION
The Fundamentals of Power Generation Transmission and Distribution Systems is an introductory course in classical power systems. It is designed to give the student an overview and introduction to the basic principles. Course work emphasizes an overall understanding of the systems, engineering, equipment, and operations of a typical power system. This course will provide a strong foundation for further study in Career Technical Education (CTE) programs such as Energy Technology or Mechatronics.

CREDITS
4 credits, 96 hours

COURSE FORMAT
This course is a lecture/lab format that incorporates simulation-based experiential learning, practical labs, and technical writing assignments.

COURSE NUMBER
Material for this course is presented to meet the requirements for a 100-level course.

PREREQUISITES
Fundamentals of Electricity and Electronics or equivalent, college Algebra, and applied math or equivalent.

INSTRUCTOR INFORMATION
Recommended Qualifications: Master’s Degree in Electrical Engineering: Mechanical, Electrical, or Systems. Three years of practical work experience in the utility industry or other field that manages electrical power systems. Working knowledge and background in subject/topic area, and experience teaching secondary, or post-secondary/adult students.

TEACHING METHODS AND ASSIGNMENTS FOR ACHIEVING LEARNING OUTCOMES
This course is divided into seven learning units. Each unit addresses a specific concept related to electrical generation, power transmission, and power distribution systems. The course is designed to provide the student with knowledge and skills that will have direct application to further study in power systems. Each topic has a recommended length (topic hours) assigned. Topic hours are a guideline for instruction that is intended to be adapted to the individual instructor’s teaching style. As a general rule, the ratio of lecture to lab is 1:3. Included in the instructional materials are example worksheets, homework assignments, and quizzes. Students are expected to spend additional study/practice outside of the class time. The generally accepted ratio of class to study time is 1:4 for this course. Each topic lists suggested time allocation. Total time allocated includes an hour course introduction, a 2-hour review, and a 2-hour written exam.
STUDENT TEXTS, READING AND OTHER MATERIALS


BIBLIOGRAPHY


STUDENT LEARNING OUTCOMES

Upon successful completion of this course students will be able to:

- Determine the function, operating parameters, and selection criteria for power system equipment
- Examine the physical and electrical configurations of power generators to determine the loading characteristics and profiles
- Examine the structure, topology, and equipment of a power transmission system
- Examine the structure, topology, and equipment of a power distribution system
- Classify transmission and distribution systems based on physical and electrical criteria
- Understand the effects that contingencies have on Transmission and Distribution Systems
# ASSESSMENT RUBRIC

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>EXEMPLARY 4</th>
<th>SATISFACTORY 3</th>
<th>DEVELOPING 2</th>
<th>BEGINNING 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understand and explain the effect system abnormalities have on power system loading and protection</td>
<td>Explanation shows complete understanding of power system abnormalities and their effects</td>
<td>Explanation shows substantial understanding of power system abnormalities and their effects</td>
<td>Explanation shows some understanding of power system abnormalities and their effects</td>
<td>Explanation shows very limited understanding of power system abnormalities and their effects</td>
</tr>
<tr>
<td>Examine the physical and electrical configurations of power generators to determine the loading characteristics and profiles</td>
<td>Uses complex and refined reasoning to determine characteristics and profiles</td>
<td>Uses effective reasoning to determine characteristics and profiles</td>
<td>Some evidence of reasoning used to determine characteristics and profiles, but answers not accurate or thought out</td>
<td>Little evidence of reasoning and unable to determine characteristics and profiles</td>
</tr>
<tr>
<td>Strategy/Procedures</td>
<td>Typically uses an efficient and effective strategy to solve the problem(s)</td>
<td>Typically uses an effective strategy to solve the problem(s)</td>
<td>Sometimes uses an effective strategy to solve problems, but does not do it consistently</td>
<td>Rarely uses an effective strategy to solve problems</td>
</tr>
<tr>
<td>Classify Transmission and Distribution systems based on physical and electrical criteria</td>
<td>Classification is detailed and accurate, and explanation is detailed and clear</td>
<td>Classification is mostly accurate, and explanation is clear</td>
<td>Classification is partly accurate, concept is understood, application is weak, while explanation includes critical components but difficult to understand</td>
<td>Classification is wrong or missing, while explanation misses several or all components and difficult to understand</td>
</tr>
<tr>
<td>Classify the structure, topology, and equipment of a power distribution system</td>
<td>Classification is detailed and accurate, and explanation is detailed and clear</td>
<td>Classification is mostly accurate, and explanation is clear</td>
<td>Classification is partly accurate, concept is understood, application is weak, while explanation includes critical components but difficult to understand</td>
<td>Classification is wrong or missing, while explanation misses several or all components and difficult to understand</td>
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<td>Sometimes uses an effective strategy to solve problems, but does not do it consistently</td>
<td>Rarely uses an effective strategy to solve problems</td>
</tr>
<tr>
<td>Effects that contingencies have on Transmission and Distribution Systems</td>
<td>Explanation shows complete understanding of power system contingency and its effects</td>
<td>Explanation shows substantial understanding of power system contingency and its effects</td>
<td>Explanation shows some understanding of power system contingency and its effects</td>
<td>Explanation shows very limited understanding of power system contingency and its effects</td>
</tr>
</tbody>
</table>
### UNIT 1: OVERVIEW OF POWER GENERATION, TRANSMISSION, AND DISTRIBUTION SYSTEMS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.1 Overview of a Typical Power System</strong>&lt;br&gt;Lecture - 1 hr.</td>
<td>The student will be able to:&lt;br&gt;• Identify and describe the basic elements of a power system, configuration, interconnection, operating parameters, capabilities, and limitations&lt;br&gt;- Power Generation&lt;br&gt;- Power Transmission - Nominal system voltages&lt;br&gt;- Power Distribution - Nominal system voltages&lt;br&gt;- Consumer load&lt;br&gt;- AC vs. DC transmission systems</td>
</tr>
<tr>
<td><strong>1.2 Elements of a Power System</strong>&lt;br&gt;Lecture - 2 hrs.</td>
<td>The student will be able to:&lt;br&gt;• Identify and describe elements of a power system, including&lt;br&gt;- Power Generators&lt;br&gt;- Voltage and frequency controls&lt;br&gt;- AC power transmission systems&lt;br&gt;- Power Distribution systems&lt;br&gt;- Types of distribution system configurations&lt;br&gt;- Arrangements of distribution substation configurations—medium voltage&lt;br&gt;- Arrangements of distribution substation configurations—high voltage&lt;br&gt;- Secondary Distribution Systems&lt;br&gt;- Nominal system voltages&lt;br&gt;- Types of secondary distribution system configurations&lt;br&gt;- Arrangements of distribution substation configurations&lt;br&gt;- Emergency and Standby systems&lt;br&gt; - Sources&lt;br&gt; - Generation types</td>
</tr>
<tr>
<td><strong>1.3 Power Circuit Analysis</strong>&lt;br&gt;Lecture - 9 hrs.</td>
<td>The student will be able to:&lt;br&gt;• Power in AC circuits&lt;br&gt; - Calculate complex power&lt;br&gt; - Calculate apparent power&lt;br&gt; - Calculate instantaneous power&lt;br&gt; - Calculate power factor&lt;br&gt;• Describe 3-phase power systems&lt;br&gt; - 3-phase rotating vectors&lt;br&gt; - 3-phase voltage vectors phase to phase&lt;br&gt; - 3-phase voltage vectors phase to neutral&lt;br&gt; - Calculate balance conditions using conventions of voltage, current and power&lt;br&gt;• Apply per-unit system conversions&lt;br&gt; - To power-current-impedance-voltage&lt;br&gt; - To determine per-unit reactance of a system</td>
</tr>
</tbody>
</table>

Notes:
# UNIT 2: TRANSMISSION AND DISTRIBUTION SYSTEM EQUIPMENT

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
</table>
| **2.1 Power Cable Systems**    | The student will be able to:                                                                                                       - Identify and describe the elements of a typical power transmission system, including  
                                  - Design specifications  
                                  - Conductors  
                                  - Insulation  
                                  - Shielding  
                                  - Cable ratings  
                                  - Cable selection criteria  
                                  Lecture - 1 hr.                                                                                                                                 |
| **2.2 Power Cable Installations** | The student will be able to:                                                                                                       - Identify and describe the elements and characteristics of a power cable system including  
                                - Open Wire  
                                - Aerial  
                                - Above Ground Conduit  
                                - Underground Duct  
                                - Direct Burial  
                                - Underwater  
                                - Transmission line modeling  
                                Lecture - 1 hr.                                                                                                                                 |
| **2.3 Transformer Models**      | The student will be able to:                                                                                                       - Explain the fundamental principles of transformers, including  
                                - Winding configurations  
                                - Open circuit characteristics  
                                - Load Characteristics  
                                - Losses  
                                - Insulation  
                                - Impedance  
                                - Connections  
                                - Loading methods  
                                - Transformer classification  
                                - Transformer modeling  
                                Lecture - 1 hr.                                                                                                                                 |
| **2.4 Voltage Regulators**      | The student will be able to:                                                                                                       - Explain the fundamental purpose and function of a voltage regulator, including  
                                - Types  
                                - Ratings  
                                - Applications  
                                - Control functions  
                                - Arrangements  
                                - Protection  
                                Lecture - 1 hr.                                                                                                                                 |
| **2.5 Circuit Breakers**        | The student will be able to:                                                                                                       - Explain the fundamentals of circuit breakers, including  
                                - Purpose and function of a circuit breaker  
                                - Classes  
                                - Application  
                                - Component parts  
                                - Operations  
                                Lecture - 1 hr.                                                                                                                                 |
<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
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</thead>
<tbody>
<tr>
<td><strong>2.6 Circuit Re-closers</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td>• Demonstrate an understanding of circuit re-closers as to their</td>
</tr>
<tr>
<td></td>
<td>- Purpose</td>
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<tr>
<td></td>
<td>- Classes</td>
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<td></td>
<td>- Application</td>
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<td></td>
<td>- Component parts</td>
</tr>
<tr>
<td></td>
<td>- Operations</td>
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<tr>
<td><strong>2.7 Power Capacitors</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td>• Demonstrate an understanding of power capacitors as to their</td>
</tr>
<tr>
<td></td>
<td>- Purpose</td>
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<td>- Classes</td>
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<td>- Application</td>
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<td></td>
<td>- Component parts</td>
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<tr>
<td></td>
<td>- Operations</td>
</tr>
<tr>
<td></td>
<td>- Types of installations</td>
</tr>
<tr>
<td><strong>2.8 Power System Equipment Lab</strong></td>
<td>Performance Objectives, the student will:</td>
</tr>
<tr>
<td>Lab - 3 hrs.</td>
<td>• Properly connect power transmission equipment as to phase, polarity, and size.</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 2.7-1 Power System</td>
</tr>
<tr>
<td><strong>2.9 Distribution Substation</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td>• Compare and describe various distribution substations</td>
</tr>
<tr>
<td>Lab - 3 hrs.</td>
<td>• Describe the need for distribution substations</td>
</tr>
<tr>
<td></td>
<td>Performance Objectives, the student will:</td>
</tr>
<tr>
<td></td>
<td>• Explain the purpose function and operation of a substation</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 2.8-1 Distribution Substation</td>
</tr>
<tr>
<td><strong>2.10 Simple Generator</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td>• Describe the components and operation of a simple generator</td>
</tr>
<tr>
<td>Lab - 3 hrs.</td>
<td>Performance Objectives, the student will:</td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 2.9-1 Simple Generator</td>
</tr>
</tbody>
</table>
### UNIT 3: POWER GENERATION

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3.1 Combustion Technology</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td>• Explain general combustion theory</td>
</tr>
<tr>
<td>Lab - 3 hrs.</td>
<td>• Identify and discuss various fuel sources</td>
</tr>
<tr>
<td></td>
<td><strong>Performance Objectives, the student will:</strong></td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 3.1-1 Boiler</td>
</tr>
<tr>
<td><strong>3.2 Turbine/Generator Technology</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1.5 hrs.</td>
<td>• Explain General Turbine/Generation Theory</td>
</tr>
<tr>
<td>Lab - 3 hrs.</td>
<td>• Identify and explain Turbine Components</td>
</tr>
<tr>
<td></td>
<td>• Identify and explain Generator Components</td>
</tr>
<tr>
<td></td>
<td><strong>Performance Objectives, the student will:</strong></td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 3.2-1 Generator</td>
</tr>
<tr>
<td><strong>3.3 Electrical Generation Fundamentals</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1.5 hrs.</td>
<td>• Identify and discuss various power sources, including</td>
</tr>
<tr>
<td>Lab - 3 hrs.</td>
<td>- Resistive Loads</td>
</tr>
<tr>
<td></td>
<td>- Coincident Loads</td>
</tr>
<tr>
<td></td>
<td>- Non-coincident loads</td>
</tr>
<tr>
<td></td>
<td>- Load Profiles</td>
</tr>
<tr>
<td></td>
<td><strong>Performance Objectives, the student will:</strong></td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 3.3-1 Synchronize</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 4: TRANSMISSION AND DISTRIBUTION ARCHITECTURE

<table>
<thead>
<tr>
<th>Topics</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Transmission and Distribution</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>System Structure</td>
<td>• Demonstrate an understanding of</td>
</tr>
<tr>
<td></td>
<td>- Structural Features</td>
</tr>
<tr>
<td></td>
<td>- Structural Topology</td>
</tr>
<tr>
<td></td>
<td>- Loop Flow</td>
</tr>
<tr>
<td></td>
<td>- Radial Flow</td>
</tr>
<tr>
<td></td>
<td>- Station and Substations</td>
</tr>
<tr>
<td></td>
<td>- Configurations</td>
</tr>
<tr>
<td>4.2 Three Phase Transmission</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate an understanding of</td>
</tr>
<tr>
<td></td>
<td>- The underlying principle of three phase transmission</td>
</tr>
<tr>
<td></td>
<td>- Load Balancing of three phase systems</td>
</tr>
<tr>
<td></td>
<td>- Electrical Connections Wye, Delta, Open Delta</td>
</tr>
<tr>
<td></td>
<td>- Phase Analysis</td>
</tr>
<tr>
<td></td>
<td>- DC transmission</td>
</tr>
<tr>
<td></td>
<td>- Power flow analysis</td>
</tr>
<tr>
<td>4.3 Transformer Connection</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate an understanding of</td>
</tr>
<tr>
<td></td>
<td>- Transformer connections</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate an understanding of the theory of stepping transformers</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate an understanding of the theory and practice of transformer isolation</td>
</tr>
</tbody>
</table>

Notes:
### UNIT 5: POWER SYSTEM LOADING PROTECTION AND COORDINATION

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>5.1 System Protection Methods</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Describe and draw overcurrent protection coordination</td>
</tr>
<tr>
<td></td>
<td>• Explain the general accepted methods of system protection differential</td>
</tr>
<tr>
<td></td>
<td>• Describe and draw differential protection coordination</td>
</tr>
<tr>
<td></td>
<td><strong>Performance Objectives, the student will:</strong></td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 5.1-1 Protective Relay (Shwitzer Relay)</td>
</tr>
<tr>
<td><strong>5.2 Typical System Contingencies</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>Recognize and provide possible solutions to</td>
</tr>
<tr>
<td></td>
<td>• Short Circuits</td>
</tr>
<tr>
<td></td>
<td>• Load Surges</td>
</tr>
<tr>
<td></td>
<td>• Loss of Synchronization</td>
</tr>
<tr>
<td></td>
<td>• Lightning Strikes</td>
</tr>
<tr>
<td></td>
<td><strong>Performance Objectives, the student will:</strong></td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 5.2-1 Identify System Contingencies</td>
</tr>
</tbody>
</table>

Notes:
<table>
<thead>
<tr>
<th>UNIT 6: POWER SYSTEM INSTRUMENTS AND METERS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OBJECTIVES</strong></td>
<td></td>
</tr>
<tr>
<td><strong>6.1 Power System Measurement</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Explain the parameters of measures in a power system</td>
</tr>
<tr>
<td>Lab - 1 hr.</td>
<td>• Describe the information derived from measures of</td>
</tr>
<tr>
<td></td>
<td>- Load magnitude</td>
</tr>
<tr>
<td></td>
<td>- Load characteristics</td>
</tr>
<tr>
<td></td>
<td>- Energy Consumption</td>
</tr>
<tr>
<td></td>
<td>- Load factor</td>
</tr>
<tr>
<td></td>
<td>- Power factor</td>
</tr>
<tr>
<td></td>
<td>- Voltage</td>
</tr>
<tr>
<td></td>
<td>- Current</td>
</tr>
<tr>
<td></td>
<td>• Describe the instruments used to gather and transmit information</td>
</tr>
<tr>
<td></td>
<td>- Alternating Current</td>
</tr>
<tr>
<td></td>
<td>- Direct Current</td>
</tr>
<tr>
<td><strong>Performance Objectives, the student will:</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 6.1-1 PMU</td>
</tr>
<tr>
<td><strong>6.2 Power System Instruments</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Describe the function operation and methods of measurement for each of the</td>
</tr>
<tr>
<td>Lab - 1 hrs.</td>
<td>following primary instruments:</td>
</tr>
<tr>
<td></td>
<td>- Ammeter</td>
</tr>
<tr>
<td></td>
<td>- Voltmeter</td>
</tr>
<tr>
<td></td>
<td>- Wattmeter</td>
</tr>
<tr>
<td></td>
<td>- Var-meter</td>
</tr>
<tr>
<td></td>
<td>- Power factor meter</td>
</tr>
<tr>
<td></td>
<td>- Frequency meter</td>
</tr>
<tr>
<td></td>
<td>• Describe the function, operation, and method of measurements for portable instruments</td>
</tr>
<tr>
<td></td>
<td>• Describe the function, operation, and method of measurement for each of the</td>
</tr>
<tr>
<td></td>
<td>following secondary instruments:</td>
</tr>
<tr>
<td></td>
<td>- Temperature indicator</td>
</tr>
<tr>
<td></td>
<td>- Thermometer</td>
</tr>
<tr>
<td></td>
<td>- Pyrometer</td>
</tr>
<tr>
<td></td>
<td>- Megohmetar</td>
</tr>
<tr>
<td></td>
<td>- Ground ohmeter</td>
</tr>
<tr>
<td></td>
<td>- Ground detector</td>
</tr>
<tr>
<td></td>
<td>- Ocilloscope</td>
</tr>
<tr>
<td></td>
<td>- Watt hour meter</td>
</tr>
<tr>
<td></td>
<td>- Demand meter</td>
</tr>
<tr>
<td></td>
<td>- Syncroscope</td>
</tr>
<tr>
<td><strong>Performance Objectives, the student will:</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 6.2-1 Primary Instruments</td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 6.2-2 Secondary Instruments</td>
</tr>
<tr>
<td><strong>6.3 Connection and Collection of Information</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Use meters and instruments to measure and interpret information from</td>
</tr>
<tr>
<td>Lab - 3 hrs.</td>
<td>instruments and meters</td>
</tr>
<tr>
<td><strong>Performance Objectives, the student will:</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 6.3-1 Using Instruments in a System</td>
</tr>
</tbody>
</table>
## UNIT 7: POWER SYSTEM OPERATIONS.

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.1 Topology of a Power System</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Identify and discuss the generative sources, transmission system and distribution system components</td>
</tr>
<tr>
<td></td>
<td>• Identify and discuss the primary elements of the power system control network</td>
</tr>
<tr>
<td></td>
<td>• Using standard procedure protocol, determine and explain operating parameters and control functions</td>
</tr>
<tr>
<td></td>
<td>• Delineate and discuss supervisory control and central operations control</td>
</tr>
<tr>
<td></td>
<td><strong>Performance Objectives, the student will:</strong></td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 7.1-1 Topology</td>
</tr>
<tr>
<td>7.2 Switching and Bus Configurations of a Distribution System</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Identify and discuss the switching and bus control</td>
</tr>
<tr>
<td></td>
<td>• Identify and state the purpose of direct control, remote mechanical control, and electrically operated switch boards</td>
</tr>
<tr>
<td></td>
<td><strong>Performance Objectives, the student will:</strong></td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 7.2-1 Basic Bus</td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 7.2-2 Advanced Bus</td>
</tr>
<tr>
<td>7.3 Operations of a Coordinated Power System</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Interpret, operating procedures, equipment manuals to develop a functioning power system</td>
</tr>
<tr>
<td></td>
<td><strong>Performance Objectives, the student will:</strong></td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 7.3-1 Team Lab</td>
</tr>
</tbody>
</table>

Notes:
POWER GENERATION
LAB 2.7-1 POWER EQ PERFORMANCE OBJECTIVE

- Understand the purpose, function, and proper connection of power transmission equipment.
- Properly connect power transmission equipment as to phase, polarity, and size.

LAB TYPE
Individual or Team

TIME REQUIRED
3 hours

INSTRUCTOR PREPARATION
Prepare test board (breadboard) components, power supply, and interconnection devices. Provide a step-by-step assembly procedure for a functioning power circuit.

BACKGROUND
Power transmission and distributions systems are composed of interoperating components that operate at multiple voltages and over a geographically dispersed area. To gain an understanding of this system it is important to see one function on a small scale.

SAFETY REQUIREMENTS
Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range that may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material.

An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical or otherwise, from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedures.

Most accidents are the result of carelessness when a student is concentrating on a lesson, momentarily neglecting safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.
TEST EQUIPMENT

• Multimeter
• AC Power Supply
• Oscilloscope

MATERIALS NEEDED

• Breadboard
• Relays, Re-closer
• Circuit Breakers
• Resistors, Capacitors, and Inductors

CRITICAL TASKS STUDENTS MUST COMPLETE

• Assemble the components of a functioning, small scale, low voltage power system using a schematic diagram and directions, test for proper operation, polarity, phase, and ground.
• Interconnect block components (Load to Source).

FINDINGS

None

ADDITIONAL INFORMATION

None

RECOMMENDED MATERIALS

None
POWER GENERATION
LAB 2.8-1 DISTRIBUTION SUBSTATION

PERFORMANCE OBJECTIVE

- Understand the purpose function and operation of a substation

LAB TYPE

Individual or Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

Prepare test board (breadboard) components, power supply, and interconnection devices. Provide a step-by-step assembly procedure for a functioning power circuit with a substation directional control station.

BACKGROUND

Power transmission and distributions systems are composed of interoperating components that operate at multiple voltages and over a geographically dispersed area. To gain an understanding of this system it is important to see one function on a small scale. The addition of a substation will introduce multiple AC sources and allow switching and re-closer. This is the first exercise that will allow for the healing of a fault in a power system.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range that may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material.

An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical or otherwise, from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedures.

Most accidents are the result of carelessness when a student is concentrating on a lesson, momentarily neglecting safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.
TEST EQUIPMENT

• Multimeter
• AC Power Supply
• Oscilloscope

MATERIALS NEEDED

• Breadboard
• Relays, Re-closer
• Circuit Breakers
• Resistors, Capacitors, and Inductors
• Substation components, including manual and remotely operated switches

CRITICAL TASKS STUDENTS MUST COMPLETE

• Assemble a functioning, small scale, low voltage power system using a schematic diagram and directions.
• Operate the system according to proper procedures.
• Interconnect substation components.
• Operate substation components manually (locally) and remotely.

FINDINGS

• The student will submit a brief written narrative describing the primary function of a distribution substation, including power flow input/output, control and switching configurations, physical structure, and plot plan. The student will include a schematic diagram of a substation using standard industry symbology.

ADDITIONAL INFORMATION

None

RECOMMENDED MATERIALS

None
POWER GENERATION
LAB 2.9-1 SIMPLE GENERATOR

PERFORMANCE OBJECTIVE

- Assemble a simple generator from component parts and a prime mover source.

LAB TYPE

Individual

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

Prepare test board (breadboard) components, power supply, and interconnection devices. Provide a step-by-step assembly procedure for a functioning simple generator.

BACKGROUND

The generator is the primary source of alternating current power in a domestic power system. In order to fully understand the source of AC, students will use component parts to assemble a small-scale generator and place it under load to observe the characteristics of the load on the generator.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range that may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material.

An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical or otherwise, from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on a lesson, momentarily neglecting safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.

TEST EQUIPMENT

- Multimeter
- Power meter
MATERIALS NEEDED

• Magnets
• Shielded wire
• Battery or other power source
• Block of wood
• Generator component parts kit

CRITICAL TASKS STUDENTS MUST COMPLETE

• Read and understand the exercise instruction sheet.
• Ensure all component parts are available.
• Complete a written report as to the purpose and function of each component in the assembly of the generator.
• Assemble the components according to the directions provided.
• Test the assembled generator for proper operation.

FINDINGS

• Each student will submit a written report describing the function of the generator assigned for assembly. Describe the type, size, input, and output parameters.
• Each student will compare the assembled generator with another in a student exercise and note similarities and differences.

ADDITIONAL INFORMATION

None

RECOMMENDED MATERIALS

• Generator assembly kit
• Generators disassembled and boxed into component parts
• Hand tools
• Multimeter
• O-scope
POWER GENERATION
LAB 3.1-1 BOILER

PERFORMANCE OBJECTIVE

- Function a prime mover that utilizes steam under pressure.

LAB TYPE

Individual

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

Make a basic steam (rankine) cycle P&ID diagram available to each student. Provide the student with a standard operating procedures manual that includes checklists and instructor approval by signature for all critical steps in the process. The instructor may elect to provide a demonstration of the sequence as part of the student preparation for this performance lab.

BACKGROUND

The first priority of boiler operation is to clear the furnace of gases that would cause an explosion during initial ignition. This is accomplished by purging the furnace. During a purge, the furnace is flushed with 12500000 pounds per hour of air (5669875 kilograms per hour). The purge removes any lingering gases and particulate in the furnace prior to the ignition. A purge normally takes about five minutes on an actual boiler; however, the purge time may be shortened depending on the simulator. Individual burners/igniters have safety lockouts that insure a furnace is purged prior to ignition. Therefore, a burner/igniter will not start without performing a purge.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range that may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material.

An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical or otherwise, from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on a lesson, momentarily neglecting safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.
TEST EQUIPMENT

- Combustion Simulator

MATERIALS NEEDED

- PC to run Combustion Technology Simulator

CRITICAL TASKS STUDENTS MUST COMPLETE

- For oil-based system
  - Acknowledge all trip alarms that might be indicated.
  - Close dampers to all lines before starting fans.
  - Start forced draft (FD) fan.
  - Start induced draft fans (ID) fan.
  - Increase Air flow for ID fan and FD fans by certain increments until a draft psi is -1.5 (assuming the simulator is a balanced draft system) and the Secondary Air Flow rate to be about 12500000 pounds per hour without tripping the boiler alarms.
  - Purge system.
  - Light Fires.
  - Bring the boiler to full operating capacity.
  - Operate the boiler at full operating capacity and transfer the output to a load.

FINDINGS

- The rankine cycle is the most used method of energy transfer to produce useful power. The student should be able to trace a drop of water through the steam cycle providing temperature, pressure, and state throughout the cycle. This may be presented as either a written or oral demonstration.
- The student will then describe the function and purpose of each major step in the startup and operation of a simple boiler.

ADDITIONAL INFORMATION

Bibliography:


RECOMMENDED MATERIALS

- Hampden Model H-186-1 Combustion Technology Simulator
POWER GENERATION
LAB 3.2-1 GENERATOR

PERFORMANCE OBJECTIVE

- Operate a simple turbine generator.

LAB TYPE

Individual or Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

The turbine simulator available for the simulated performance lab may be either a single stage or multiple stage turbine. Provide the student with a properly annotated schematic diagram of the system in use. Include in both the narrative and the schematic, a link to the boiler used during previous performance exercises; this will complete the Rankine cycle performance objective for the previous three exercises. Provide the student with a standard operating procedures manual that includes checklists and instructor approval by signature for all critical steps in the process. The instructor may elect to provide a demonstration of the sequence as part of the student preparation for this performance lab.

BACKGROUND

The steam powered turbine generator is the primary source of alternating current power. Understanding the transfer of energy from the fuel to the steam and then consuming that energy through the multiple stages of a turbine is a critical component of conservation. The most effective method of demonstrating the operation and efficiency of a turbine generator is to operate and optimize the operation of a system.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range that may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material.

An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical or otherwise, from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on a lesson, momentarily neglecting safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.
TEST EQUIPMENT
None

MATERIALS NEEDED
• Turbine Generator simulator

CRITICAL TASKS STUDENTS MUST COMPLETE
• Cold Start Pre-Operation checklist
  - Determine the status of available resources steam-lube oil-condenser cooling.
  - Using a checklist tailored to the individual system each student will conduct a cold start of the turbine generator system and bring the generator to full capability.
  - The student will prepare the turbine generator to be cross connected to a load.

FINDINGS
• Provide a written narrative on the proper operation of a turbine generator. The student will describe the normal operating parameters, observations on variance, and an explanation of the interactions between the low-pressure turbine and main condenser. Part of the finding of this performance exercise may include a critical thinking element on the use of various sources of chill water for the condenser and how variations in the condensate will affect the performance of the system.

ADDITIONAL INFORMATION
None

RECOMMENDED MATERIALS
None
POWER GENERATION
LAB 3.3-1 SYNCHRONIZE

PERFORMANCE OBJECTIVE

- Demonstrate the principles and practices of power generation synchronization.

LAB TYPE

Individual or Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

The instructor should prepare a proper manual of start up, operating, and synchronization procedures that is compatible with the simulation hardware or software being used. The procedures should have “checkpoint” questions at critical points to ensure the performance objectives are reinforcing the theoretical foundations in the course material.

BACKGROUND

The final output from a boiler generator is the connection of the generator to an energized load bus. The differences in the theory and practice of this critical step are often quite remarkable. The purpose of the exercise is to demonstrate and have the students apply theory into practical skill, the synchronization of a generating plant. Before attempting to conduct this exercise, the instructor must be sure the students have an understanding of the overall system as well as the theory of synchronization. Prior to conducting the lab, it is recommended that the instructor administer a written exam to ensure that the students have achieved a minimum level of competence.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range which may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material.

An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical or otherwise, from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on a lesson, momentarily neglecting safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.
TEST EQUIPMENT
None

MATERIALS NEEDED
None

CRITICAL TASKS STUDENTS MUST COMPLETE
- Using a simulator or other device, operations checklist and operating procedures manual, the student will demonstrate the following basic synchronization tasks:
  - Energize a dead bus.
  - Perform iso-synchronous operations.
  - Correctly perform paralleling operations.
  - Demonstrate the operation of generators in parallel and load sharing.
  - Observe generator response to inductive, resistive, and capacitive loads.
  - Calculate power factor.
  - Observe diesel generator auto-start and loading.

FINDINGS
- The student will write a short narrative that describes the relationship among multiple power generation sources, describe the procedures that an operator must master in order to synchronize various types and sizes of generating equipment.

ADDITIONAL INFORMATION
None

RECOMMENDED MATERIALS
None
POWER GENERATION
LAB 5.1-1 PROTECTIVE RELAY

PERFORMANCE OBJECTIVE

• To demonstrate the placement, function and value of a protective relay systems that provide signal for a physical disconnect to a circuit breaker to protect power systems from events.

LAB TYPE

Individual or Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

The instructor should develop exercises that will demonstrate the use of protective relays in a power system. The system should be of sufficient size to operate both with and without protective relays.

BACKGROUND

The electrical power system is designed to provide continuous power to consumers without interruption. In order to maintain this, the system must be able to respond to a variety of both types and magnitudes of variances. Most small variance (events) are able to be compensated for by control systems. However, larger events must be handled through the use of hardware protection systems. They include overcurrent protection, directional protection of parallel transformers, partial differential protection of parallel transformers, earth faults on transformer windings, and unrestricted and restricted earth fault protection.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range that may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material.

An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical or otherwise, from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on a lesson, momentarily neglecting safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.
TEST EQUIPMENT

- Multimeter
- Oscilloscope
- Power Meter

MATERIALS NEEDED

- Low voltage power supply
- Power transformer (step up and step down)
- Interconnection material
- Electrical safety PPE
- Simulated Power transmission and distribution system

CRITICAL TASKS STUDENTS MUST COMPLETE

- Establish a simple power transmission and distribution system that includes a generation, high voltage, and low voltage element.
- Interconnect the system to an appropriate load profile.
- Develop a schematic (one line) diagram of the system.
- Determine the critical nodes of the system that could be affected by an event.
- Develop and plan to insert protective relays into the system to provide protection.
- Ensure the plan is approved
- Using a DE-ENERGIZED system, insert protective devices into the existing system.
- Under the supervision of the instructor, test the protective devices for proper operation and isolation.

FINDINGS

- The student will submit a written analysis of the experiment, including the findings and outcomes of the use of protective relays in the system. Additionally, the student may be assigned to provide either a written or oral description of the result of the presented event and the hardware failures expected in the absence of the protective relay.

ADDITIONAL INFORMATION

None

RECOMMENDED MATERIALS

None
POWER GENERATION
LAB 5.2-1 IDENTIFY SYSTEM ABNORMALITIES

PERFORMANCE OBJECTIVE

• To demonstrate the ability of protective relay systems to respond to system placements, and to demonstrate function and value of a protective relay that provide a signal for a physical disconnect to protect power systems from events.

LAB TYPE

Individual or Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

The instructor should develop exercises that will simulate short circuits, load surges, loss of synchronization, and lightning strikes on the power system used in the previous exercises. These exercises should test the ability of protective relays to isolate and protect transformers in both upstream and downstream power schemes.

BACKGROUND

The electrical power system is designed to provide continuous power to consumers without interruption. In order to maintain this, the system must be able to respond to a variety of types and magnitudes of variances. Most small variance (events) are able to be compensated for by control systems. However, larger events must be handled through the use of hardware protection systems.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range that may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material.

An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical or otherwise, from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on a lesson, momentarily neglecting safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.
TEST EQUIPMENT

- Multimeter
- Oscilloscope
- Power Meter

MATERIALS NEEDED

- Low voltage power supply
- Power transformer (step up and step down)
- Interconnection material
- Electrical safety PPE
- Simulated Power transmission and distribution system

CRITICAL TASKS STUDENTS MUST COMPLETE

- Establish a simple power transmission and distribution system that includes a generation, high voltage, and low voltage element with an interconnected isolation scheme in place and tested.
- Interconnect the system to an appropriate load profile.
- Under the supervision of the instructor, test the protective devices for proper operation and isolation for the specific events listed at the beginning of the exercise.
- Use the lab results sheet provided to record the results.

FINDINGS

- The student will provide an analysis of each event using the data collected during the operation of each event. The student will determine if the protective system functioned normally, what equipment was protected, and what would have occurred had the protection either not been in place or malfunctioned. The student should submit a written analysis of the experiment, the findings, and outcomes of the use of protective relays in the system. Additionally the student may be assigned to provide either a written or oral description of the result of the presented event and the hardware failures expected in the absence of the protective relay.

ADDITIONAL INFORMATION

None

RECOMMENDED MATERIALS

None
POWER GENERATION
LAB 6.1-1 PMU

PERFORMANCE OBJECTIVE

• To program and operate a power management system meter connected to 3-phase 208 VAC power system.

LAB TYPE

Individual or Team

TIME REQUIRED

3 hours

BACKGROUND

The core of power system energy management is the ability to accurately monitor, measure, translate, and communicate a full range of energy parametrics using equipment that is installed in a power system. There are a variety of metering systems in use. Understanding the functionality of a typical system will provide insight into the capabilities and limitations of systems in general.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range that may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris—oil, water, or other slippery material. An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical or otherwise, from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on a lesson, momentarily neglecting safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.

TEST EQUIPMENT

• Power Monitoring Unit (Multifunction meter)
• Resistive Load <4 amp

MATERIALS NEEDED

• Single Phase 120 or 208 VAC power source
CRITICAL TASKS STUDENTS MUST COMPLETE

- Establish Primary power to the test board.
- Connect the power and energy meter to the primary power and to a load of known value.
- Using the power meter function diagram, set the meter to perform the following measurements:
  - Load Magnitude (kw)
  - Energy Consumption (kwh)
  - Load factor (LF)
  - Power Factor (PF)
  - Voltage (volts)
  - Current (amps)
- Establish a communication link between the meter and a control system.
- Collect power and energy data from the meter using the control system.

FINDINGS

- The student will determine what measurements are direct readings taken from connection with the power system, what readings are calculated from direct readings, and the accuracy of the calculated readings.
- The student will submit a written schematic diagram of the meter as connected to the system, including all parameters of current and voltage transformers.

ADDITIONAL INFORMATION

None

RECOMMENDED MATERIALS

None
POWER GENERATION
LAB 6.2-1 PRIMARY INSTRUMENTS

PERFORMANCE OBJECTIVE

- Use primary power system measurement instruments to collect data from a power system.

LAB TYPE

Individual or Team

TIME REQUIRED

1 hour

INSTRUCTOR PREPARATION

The instructor must have a predetermined power circuit that is functioning normally and has test points available for the student to connect instruments and collect readings. The instructor must have available personal protective equipment PPE appropriate to the system under test. Additionally, the instructor must ensure that the students are properly trained in the use of PPE.

The instructor will develop and have fully functioning and malfunctioning equipment, as well as leads and ancillary items, for use during the equipment inspections.

BACKGROUND

Power system technicians will be called upon to operate on energized power systems, taking measurements for the purpose of operations, troubleshooting, repair, and data collection. Not all instruments will be hard-wired into the system under test; therefore, the technician must have an understanding of the variety of instruments available, the proper use, function, capabilities, limitations, and output methods for each instrument.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range that may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris—oil, water, or other slippery material. An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical or otherwise, from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on a lesson, momentarily neglecting safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.
TEST EQUIPMENT

- Ammeter
- Voltmeter
- Wattmeter
- Varmeter
- Power Factor Meter
- Frequency Meter

MATERIALS NEEDED

- Functioning, energized 208 VAC three-phase power system

CRITICAL TASKS STUDENTS MUST COMPLETE

- Given a lab sheet, schematic diagram, and each of the above test equipment, the student will collect information from the power system.
- The student will inspect each piece of test equipment, including test leads, and all ancillary items to determine if there has been degradation of the safety or function due to use, misuse, or malfunction.

FINDINGS

- The student will submit a written report on the function, capabilities, limitations, and output for each piece of equipment used in the experiment. The student will submit a written “gripe log” description of any and all discrepancies noted during inspections.

ADDITIONAL INFORMATION

None

RECOMMENDED MATERIALS

None
POWER GENERATION
LAB 6.2-2 SECONDARY INSTRUMENTS

PERFORMANCE OBJECTIVE

● Use secondary power system measurement instruments to collect data from a power system.

LAB TYPE

Individual or Team

TIME REQUIRED

1 hour

INSTRUCTOR PREPARATION

The instructor must have a predetermined power circuit that is functioning normally, and has test points available for the student to connect instruments and collect readings. The instructor must have available personal protective equipment PPE appropriate to the system under test. Additionally, the instructor must ensure that the students are properly trained in the use of PPE.

The instructor will develop and have fully functioning and malfunctioning equipment, as well as leads and ancillary items, for use during the equipment inspections.

BACKGROUND

Power system technicians will be called upon to operate on energized power systems, taking measurements for the purpose of operations, troubleshooting, repair, and data collection. Not all instruments will be hard-wired into the system under test, therefore the technician must have an understanding of the variety of instruments available, the proper use, function, capabilities, limitations, and output methods for each instrument.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range that may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material. An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical or otherwise, from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on a lesson, momentarily neglecting safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.
TEST EQUIPMENT

- Temperature indicators
- Megohmmeter
- Ground Ohmmeter
- Ground Detector
- Oscillograph
- Watt Hour Meter
- Demand Meter
- Syncroscope

MATERIALS NEEDED

- Functioning, energized 208 VAC three-phase power system

CRITICAL TASKS STUDENTS MUST COMPLETE

- Given a lab sheet, schematic diagram, and each test equipment above, the student will collect information from the power system.
- The student will inspect each test equipment, including test leads, and all ancillary items to determine if there has been degradation of the safety or function due to use, misuse, or malfunction.

FINDINGS

- The student will submit a written report on the function, capabilities, limitations, and output for each equipment used in the experiment. The student will submit a written “gripe log” description of any and all discrepancies noted during inspections.

ADDITIONAL INFORMATION

None

RECOMMENDED MATERIALS

None
POWER GENERATION
LAB 6.3-1 USING INSTRUMENTS IN A SYSTEM

PERFORMANCE OBJECTIVE

- Use primary and secondary power system measurement instruments to collect data from a power system, verify the accuracy of the data, and use multiple instruments to re-verify those readings.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

The instructor must have a predetermined power circuit that is functioning normally, and has test points available for the student to connect instruments and collect readings. The instructor must have available personal protective equipment PPE appropriate to the system under test. Additionally, the instructor must ensure that the students are properly trained in the use of PPE.

The instructor will develop and have fully functioning and malfunctioning equipment, as well as leads and ancillary items, for use during the equipment inspections.

BACKGROUND

Power system technicians will be called upon to operate on energized power systems, taking measurements for the purpose of operations, troubleshooting, repair, and data collection. Not all instruments will be hard-wired into the system under test, therefore the technician must have an understanding of the variety of instruments available, the proper use, function, capabilities, limitations, and output methods for each instrument.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range that may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material. An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical or otherwise, from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on a lesson, momentarily neglecting safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.
TEST EQUIPMENT
- Ammeter
- Voltmeter
- Wattmeter
- Varmeter
- Power Factor Meter
- Frequency Meter
- Temperature indicators
- Megohmmeter
- Ground Ohmmeter
- Ground Detector
- Oscillograph
- Watt Hour Meter
- Demand Meter
- Syncroscope

MATERIALS NEEDED
- Functioning, energized 208 VAC three-phase power system

CRITICAL TASKS STUDENTS MUST COMPLETE
- Given a lab sheet, schematic diagram, and each test equipment above, the team will work together to collect information from the power system.

  - The team will inspect each test equipment, including test leads, and all ancillary items to determine if there has been degradation of the safety or function due to use, misuse, or malfunction.

FINDINGS
- The team will submit a written report on the function, capabilities, limitations, and output for each piece of equipment used in the experiment.

  - The team will submit a written “gripe log” description of any and all discrepancies noted during inspections.

ADDITIONAL INFORMATION
None

RECOMMENDED MATERIALS
None
POWER GENERATION
LAB 7.1-1 TOPOLOGY

PERFORMANCE OBJECTIVE

- Diagram a one-line power grid network that represents a basic bus topology.

LAB TYPE

Individual

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

Using all available resources and materials the instructor will write a problem-based scenario that describes a basic bus power distribution system.

BACKGROUND

This laboratory exercise is the first foundational exercise for the distributed generation topology exercises. The student gains an understanding of both the systems and the software/simulation that is being utilized to develop the basic bus power system.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range that may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material. An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical or otherwise, from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on a lesson, momentarily neglecting safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.

TEST EQUIPMENT

- Multimeter
- Oscilloscope
- Multifunction power-meter
- Power grid design and simulation software
MATERIALS NEEDED

- Electrical power distribution trainer
- Grid load monitoring trainer
- PAC controller, PLC or SCADA system
- Power System Simulator

CRITICAL TASKS STUDENTS MUST COMPLETE

- Read and understand the project problem statement. Conduct secondary research and write a project proposal and submit for approval.
- Establish a 3-phase base load generation point.
- Primary node power monitoring: program multifunction power meter.
- Connect transmission line topology at 300 mile 600kv.
- Establish primary node with one branch load.
- Interconnect multifunction power meter to the branch.
- Test system for normal operation.

FINDINGS

- Students will submit a written analysis of the exercise.

ADDITIONAL INFORMATION

Recommended materials:

- Hampden Model H-190-1 Smart Grid Electrical Distribution Trainer
- Hampden Model H-190-2 Smart Grid Load Monitoring Trainer
- Siemens PSSE
- Paladin Designbase 2.0 Software Simulation
POWER GENERATION
LAB 7.2-1 BASIC BUS

PERFORMANCE OBJECTIVE
• Diagram a one-line power grid network that represents a basic (single) bus topology.

LAB TYPE
Individual

TIME REQUIRED
3 hours

INSTRUCTOR PREPARATION
Using all available resources and materials the instructor writes a problem-based scenario that describes a basic bus power distribution system.

BACKGROUND
This laboratory exercise is the first foundational exercise for the IEMS distributed generation topology exercises used during follow-on course material. The student will begin to gain an understanding of both the systems and the software/simulation that is being utilized to develop the basic bus power system.

SAFETY REQUIREMENTS
Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range that may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material. An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical or otherwise, from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on a lesson, momentarily neglecting safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.

TEST EQUIPMENT
• Multimeter
• Oscilloscope
• Multifunction power-meter
• Power grid design and simulation software
MATERIALS NEEDED

- Electrical power distribution trainer
- Grid load monitoring trainer
- PAC controller, PLC or SCADA system

CRITICAL TASKS STUDENTS MUST COMPLETE

- Read and understand project problem statement provided by the instructor.
- Conduct secondary research on the origins of the problem, potential solutions and barriers to success. Write a project proposal and submit to the instructor for review and approval.
- Establish a three-phase base load generation point using a rankine cycle turbine plant.
- Program a primary node power monitoring multifunction power meter to capture outbound power from the generation plant.
- Connect transmission line topology at 300 mile 600kv.
- Establish primary node with one branch load.
- Interconnect multifunction power meter to the branch.
- Test system for normal operation.

FINDINGS

- Students will submit a written analysis of the exercise, including P&ID of the topology, critical paths, nodes, and problems.

ADDITIONAL INFORMATION

Recommended materials:

- Hampden Model H-190-1 Smart Grid Electrical Distribution Trainer
- Hampden Model H-190-2 Smart Grid Load Monitoring Trainer
- Siemens PSSE
- Paladin Designbase 2.0 Software Simulation
POWER GENERATION  
LAB 7.2-2 ADVANCED BUS

PERFORMANCE OBJECTIVE

- Diagram a one-line power grid network that represents an advanced (multiple) bus topology.

LAB TYPE

Individual

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

Using all available resources and materials, the instructor writes a problem-based scenario that describes an advanced bus power distribution system.

BACKGROUND

This laboratory exercise is the second foundational exercise for the IEMS distributed generation topology exercises. The students continue to gain an understanding of both the systems and the software/simulation that is being utilized to develop the basic bus power system.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range that may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material. An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical or otherwise, from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on a lesson, momentarily neglecting safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.

TEST EQUIPMENT

- Multimeter
- Oscilloscope
- Multifunction power-meter
- Power grid design and simulation software
MATERIALS NEEDED

- Electrical power distribution trainer
- Grid load monitoring trainer
- PAC controller, PLC, or SCADA system

CRITICAL TASKS STUDENTS MUST COMPLETE

- Read and understand the project problem statement. Conduct secondary research and write a project proposal and submit for approval.
- Establish a 3-phase base load generation point.
- Monitor primary node power: program multifunction power meter.
- Connect transmission line topology at 300 mile 600kv.
- Establish primary node with one branch load.
- Interconnect multifunction power meter to the branch.
- Test system for normal operation.
- Establish a secondary node with two branches.
- Interconnect multifunction power meter to the branch.
- Test system for normal operation.

FINDINGS

- Students will submit a written analysis of the exercise.

ADDITIONAL INFORMATION

Recommended materials:

- Hampden Model H-190-1 Smart Grid Electrical Distribution Trainer
- Hampden Model H-190-2 Smart Grid Load Monitoring Trainer
POWER GENERATION
LAB 7.3-1 TEAM LAB

PERFORMANCE OBJECTIVE

- Diagram a one-line power grid network that represents an advanced (multiple) bus topology with multiple possible route configurations for the branch load requirements.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

Using all available resources and materials, the instructor writes a problem-based scenario that describes an advanced bus power distribution system.

BACKGROUND

This laboratory exercise is the third and final foundational exercise for the IEMS distributed generation topology exercises. The students continue to gain an understanding of both the systems and the software/simulation that is being utilized to develop the basic bus power system. This exercise introduces the student to the concept of multiple configurations along a branch. The exercise is designed to foster discussion, teamwork, and problems, solving in the power distribution network design.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range that may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material. An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical or otherwise, from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on a lesson, momentarily neglecting safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.
TEST EQUIPMENT

• Multimeter
• Oscilloscope
• Multifunction power-meter
• Power grid design and simulation software

MATERIALS NEEDED

• Electrical power distribution trainer
• Grid load monitoring trainer
• PAC controller, PLC, or SCADA system

CRITICAL TASKS STUDENTS MUST COMPLETE

• Read and understand the project problem statement. Conduct secondary research and write a project proposal and submit for approval.
• Establish a 3-phase base load generation point.
• Monitor primary node power: program multifunction power meter.
• Connect transmission line topology at 300 mile 600kv.
• Establish primary node with one branch load.
• Interconnect multifunction power meter to the branch.
• Test system for normal operation.
• Establish a secondary node with two branches.
• Interconnect multifunction power meter to the branch.
• Test system for normal operation.

FINDINGS

• Teams will submit a written analysis of the exercise.

ADDITIONAL INFORMATION

Recommended materials:
• Hampden Model H-190-1 Smart Grid Electrical Distribution Trainer
• Hampden Model H-190-2 Smart Grid Load Monitoring Trainer
• Siemens PSSE
SCADA INDUSTRIAL CONTROL SYSTEMS
COURSE DESIGN GUIDE

COURSE TITLE
Supervisory Control and Data Acquisition (SCADA) Industrial Control Systems

CATALOG DESCRIPTION
This course introduces students to Supervisory Control and Data Acquisition (SCADA) systems concepts, including basic architecture and technology. This course includes how SCADA software is configured. SCADA software and Remote Terminal Unit equipment requirements and simple communication techniques will be covered.

CREDITS
4 credits, 96 hours

COURSE FORMAT
This course is a lecture/lab format that incorporates industry related lab exercises and activities during in-class, instructor supervised labs.

COURSE NUMBER
Materials for this course is presented to meet the requirements for a 200-level course.

PREREQUISITES
Fundamentals of Electricity, Fundamentals of Database Information Systems, College Algebra or equivalent.

INSTRUCTOR INFORMATION
Recommended Qualifications: A Master’s Degree in Engineering and three to five years of experience teaching industrial control and instrumentation. Instructors must have in-depth knowledge of the subject matter and the teaching skills to efficiently and effectively convey this knowledge to learners. Teaching skills involve using several instructional methods and resources to effectively transfer knowledge and skills from experience. Working knowledge of content, curriculum, methods, materials, and equipment in the career technical specialty of the course (Process Technology, Energy Technology, Advanced Manufacturing). Experience and ability to plan and implement lessons based on objectives for career technical programs. Experience working in a related vocational trade.

TEACHING METHODS AND ASSIGNMENTS FOR ACHIEVING LEARNING OUTCOMES
The course is divided into five learning units; each learning unit addresses a specific topic with direct application to the fundamentals of Supervisory Control and Data Acquisition (SCADA). Each topic has a recommended length (topic hours) assigned. Topic hours are a guideline for instruction that is intended to be adapted to the individual instructor’s teaching style. The ratio of lecture to lab is 1:3. Included in the instructional materials are example worksheets, homework assignments, and quizzes. Students are expected to spend additional study/practice outside of the class time. The recommended ratio of class to study time is 1:4 for this course. Each topic lists suggested time allocation. Total time allocated includes an hour course introduction, a 2-hour review, and a 2-hour written exam.
STUDENT TEXTS, READING AND OTHER MATERIALS

(recommended - used for course development)


ADDITIONAL REQUIREMENTS

• HMI/SCADA Software

BIBLIOGRAPHY


STUDENT LEARNING OUTCOMES

Upon successful completion the student will have the ability to:

• Diagram the architecture and technology of a SCADA System
• Contrast Scada Industrial Control Systems to other information systems
• Evaluate the limitations of current SCADA technology
• Design a simplified SCADA application
• Configure the Human Machine Interface of a simplified SCADA application
# ASSESSMENT RUBRIC

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>EXEMPLARY 4</th>
<th>SATISFACTORY 3</th>
<th>DEVELOPING 2</th>
<th>BEGINNING 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diagram the architecture and technology of a SCADA System</strong></td>
<td>Provided an accurate, easy-to-follow diagram with labels to illustrate the procedure or the process being studied</td>
<td>Provided an accurate diagram with labels to illustrate the procedure or the process being studied</td>
<td>Provided an easy-to-follow diagram with labels to illustrate the procedure or process, but one key step was left out</td>
<td>Did not provide a diagram OR the diagram was quite incomplete</td>
</tr>
<tr>
<td><strong>Contrast SCADA to other Information Systems</strong></td>
<td>Independently developed differentiation well-substantiated by observation of the characteristics of other information systems</td>
<td>Independently developed differentiation somewhat substantiated by observation of other information system</td>
<td>Independently developed differentiation somewhat substantiated by observation of other information systems</td>
<td>Needed instructor assistance to develop differentiation or do a basic review of information systems</td>
</tr>
<tr>
<td><strong>Evaluate the limitations of current SCADA technology</strong></td>
<td>Limitations were outlined in a step-by-step fashion that could be followed by anyone without additional explanations, and no instructor help was needed to accomplish this</td>
<td>Limitations were outlined in a step-by-step fashion that could be followed by anyone without additional explanations, but some instructor help was needed to accomplish this</td>
<td>Limitations were outlined in a step-by-step fashion, but had 1 or 2 gaps that required explanation even after instructor feedback had been given</td>
<td>Limitations that were outlined were seriously incomplete or not sequential, even after instructor feedback had been given</td>
</tr>
<tr>
<td><strong>Design a SCADA System</strong></td>
<td>Each element in the design had a function and clearly served to illustrate some aspect of SCADA so that design was complete and clearly documented</td>
<td>Each element in the design clearly served to illustrate some aspect of the SCADA design, and most elements of the design were complete and clearly documented</td>
<td>Each element in the design clearly served to illustrate some aspect of the experiment, and most of the elements of the design were complete but incompletely documented</td>
<td>The design seemed incomplete or chaotic with no clear plan, so that documentation was missing or incorrect</td>
</tr>
<tr>
<td><strong>Configure a SCADA HMI application</strong></td>
<td>Student provided a detailed and complete HMI clearly based on the SCADA design</td>
<td>Student provided a somewhat detailed HMI clearly based on the SCADA design</td>
<td>Student provided a HMI with some reference to the SCADA design</td>
<td>Student provided a non-functional HMI OR important details were overlooked</td>
</tr>
</tbody>
</table>

Notes:
### UNIT 1: HISTORY/PURPOSE

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 History and Purpose of SCADA</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 3 hrs.</td>
<td>• Define purpose and application of Scada Industrial Control Systems</td>
</tr>
<tr>
<td></td>
<td>• Classify basic building blocks of a SCADA system</td>
</tr>
<tr>
<td></td>
<td>• Differentiate analog, discrete, and digital instruments and signals</td>
</tr>
<tr>
<td></td>
<td>• Relate communication paths to SCADA design</td>
</tr>
<tr>
<td></td>
<td>• Recognize how digital technology has and is driving SCADA evolution</td>
</tr>
<tr>
<td></td>
<td>• Identify limitations of Scada Industrial Control Systems</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 2: REAL TIME SITUATIONS AWARENESS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Operator Situation Awareness</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 3 hrs.</td>
<td>• Describe real-time systems for Situation Awareness</td>
</tr>
<tr>
<td></td>
<td>• Apply real-time requirement to SCADA elements</td>
</tr>
<tr>
<td></td>
<td>• Discuss methods to convey the real-time state of the system to SCADA operators</td>
</tr>
<tr>
<td>2.2 Function and Purpose of Real-Time and Historical SCADA Databases</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 3 hrs.</td>
<td>• Organize SCADA information for effective presentation to the operator</td>
</tr>
<tr>
<td></td>
<td>• Interpret historical information to show understanding of system behavior</td>
</tr>
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<td></td>
<td>• Demonstrate effective Human Machine Interface design</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 3: EQUIPMENT SYSTEMS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
</table>
| **3.1 Command, Control and Communications in SCADA**  
  Lecture - 3 hrs.                                                                 | **The student will be able to:**  
  • Define control system elements: Sensors, Actuators and Algorithms  
  • Justify the value of control system elements for SCADA  
  • Differentiate analog and digital methods of communication  
  • Identify how information is translated between digital and analog signals  
  • Discuss medium, language, and interrupts in field communication protocols |
| **3.2 SCADA Applications**  
  Lecture - 1 hr.  
  Lab - 2 hrs.                                                                 | **The student will be able to:**  
  • Explain what the Remote Terminal Unit (RTU) function is  
  • Relate RTU to SCADA architecture  
  • Demonstrate hardware types such as PLC used for an RTU  
  • Describe the role of the SCADA Host  
  • Identify common SCADA Host functions  
  • Compare programming to configuring the SCADA Host  
  • Illustrate the flow of events in the SCADA Host |

**Performance Objectives, the student will:**  
• Describe the Remote Terminal Unit (RTU) function  
• Compare RTU to SCADA architectures  
• List hardware types such as PLC and IED that perform the function of a traditional RTU  
  - Lab Exercise: 3.2-1 RTU Hardware  
• List common SCADA Host functions  
• Describe programming compared to configuring the SCADA Host  
• Draw the flow of events in the SCADA Host  
  - Lab Exercise: 3.2-2 SCADA Host

Notes:
## UNIT 4: SCADA APPLICATIONS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Plan SCADA Design</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Discuss SCADA information retention and storage</td>
</tr>
<tr>
<td></td>
<td>• Evaluate historical versus real-time SCADA information</td>
</tr>
<tr>
<td></td>
<td>• Identify major types of SCADA applications</td>
</tr>
<tr>
<td></td>
<td>• Discuss Accounting and Quality of Data from the SCADA system</td>
</tr>
<tr>
<td></td>
<td>• Compare monitoring applications to remote control applications</td>
</tr>
<tr>
<td></td>
<td>• Plan a simplified SCADA system</td>
</tr>
<tr>
<td></td>
<td>• Evaluate alternative designs</td>
</tr>
<tr>
<td></td>
<td>• Design communication and data storage plans</td>
</tr>
<tr>
<td></td>
<td>• Schematize SCADA design</td>
</tr>
<tr>
<td></td>
<td>• Defend design in peer review</td>
</tr>
<tr>
<td></td>
<td>• Summarize SCADA role in Smart Grid</td>
</tr>
<tr>
<td>Lecture - 3 hrs.</td>
<td>Performance Objectives, the student will:</td>
</tr>
<tr>
<td>Lab - 5 hrs.</td>
<td>• Describe the requirements of a substation SCADA</td>
</tr>
<tr>
<td></td>
<td>• Document the functionality of the SCADA Host</td>
</tr>
<tr>
<td></td>
<td>• Document the communication paths available</td>
</tr>
<tr>
<td></td>
<td>• List the equipment interfaces needed</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 4.1-1 Select SCADA Design</td>
</tr>
<tr>
<td></td>
<td>• Draw a schematic of the selected SCADA Architecture</td>
</tr>
<tr>
<td></td>
<td>• Present the SCADA architecture for peer review</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 4.1-2 Propose SCADA Design</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 5: CONFIGURE SCADA SYSTEM

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>5.1 Architecture and Project Concepts</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Summarize SCADA software functions and modules</td>
</tr>
<tr>
<td></td>
<td>• Classify Human Machine Interface (HMI) Building Blocks</td>
</tr>
<tr>
<td></td>
<td>• Describe Real-Time Databases</td>
</tr>
<tr>
<td></td>
<td>• Explain Archive Databases</td>
</tr>
<tr>
<td></td>
<td>• Compare Communication Interfaces for Data Acquisition</td>
</tr>
<tr>
<td></td>
<td>• Summarize SCADA Architecture</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>Performance Objectives, the student will:</td>
</tr>
<tr>
<td>Lab - 3 hrs.</td>
<td>• Create a complete project implementing the common features needed for most real projects utilizing a SCADA software</td>
</tr>
<tr>
<td></td>
<td>• Optimize a project using the deadband</td>
</tr>
<tr>
<td></td>
<td>• Customize the Variable Selector and the Variable Database files using spreadsheet software</td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 5.1-1 SCADA Orientation</td>
</tr>
</tbody>
</table>

| **5.2 Human Machine Interface (HMI) Architecture for SCADA** | The student will be able to: |
| | • Create SCADA software project |
| | • Relate SCADA study case to SCADA Architecture |
| | • Discuss SCADA design process |
| | • Apply Real-Time Database Tags |
| | • Optimize SCADA project using deadband concepts |
| | • Demonstrate Data Acquisition using Modbus Protocol |
| | • Summarize OLE for Process Control (OPC) Standard for communication |
| Lecture - 4 hrs. | Performance Objectives, the student will: |
| Lab - 8 hrs. | • Create a complete project implementing the common features |
| | • Optimize a project using the deadband |
| | • Customize the Variable Selector and the Variable Database files using spreadsheet software |
| | • Lab Exercise: 5.2-1 Setup Project & Real Time Database |
| | • Describe three types of network protocols used in SCADA |
| | • List and explain the three components of communication |
| | • Debug communication with communication object’s status |
| | • Describe why one should optimize communication |
| | • Lab Exercise: 5.2-2 Native communication drivers |
| | • Manipulate the communication system variables |
| | • Manage double words |
| | • Manage redundant PLCs with Ethernet protocols |
| | • Map variables using a spreadsheet |
| | • Demonstrate communication status using system variables |
| | • Describe how SCADA software manages redundant PLCs |
| | • Configure variable mapping using a spreadsheet |
| | • Lab Exercise: 5.2-3 Communication optimization |
| | • Provide an overview of the OPC technology |
| | • Configure SCADA Software as an OPC Client and Server |
| | • Demonstrate optimization of the OPC communication |
| | • Demonstrate status of the OPC communication |
| | • Demonstrate how to tune the OPC communication |
| | • Demonstrate how to add logs |
| | • Describe how OPC System variables provide “system” level display |
| | • Demonstrate how to activate OPC Traces |
| | • Lab Exercise: 5.2-4 Standard Communication Drivers |
## UNIT 5: CONFIGURE SCADA SYSTEM

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
</table>
| **5.3 HMI Graphical User Interface (GUI) Objects** | The student will be able to:  
• Explain the concept of SCADA Mimics  
• Apply Windows to Mimics  
• Use basic graphical objects  
• Integrate images and layers  
• Organize HMI objects  

Performance Objectives, the student will:  
• Show how the workspace of the SCADA can be customized  
• Describe the relationship of a mimic to a workspace  
• List the ways in which the properties of a mimic provide for customized graphics  
• Demonstrate how SCADA software handles large mimics  
• Show how SCADA software can manage different resolutions for the same project  
• Using the basic graphical objects, draw the most common mimics used in a traditional SCADA project  
• Manipulate the Arrange tools that enable you to make a complete mimic  
• Import common image formats into the SCADA Software  
• Demonstrate several HMI tools to increase productivity  
• Show or hide graphical objects using the Zoom and Layers features  
• Use the Graphic Explorer to edit a graphical objects in run-time mode  

- **Lab Exercise: 5.3-1 Components of GUI**  
  • Using the basic graphical objects, draw the most common mimics used in a traditional SCADA project  
  • Manipulate the Arrange tools that enable you to make a complete mimic  
  • Import common image formats into the SCADA Software  
  • Demonstrate several HMI tools to increase productivity  
  • Show or hide graphical objects using the Zoom and Layers features  
  • Use the Graphic Explorer to edit a graphical objects in run-time mode  

| **5.4 Animation of GUI Objects** | The student will be able to:  
• Create animations  
• Modify animations  
• Classify commonly used animations  
• Apply color and text animations  
• Modify Real-Time Tags with animation  
• Design navigation using button animation  

Performance Objectives, the student will:  
• Open the animation tab in the Graphical Object properties  
• Configure an animation to change the color, open a mimic or set a value  
• Demonstrate how to have multiple animations on a graphical object  
• Demonstrate how a mimic can be embedded in another mimic  
• Demonstrate how to combine bits for an animation  

- **Lab Exercise: 5.4-1 Basic Animations**  
  • Demonstrate how a mimic can be embedded in another mimic  
  • Demonstrate how to combine bits for an animation  

- **Lab Exercise: 5.4-2 Advanced Animations**  

Notes:
# UNIT 5: CONFIGURE SCADA SYSTEM

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>5.5 Generic HMI Components</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 3 hrs.</td>
<td>• Develop SCADA project templates</td>
</tr>
<tr>
<td>Lab - 5 hrs.</td>
<td>• Describe Branching concept</td>
</tr>
<tr>
<td></td>
<td>• Use Generic Objects in SCADA development</td>
</tr>
<tr>
<td></td>
<td>• Contrast open vs closed archive databases</td>
</tr>
<tr>
<td></td>
<td>• Use Event Logs</td>
</tr>
<tr>
<td></td>
<td>• Create Alarm History Databases</td>
</tr>
<tr>
<td></td>
<td><strong>Performance Objectives, the student will:</strong></td>
</tr>
<tr>
<td></td>
<td>• Demonstrate how to have the same layout for each graphic in a project</td>
</tr>
<tr>
<td></td>
<td>• Describe the concept of a branch</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate how to manage generic objects</td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 5.5-1 Generic HMI</td>
</tr>
<tr>
<td></td>
<td>• Describe the alarm life cycle</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate how to display an alarm in a mimic</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate how to interact with an alarm</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate how to create an alarm threshold</td>
</tr>
<tr>
<td></td>
<td>• Use an alarm’s associated action</td>
</tr>
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<td></td>
<td>• Use alarm counters</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate how to manage the associated labels</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate how to use the Domain and Nature attributes</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate how to use the extended attributes</td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 5.5-2 Alarms, Labels, Attributes, and Filtering</td>
</tr>
<tr>
<td><strong>5.6 Metafiles</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 3 hrs.</td>
<td>• Analyze the value of a metafile</td>
</tr>
<tr>
<td>Lab - 3 hrs.</td>
<td>• Describe how metafiles support project auditing</td>
</tr>
<tr>
<td></td>
<td>• Justify when a metafile approach is beneficial</td>
</tr>
<tr>
<td></td>
<td><strong>Performance Objectives, the student will:</strong></td>
</tr>
<tr>
<td></td>
<td>• Describe a metafile for project generation</td>
</tr>
<tr>
<td></td>
<td>• Describe the various import sources</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate the generic import</td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 5.6-1 Project Generation</td>
</tr>
<tr>
<td><strong>5.7 Archive &amp; Historical Databases</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 3 hrs.</td>
<td>• Differentiate between file based proprietary databases and open relational databases</td>
</tr>
<tr>
<td>Lab - 5 hrs.</td>
<td>• Describe how file system databases work</td>
</tr>
<tr>
<td></td>
<td>• Compare them to relational databases</td>
</tr>
<tr>
<td></td>
<td>• Enumerate the pros and cons of each approach</td>
</tr>
<tr>
<td></td>
<td><strong>Performance Objectives, the student will:</strong></td>
</tr>
<tr>
<td></td>
<td>• Describe what an Archive Unit is</td>
</tr>
<tr>
<td></td>
<td>• Discuss the different types of Archive Units</td>
</tr>
<tr>
<td></td>
<td>• Describe differences in proprietary Archive Units</td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 5.7-1 Archive Units</td>
</tr>
<tr>
<td></td>
<td>• Document what is the Historical Database Server</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate how to configure a database Archive Unit</td>
</tr>
<tr>
<td></td>
<td>• Describe how to maintain the Archives database</td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 5.7-2 Historical Database Server</td>
</tr>
</tbody>
</table>
### UNIT 5: CONFIGURE SCADA SYSTEM

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>5.8 Scripted HMI Behaviour</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 3 hrs.</td>
<td>• Summarize scripting approaches</td>
</tr>
<tr>
<td>Lab - 6 hrs.</td>
<td>• Apply SCADA basic scripts</td>
</tr>
<tr>
<td></td>
<td>• Discuss Visual Basic Application (VBA) scripting</td>
</tr>
<tr>
<td></td>
<td>• Apply VBA scripts</td>
</tr>
<tr>
<td></td>
<td>• Explain Expressions</td>
</tr>
<tr>
<td></td>
<td>• Illustrate scripting alternatives</td>
</tr>
<tr>
<td></td>
<td><strong>Performance Objectives, the student will:</strong></td>
</tr>
<tr>
<td></td>
<td>• Describe the SCADA Basic program structure</td>
</tr>
<tr>
<td></td>
<td>• Apply the SCADA Basic syntax to create a simple script</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate how to run a script</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate how to trigger a script by clicking a button</td>
</tr>
<tr>
<td></td>
<td>• Load one or more Programs at start-up</td>
</tr>
<tr>
<td></td>
<td>• Customize an Alarm, Log, or Trend Viewer using scripts</td>
</tr>
<tr>
<td></td>
<td>• Use the Branch in a script</td>
</tr>
<tr>
<td></td>
<td>• Describe different ways to trigger a Function</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 5.8-1 Scripting</td>
</tr>
<tr>
<td></td>
<td>• Describe the VBA Workspace</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate how to manipulate a SCADA graphical object using VBA</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate how to manipulate ActiveX</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate how to read and write a comma separated values (CSV) file</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate how to manipulate an external application such as Excel</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 5.8-2 Visual Basic for Applications Scripting</td>
</tr>
<tr>
<td><strong>5.9 SCADA HMI Application</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 3 hrs.</td>
<td>• Select SCADA project</td>
</tr>
<tr>
<td>Lab - 12 hrs.</td>
<td>• Create Project and Templates</td>
</tr>
<tr>
<td></td>
<td>• Design and create reusable objects</td>
</tr>
<tr>
<td></td>
<td>• Assemble HMI objects</td>
</tr>
<tr>
<td></td>
<td>• Devise methods to complete SCADA design</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate complete SCADA design</td>
</tr>
<tr>
<td></td>
<td>• Justify design choices</td>
</tr>
<tr>
<td></td>
<td>• Evaluate design alternatives</td>
</tr>
<tr>
<td></td>
<td><strong>Performance Objectives, the student will:</strong></td>
</tr>
<tr>
<td></td>
<td>• Define selected SCADA project requirements</td>
</tr>
<tr>
<td></td>
<td>• Design and prototype Project and Templates</td>
</tr>
<tr>
<td></td>
<td>• Design communication paths and protocols</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 5.9-1 Final Project Part 1</td>
</tr>
<tr>
<td></td>
<td>• Design, prototype and create reusable objects</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 5.9-2 Final Project Part 2</td>
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<tr>
<td></td>
<td>• Assemble SCADA objects from templates</td>
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<td>• Devise methods to complete SCADA design</td>
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<td>- Lab Exercise: 5.9-3 Final Project Part 3</td>
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<td>• Demonstrate complete SCADA design</td>
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<td></td>
<td>- Lab Exercise 5.9-4 Final Project Part 4</td>
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</table>

Notes:
SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 3.2-1 RTU HARDWARE

PERFORMANCE OBJECTIVE

- Describe the Remote Terminal Unit (RTU) function.
- Compare RTU to SCADA architectures.
- List hardware types such as PLC and IED that perform the function of a traditional RTU.

LAB TYPE

Individual

TIME REQUIRED

1 hour

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

Remote Terminal Unit (RTU) is the traditional name of telemetry equipment used for data collection and control of substation equipment and other grid assets. Because of the increased availability of high speed communications and lower cost, Programmable Logic Controllers (PLC) are increasingly being used as the RTU. In addition, modern equipment is increasingly being equipped with what is essentially an embedded RTU. Such equipment is known as an Intelligent Equipment Device (IED).

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

None

MATERIALS NEEDED

None
CRITICAL TASKS STUDENTS MUST COMPLETE

- Describe the functionality of an RTU.
- Identify the core components of an RTU.
- Draw a SCADA architecture related to a transmission grid and indicate the relation of the RTU to substation equipment and the SCADA control room.
- Indicate what modules (functionality) are required to be added to an off-the-shelf PLC in order for it to function as an RTU.

FINDINGS

- Scada Industrial Control Systems have evolved as communication costs have come down.
- A modern SCADA makes use of both IEDs and PLCs to monitor and control site equipment.

ADDITIONAL INFORMATION

Bibliography:
SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 3.2-2 SCADA HOST

PERFORMANCE OBJECTIVE

- List common SCADA Host functions.
- Describe programming compared to configuring the SCADA Host.
- Draw the flow of events in the SCADA Host.

LAB TYPE

Individual

TIME REQUIRED

1 hour

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

The SCADA host is the computer that receives data from field devices. It is usually, but not always found in a control room setting. Graphical screens are used to display both realtime and historical data in the form of trend lines, tabular data, and graphical animation. The display and management of alarms is a critical role of the SCADA host whether alarms are passed through from field devices are raised at the host level based on multiple equipment criteria. In this lab we explore the components of a SCADA host software package.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Computer
- SCADA software

MATERIALS NEEDED

None
CRITICAL TASKS STUDENTS MUST COMPLETE

- List and describe the seven basic components of a SCADA host software package.
- Describe what is meant by configuring SCADA.
- Provide examples of functionality of a SCADA package that require programming.
- List three examples of different approaches to programming SCADA host software.
- Diagram the flow of events when data acquisition is performed by SCADA host software for an alarm point.
- Diagram the flow of events when an operator makes a control action that requires scaling before being transferred to the field device.

FINDINGS

- There is a common set of functionality that all SCADA host systems provide.
- The majority time of setting up a SCADA host system is done by configuring tables of information.
- Customization of a SCADA application is done by programming with scripting being the most common.

ADDITIONAL INFORMATION

Bibliography:


Recommended materials:

SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 4.1-1 SELECT SCADA DESIGN

PERFORMANCE OBJECTIVE

● Describe the requirements of a substation SCADA.
● Document the functionality of the SCADA Host.
● Document the communication paths available.
● List the equipment interfaces needed.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required, see “Materials Needed” section below.

BACKGROUND

The purpose of this lab is to summarize the information gathered in the first part of the course to demonstrate the student’s understanding of the architecture and function of a SCADA system.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

● Computer

MATERIALS NEEDED

● Notepad software
● Spreadsheet software

CRITICAL TASKS STUDENTS MUST COMPLETE

● List the requirements of a substation SCADA.
● Describe the functionality of the SCADA Host.
● Enumerate the communication paths available.
● List the equipment interfaces needed.
FINDINGS

- Equipment capability and communication infrastructure are critical components of determining a SCADA architecture.

ADDITIONAL INFORMATION

Bibliography:

Recommended materials:
SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 4.1-2 PROPOSE SCADA DESIGN

PERFORMANCE OBJECTIVE

- Draw a schematic of the selected SCADA Architecture.
- Present the SCADA architecture for peer review.

LAB TYPE

Team

TIME REQUIRED

2 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required, see “Materials Needed” section below.

BACKGROUND

This is the final project for the first part of the Scada Industrial Control Systems course. Students will create a schematic of the proposed substation SCADA and present it for review by their peers and instructor.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Computer
- SCADA software

MATERIALS NEEDED

- Notepad software
- Spreadsheet software

CRITICAL TASKS STUDENTS MUST COMPLETE

- Draw a schematic of the proposed SCADA system.
- Document communication paths to equipment.
- Identify communication protocols proposed.
- Defend the architecture to peers and instructor.
FINDINGS

- There are multiple valid architectures for any given SCADA application each has pros and cons.

ADDITIONAL INFORMATION

Bibliography:

Recommended materials:
SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 5.1-1 SCADA ORIENTATION

PERFORMANCE OBJECTIVE
● Create a project implementing the common features of most real projects utilizing SCADA.
● Optimize the project using deadband.
● Customize the Variable Selector and the Variable Database files using a spreadsheet software.

LAB TYPE
Team

TIME REQUIRED
3 hours

INSTRUCTOR PREPARATION
It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of
lab stations with computers and peripherals in good working order. Ensure that networks are active and software
dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student
files are not corrupted, and confirm that students have access to the student files. A third party software may be
required, see “Materials Needed” section below.

BACKGROUND
This is the first lab focused on hands on configuration of a SCADA system.

SAFETY REQUIREMENTS
Students will be expected to utilize electronic equipment, components and software. Provide students with basic
guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the
computer equipment.

TEST EQUIPMENT
● Computer
● SCADA software

MATERIALS NEEDED
● Notepad software
● Spreadsheet software

CRITICAL TASKS STUDENTS MUST COMPLETE
● Design complete project that meets the following features:
  - This building has three floors.
  - The first floor has three rooms. The second and third floors have five rooms and are identical.
  - All rooms have one air conditioner and one light.
  - One room on the first floor has two air conditioners and two lights.
- Collect the data from one PLC and one OPC server.
- Use the same layout for each mimic.
- Good, clear navigation among mimics.
- Display all data about all the air conditioners and lights.
- Manage the alarms.
- Archive the data and display them on trends and logs.
- Display the status of the devices we are communicating with.
  - Manage several user profiles.
  - Add the following variables using Notepad:
    - Temperature
    - Setpoint
    - On
  - Add the variables for the first floor using a spreadsheet.
  - Configure the deadband for all Temperature and Luminosity variables to 1 percent of their value.

**FINDINGS**

- It is important to understand the architecture of the SCADA software that is being used.
- Good design involves making use of built in functionality and minimizing custom programming.

**ADDITIONAL INFORMATION**

Bibliography:

Recommended materials:
SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 5.2-1 SETUP PROJECT AND REAL TIME DATABASE

PERFORMANCE OBJECTIVE

● Create a complete project implementing the common features needed for most real projects utilizing a SCADA software.
● Optimize the project using the deadband.
● Customize the Variable Selector and the Variable Database files using a spreadsheet software.

LAB TYPE
Team

TIME REQUIRED
2 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required, see “Materials Needed” section below.

BACKGROUND

This lab gives an overall orientation to a SCADA project starting from the real-time database naming convention through the animations of graphical objects on the screen.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

● Computer
● SCADA software

MATERIALS NEEDED

● Notepad software
● Spreadsheet software
CRITICAL TASKS STUDENTS MUST COMPLETE

• Determine a variable naming rule for our project:
  - Field 1: BUILDING
  - Field 2: FLOOR_XX where XX is the floor number
  - Field 3: DeviceType_DeviceID where
    - DeviceType is AC for air conditioners and LT for lights.
    - DeviceID is the identifier of the device
  - Field 4: The information itself (Temp for temperature, etc.)

This naming rule is not the only appropriate one. With some experience you will know what suits a particular project.

• Design complete project that meets the following features:
  - This building has three floors.
  - The first floor has three rooms. The second and third floors have five rooms and are identical.
  - All rooms have one air conditioner and one light.
  - One room on the first floor has two air conditioners and two lights.
  - Collect the data from one PLC and one OPC server.
  - The same layout for each mimic.
  - Good, clear navigation among mimics.
  - Display all data about all the air conditioners and lights.
  - Manage the alarms.
  - Archive the data and display them on trends and logs.
  - Display the status of the devices we are communicating with.
  - Manage several User profiles.

• Add the following variables using Notepad:
  - Temperature
  - Setpoint
  - On

• Add the variables for the first floor using a spreadsheet.

• Configure the deadband for all Temperature and Luminosity variables to 1 percent of their value.

FINDINGS

• The real-time database is the core of PcVue.
• You must decide on a suitable naming rule.
• A variable has many properties.
• The status of a variable indicates its validity.


**ADDITIONAL INFORMATION**

Bibliography:


Recommended materials:

SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 5.2-2 NATIVE COMMUNICATION DRIVERS

PERFORMANCE OBJECTIVE

- Describe three types of network protocols that are used in SCADA application.
- List and explain the three components of communication: network, node, and frame.
- Debug failed communication using the communication object’s status.
- Describe why you must optimize communication.

LAB TYPE

Team

TIME REQUIRED

2 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required, see “Materials Needed” section below.

BACKGROUND

After determining the real-time database naming structure, the next fundamental portion of a SCADA project is setting up communications to field devices. There are many protocols used for this purpose but one of the oldest and most commonly found is Modbus. This lab will use a Modbus simulator to illustrate how communications are configured and optimized. This is the heart of a SCADA system.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Computer
- SCADA software

MATERIALS NEEDED

- We will use the Modbus Poll and Modbus Slave (Evaluation license)
CRITICAL TASKS STUDENTS MUST COMPLETE

- Create basic communication using the third party tools:
  - Install a Modbus tools package
  - Start the Modbus TCP/IP Slave
    - Run the shortcut Modbus Slave
    - Load the Training slave configuration
    - Select the TCP/IP option
    - Finally you should have the Slave HMI
    - You can change the data values
  - Start the Modbus TCP/IP Master
    - Open the shortcut Modbus Poll
    - By default a frame is configured. It is set for reading 10 words from address 0 to Slave no.1.
      So you only have to select Connection / Connect...
    - We are going to create a frame to read the bits
      - Select Connection / Connect
      - Select TCP/IP
      - Now you are able to read and write the bits
  - Check the frames using Display / Communication

- Create a new Network with the following parameters:
  - Protocol: Modbus TCP/IP (XBUS-IP-MASTER)
  - Network name: XBUS_IP

- Create a new Node with the following parameters:
  - Node name: PLC1
  - Equipment type: MODBUS DEC
  - TCP/IP address: 127.0.0.1 (your computer’s address)
  - Slave address: 1

- Create two new Frames with the following parameters:
  - For one frame, select the starting address 0
    - What happened? Why?

- Communicate with SCADA software and the Modbus Slave tool:
  - Create two equipment variables with the following properties:
    - Map these 2 variables by selecting a valid address
  - Start the Modbus Slave
  - Start the communication and check the variable’s values
  - Disconnect the Modbus Slave. What are the variable’s values?
  - In the Modbus Slave, set the Word value to 150. What is the value of the SCADA software variable? Why?

- Disconnect the Modbus Slave and check the different Communication status. Also check the Event viewer.
  - Try to read data to an Illegal Address (i.e. address 11) and check the frame reply.
  - Try to send an Illegal Function (i.e. Write Input Registers) and check the frame reply. What do you see?
FINDINGS

- SCADA software is able to communicate with many protocols on a serial network, an Ethernet network or proprietary networks.
- The communication configuration uses three objects: network, node, and frame.
- You can debug failed communication using the communication object’s status.
- The communication MUST be optimized.

ADDITIONAL INFORMATION

Bibliography:


Recommended materials:

SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 5.2-3 COMMUNICATION OPTIMIZATION

PERFORMANCE OBJECTIVE

- Manipulate the communication system variables.
- Manage double words.
- Manage redundant PLCs with Ethernet protocols.
- Map variables using a spreadsheet.
- Demonstrate how to view the communication status using the system variables.
- Describe how SCADA software can manage redundant PLCs on an Ethernet network.
- Configure the variable mapping using a spreadsheet.

LAB TYPE

Team

TIME REQUIRED

2 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required, see “Materials Needed” section below.

BACKGROUND

Communication is the heart of a SCADA system. The SCADA host software must manage the communication requests going out to the field so as not to overwhelm the infrastructure. It must also prioritize communication to ensure that critical messages do not get buried in a queue of less important messages waiting to be processed.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Computer
- SCADA software

MATERIALS NEEDED

- We will use the Modbus Poll and Modbus Slave (Evaluation license).
CRITICAL TASKS STUDENTS MUST COMPLETE

- Check the system variables generated by SCADA software:
  - Start the Modbus Slave and check the system variable values.
  - Stop the Modbus Slave and check the system variable values.
- Check the difference between the MLsb address zone and the LMsb address zone:
  - Create a frame with the following parameters:
    - Create a variable having the following properties and map it on the R.DOUBLEWORDS frame
    - Start the Modbus Slave and change the values as follows. For each step check the variable value.
    - Change the address zone for the frame R.DOUBLEWORDS to MLsb.
    - Redo step 3 and observe the difference.
- Configure a Standby node and test it using the Modbus Slave:
  - The Standby node must have the following parameters:
    - Load the Slave 2 configuration file in Modbus Slave using File/Open.
    - Close down the On Duty slave to simulate a communication failure.

FINDINGS

- You can display the communication status using the system variables.
- PcVue can manage redundant PLCs when using an Ethernet network for communication.
- You can configure the variable mapping using Microsoft Excel.

ADDITIONAL INFORMATION

Bibliography:

Recommended materials:
SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 5.2-4 STANDARD COMMUNICATION DRIVERS

PERFORMANCE OBJECTIVE

- Provide an overview of the OPC technology.
- Configure SCADA Software as an OPC Client and Server.
- Demonstrate optimization of the OPC communication.
- Demonstrate how to display the status of the OPC communication.
- Demonstrate how to tune the OPC communication.
- Demonstrate how to add logs.
- Describe how OPC System variables are generated and can be used to create a “system” level display.
- Demonstrate how to activate the OPC Traces for OPC communication debugging.

LAB TYPE

Team

TIME REQUIRED

2 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required, see “Materials Needed” section below.

BACKGROUND

Object Linking and Embedding (OLE), a Microsoft framework, was extended by interested industrial automation companies to provide a de facto standard called OLE for Process Control (OPC). The OPC standard has greatly reduced the number of proprietary networks used in SCADA applications and is very common in modern SCADA communications.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Computer
- SCADA software

MATERIALS NEEDED

- OPC server and client
CRITICAL TASKS STUDENTS MUST COMPLETE

- Create a basic architecture using OPC Server and Client.
  - Install the OPC package:
    - Load the Server configuration file
    - Start the Client
    - Establish connection
    - Create a Group
    - Set item subscriptions
    - Follow the same procedure for the On_Off and Setpoint items
  - What do you see when the values are refreshed?
- Connect SCADA Software to the OPC Server.
  - Open the Variables Selector. What is the meaning of (PLC)?
  - Switch off the OPC Server. What happens in SCADA Software?
- Create a text item in the OPC Server then configure SCADA Software to see the text value.
  - Switch off the OPC Server. Check the value of the following variables:
  - Can you explain the value of SYSTEM.OPC.SRV1.ON?
- Change the reconnection period to 20 seconds and check the result by switching off the OPC server.
- Change the deadband of the OPC group to 30% and check the value of the variables in the Variables Selector.
- Activate the traces and check the Event Viewer.

FINDINGS

- OPC provides interoperability between applications.
- SCADA software can be both an OPC DA Server and Client and also an OPC XML-DA Client.
- There are three steps to configuring any OPC Client: Connection, Group creation, Item subscription.
- All items subscribed in single group will be refreshed according the polling period and the deadband of the group.
- The OPC Server notifies the client(s) only when the item value changes according the deadband.
- An item notification includes three main properties: Value, Timestamp, Quality (VTQ).
ADDITIONAL INFORMATION

Bibliography:


Recommended materials:

SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 5.3-1 COMPONENTS OF GUI

PERFORMANCE OBJECTIVE

- Show how the workspace of the SCADA can be customized.
- Describe the relationship of a mimic to a workspace.
- List the ways in which the properties of a mimic provide for customized graphics.
- Demonstrate how SCADA software handles large mimics.
- Show how SCADA software can manage different resolutions for the same project.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

The graphical interface, sometimes called the Human Machine Interface (HMI), is the visible part of a SCADA system. One of the key purposes of SCADA is to provide operators with “Situation Awareness.” An uncluttered, well thought out graphical interface is a large part of the effectiveness of the SCADA system for operator efficiency.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Computer
- SCADA software

MATERIALS NEEDED

None
CRITICAL TASKS STUDENTS MUST COMPLETE

- Change some of the Workspace’s properties and check the effect.
- Create the Homepage mimic.
  - Where is the Homepage file physically located?
  - What happens if you copy the Homepage file to another project?
- Change the properties of the Homepage mimic.
- Configure the TRAINING project to open the Homepage mimic automatically.
  - Restart SCADA software to test it
- Open the mimic BigMimic_Scale.
  - Check the properties and the effect
- Open the mimic BigMimic_Scroll.
  - Check the properties and the effect
- Open the mimic BigMimic.Navigator.
  - Check the properties and the effect
- Activate the option Adapt mimic size to screen resolution.
  - Change the resolution of your screen
  - Open the Homepage mimic
- Activate the option Mimics open mode / <Design mode>.
  - Test it

FINDINGS

- Using the basic graphical objects you can draw the most common mimics used in a traditional SCADA project.
- There are many Arrange tools that enable you to make a complete mimic.
- The most common image formats are supported.

ADDITIONAL INFORMATION

Bibliography:

Recommended materials:
SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 5.3-2 GUI OBJECTS

PERFORMANCE OBJECTIVE

● Using the basic graphical objects draw the most common mimics used in a traditional SCADA project.
● Manipulate the Arrange tools that enable you to make a complete mimic.
● Import common image formats into the SCADA software.
● Demonstrate several HMI tools to increase productivity.
● Show or hide graphical objects using the Zoom and Layers features.
● Use the Graphic Explorer to edit a graphical objects in runtime mode.

LAB TYPE

Team

TIME REQUIRED

2 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

Creating the graphical interface can be a labor intensive and tedious process prone to human error. Productivity tools have been created by SCADA vendors to assist in this process, thereby increasing productivity and reducing errors.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

● Computer
● SCADA software

MATERIALS NEEDED

● None
CRITICAL TASKS STUDENTS MUST COMPLETE

- Create a new mimic – Basic objects:
  - Insert several basic graphical objects
  - “Play” with them (copy, paste, multiple selections).
  - Draw a polygon representing a triangle. How many points have been created? Why?
  - Right-click on one point of this polygon. What is displayed?
- Change properties of several objects.
- Use the Arrange tools to group/ungroup, lock/unlock, align, order and resize objects.
- Create a normal button.
  - Try to change the background of the button. Why are you unable to do so?
- Using images:
  - Insert the image ICO_OK.bmp in the mimic.
    - Select the background as the transparent color.
    - Using the Aspect tab, change the image to the Button appearance so that it looks like a button.
  - For our project:
    - Create a new mimic: Floor 1 and save it.
    - Insert the image Floor1.jpg.
- Insert the image Misc_Image15.bmp from the MISCELLANEOUS library.
- Insert the image bulb_off.bmp.
  - Configure the Rollover effect using the bitmap bulb_on.bmp.
  - Switch the mimic to Runtime mode and test.
- Customize the Color palette by adding some solid, blinking and gradient colors.
  - Use the Color Picker and Dropper tools.
- Apply an indexed color to a shape. Change this color in the Color Palette. What happens?
- Configure 200% to 450% as a zoom range for the shape. Zoom the window to 200%, 238% and 476%.
- Assign the Layers 0, 1 and 2 to any shape. Display the Layers toolbar and change the active layers to 0 only, then 3 only.
- Exercise the Drawing Properties Manager in the three modes.
- Exercise the Graphic Explorer in Design and Runtime modes.
- Create a group including several shapes. What do you see in the Graphic Explorer?

FINDINGS

- There are many HMI tools to increase your productivity.
- You can show or hide graphical objects using the Zoom and Layers features.
- The Graphic Explorer is useful to edit a graphical object in Runtime mode.
ADDITIONAL INFORMATION

Bibliography:


Recommended materials:

SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 5.4-1 BASIC ANIMATIONS

PERFORMANCE OBJECTIVE

- Open the animation tab in the Graphical Object properties.
- Configure an animation to change the color, open a mimic, or set a value.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

Animations are used in the graphical interface for many purposes including highlighting critical information, making objects reusable depending on context and decluttering the screen. In this lab, we explore some of the basic animation procedures.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Computer
- SCADA software

MATERIALS NEEDED

- SCADA application with simulator to change value of variables

CRITICAL TASKS STUDENTS MUST COMPLETE

- Manipulate the basic Bit animations.
  - Create a new mimic – Animations:
    - Add a rectangle and a text button “Switch the light.”
  - For our project:
    - Open the mimic Floor1.
    - Add some graphical objects in two of the rooms to display the Light state and control it.
• Manipulate the basic register animations.
  - In the “Animations” mimic add a text “XXXX” and a text button
    - “Set Temperature.”
  
  - For the Simulator installed, set the register:
    - “BUILDING.FLOOR_01.AC_01.TEMP” with the same value as the register
      “BUILDING.FLOOR_01.AC_01.SETPOINT”
    - Switch to run-time mode and test by clicking the button.
  
  - For our project:
    - Open the mimic Floor1.
    - Add some graphical objects to two rooms to display and control the temperature.
  
  - Add a rectangle and try to animate it to display a register value. What happened? Why?

• Copy/Paste the animated Text several times.
  - Change the format as follows:
    - Add a Text “Time.”
      - Animate it.
    - Add a rectangle.
      - Animate it using the Color / Bargraph animation.
    - Add a rectangle.
      - Animate it using the Color / Bargraph animation.
    - Add two text buttons: “Open a mimic” and “Close a mimic.”
      - Animate these objects.
    - Edit the Text button “Open a mimic” and select Close option. What happened? Why?

FINDINGS

• An animation is just an extra tab added to the Graphical Object properties.
• You can configure an animation to change the color, open a mimic, or set a value.

ADDITIONAL INFORMATION

Bibliography:

Recommended materials:
SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 5.4-2 ADVANCED ANIMATIONS

PERFORMANCE OBJECTIVE

- Demonstrate how to have multiple animations on a graphical object.
- Demonstrate how a mimic can be embedded in another mimic.
- Manipulate the control animation interlock condition property.
- Demonstrate how to combine bits for an animation.

LAB TYPE
Team

TIME REQUIRED
2 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required, see “Materials Needed” section below.

BACKGROUND

This lab continues with advanced features of animations.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT
- Computer
- SCADA software

MATERIALS NEEDED
- Simulation application that has changing values of variables for animation purposes

CRITICAL TASKS STUDENTS MUST COMPLETE
- Create a Text colored button.
  - Animate it.
- Select any graphical object with a control animation and add a comment.
  - Switch to run-time mode and try it out.
• Create the bit variable GENERAL.CONTROL_OK (in command mode).
  - Configure an interlock condition for any graphical object with a control animation.
  - Switch to run-time mode and try it out.
  - Try the foreground and modal options.
• Create a small mimic called “Mimic embedded.”
  - Save and close it.
  - Add a Text button “Open an included mimic.”
  - Configure it to open the “Mimic embedded” mimic.
  - Switch to run-time mode and try it out.
• Copy the text Button “Switch the light” three times.
  - Modify the three new objects to switch all lights on the first floor.
  - Add a rectangle and animate it according to this “customer” requirement:
    - Gray -> No lights on
    - Green -> One light on
    - Orange -> Two lights on
    - Dark red -> Three lights on
    - Red -> All lights on
• For our project:
  - Open the mimic Floor 1.
  - Insert the images “Bulb_off.bmp” and “Bulb_on.bmp” in one room.
  - Animate these objects.
• Add any graphical object.
  - Animate it to move according to values of the variable.
  - @BUILDING.FLOOR_01.AC_01.SETPOINT
  - Switch to run-time mode and try it out.
  - Modify it to become a slider.
• Make a slider follow the vertical bargraph.
• Create a new colored button and animate it using:
  - Send / Bit with Color. What happened?
• Create a new button and animate it using Link.
  - Close and Send / Bit. Did the bit value change?
  - Why?
• When the action is not authorized, a dialog box displays two messages:
  - “An interlock condition prohibits this action” plus a second text.
  - How do you change what appears in the second text?
FINDINGS

- You can have more than one animation on a graphical object.
- A mimic can be embedded in another mimic. It becomes the child mimic. This feature is important to make pop-up mimics.
- Every control animation has an interlock condition property.
- The Color-Bit group animation is very useful when you want to combine up to four bits.

ADDITIONAL INFORMATION

Bibliography:

Recommended materials:
SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 5.5-1 GENERIC HMI

PERFORMANCE OBJECTIVE

● Demonstrate how to have the same layout for each graphic in a project.
● Describe the concept of a branch.
● Demonstrate how to manage generic objects.

LAB TYPE

Team

TIME REQUIRED

2 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required, see “Materials Needed” section below.

BACKGROUND

This lab explores methods of productivity using the branching concept. The branching concept allows the tag names to be substituted at run time and thereby create objects that are context sensitive.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

● Computer
● SCADA software

MATERIALS NEEDED

● SCADA application with simulator to change variables for animation
CRITICAL TASKS STUDENTS MUST COMPLETE

- Create the template MyTemplate according the following specifications:
  - Window properties / Display tab / Window Style frame
  - Graphics
- Use Mimic Templates to have the same look and feel for the whole application.
- Use Branches to create generic mimics.
- Use Symbols to create generic graphical objects.
- Make a Symbol animated and use Branches.
- The * character means “Me” and it is used to forward the current branch.

FINDINGS

- Use Mimic Templates to have the same look and feel for the whole application.
- Use Branches to create generic mimics.
- Use Symbols to create generic graphical objects.
- A Symbol can be animated and it can use Branches.
- The * character means “Me” and it is used to forward the current branch.
- To connect all animations of a mimic, the SCADA software applies this formula:
  - MIMIC BRANCH + .SYMBOL BRANCH + .VARIABLE ANIMATED = VARIABLE

ADDITIONAL INFORMATION

Bibliography:


Recommended materials:

SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 5.5-2 ALARMS, LABELS, ATTRIBUTES, AND FILTERING

PERFORMANCE OBJECTIVE

● Describe the alarm life cycle.
● Demonstrate how to create an alarm.
● Demonstrate how to display an alarm in a mimic.
● Demonstrate how to interact with an alarm.
● Demonstrate how to create an alarm threshold.
● Use an alarm’s associated action.
● Use alarm counters.
● Demonstrate how to manage the associated labels.
● Demonstrate how to use the Domain and Nature attributes.
● Demonstrate how to use the extended attributes.

LAB TYPE
Team

TIME REQUIRED
3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

Alarm management is one of the primary functions of a SCADA system. This lab covers alarm management including filtering. Filtering provides a way to focus on areas of interest within the overall SCADA application.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

● Computer
● SCADA software

MATERIALS NEEDED

None
CRITICAL TASKS STUDENTS MUST COMPLETE

- Create a Bit variable called GENERAL.ALARM1.
- Configure it as an alarm and a command.
  - Command allows you to force it at run-time from a Send animation. Alarms do not normally have the Command property set.
- Create a new mimic called “Alarms” and save it.
- Insert a Text button and animate it to set the variable GENERAL.ALARM1.
- Insert a graphical object and animate it to display the alarm status.
- Insert an Alarm Viewer macro animation in the mimic. Keep all the default parameters.
- Modify some Alarm Viewer properties and check what happens at run time.
- Try to change the colors of the alarm statuses in the Alarm Viewer.
- Create high (30) and low (15) alarm thresholds for the variable BUILDING.FLOOR_01.AC_01.TEMP.
- Add a Text button to the mimic Alarms to set the Temperature value.
  - Switch to run-time mode and try it out.
- Configure an associated action to allow the operator to open the Floor1 mimic when the high or low temperature limits occur.
  - Switch to run-time mode and try it out.
- Create the registers SYSTEM.NOACKON.ALL and SYSTEM.ACKON.ALL.
  - Add two Texts in the Alarms mimic and animate them to display the counters.
  - Create the associated label ON_OFF and configure it.
- Apply it to the variables BUILDING.FLOOR_01.LT_01.ON and BUILDING.FLOOR_01.LT_01.CMD.
- Create the associated label ALARMS and configure it.
- Apply it to the variables BUILDING.FLOOR_01.AC_01.TEMP_high.
  and BUILDING.FLOOR_01.AC_01.TEMP_low.
  - Switch to Run-time mode and check these alarms in the mimic Alarms.
- Open the mimic Animations.
- Add a text object and display the associated label for the variable BUILDING.FLOOR_01.LT_01.ON.
- Open the mimic Animations.
- Add a text button object and animate it to set the variable BUILDING.FLOOR_01.LT_01.CMD with a confirmation box.
- Create the Domains FLOOR1, FLOOR2, and FLOOR3.
- Create the Natures AIRCOND and LIGHT.
- Configure the Domain and Nature attributes for the variables:
  - BUILDING.FLOOR_01.AC_01.ON
  - BUILDING.FLOOR_01.AC_01.TEMP_high
  - BUILDING.FLOOR_01.AC_01.TEMP_low
• Create the Bit variable BUILDING.FLOOR_01.AC_01._INFO.
  - For our project we must display the make, model, and serial number details. So we will use extended
    text attributes 3, 4 and 5.
• Add the following extended text attributes:
  - Attribute: 3, Content: MITSUBISHI
  - Attribute: 4, Content: AC-100
  - Attribute: 5, Content: SN - 12 99876
• Open the mimic Animations.
• Display the Domain and the Nature of the variable BUILDING.FLOOR_01.AC_01.ON.
• Switch to Run-time mode and test it.
• Display the extended text attributes of the variable BUILDING.FLOOR_01.AC_01._INFO.
• Open the mimic Alarms.
• Modify the Alarm Viewer properties to display the Domain and the Nature.
• Set the temperature of BUILDING.FLOOR_01.AC_01.TEMP to trigger an alarm and check the Alarm Viewer.
• Use the filtering function in the Alarm Viewer.

FINDINGS
• An alarm is a special case of a bit with extra status.
• You can display an alarm using an animation and the Alarm Viewer macro animation.
• SCADA software typically manages four threshold systems.
• The associated action for an alarm is a good feature for improving the operator’s reactivity.
• You can use SYSTEM variables to count the active alarms.
• The Associated Labels are useful to associate text with the various states of a bit and/or an alarm.
• The Domain and Nature attributes can be used to categorize the data and to filter items in macro animations.

ADDITIONAL INFORMATION
Bibliography:
Recommended materials:
SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 5.6-1 PROJECT GENERATION

PERFORMANCE OBJECTIVE
- Describe a meta file for project generation.
- Describe the various import sources.
- Demonstrate the generic import.

LAB TYPE
Team

TIME REQUIRED
3 hours

INSTRUCTOR PREPARATION
It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND
This lab covers a productivity tool found with many SCADA software systems, namely the ability to store the configuration parameters for the software in a neutral format. This has a number of advantages from ease of auditing the configuration to the ability to move from one SCADA system vendor to another.

SAFETY REQUIREMENTS
Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT
- Computer
- SCADA software

MATERIALS NEEDED
None

CRITICAL TASKS STUDENTS MUST COMPLETE
- Import a WAGO CoDeSys project given a set of parameters.
  - After generation check the configuration of the communication and variables.
- Create a Generic XML Import using the provide XML file.
  - Check via the Variables Selector.
• Modify the provided file “VarExample.xml” as described in the table provided and synchronize the most recent Import.
  - Check the result in the Variables Selector.

FINDINGS

• You can dramatically reduce development time using the meta files.
• SCADA packages support limited specific imports but many allow for generic XML import.

ADDITIONAL INFORMATION

Bibliography:

Recommended materials:
PERFORMANCE OBJECTIVE

- Describe what an Archive Unit is.
- Discuss the different types of Archive Unit.
- Describe differences in proprietary Archive Units.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

Archive units define what will be archived and not how. They are the building blocks of the historical database.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Computer
- SCADA software

MATERIALS NEEDED

None
CRITICAL TASKS STUDENTS MUST COMPLETE

- Create a proprietary Archive Unit.
- Configure the parameters according to the following table:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Name</td>
<td>PROP_UNIT1</td>
</tr>
<tr>
<td>Folder Size</td>
<td>100 MB</td>
</tr>
<tr>
<td>File Size</td>
<td>1000 KB</td>
</tr>
<tr>
<td>Back-up Folder</td>
<td>C:\BACKUP</td>
</tr>
<tr>
<td>Triggering Bit</td>
<td>GENERAL.BACKUP</td>
</tr>
</tbody>
</table>

FINDINGS

- Scada Industrial Control Systems support several recording formats.
- The proprietary format is usually the most efficient and least open to other software.
- The SCADA software can manage several Archive Units in parallel in multiple formats.

ADDITIONAL INFORMATION

Bibliography:

Recommended materials:
SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 5.7-2 HISTORICAL DATABASE SERVER

PERFORMANCE OBJECTIVE

- Document what the Historical Database Server is.
- Demonstrate how to configure a database Archive Unit.
- Describe how to maintain the Archives database.

LAB TYPE

Team

TIME REQUIRED

2 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

Historical data is sometimes kept in proprietary formats such as file systems and in other cases in commercially available relational databases such as SQL Server. This lab explores the differences between the two approaches.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Computer
- SCADA software

MATERIALS NEEDED

None

CRITICAL TASKS STUDENTS MUST COMPLETE

- Configure the Database connection.
- Create the Database and the tables.
- Create the Archive Unit.
Using the Database Manager perform the following tasks:
- Local and remote navigation and browsing to select database files.
- Keeping an index of the locations of the databases you administer.
- Replicating databases.
- Viewing and maintaining database properties.
- Viewing and maintaining database contents.
- File compaction and deletion.
- Administering security measures.
- Moving a SQL Server Database from one computer to another.

Create a Maintenance Plan consisting of a schedule and a list of tasks.
- The schedule decides when and how often the Maintenance Plan runs.
- The list of tasks determines what the Maintenance plan does.
  - The tasks are executed in a configured sequence. The first task in the sequence starts when the Maintenance Plan runs; the second task starts when the first has finished and so on.

Configure the Maintenance plan to do the following tasks.
- Purge: Limits the age of records in the database by deleting those older than a defined period.
- Export: Exports data from the database, for a defined period, in text, ADTG or XML formats.
- Defrag: Defragments the database’s index. Only available for SQL Server databases.
- Custom: Executes a custom Transact-SQL script. Only available for SQL Server databases.
- Shrink: Removes unused space in the Database’s files thus reducing the space occupied on the hard drive. Only available for SQL Server databases.

FINDINGS
- The HDS is a server component that manages the writing and retrieval of realtime data in a relational database from the SCADA software.
- It is possible to customize the Database using several tables.
- SCADA software provides tools to maintain the Database.

ADDITIONAL INFORMATION

Bibliography:

Recommended materials:
SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 5.8-1 SCRIPTING

PERFORMANCE OBJECTIVE

- Describe the SCADA Basic program structure.
- Apply the SCADA Basic syntax to create a simple script.
- Demonstrate how to run a script.
- Demonstrate how to trigger a script by clicking a button.
- Load one or more Programs at start-up.
- Customize an Alarm, Log, or Trend Viewer using scripts.
- Use the Branch in a script.
- Describe different ways to trigger a Function.

LAB TYPE
Team

TIME REQUIRED
3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required, see “Materials Needed” section below.

BACKGROUND

Most Scada Industrial Control Systems have some sort of scripting capability. Often they are variations of the BASIC programming language.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Computer
- SCADA software

MATERIALS NEEDED

- We need to use a basic simulator for changing the values of variables.
- The simulator is located here: USB key\Tools\Simulator
- Please install it by running the Setup.exe file and following the instructions.
CRITICAL TASKS STUDENTS MUST COMPLETE

- Exercise 1
  - Create the GLOBAL.SCB program with the following string (comment): “This is my first program.”
  - Load it
    - Check whether there is a syntax error.
  - Add a deliberate error (for example delete the comment character) then load the program.

- Exercise 2
  - Configure the SCADA software to load the GLOBAL.SCB program automatically.
  - Restart the SCADA system and check whether the Global program is loaded.

- Exercise 3
  - Open the Mimic “Animations.”
  - Add a button.
  - Animate it to run Function 1 in GENERAL.SCB Program.
  - Switch to Run-time and try it.

- Exercise 4
  - Edit the program GENERAL.SCB.
  - Create the Function “OpenWindow” for opening the mimic.
  - Load the Program and check there is no error.
  - Open the mimic “Animations,” add a button and animate it.
  - Switch to Run-time mode and try it.

- Exercise 5
  - Modify the Function “OpenWindow” to open the “Floor 1” mimic but close the current mimic.
  - You must be able to copy and use the button and program in any mimic in your application without modification.

- Exercise 6
  - Create the Mimic “POP_Message”. Add a text. Save and close.
  - Create an event for opening the mimic “POP_Message.”
  - Check whether it is working.

- Exercise 7
  - Create a Key action for triggering the Function “OpenPopup” from the Program “GENERAL.SCB.”
  - Check whether it is working.

- Exercise 8
  - Create a Cyclic action for triggering the Function “OpenPopup” from the Program “GENERAL.SCB.”
  - Check whether it is working.

- Exercise 9
  - Create a Scheduled action for triggering the Function “OpenPopup” from the Program “GENERAL.SCB” every day at the same time.
  - Check whether it is working.
FINDINGS

- SCADA Basic is a proprietary scripting language that provides programmatic access to almost all objects of the SCADA system.
- SCADA Basic scripts are a set of Programs.
- A Program is a set of Functions.
- A Function can receive arguments as Input and can return a value as Output.
- The Global program is mandatory as soon you want to use built-in instructions.
- All Functions and Variables declared in the Global program are Public.
- You can customize the Viewers by using the Functions ALARMDISPLAY, LOGDISPLAY and TREND.
- You can make a script generic by using the Branch.
- There are many ways to trigger a Function.

ADDITIONAL INFORMATION

Bibliography:

Recommended materials:
SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 5.8-2 VISUAL BASIC FOR APPLICATIONS SCRIPTING

PERFORMANCE OBJECTIVE

- Describe the VBA Workspace.
- Demonstrate how to manipulate a SCADA graphical object using VBA.
- Demonstrate how to manipulate ActiveX.
- Demonstrate how to read and write a comma separated values (CSV) file.
- Demonstrate how to manipulate an external application such as Excel.

LAB TYPE
Team

TIME REQUIRED
3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

Visual Basic for Applications is a subset of the Visual Basic programming environment. It is a rich language and the student is assumed to have a rudimentary understanding of its syntax prior to performing this lab. This is not a course on VBA, but focuses on how VBA works within the context of a SCADA software system.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Computer
- SCADA software

MATERIALS NEEDED

None
CRITICAL TASKS STUDENTS MUST COMPLETE

• Exercise 1
  - Close all mimics.
  - Display the VBA Workspace.
  - Check the Main project.
  - Select the ThisProject Object and check its properties.
  - Return to the HMI and open the “Homepage” mimic.
  - Return to the VBA Workspace and check the VBA projects.
  - Change the Property Name of the Mimic “Homepage.”

• Exercise 2
  - Add an event and script to display a message after start-up.
  - Restart to check it.

• Exercise 3
  - Use the This Project Object.
    - Display in a dialog the Path of the PcVue project.
    - Display in a dialog the name of the User logged automatically after a login.

• Exercise 4
  - Use the Mimics Collection Object.
    - Open the “Homepage” and “VbaScript” mimics.
    - In ThisProject Object add a script to display the file name of the “Homepage.”
    - Execute and check it.
    - In ThisProject Object add a script displaying the file name of every mimic opened.
    - Execute it and check.

• Exercise 5
  - Use the Window Object.
    - Open the “VbaScript” mimic.
    - In ThisProject Object add a script displaying the coordinates of “VbaScript” mimic.

• Exercise 6
  - Use the Graphic Object.
    - Open the “VbaScript” mimic.
    - Add a button and change its name to “Mybutton.”
    - Create a script triggered by “MyButton” displaying its width and height.
    - Add another graphic Object (rectangle for example).
    - Rename it to “MySecondButton”. Don’t click the option VBA Control.
    - Modify the previous script to display the coordinates of MySecondButton.

• Exercise 7
  - Use the Variable Object; check the Type.
- Open the “VbaScript” mimic.
- Add a button and change its name to “btn_CheckVariableType.”
- Create a script triggered by “btn_CheckVariableType” to display the type of the variable BUILDING.FLOOR_01.AC_01_TEMP.
- Add a button and change its name to “btn_ReadWriteVariable.”
- Create a script triggered by “btn_ReadWriteVariable” to display the value of the variable BUILDING.FLOOR_01.AC_01_TEMP and test.
- Modify the code to set the value and test.
- Add a button and change its name to “btn_ReadWriteVariable.”
- Create a script triggered by “btn_ReadWriteVariable” to display the value of the variable BUILDING.FLOOR_01.AC_01_TEMP and test.
- Modify the code to set the value and test.
- Add a button and animate it to change the value of the variable BUILDING.FLOOR_01.AC_01.SETPOINT.
- Create a script to display the value of the variable BUILDING.FLOOR_01.AC_01_TEMP and test. This script is triggered when this variable changes its value.

Exercise 8
- Open the mimic “VbaScript”
- Insert the ActiveX MsForms2 ComboBox and ListBox.
- Add a script to behave as follows:
  - Fill the ComboBox with some items when the mimic opens.
  - When the user double-clicks on one item it is added in the ListBox.

Exercise 9
- Add a button in the mimic “VbaScript” named “btn_WriteFile.”
- Add a script triggered by “btn_WriteFile” for creating the CSV file “Training.txt.”
- Add a button in the mimic “VbaScript” named “btn_ReadFile.”
- Add a script triggered by “btn_ReadFile” for reading the CSV file “Training.txt.”

FINDINGS

• The VBA environment is powerful and able to manipulate COM Objects, ActiveX, and OLE Automation application.
• All Objects belong to a single Library.
• The Main Project is always available.
• Each mimic opened adds a new VBA Project in the Project Explorer.
• The Object Browser is an important tool that lets you check the properties, methods, and events of all available Objects.
• The HMI Objects Tree represents the hierarchy of SCADA Objects.
• Manipulating an ActiveX is no more complex than manipulating a SCADA Graphic Object.
• You can add a Library into VBA; then you are able to manipulate its Objects as you would any other COM Object.
• The way to manipulate an Excel file is the same for Microsoft Word, Access, or SQL Server.
ADDITIONAL INFORMATION

Bibliography:


Recommended materials:

SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 5.9-1 FINAL PROJECT PART 1

PERFORMANCE OBJECTIVE
- Define selected SCADA project requirements.
- Design and prototype Project and Templates.
- Design communication paths and protocols.

LAB TYPE
Team

TIME REQUIRED
3 hours

INSTRUCTOR PREPARATION
It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of
lab stations with computers and peripherals in good working order. Ensure that networks are active and software
dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student
files are not corrupted, and confirm that students have access to the student files. A third party software may be
required, see “Materials Needed” section below.

BACKGROUND
Part 1 of the final project.

SAFETY REQUIREMENTS
Students will be expected to utilize electronic equipment, components, and software. Provide students with basic
guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the
computer equipment.

TEST EQUIPMENT
- Computer
- SCADA software

MATERIALS NEEDED
- Spreadsheet
- Notepad
CRITICAL TASKS STUDENTS MUST COMPLETE

- Describe SCADA final project.
- Analyze project for reusable components.
- Design project look and feel.
- Create templates for project navigation.
- Design communication networks and implement protocols.

FINDINGS

- Careful design in the front end is key to a successful project.

ADDITIONAL INFORMATION

Bibliography:

Recommended materials:
SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 5.9-2 FINAL PROJECT PART 2

PERFORMANCE OBJECTIVE

- Design, prototype, and create reusable objects.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required, see “Materials Needed” section below.

BACKGROUND

In this lab, the students will design the portions of the system that are repeatable and potentially tedious to complete without reusable objects. There is a tradeoff, however, between elegant design and productivity.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Computer
- SCADA software

MATERIALS NEEDED

- Spreadsheet
- Notepad

CRITICAL TASKS STUDENTS MUST COMPLETE

- Analyze project for reusable components.
- Design real-time database for maximum use of branching.
- Develop mimic templates.
- Prototype and test reusable symbols.
FINDINGS

- Prototyping and testing reusable components is a time consuming process initially but will save much time at the end of the project.

ADDITIONAL INFORMATION

Bibliography:

Recommended materials:
SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 5.9-3 FINAL PROJECT PART 3

PERFORMANCE OBJECTIVE

● Assemble SCADA objects from templates.
● Devise methods to complete SCADA design.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required, see “Materials Needed” section below.

BACKGROUND

This lab is where the application comes together. This is an assembly process if the design is right.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

● Computer
● SCADA software

MATERIALS NEEDED

● Spreadsheet
● Notepad

CRITICAL TASKS STUDENTS MUST COMPLETE

● Configure communication networks and frames and test communications.
● Layout mimics and instantiate symbols using branching concepts learned.
● Customize as required using basic scripting.
FINDINGS

- The SCADA application can be assembled quickly now with the proper design in place.

ADDITIONAL INFORMATION

Bibliography:

Recommended materials:
SCADA INDUSTRIAL CONTROL SYSTEMS
LAB 5.9-4 FINAL PROJECT PART 4

PERFORMANCE OBJECTIVE

- Demonstrate complete SCADA design.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

Each group is given time to demonstrate the application and highlight the design attributes that make the project the best.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Computer
- SCADA software

MATERIALS NEEDED

None

CRITICAL TASKS STUDENTS MUST COMPLETE

- Demonstrate functionality.
- Defend design choices.

FINDINGS

- A completed SCADA Host application is ready to be attached to real equipment in the next course.
ADDITIONAL INFORMATION

Bibliography:


Recommended materials:

SCADA INDUSTRIAL CONTROL EQUIPMENT
COURSE DESIGN GUIDE

COURSE TITLE
Programmable Logic Controllers (PLC) based Remote Terminal Units (RTU)

CATALOG DESCRIPTION
This course introduces students to PLC and RTU equipment used in SCADA systems with emphasis on practical use. Key concepts of PLCs are discussed using a comprehensive approach to enhance learning. The course begins with basic concepts and progresses to system-level applications. Basic information is provided and discussed through applications, testing procedures, and operational aspects of PLC equipment and systems.

CREDITS
4 credits, 96 hours

COURSE FORMAT
This course is a lecture/lab format that incorporates industry related lab exercises and activities during in-class, instructor-supervised labs.

COURSE NUMBER
Material for this course is presented to meet the requirements for a 200-level undergraduate course in an applied science or career technical program.

PREREQUISITES
SCADA Systems

INSTRUCTOR INFORMATION
Recommended Qualifications: Master’s Degree in engineering and three to five years of experience teaching industrial control and instrumentation. Instructors must have in-depth knowledge of the subject matter and the teaching skills to efficiently and effectively convey this knowledge to learners. Teaching skills involve using several instructional methods and resources to effectively transfer knowledge and skills from experience. Working knowledge of content, curriculum, methods, materials, and equipment in the career technical specialty will be used in the course. (Process Technology, Energy Technology, Advanced Manufacturing). Experience and ability to plan and implement lessons based on objectives for career technical programs. Experience working in a related vocational trade.

TEACHING METHODS AND ASSIGNMENTS FOR ACHIEVING LEARNING OUTCOMES
The course is divided into six learning units. Each learning unit addresses a specific topic with direct application to the fundamentals of Scada Industrial Control Equipment. Each topic has a recommended length (topic hours) assigned. Topic hours are a guideline for instruction that is intended to be adapted to the individual instructor’s teaching style. The ratio of lecture to lab is 1:3. Included in the instructional materials are example worksheets, homework assignments, and quizzes. The recommended ratio of class to study time is 1:4 for this course. Students are expected to spend additional study/practice time outside of the class time. Each topic lists suggested time allocation. Total time allocated includes a one-hour course introduction, a two-hour review, and a two-hour written exam.
STUDENT TEXTS, READING AND OTHER MATERIALS


ADDITIONAL REQUIREMENTS

- PLC Hardware or Simulator
- PLC Ladder Logic Programming Software
  - Automation Studio
  - The Constructor
  - CMH PLC Trainer
## ASSESSMENT RUBRIC

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>EXEMPLARY 4</th>
<th>SATISFACTORY 3</th>
<th>DEVELOPING 2</th>
<th>BEGINNING 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select the PLC Hardware appropriate for a SCADA RTU</td>
<td>Explanations indicate a clear and accurate understanding of the requirements of an RTU and an appropriate PLC Hardware</td>
<td>Explanations indicate a relatively accurate understanding of an RTU and an appropriate PLC Hardware</td>
<td>Explanations indicate relatively accurate understanding of an RTU and an appropriate PLC Hardware</td>
<td>Explanations do not illustrate much understanding of an RTU and an appropriate PLC Hardware</td>
</tr>
<tr>
<td>Plan the logic required to monitor or operate Scada Industrial Control Equipment</td>
<td>Plan is neat with clear measurements and labeling for all components</td>
<td>Plan is neat with clear measurements and labeling for most components</td>
<td>Plan provides clear measurements and labeling for most components</td>
<td>Plan does not show measurements clearly or is otherwise inadequately labeled</td>
</tr>
<tr>
<td>Design a ladder logic program to implement RTU logic</td>
<td>Great care taken in design process so that the logic is clear, linear, and follows plans accurately</td>
<td>Design was careful and accurate for the most part, but 1-2 details could have been refined for cleaner logic</td>
<td>Design accurately followed the plans, but 3-4 details could have been refined for cleaner logic</td>
<td>Design appears careless or haphazard, and many details need refinement for a strong or efficient logic</td>
</tr>
<tr>
<td>Program the RTU using ladder logic</td>
<td>Program functions extraordinarily well, holding up under all scenarios</td>
<td>Program functions well, holding up to standard operation</td>
<td>Program functions relatively well, but some problems with implementation</td>
<td>Fatal flaws in program</td>
</tr>
<tr>
<td>Troubleshoot RTU equipment</td>
<td>Clear evidence of troubleshooting, testing, and refinements using innovative techniques</td>
<td>Clear evidence of troubleshooting, testing, and refinements using standard techniques</td>
<td>Some evidence of troubleshooting, testing, and refinements</td>
<td>Little evidence of troubleshooting, testing, or refinements</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 1: RTU/PLC SYSTEMS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 PLC Based RTUs</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Review functions of IED, PLC, and RTUs in SCADA</td>
</tr>
<tr>
<td></td>
<td>• List functions of modern PLC systems</td>
</tr>
<tr>
<td></td>
<td>• Identify gaps between RTU and PLC equipment</td>
</tr>
<tr>
<td></td>
<td>• Illustrate use of PLC in RTU applications</td>
</tr>
<tr>
<td>1.2 PLC Overview</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td>• Describe the invention and the development history of programmable logic</td>
</tr>
<tr>
<td>Lab - 1 hr.</td>
<td>controller (PLC) systems</td>
</tr>
<tr>
<td></td>
<td>• Discuss the benefits of PLCs over electromechanical relay logic systems</td>
</tr>
<tr>
<td></td>
<td>• Distinguish between fixed and modular PLC devices</td>
</tr>
<tr>
<td></td>
<td>• Discuss different types of microprocessors</td>
</tr>
<tr>
<td></td>
<td>• Explain different types of random access memory (RAM) devices and their</td>
</tr>
<tr>
<td></td>
<td>use in PLC systems</td>
</tr>
<tr>
<td></td>
<td>• List different types of read-only memory (ROM) devices</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate the use of the address decoder circuit in a PLC system</td>
</tr>
<tr>
<td></td>
<td>• Define the major components of a PLC power supply</td>
</tr>
<tr>
<td>Performance Objectives, the student will:</td>
<td>• Identify programmable logic controllers (PLCs) and their components</td>
</tr>
<tr>
<td></td>
<td>• Describe the characteristics that distinguish between fixed and modular PLC devices</td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 1.2-1 PLC Overview</td>
</tr>
</tbody>
</table>

Notes:
### UNIT 2: PLC HARDWARE, CONFIGURATION, AND BASIC LADDER LOGIC PROGRAMMING

#### TOPICS

<table>
<thead>
<tr>
<th>2.1 PLC Selection, Components, and Communication</th>
<th>2.2 Number System and Codes Used in PLC SCADA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture - 1 hr. Lab - 1 hr.</td>
<td>Lecture - 1 hr. Lab - 1 hr.</td>
</tr>
</tbody>
</table>

#### OBJECTIVES

**The student will be able to:**

- Identify important questions to determine which PLC device to select
- Distinguish between integrated and modular PLC types
- Select modular series processor and chassis
- Select input or output modules for PLCs
- Recognize and explain how to connect sensors and switches to PLC ports
- Describe the different types of PLC memory
- Describe the method to connect PLC devices to programming modules

**Performance Objectives, the student will:**

- Describe how to do the addressing of input and output modules for PLCs
- Deconstruct the PLC controller files
- Demonstrate how to connect PLC communication ports

- Lab Exercise: 2.1-1 PLC Components

**The student will be able to:**

- Explain the decimal number system
- Explain integer numbers, fractional numbers, and real numbers
- Describe the binary number system
- Convert decimal numbers to binary and vice versa
- Explain the hexadecimal number system
- Convert binary numbers to hexadecimal numbers and vice versa
- Explain the octal number system
- Convert binary numbers to octal numbers and vice versa
- Explain the binary coded decimal number system and its use
- Convert decimal numbers to binary coded decimals
- Explain the Gray code number system and its use
- Explain ASCII and EBCDIC alphanumeric codes

**Performance Objectives, the student will:**

- Enumerate binary, octal, and hexadecimal number systems
- Perform binary math operations such as add, subtract, multiply, and divide
- Convert to and from each of the common number systems

- Lab Exercise: 2.2-1 Number Systems

**Notes:**
## UNIT 2: PLC HARDWARE, CONFIGURATION, AND BASIC LADDER LOGIC PROGRAMMING

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.3 Input/Output Devices and Motor Controls</td>
<td><strong>The student will be able to:</strong></td>
</tr>
<tr>
<td></td>
<td>• Identify the electrical symbols for various switches</td>
</tr>
<tr>
<td></td>
<td>• Describe the operation of proximity, Hall effect, ultrasonic, and RADAR sensors</td>
</tr>
<tr>
<td></td>
<td>• Name the common indicators used in PLC systems</td>
</tr>
<tr>
<td></td>
<td>• Explain the purpose of using indicators in a PLC system</td>
</tr>
<tr>
<td></td>
<td>• Explain the difference between a power relay and a control relay</td>
</tr>
<tr>
<td></td>
<td>• Describe the operation of a relay</td>
</tr>
<tr>
<td></td>
<td>• Describe the operation of a solenoid</td>
</tr>
<tr>
<td></td>
<td>• Name the two major types of motor control devices</td>
</tr>
<tr>
<td></td>
<td>• Name two types of overload relays</td>
</tr>
<tr>
<td></td>
<td>• Explain the difference between temperature and thermal overload relays</td>
</tr>
<tr>
<td></td>
<td><strong>Performance Objectives, the student will:</strong></td>
</tr>
<tr>
<td></td>
<td>• Demonstrate proficiency with circuit symbols for I/O devices</td>
</tr>
<tr>
<td></td>
<td>• Draw a schematic diagram for a PLC’s I/O devices</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 2.3-1 I/O Devices</td>
</tr>
<tr>
<td>2.4 Creating Relay Logic Diagrams</td>
<td><strong>The student will be able to:</strong></td>
</tr>
<tr>
<td></td>
<td>• Use symbols to represent different types of input and output devices</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate understanding of standard rules for adding comments on relay logic devices</td>
</tr>
<tr>
<td></td>
<td>• Design relay logic circuits for industrial control problems</td>
</tr>
<tr>
<td></td>
<td><strong>Performance Objectives, the student will:</strong></td>
</tr>
<tr>
<td></td>
<td>• Create relay logic diagrams using the standard relay logic rules</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 2.4-1 Creating Relay Logic Diagrams</td>
</tr>
</tbody>
</table>
# UNIT 2: PLC HARDWARE, CONFIGURATION, AND BASIC LADDER LOGIC PROGRAMMING

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5 PLC Programming</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• List the rules for creating a PLC ladder logic diagram</td>
</tr>
<tr>
<td></td>
<td>• Convert a relay logic diagram to a PLC ladder logic diagram</td>
</tr>
<tr>
<td></td>
<td>• Create ladder logic diagrams when the PLC is in the offline mode</td>
</tr>
<tr>
<td></td>
<td>• Download PLC ladder logic diagrams and test them on a trainer</td>
</tr>
<tr>
<td></td>
<td>• Use the force instruction for troubleshooting</td>
</tr>
<tr>
<td></td>
<td>• Create and print program reports</td>
</tr>
<tr>
<td></td>
<td>• Save and open ladder diagram project files</td>
</tr>
</tbody>
</table>

**Performance Objectives, the student will:**

- Describe the PLC data files
- Demonstrate how to connect input and output devices to PLC input/output ports
- Demonstrate PLC ladder logic and verify the operation using various I/O types
- Create PLC ladder logic diagrams with normally open and normally closed contacts associated with PLC output devices and verify their operation
- Use ladder logic diagrams to illustrate contacts to seal (lock) motors for continuous operation to illustrate that motors can turn on and off with output or internal circuits
- Construct PLC ladder logic diagrams that use the latch and unlatch instructions and verify operation
- Lab Exercise: 2.5-1 PLC Programming Basics
- Create relay logic diagrams from problem descriptions and demonstrate using ladder logic
- Analyze control problem descriptions and create and implement their relay logic diagrams and verify operation
- Create relay logic diagrams from PLC ladder logic diagrams to force instruction to turn input and output ports on and off
- Lab Exercise: 2.5-2 PLC Device Control

Notes:
# UNIT 3: INTERMEDIATE PLC INSTRUCTIONS AND THEIR APPLICATIONS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3.1 Programming Logic Gate Functions</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td>• Describe combinational and sequential logic gate circuits</td>
</tr>
<tr>
<td>Lab - 5 hrs.</td>
<td>• Create PLC ladder logic programs for logic gates</td>
</tr>
<tr>
<td></td>
<td>• Create Boolean expressions and logic gate circuits from truth tables</td>
</tr>
<tr>
<td></td>
<td>• Convert Boolean expressions to PLC ladder logic diagrams</td>
</tr>
<tr>
<td></td>
<td>• Convert PLC ladder logic diagrams to logic gate circuits and Boolean expressions</td>
</tr>
<tr>
<td></td>
<td><strong>Performance Objectives, the student will:</strong></td>
</tr>
<tr>
<td></td>
<td>• Convert logic gate circuits into ladder logic diagrams</td>
</tr>
<tr>
<td></td>
<td>• Create ladder logic diagrams from truth tables</td>
</tr>
<tr>
<td></td>
<td>• Create ladder logic diagrams from logic gate circuits</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate operation of the ladder logic diagrams</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 3.1-1 Logic Gates</td>
</tr>
<tr>
<td></td>
<td>• Create ladder logic diagrams from Boolean expressions and verify using ladder logic</td>
</tr>
<tr>
<td></td>
<td>• Extract Boolean expressions from ladder logic programs</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate proficiency in starting from a general problem description, drawing the truth table, finding and recording the Boolean expression and logic gate circuit in the problem statement, creating the ladder logic diagram, implementing and verifying the program on the PLC</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 3.1-2 Boolean Expressions</td>
</tr>
</tbody>
</table>

| **3.2 Timer Instructions**   | The student will be able to:                                                                                                               |
| Lecture - 1 hr.              | • Create PLC ladder logic diagrams using timers                                                                                           |
| Lab - 3 hrs.                 | • Design timer instructions to interlock each other                                                                                       |
|                               | • Develop cascade timer instructions                                                                                                      |
|                               | **Performance Objectives, the student will:**                                                                                           |
|                               | • Control PLC output ports using non-retentive timers                                                                                     |
|                               | • Create ladder logic diagrams using timer on-delay (TON) instructions                                                                   |
|                               | • Create a PLC ladder logic diagram using the timer ON-delay (TON) and time OFF-delay (TOF) instruction and verify operations            |
|                               | - Lab Exercise: 3.2-1 Timer Instructions                                                                                                 |

| **3.3 Counter Instructions** | The student will be able to:                                                                                                               |
| Lecture - 1 hr.              | • Create PLC ladder logic diagrams to demonstrate timers and counters                                                                   |
| Lab - 3 hrs.                 | • Connect different counter instructions and cascade counter instructions                                                              |
|                               | **Performance Objectives, the student will:**                                                                                           |
|                               | • Create PLC ladder logic diagrams using counter instructions                                                                         |
|                               | • Create PLC ladder logic diagrams for circuits that use counter and timer instructions                                                 |
|                               | • Create a PLC ladder logic diagram using the timer OFF-delay (TOD) instructions, the counter and timer instructions                        |
|                               | • Create a PLC ladder logic diagram using the timer OFF-delay (TOF) instructions, the retentive TOD instruction and counter instructions  |
|                               | - Lab Exercise: 3.3-1 Counter Instructions                                                                                              |

Notes:
## UNIT 3: INTERMEDIATE PLC INSTRUCTIONS AND THEIR APPLICATIONS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3.4 Math Instructions</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Create PLC programs demonstrating knowledge of four basic math instructions</td>
</tr>
<tr>
<td></td>
<td>• Design logic using advanced math instructions including move, shift left, and shift right</td>
</tr>
<tr>
<td></td>
<td>• Use NOT instruction in PLC ladder logic diagrams</td>
</tr>
<tr>
<td></td>
<td>• Use AND instruction in PLC ladder logic diagrams</td>
</tr>
<tr>
<td></td>
<td>• Use OR instructions in PLC ladder logic diagrams</td>
</tr>
<tr>
<td></td>
<td>• Use XOR instructions in PLC ladder logic diagrams</td>
</tr>
<tr>
<td></td>
<td>• Cascade the NOT instruction to AND, OR, and XOR to create NAND, NOR, and XNOR instructions</td>
</tr>
<tr>
<td></td>
<td>• Create a PLC ladder logic diagram that uses the bit shift left (BSL)</td>
</tr>
<tr>
<td></td>
<td>• Create a PLC ladder logic diagram that uses the bit shift right (BSR)</td>
</tr>
<tr>
<td></td>
<td><strong>Performance Objectives, the student will:</strong></td>
</tr>
<tr>
<td></td>
<td>• Create a ladder diagram to practice using math instructions</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 3.4-1 Math Instructions</td>
</tr>
</tbody>
</table>

| **3.5 Compare, Jump and MCR Instructions** | The student will be able to:                                               |
|                                             | • Describe how to use a compare instruction to energize a coil             |
|                                             | • Design cascade compare instructions to set upper and lower limits in a control system |
|                                             | • Discuss the use of the jump (JMP) and label (LBL) instructions to navigate rungs in a PLC ladder logic diagram |
|                                             | • Use compare instructions to energize the jump (JMP) instructions        |
|                                             | • Explain how a master control reset (MCR) instruction can halt the operation of a section of a PLC ladder logic diagram |
|                                             | **Performance Objectives, the student will:**                             |
|                                             | • Compare the sum of two values                                           |
|                                             | • Test the content of a counter-accumulated register and demonstrate success by turning on a pilot light |
|                                             | • Manipulate counter-accumulated registers using add, subtract, multiply, and divide instructions and use compare instructions to test the results |
|                                             | • Solve an equation that will convert unit dimensions using compare instructions |
|                                             | • Create PLC ladder logic diagrams that contain jump (JMP) and master control reset (MCR) instructions and verify using PLC station or PLC simulator |
|                                             |   - Lab Exercise: 3.5-1 Compare, Jump and MCR Instructions                |

Notes:
## UNIT 4: ADVANCED PLC INSTRUCTIONS AND APPLICATIONS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
</table>
| **4.1 Subroutine Functions** | The student will be able to:  
- Describe the function of subroutine(s) in a PLC ladder logic diagram  
- Design PLC ladder logic diagrams that incorporate one or more subroutines  
- Create ladder logic diagrams for subroutine files  
- Name or rename subroutine files  
- Use input devices to call subroutine files  
- Use compare instructions in the main PLC ladder logic diagram to call subroutine files  
- Explain the difference between interrupt routines and subroutines  
Performance Objectives, the student will:  
- Create a PLC ladder logic diagram using subroutine files  
  - Lab Exercise: 4.1-1 Subroutine Instructions |
| Lecture - 1 hr.  
Lab - 3 hrs. | |
| **4.2 Data Handling** | The student will be able to:  
- Describe how it is possible to move data from one register to another.  
- Demonstrate the use of stacks for storing and retrieving data  
- Explain how to move data between tables  
- Demonstrate verification of PLC instructions for number system conversion  
Performance Objectives, the student will:  
- Demonstrate how to use data handling instructions in ladder logic diagrams  
- Create ladder logic diagrams using data handling instructions  
- Design ladder logic to use timer, counter, and move instructions to create a 24-hour clock that can record up to three interruptions  
  - Lab Exercise: 4.2-1 Data Handling |
| Lecture - 1 hr.  
Lab - 3 hrs. | |
| **4.3 Sequencer Instructions** | The student will be able to:  
- Describe the operation of the sequencer output instruction  
- Describe the operation of the sequencer compare instruction  
- Describe the operation of the sequencer load instruction  
- Demonstrate how to connect sequencer instructions to increase the number of sequencer steps  
- Demonstrate how to connect sequencer instructions to increase the number of sequencer outputs  
Performance Objectives, the student will:  
- Create PLC ladder logic diagrams that use sequencer output instructions and verify  
- Create PLC ladder logic diagrams that use sequencer output instructions that have variable times between their operating steps and verify  
- Create PLC ladder logic diagrams that use sequencer output instructions that have fixed times between their operating steps and verify  
  - Lab Exercise: 4.3-1 Sequencer Instructions |
| Lecture - 1 hr.  
Lab - 3 hrs. | |

Notes:
# UNIT 4: ADVANCED PLC INSTRUCTIONS AND APPLICATIONS

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<th>TOPICS</th>
<th>OBJECTIVES</th>
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| **5.1 Troubleshooting and Servicing** | The student will be able to:  
- Explain the meaning of PLC indicator lights  
- Apply forced instructions to check PLC input and output ports  
- Debug PLC programming software to find CPU fault errors  
- Demonstrate how corrective actions can correct CPU fault errors  

Performance Objectives, the student will:  
- Demonstrate proficiency in troubleshooting PLCs  
  - Lab Exercise: 5.1-1 Troubleshooting |

| **5.2 PLC Networks**  | The student will be able to:  
- Name the common devices used in a PLC network  
- Describe the three main elements of a PLC network  
- Describe the characteristics of twisted pair, coaxial, and fiber-optic cable  
- Configure a PLC network  
- Apply service communications instructions and message read/write instructions to create PLC ladder logic diagrams  

Performance Objectives, the student will:  
- Demonstrate how to connect two PLC slave stations to one PLC master  
  - Lab Exercise: 5.2-1 PLC Networks |

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<td>• Define control objective</td>
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<td>• Design Control Logic</td>
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<td>• Implement design with Ladder Logic</td>
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<td><strong>Performance Objectives, the student will:</strong></td>
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<td>• Write the specifications for a PLC-based control system</td>
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<td>• Implement ladder logic on PLC</td>
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<td>• Test program with simulated I/O</td>
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<td>• Optimize design</td>
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<td>• Commission application</td>
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<td>• Critique results</td>
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<td>• Program the PLC ladder logic on the PLC or PLC simulator</td>
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<td>• Analyze performance of the PLC Ladder Logic program and optimize performance of the loop and communications</td>
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<td>• Commission the PLC application actual I/O</td>
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Notes:
SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 1.2-1 PLC OVERVIEW

PERFORMANCE OBJECTIVE

- Identify programmable logic controllers (PLCs) and their components.
- Describe the characteristics that distinguish between fixed and modular PLC devices.

LAB TYPE

Individual

TIME REQUIRED

1 hour

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

There are a wide variety of RTU and PLC packages on the market, but they generally have common components. This lab explores the basic parts of a PLC.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- PLC Trainer
- PLC (fixed and modular type)

MATERIALS NEEDED

Indicator lights with power source and I/O Port

CRITICAL TASKS STUDENTS MUST COMPLETE

- Describe the difference between fixed and modular programmable logic controllers.
- Identify the type of PLC used in the lab trainer.
- Identify the type of PLC simulated in the PLC simulator software.
- Define the CPU that the PLC lab trainer uses.
- Describe the difference between discrete (fixed) input/output ports and analog (variable) input/output ports.
- Define the number of fixed and variable input and output ports are on the PLC lab trainer.
- Define the number of fixed and variable input and output ports are on the PLC simulator software.
• Identify the type of communication interface is used to connect the communication module that connects the PC to the PLC lab trainer.

• Name the four different components found in a typical PLC device.

• Identify the input voltage you to have for a PLC.

• Identify the voltage level on the input module(s).

• Identify the voltage level on the output module(s).

• Explain why each input and output port is connected to the CPU using optoisolators.

FINDINGS

• PLCs are composed of various modules that are combined to meet application needs.

• PLCs are packaged for fixed use or have a modular architecture for future expansion.

ADDITIONAL INFORMATION

Bibliography:

SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 2.1-1 PLC COMPONENTS

PERFORMANCE OBJECTIVE

● ● • Describe how to do the addressing of input and output modules for PLCs.
● ● • Deconstruct the PLC controller files.
● ● • Demonstrate how to connect PLC communication ports.

LAB TYPE
Individual

TIME REQUIRED
1 hour

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

The primary purpose of a PLC is to orchestrate the behaviour and gather data from sensors and instruments. The electrical connection to these devices is through the Input and Output (I/O) modules of the PLC. This lab focuses on the I/O from a configuration and wiring perspective.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

● • PLC or PLC trainer

MATERIALS NEEDED
None

CRITICAL TASKS STUDENTS MUST COMPLETE

● • Identify input / output ports available on the PLC.
● • Describe communication speeds for PLC to SCADA host computer.
● • Demonstrate how to connect to input and output devices.
FINDINGS
I/O is a critical part of the PLC and is the direct link to sensors, instruments and final control devices such as switches. The connection wiring from PLC I/O modules to the end device is very important to successfully communicating with these devices.

ADDITIONAL INFORMATION
Bibliography:
SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 2.2-1 NUMBER SYSTEMS

PERFORMANCE OBJECTIVE

- Enumerate binary, octal, and hexadecimal number systems.
- Converting to and from each of the common number systems.

LAB TYPE

Individual

TIME REQUIRED

1 hour

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

Different components of a PLC use a variety of numbering systems. A working knowledge of binary, octal, and hexadecimal numbering systems is required to configure a PLC.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Scientific Calculator

MATERIALS NEEDED

None

CRITICAL TASKS STUDENTS MUST COMPLETE

- Match number system names to the base number they represent.
- Convert from binary to decimal.
- Convert from decimal to binary.
- Convert from decimal to BCD.
- Convert from BCD to decimal.
- Convert from decimal to octal.
- Convert from octal to decimal.
- Convert from decimal to hexadecimal.
• Convert from Gray code to hexadecimal.
• Convert from mixed number type to decimal.
• Convert from decimal to mixed number type.

**FINDINGS**

• Converting between numbering systems is a straightforward exercise when you understand the basis for each type.

**ADDITIONAL INFORMATION**

Bibliography:

SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 2.3-1 I/O DEVICES

PERFORMANCE OBJECTIVE

● Demonstrate proficiency with circuit symbols for input and output (I/O) devices.
● Draw a schematic diagram for a PLCs I/O devices.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

Successful control and monitoring of equipment requires that the PLC is wired in a logical way to the devices. This lab is designed to demonstrate proficiency in documenting the circuits required.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

None

MATERIALS NEEDED

None

CRITICAL TASKS STUDENTS MUST COMPLETE

● Draw and label normally open and normally closed switches.
● Draw and label normally open and normally pushbuttons.
● Draw and label normally open and normally closed limit switches.
● Draw and label normally open and normally closed proximity switches.
● Draw and label normally open and normally closed liquid level switches.
● Draw and label green and red pilot lights.
● Draw and label electric pump motor.
● Draw and label electric fan motor.
- Draw and label relay coil and two associated contacts: normally open and normally closed contacts.
- Draw and label normally open solenoid.
- Draw and label a fire alarm bell.
- Draw a schematic diagram for a PLC by connecting two switches and two pushbuttons to the input module. and connect three outputs to the output module. Make at least one of the input switches normally closed.

**FINDINGS**

- Circuit diagrams are the first step in determining how the PLC will interact with end devices such as contacts, alarms, motors, and other equipment.

**ADDITIONAL INFORMATION**

Bibliography:
SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 2.4-1 CREATING RELAY LOGIC DIAGRAMS

PERFORMANCE OBJECTIVE

• Create relay logic diagrams for circuits.

LAB TYPE

Individual

TIME REQUIRED

1 hour

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

Relay logic diagrams, also called ladder logic diagrams, build on the basic circuitry of the previous lab to diagram the logic of the PLC.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

None

MATERIALS NEEDED

None

CRITICAL TASKS STUDENTS MUST COMPLETE

• Draw the relay logic diagram for a circuit that operates as follows:
  - When switch one is closed, the green pilot light comes on.
  - When switch two is closed, the red pilot light comes on.
  - When switch one and two are closed, only the white pilot light is on.
• Draw the relay logic diagram for a circuit that operates as follows:
  - The master switch is the start/stop switch.
  - Press the green pushbutton to turn on motor one and motor two along with the white pilot light and the green pilot light until the master switch is opened.
  - The red pushbutton will run motor one and motor two and the red pilot light will be lit while it is depressed.
• Draw the relay logic diagram for a circuit that operates as follows:
  - When the red pushbutton is pressed, both the white pilot light will come on and motor one will be energized.
  - When switch one is closed, both the white pilot light and the green pilot light come on, and motor one and motor two are energized.

FINDINGS

• Ladder logic diagrams are a way to document and ultimately program a PLC’s logic and operation.
• Proficiency in reading and constructing logic diagrams are critical to the understanding of the way in which the PLC interacts with the end devices.

ADDITIONAL INFORMATION

Bibliography:
SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 2.5-1 PLC PROGRAMMING BASICS

PERFORMANCE OBJECTIVE

- Describe the PLC data files.
- Demonstrate how to connect input and output devices to PLC input/output ports.
- Demonstrate PLC ladder logic and verify the operation using various I/O types.
- Create PLC ladder logic diagrams with normally open and normally closed contacts associated with PLC output devices and verify their operations.
- Use ladder logic diagrams to illustrate contacts to seal (lock) motors for continuous operation to illustrate that motors can turn on and off with output or internal circuits.
- Construct PLC ladder logic diagrams that use the latch and unlatch instructions and verify operations.

LAB TYPE
Team

TIME REQUIRED
3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

Translation of logic diagrams to the PLC demonstrates how logic is programmed into the PLC.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Computer
- PLC or PLC Trainer
- Single-pole, single-throw switches (2)
- Limit switch (3)
- Thermostat switch
- Normally open push button
- Normally closed push button
- Red, green, and white pilot lights
• Split-phase AC induction motor (2) (fractional horsepower)
• Bell (6-volt)

**MATERIALS NEEDED:**

None

**CRITICAL TASKS STUDENTS MUST COMPLETE**

• Describe PLC scan rate.
• Name and describe the three PLC operational cycles.
• Describe the files found in the PLC programming software such as status, bit, timer, counter, control, and integer.
• Given a relay ladder logic diagram that connects two input and output devices, program the PLC to implement the logic.
• Given a relay ladder logic diagram that use PLC coils and contacts to seal output ports, explain the circuit and program the PLC to implement the logic.
• Given a relay ladder logic diagram that use normally open and normally closed contacts associated with PLC output devices, explain the circuit and program the PLC to implement the logic.
• Given a relay ladder logic diagram that uses contacts to seal (lock) motors for continuous operation, explain the circuit and program the PLC to implement the logic.
• Given a relay ladder logic diagram that uses latch and unlatch instructions, explain the circuit and program the PLC to implement the logic.

**FINDINGS**

• Successful completion of this lab requires assignment of the circuit to the I/O of the PLC.
• Successful completion of this lab requires downloading ladder logic programs into the PLC.
• Successful completion of this lab requires skill in moving between run and monitor modes in the PLC.

**ADDITIONAL INFORMATION**

Bibliography:

SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 2.5-2 PLC DEVICE CONTROL

PERFORMANCE OBJECTIVE

- Create relay logic diagrams from problem descriptions and demonstrate using ladder logic.
- Analyze control problem descriptions and create and implement their relay logic diagrams and verify operations.
- Create relay logic diagrams from PLC ladder logic diagrams to force instructions to turn input and output ports on and off.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

Control problems do not typically start from a logic diagram but rather from a general problem description that must be translated to logic before being implemented in PLC ladder logic.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Computer
- PLC or PLC Simulator
- Single-pole, single-throw switches (2)
- Normally open pushbuttons (2)
- Normally closed pushbutton
- Red, green, and white pilot lights
- Split phase AC induction motors (2) (fractional horsepower)

MATERIALS NEEDED

None
CRITICAL TASKS STUDENTS MUST COMPLETE

- Given general problem descriptions that require connecting switches to lights, draw the relay logic diagram for the circuit, define how the devices are connected to the I/O modules, create the ladder logic program and download to the PLC or simulator, and verify operations.

- Given general problem descriptions that require connecting switches to lights as well as controlling the running of the motors, draw the relay logic diagram for the circuit, define how the devices are connected to the I/O modules, create the ladder logic program and download to the PLC or simulator, and verify operations.

- Given a relay logic diagram for starting and stopping a motor using a start and stop switch, assign the input and output ports to the devices, create the ladder logic program and download to the PLC or simulator, and verify operations.

FINDINGS

- A disciplined organized approach is required to go from general problem descriptions to a functioning PLC program.

ADDITIONAL INFORMATION

Bibliography:

SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 3.1-1 LOGIC GATES

PERFORMANCE OBJECTIVE

● Convert logic gate circuits into ladder logic diagrams.
● Create ladder logic diagrams from truth tables.
● Create ladder logic diagrams from logic gate circuits.
● Verify operation of the ladder logic diagrams.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

Logic gate circuits and truth tables are ways of expressing a general problem statement. To successfully provide PLC programming and support, it is a required skill to analyze these forms of problem description and implement in a PLC ladder logic program.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

● Computer
● PLC or PLC Simulator
● Single-pole, single throw switches (5)
● Normally open pushbuttons (3)
● Red, green, and white pilot light
● Split-phase AC induction motor (fractional horsepower)

MATERIALS NEEDED

None
CRITICAL TASKS STUDENTS MUST COMPLETE

- Draw the logic gate symbols, write the truth tables and draw the PLC logic diagrams, program the PLC ladder logic, and verify utilizing switches and pilot light that incorporate the following logic gates:
  - AND
  - OR
  - NAND
  - NOR
  - XOR
  - XNOR
- Given a truth table, create a combinational logic circuit. Generate Boolean expressions from the combinational logic circuit. Create a ladder logic diagram from the Boolean expressions and create and verify the circuit.
- Given a PLC ladder logic diagram, create a logic gate diagram and vice versa. Download PLC program and verify operation.

FINDINGS

- Logic gate circuits and truth tables are an unambiguous way of defining control logic.

ADDITIONAL INFORMATION

Bibliography:

SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 3.1-2 BOOLEAN EXPRESSIONS

PERFORMANCE OBJECTIVE

- Create ladder logic diagrams from Boolean expressions and verify using ladder logic.
- Extract Boolean expressions from ladder logic programs.
- Demonstrate proficiency in starting from a general problem description, drawing the truth table, finding and recording the Boolean expression and logic gate circuit in the problem statement, creating the ladder logic diagram, and implementing and verifying the program on the PLC.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

This lab continues from the previous lab in building skill in moving between the forms of logic expression.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Computer
- PLC or PLC Simulator
- Single-pole, single throw switch
- Thermostat switch
- Normally open pushbuttons (2)
- Red and green pilot light

MATERIALS NEEDED

None
CRITICAL TASKS STUDENTS MUST COMPLETE

- Draw the PLC logic diagram of a Boolean expression and program it on the PLC lab station.
- Extract the Boolean expression from a PLC logic diagram, and from that, construct the ladder logic program to be downloaded to the PLC lab station and verified.
- Given a Boolean expression with terms tied to I/O devices, draw the PLC diagram for this expression, create the PLC ladder logic program, download to PLC, and verify.
- Given a general problem description, draw the truth table, find and record the Boolean expression, draw the logic gate circuit, draw the ladder logic diagram, convert to a PLC ladder logic program, download to the PLC lab station, and verify operation.

FINDINGS

- Complex control problems can be systematically analyzed and documented using a combination of Boolean expressions, truth tables, and logic gate circuits.
- Logic documentation is key to successful implementation of PLC ladder logic.

ADDITIONAL INFORMATION

Bibliography:
SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 3.2-1 TIMER INSTRUCTIONS

PERFORMANCE OBJECTIVE

- Control PLC output ports using non-retentive timers.
- Create ladder logic diagrams using timer on-delay (TON) instructions.
- Create a PLC ladder logic diagram using the timer ON-delay (TON) and time OFF-delay (TOF) instruction and verify operations using the PLC or PLC simulator.

LAB TYPE
Team

TIME REQUIRED
3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

The expression of logic in real world problems often includes delays before executing the reasoning to allow for other actions to occur.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Computer
- PLC or PLC Simulator
- Single-pole, single-throw switches (2)
- Red, green, and white pilot lights
- Split-phase AC induction motors (2) (fractional horsepower)

MATERIALS NEEDED
None
CRITICAL TASKS STUDENTS MUST COMPLETE

- Program non-retentive timers to control PLC output ports.
- Demonstrate how to create ladder logic diagrams using timer on-delay instructions.
- Given a general description of a circuit with a sequence of events, program the PLC station to solve the problem.

FINDINGS

- Timer instructions allow for temporal reasoning in PLC ladder logic.

ADDITIONAL INFORMATION

Bibliography:
SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 3.3-1 COUNTER INSTRUCTIONS

PERFORMANCE OBJECTIVE

• Create PLC ladder logic diagrams using counter instructions and verify operation using the PLC or PLC simulator.
• Create PLC ladder logic diagrams for circuits that use counter and timer instructions and verify using the PLC or PLC simulator.
• Create a PLC ladder logic diagram using the timer OFF-delay (TOD) instructions as well as the counter and timer instructions, and verify using a PLC station or PLC simulator.
• Create a PLC ladder logic diagram using the timer OFF-delay (TOF) instructions as well as the retentive TOD instruction and counter instruction, and verify using a PLC station or PLC simulator.

LAB TYPE
Team

TIME REQUIRED
3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

Many problems in practice involve controlling the sequence of events and the timing of operations. This is done with a combination of counters and timers in the PLC ladder logic.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

• Computer
• PLC or PLC Simulator
• Single-pole, single-throw switch
• Temperature switch
• Normally open pushbuttons (2)
• Red, green, and white pilot lights
• Bell (6-volt)
• Split-phase AC induction motors (2) (fractional horsepower)
MATERIALS NEEDED
None

CRITICAL TASKS STUDENTS MUST COMPLETE

● Given a problem that uses counters to control the operation of a fan, create the ladder logic and verify using the PLC or PLC simulator.

● Given a problem that combines the use of pushbuttons, counters, and retentive ON-delay instructions to control lights, create the ladder logic and verify using the PLC or PLC simulator.

● Given a problem that closes a temperature switch to start a sequence of events of running one motor and then a second motor and finally ringing a bell multiple times, create the ladder logic and verify using the PLC or PLC simulator.

● Given other problems combining sequence of events over time, create the ladder logic program and verify using the PLC or PLC simulator.

FINDINGS

● The sequence and timing of events is possible in a PLC using a combination of timers and counters.

ADDITIONAL INFORMATION

Bibliography:

SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 3.4-1 MATH INSTRUCTIONS

PERFORMANCE OBJECTIVE

• Create a ladder diagram using math instructions.

LAB TYPE

Individual

TIME REQUIRED

1 hour

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

Math instructions are necessary to effectively control equipment.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

• Computer
• PLC or PLC Simulator
• Single-pole, single-throw switch
• Thermostat switch
• Normally open pushbuttons (3)
• Red, green, and white pilot lights

MATERIALS NEEDED

None
CRITICAL TASKS STUDENTS MUST COMPLETE

- Describe the addition math instruction and provide an example.
- Describe the subtraction math instruction and provide an example.
- Describe the multiplication math instruction and provide an example.
- Describe the division math instruction and provide an example.
- Describe the Move, Bit Shift Left, and Bit Shift Right math instructions.
- Draw a relay logic diagram for a circuit that uses math instructions and create and verify the ladder logic for this design.
- Create a program using bit shift left or bit shift right to turn on a sequence of pilot lights so that one is on at a time for a duration of 1 second.

FINDINGS

- Basic math instructions are useful in PLC ladder logic programming.

ADDITIONAL INFORMATION

Bibliography:

SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 3.5-1 COMPARE, JUMP, AND MCR INSTRUCTIONS

PERFORMANCE OBJECTIVE

● Compare the sum of two values.
● Test the content of a counter-accumulated register and demonstrate success by turning on a pilot light.
● Manipulate counter-accumulated registers using add, subtract, multiply, and divide instructions, and use compare instructions to test the results.
● Solve an equation that will convert unit dimensions using the compare instruction.
● Create PLC ladder logic diagrams that contain jump (JMP) and master control reset (MCR) instructions, and verify using PLC station or PLC simulator.

LAB TYPE
Team

TIME REQUIRED
3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

More complex logic is enabled with the use of the compare functions to determine the relationship of two variables; the jump function to skip over logic based on that comparison and the master control reset instructions to clear previously calculated temporary data.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

● Computer
● PLC or PLC Trainer
● Single-pole, single-throw switches (2)
● Thermostat switch
● Normally open pushbuttons (2)
● Red, green, and white pilot lights
● Split-phase AC induction motor (2) (fractional horsepower)
● Bell (6-volt)
MATERIALS NEEDED

None

CRITICAL TASKS STUDENTS MUST COMPLETE

- Describe the equal-to, greater-than, less-than-or-equal-to, and greater-than-or-equal-to instructions, and provide examples of each.
- Program the PLC station to use two counters to count the pressing of two push buttons.
- Enable an add instruction and add the counters together.
- Turn on green, red, or white pilot lights if the sum is greater to, less than, or equal to a value.
- Program the PLC station to count the number of times a button is pushed, and turn on a light if the number is equal to either one of two values.
- Use the counters for two push buttons to activate lights so that the red light is on when the count is less than the lower limit, the green light is on when the count is between the upper and lower limit, and the white light is on when the count exceeds the upper limit. If the difference between the counts is greater than a predetermined value, sound the bell continuously. The program is to be reset by the master reset switch.
- Repeat the task above using multiply and divide rather than accumulating counts.
- Repeat the task above incorporating logic so that the bell will sound when the sum is equal to a predetermined number. The bell should sound for one second and then go silent for one second until the sum is changed or the master reset is pressed.
- Design logic to perform unit conversions between yards, feet, and inches, and implement in ladder logic code on the PLC.
- Describe the jump and master control reset functions and provide examples of each.
- Create a master control relay system.
- Create a system that turns on two motors and a white light via a push button.
- When the thermostat switch is closed, then only the green pilot light comes on without starting the motors.
- When a third switch is closed, the red light should blink once per second.

FINDINGS

- Compare and Jump instructions provide the capability of conditioned-based logic.
- Master control reset instructions clear previously calculated working data.

ADDITIONAL INFORMATION

Bibliography:

SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 4.1-1 SUBROUTINE INSTRUCTIONS

PERFORMANCE OBJECTIVE

- Create a PLC ladder logic diagram used as a main and two subroutine files.
- Verify using PLC station or PLC simulator.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

This lab introduces the students to the value of organizing logic in well-designed subroutines.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Computer
- Single-pole, single-throw switch
- Thermostat switch
- Normally open push-buttons (2)
- Red and green pilot lights

MATERIALS NEEDED

None
CRITICAL TASKS STUDENTS MUST COMPLETE:

- Create a PLC program that has two subroutines and carries out the following logic:
  - Turning on a switch activates the first subroutine that turns on a light if a switch is set.
  - The thermostat switch activates the second subroutine that turns on a second light if a second switch is set.
- Create a ladder logic program that has three subroutines:
  - Pressing the push button once scans the first subroutine that turns a green light on for five seconds.
  - Pressing the push button twice scans the second subroutine that turns a red light on for ten seconds.
  - Pressing the push button three times scans the third subroutine that turns a white light on for thirty seconds.

FINDINGS

- Subroutines provide a way to organize the logic of the code so that it is easy to access from anywhere in the ladder logic.

ADDITIONAL INFORMATION

Bibliography:
SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 4.2-1 DATA HANDLING

PERFORMANCE OBJECTIVE

● Demonstrate how to use data handling instructions in ladder logic diagrams.
● Create ladder logic diagrams using data handling instructions.
● Design ladder logic to use a timer and counter and to move instructions to create a 24-hour clock that can record up to three interruptions.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

Lookup tables are useful in many PLC applications. This lab will introduce the students to various ways to manage data within the context of the ladder logic program.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

● Computer
● PLC or PLC Trainer
● Single-pole, single-throw switch
● Normally open push button

MATERIALS NEEDED

None
CRITICAL TASKS STUDENTS MUST COMPLETE

- Create a PLC ladder logic diagram that demonstrates the use of move to BCD and from BCD instructions, and verify using the PLC station.
- Create a PLC ladder logic diagram that demonstrates the use of last-in last-out load instructions and verify using the PLC station.
- Create a PLC ladder logic diagram that demonstrates the use of first-in first-out load instructions and verify using the PLC station.
- Use timer, counter, and move instructions to create a 24-hour clock that can record up to three interruptions, and verify the operation of the resultant ladder logic diagram by implementing in the PLC station.

FINDINGS

- Manipulating stacks of data is a standard way to manage large amounts of data in an orderly manner.

ADDITIONAL INFORMATION

Bibliography:

SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 5.1-1 TROUBLESHOOTING

PERFORMANCE OBJECTIVE

● Demonstrate proficiency in troubleshooting PLCs.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

The problems in this lab appear simple, but are prone to errors. The information covered in the lecture on troubleshooting tips are invaluable in successfully implementing these types of problems.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

● Computer
● PLC or PLC Trainer
● Single-pole, single-throw switch
● Split-phase AC induction motor (2) (fractional horsepower)

MATERIALS NEEDED

None
CRITICAL TASKS STUDENTS MUST COMPLETE

- Create a ladder logic diagram for the following problem in which breaker #1 and breaker #2 alternately or are energized.
  - When commanded (by the switch), breaker #1 is energized. If breaker #1 is energized for more than 30 seconds, breaker #2 is energized until the demand switch is opened.
  - When commanded (by switch) the second time breaker #2 is energized. If breaker #2 is energized for more than 30 seconds, breaker #1 is energized until the demand switch is opened.
- Write a program that will read two inputs from modules I:3 and I:5, then divide the data from I:3 by the data from port I:5.

FINDINGS

- Troubleshooting techniques are valuable tools in implementing complex logic.

ADDITIONAL INFORMATION

Bibliography:
SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 5.2-1 PLC NETWORKS

PERFORMANCE OBJECTIVE

- Demonstrate knowledge of how to connect two PLC slave stations to one PLC master station, defining nodes to all three.
- Apply the Who Active Go online command to verify node addresses.
- Download PLC ladder logic to each node and verify operation of the network.
- Apply the Read setting in the master PLC ladder logic diagram.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

Networks of PLCs are used in automation of larger substations. This lab provides the opportunity to set up a PLC network and share data.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Computer
- PLC or PLC Trainer (3)
- Single-pole, single-throw switches (6)
- Normally open push button (2)
- Red and green pilot lights

MATERIALS NEEDED

None
Critical tasks students must complete:

- Connect three PLC stations in a local area network.
- Program the master station with the following tasks:
  - The master PLC program will have two message instructions.
  - When the green push button on the master PLC is pressed, it should use a latch function to go to the first message instruction.
    - This message instruction reads the status of the timers and counters that are on slave PLC station #1.
    - Press the red push button in order to unlatch and exit the message instruction.
    - The green pilot light indicates that the PLC is servicing message instruction #1.
  - When the black switch on the master PLC station is closed, it should use a latch function to go to the second message instruction.
    - This message instruction reads the status of the timers and counters that are on slave PLC station #2.
    - Press the red push button in order to unlatch and exit the message instruction. The red pilot light indicates that the PLC is servicing message instruction #2.
    - The red push button is used to unlatch the input bits B3/0 and B3/1.
    - All the data gathered by the master PLC station should reside in integer file (N7) locations of the master PLC.
  - Each individual slave PLC station should have a program that will continuously implement the following tasks:
    - The green pilot light is on for five seconds while the red one is off.
    - The red pilot light is on for eight seconds while the green one is off.
- Demonstrate that the PLC network functions as required.
- Modify the programs created in the tasks above to implement the following changes:
  - Add message.
    - Write instructions in order to be able to vary the time duration for which the red and green lights on the slave PLC stations stay on.
  - Demonstrate that the network incorporates the changes.

**FINDINGS**

- Networks of PLCs can synchronize activities by sharing variables stored in registers.

**ADDITIONAL INFORMATION**

Bibliography:
SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 6.1-1 SPECIFY REQUIREMENTS

PERFORMANCE OBJECTIVE

- Starting from a general problem statement, write the specifications for a PLC control system.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

In the final project for this class, students will choose or be given substation automation problems and complete a full project using the skills obtained.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Computer
- PLC or PLC Trainer
- Single-pole, single-throw switches (2)
- Limit switch (3)
- Thermostat switch
- Normally open push button
- Normally closed push button
- Red, green, and white pilot lights
- Split-phase AC induction motor (2) (fractional horsepower)
- Bell (6-volt)

MATERIALS NEEDED

None
CRITICAL TASKS STUDENTS MUST COMPLETE

- Write a general description of the problem definition.
- Construct truth tables required.
- Extract Boolean logic where possible.

FINDINGS

- Building on skills of this class, fully specify the problem to be addressed.

ADDITIONAL INFORMATION

Bibliography:

SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 6.1-2 DESIGN CONTROL LOGIC

PERFORMANCE OBJECTIVE

● Design PLC ladder logic diagram that meets the specification defined in Lab 6.1-1.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

In the final project for this class, students will choose or be given substation automation problems and complete a full project using the skills obtained.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

● Computer
● PLC or PLC Trainer
  ● Single-pole, single-throw switches (2)
  ● Limit switch (3)
● Thermostat switch
● Normally open push button
● Normally closed push button
● Red, green, and white pilot lights
● Split-phase AC induction motor (2) (fractional horsepower)
● Bell (6-volt)

MATERIALS NEEDED

None
CRITICAL TASKS STUDENTS MUST COMPLETE

- Construct the control logic diagram from specifications.

FINDINGS

- Well-documented problem statements lead to straightforward control.
- Ambiguous requirements are identified when constructing control logic diagrams.

ADDITIONAL INFORMATION

Bibliography:

SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 6.2-1 IMPLEMENT LADDER LOGIC

PERFORMANCE OBJECTIVE

- Program the PLC ladder logic on the PLC or PLC simulator.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

In the final project for this class, students will choose or be given substation automation problems and complete a full project using the skills obtained.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Computer
- PLC or PLC Trainer
- Single-pole, single-throw switches (2)
- Limit switch (3)
- Thermostat switch
- Normally open push button
- Normally closed push button
- Red, green, and white pilot lights
- Split-phase AC induction motor (2) (fractional horsepower)
- Bell (6-volt)

MATERIALS NEEDED

None
CRITICAL TASKS STUDENTS MUST COMPLETE

- Implement control logic diagram in ladder logic program.
- Assign and connect I/O.

FINDINGS

- Varies per project

ADDITIONAL INFORMATION

Bibliography:

SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 6.2-3 OPTIMIZE PROGRAM

PERFORMANCE OBJECTIVE

- Analyze performance of the PLC Ladder Logic program and optimize performance of the loop and communications.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION:

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

In the final project for this class, students will choose or be given substation automation problems and complete a full project using the skills obtained.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

- Computer
- PLC or PLC Trainer
- Single-pole, single-throw switches (2)
- Limit switch (3)
- Thermostat switch
- Normally open push button
- Normally closed push button
- Red, green, and white pilot lights
- Split-phase AC induction motor (2) (fractional horsepower)
- Bell (6-volt)

MATERIALS NEEDED

None
CRITICAL TASKS STUDENTS MUST COMPLETE

- Review performance of the downloaded program.
- Identify areas for improvement.
- Modify design and re-implement as required.

FINDINGS

- Varies by project

ADDITIONAL INFORMATION

Bibliography:

SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 6.2-4 TROUBLESHOOT PROJECT

PERFORMANCE OBJECTIVE

● Troubleshoot the problems introduced in the operation of the PLC ladder logic program.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND

In the final project for this class, students will choose or be given substation automation problems and complete a full project using the skills obtained.

SAFETY REQUIREMENTS

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT

● Computer
● PLC or PLC Trainer
  ● Single-pole, single-throw switches (2)
  ● Limit switch (3)
  ● Thermostat switch
  ● Normally open push button
  ● Normally closed push button
  ● Red, green, and white pilot lights
  ● Split-phase AC induction motor (2) (fractional horsepower)
  ● Bell (6-volt)

MATERIALS NEEDED

None
CRITICAL TASKS STUDENTS MUST COMPLETE

• Ensure that modifications made to the program operate as planned.

FINDINGS

• Varies by project

ADDITIONAL INFORMATION

Bibliography:

SCADA INDUSTRIAL CONTROL EQUIPMENT
LAB 6.2-5 COMMISSION

PERFORMANCE OBJECTIVE
• Commission the PLC application.

LAB TYPE
Team

TIME REQUIRED
3 hours

INSTRUCTOR PREPARATION
It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

BACKGROUND
In the final project for this class, students will choose or be given substation automation problems and complete a full project using the skills obtained.

SAFETY REQUIREMENTS
Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

TEST EQUIPMENT
• Computer
• PLC or PLC Trainer
  • Single-pole, single-throw switches (2)
  • Limit switch (3)
  • Thermostat switch
• Normally open push button
• Normally closed push button
• Red, green, and white pilot lights
• Split-phase AC induction motor (2) (fractional horsepower)
• Bell (6-volt)

MATERIALS NEEDED
None
CRITICAL TASKS STUDENTS MUST COMPLETE

- Demonstrate to instructor that the ladder logic fully meets the specification.

FINDINGS

- Varies by project

ADDITIONAL INFORMATION

Bibliography:

**SCADA INDUSTRIAL CONTROL EQUIPMENT**

**LAB 6.2-6 CRITIQUE APPLICATION**

**PERFORMANCE OBJECTIVE**

- Critique the results of the PLC application and identify ways to improve future versions.

**LAB TYPE**

Team

**TIME REQUIRED**

3 hours

**INSTRUCTOR PREPARATION**

It is assumed that this is a computer lab software-based exercise. Ensure that there is an appropriate number of lab stations with computers and peripherals in good working order. Ensure that networks are active and software dongles are in place. Ensure that all lab stations are logged in as student users. Check to ensure that the student files are not corrupted, and confirm that students have access to the student files. A third party software may be required.

**BACKGROUND**

In the final project for this class, students will choose or be given substation automation problems and complete a full project using the skills obtained.

**SAFETY REQUIREMENTS**

Students will be expected to utilize electronic equipment, components, and software. Provide students with basic guidelines as established by the individual computer lab in order to ensure user safety and the integrity of the computer equipment.

**TEST EQUIPMENT**

- Computer
- PLC or PLC Trainer
  - Single-pole, single-throw switches (2)
  - Limit switch (3)
- Thermostat switch
- Normally open push button
- Normally closed push button
- Red, green, and white pilot lights
- Split-phase AC induction motor (2) (fractional horsepower)
- Bell (6-volt)

**MATERIALS NEEDED**

None
CRITICAL TASKS STUDENTS MUST COMPLETE:

- Demonstrate completed project to peers.
- Defend design decisions.
- Acknowledge areas for improvement.

FINDINGS

- Varies by project

ADDITIONAL INFORMATION

Bibliography:

INTELLIGENT ENERGY SYSTEMS - FUNDAMENTALS

COURSE DESIGN GUIDE

COURSE TITLE
Intelligent Energy Systems - Fundamentals

CATALOG DESCRIPTION
This course lays the foundation for studies of Intelligent Energy Systems, commonly referred to as Smart Grid. The intent of the course is to introduce the student to the national and international program policies and emerging technology that are designed to modernize electric power transmission and distributions systems. The course explores the role of government in the modernization and optimization of energy infrastructure including distributed generation, renewable energy sources, and distributed automation.

CREDITS
3.0 credits, 48 hours

COURSE FORMAT
The course is a lecture format with opportunity to integrate research and composition activities following a recursive writing process.

COURSE NUMBER
Materials for this course are presented to meet the requirements for a 100-level course. The course is intended to meet the criteria as a writing intensive or research intensive course.

PREREQUISITES
College English Composition or equivalent

INSTRUCTOR INFORMATION
Recommended Qualifications: Master’s degree or higher in Engineering, Information Systems, Public Administration or related field; working knowledge and experience in public policy or utility management; experience teaching post-secondary education.

TEACHING METHODS AND ASSIGNMENTS FOR ACHIEVING LEARNING OUTCOMES
The course material is presented in a lecture format. Each topic area has a suggested time allocation. Total time includes an hour course introduction, a 2-hour review, and a 2-hour written exam.

BIBLIOGRAPHY

STUDENT LEARNING OUTCOMES

Upon successful completion the student will have the ability to:

- Determine the structure and foundation of civil government and citizen relationships with an emphasis on their influence on energy infrastructure
- Classify civil infrastructure according to purpose, use, and maintenance
- Develop an understanding of the continuum of public safety and regulation on the U.S. energy infrastructure
- Analyze the impact of historic widespread power disruptions, how they influenced future energy infrastructure and policy
- Demonstrate the understanding of the hierarchical functions and operations of the current interconnected electrical grid
- Appraise the impact of implementing smart technologies to utility grid systems
<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>EXEMPLARY 4</th>
<th>SATISFACTORY 3</th>
<th>DEVELOPING 2</th>
<th>BEGINNING 1</th>
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<td>Determine the structure and foundation of civil government and citizen relationships with an emphasis on their influence on energy infrastructure</td>
<td>Demonstrates excellent evaluation of structures and foundations of civil government and citizen relationships</td>
<td>Demonstrates average evaluation of structures and foundations of civil government and citizen relationships</td>
<td>Demonstrates essential evaluation of structures and foundations of civil government and citizen relationships</td>
<td>Demonstrates limited or no evaluation of structures and foundations of civil government and citizen relationships</td>
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<tr>
<td>Classify civil infrastructure according to purpose, use, and maintenance</td>
<td>Shows clear understanding of purpose, use, and maintenance as related to civil infrastructure</td>
<td>Shows competent understanding of purpose, use, and maintenance as related to civil infrastructure</td>
<td>Shows primary understanding of purpose, use, and maintenance as related to civil infrastructure</td>
<td>Shows incomplete understanding of purpose, use, and maintenance as related to civil infrastructure</td>
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<td>Analyze the impact of historic widespread power disruptions how they influenced future energy infrastructure and policy</td>
<td>Demonstrates a clear analysis of historic events and its impact on future energy policies</td>
<td>Demonstrates sufficient analysis of historic events and its impact on future energy policies</td>
<td>Demonstrates low-level analysis of historic events and its impact on future energy policies</td>
<td>Demonstrates a finite analysis of historic events and its impact on future energy policies</td>
</tr>
<tr>
<td>Demonstrate understanding of the hierarchical functions and operations of the current interconnected electrical grid</td>
<td>Shows mastery in understanding the hierarchical functions and operations of electrical grid</td>
<td>Shows sound understanding in the hierarchical functions and operations of electrical grid</td>
<td>Shows essential understanding in the hierarchical functions and operations of electrical grid</td>
<td>Shows foundational understanding in the hierarchical functions and operations of electrical grid</td>
</tr>
<tr>
<td>Appraise the impact of implementing smart technologies to utility grid systems</td>
<td>Exhibits excellent analysis of implementing smart technologies to current utility grid systems</td>
<td>Exhibits average analysis of implementing smart technologies to current utility grid systems</td>
<td>Exhibits primary analysis of implementing smart technologies to current utility grid systems</td>
<td>Exhibits deficient analysis of implementing smart technologies to current utility grid systems</td>
</tr>
</tbody>
</table>
## UNIT 1: GOVERNMENT & CIVIL ROLES IN ENERGY SYSTEMS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.1 Foundations of Government</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>- Identify the various forms of Government (Federal, State, Local, and special interest) as its purpose, ownership, and responsibility as they relate to energy</td>
</tr>
<tr>
<td></td>
<td>- Identify the type and roles of citizens (individual, corporate, other legal entity)</td>
</tr>
<tr>
<td></td>
<td>- Discuss the origins of citizen rights and liberties</td>
</tr>
<tr>
<td></td>
<td>- Discuss the purpose and impact of laws and policies on a society, its citizens, and economy</td>
</tr>
<tr>
<td><strong>1.2 Civil Infrastructure</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 3 hrs.</td>
<td>- Identify the types, purpose, and benefits of civil infrastructure:</td>
</tr>
<tr>
<td></td>
<td>- Transportation</td>
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<tr>
<td></td>
<td>- Communications</td>
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<tr>
<td></td>
<td>- Waste</td>
</tr>
<tr>
<td></td>
<td>- Energy</td>
</tr>
<tr>
<td></td>
<td>- Water</td>
</tr>
<tr>
<td><strong>1.3 Public Works/Public Services</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td>- Define public works and public services</td>
</tr>
<tr>
<td></td>
<td>- Discuss the impact of public works and services on the economy</td>
</tr>
<tr>
<td></td>
<td>- Demonstrate understanding of the role of public works organizations in energy infrastructure</td>
</tr>
</tbody>
</table>

Notes:
### UNIT 2: IMPACT OF REGIONAL AND NATIONAL EVENTS ON REGULATIONS GOVERNING THE MODERNIZATION OF PUBLIC UTILITIES

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
</table>
| 2.1 The Causes and Effects of Wide Scale Power Outages in the United States Since 1960 | The student will be able to:  
  - Define a wide-scale power outage  
  - Identify key power events in the United States since 1960  
  - For each event, identify the cause of the event, area, and population affected, duration of the event, and secondary effects of the outage |
| Lecture - 1 hr. |  
| 2.2 Brownouts and rolling brownouts | The student will be able to:  
  - Define brownouts and rolling brownouts  
  - Identify key regional brownout events, their root causes, population affected, and secondary effects |
| Lecture - 1hr. | |

Notes:
## UNIT 3: PUBLIC UTILITY POLICY

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
</table>
| 3.1 Energy Utility Basics                                              | **The student will be able to:**  
  - Discuss the life cycle of electricity, who owns it, and how it is regulated  
  - Identify the roles of various state and federal agencies responsible for the management and monitoring of energy industry and utilities  
  - Demonstrate how power is distributed via interstate and intrastate transmission lines  
  - Identify interconnection grids, regional grids                          |
| 3.2 PURPA 1978 (Public Utility Regulatory Policies Act of 1978)        | **The student will be able to:**  
  - Explain PURPA 1978  
  - Identify key points of PURPA 1978 in student readings assignments  
  - Discuss the intent of the act  
  - Identify results and implications that the act had on the future of the energy market |
| 3.3 Energy Policy Act of 1992                                           | **The student will be able to:**  
  - Explain Energy Policy Act 1992 and identify the key points of the act  
  - Identify amendments and changes to existing energy policy that the act enables  
  - Discuss impact of the act on overall energy policy/regulations          |
| 3.4 Energy Regulation vs. Deregulation Models                           | **The student will be able to:**  
  - Apply and discuss amendments and policies of Energy Policy Act 1992 towards Regulation vs. Deregulation Models  
  - Compare regulation/deregulation models and identify areas of the market that are likely to grow |
| 3.5 Energy Policy Act of 2005                                           | **The student will be able to:**  
  - Introduce Energy Policy Act and identify the key points of the act  
  - Identify amendments and changes to existing energy policy that the act enables  
  - Discuss impact of the act on overall energy policy/regulations          |
| 3.6 Energy Independence and Security Act of 2007 - EISA 2007            | **The student will be able to:**  
  - Explain EISA 2007 and identify the key points of the act  
  - Identify amendments and changes to existing energy policy that the act enables  
  - Discuss impact of act on overall energy policy/regulations  
  - Compare and discuss how this act differs from EPA act 2005  
  - Evaluate and explain what effects this has on the idea of smart grids |
| 3.7 Renewable Energy Policy                                              | **The student will be able to:**  
  - Identify the common trends/sources of renewable energy generation  
  - Discuss how legislation has impacted the renewable energy market in comparison to the “traditional” energy market (regulated market)  
  - Analyze how renewable energy will impact the current state of electrical grids and future smart grids |
## UNIT 3: PUBLIC UTILITY POLICY

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.8 EISA Act 2007 Impact on the Energy Market</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td>• Identify the intended outcomes and goals of EISA act 2007</td>
</tr>
<tr>
<td></td>
<td>• Summarize and analyze the connections between intended outcomes of the Energy Policy Act 1992/2005 and the EISA act 2007 Policy</td>
</tr>
<tr>
<td></td>
<td>• Identify strategic goals and objectives of EISA act 2007 and the impact it has on the energy market</td>
</tr>
<tr>
<td></td>
<td>• Determine and explain what the impact will be of this policy on the energy market</td>
</tr>
<tr>
<td></td>
<td>• Hypothesize how this policy will affect future energy legislation</td>
</tr>
<tr>
<td>3.9 National Institute of Standards and Technology Framework</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Roadmap for Smart Grid Interoperability Standards, 2.0</td>
<td>• Identify the main goal of the NIST framework for Smart Grids</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td>• Analyze how the goals of the NIST framework will change the current state of electrical grids</td>
</tr>
<tr>
<td></td>
<td>• Summarize what policies and acts promoted the idea of the NIST</td>
</tr>
<tr>
<td></td>
<td>• Recognize and explain security concerns and needs that smart grids present to the energy industry</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 4: ENERGY GRID “SYSTEMS” CHARACTERISTICS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
</table>
| 4.1 Systems Thinking Approach to Energy Grids | The student will be able to:  
- Explain the process of understanding how elements of an overall system influence one another  
- Describe the impact that component parts of a system have on the overall system  
- Describe the concept of system, subsystem, and multiple system interactions  
- Explain the “theory of constraints” |
| Lecture - 3 hrs. |  |
| 4.2 Traditional vs “Smart” Utility Systems Hierarchy and Characteristics | The student will be able to:  
- Describe the hierarchical design characteristics of both traditional power and emerging “smart” power systems designs  
- Analyze the differences in both traditional and “smart” power system designs in terms of generation, transmission, distribution, monitoring and control  
- Identify the advanced metering needs of emerging “smart” systems  
- Describe the characteristics of a “smart” grid system as defined by the Energy Independence and Security Act of 2007 |
| Lecture - 3 hrs. |  |

Notes:
<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
</table>
| 5.1 Increasing Utility Grid System Efficiency | The student will be able to:  
  - Assess the impact that improvements, modifications, or changes have on the efficiency of a utility grid system for each of the following:  
    - Control Systems  
    - Two-Way Communications  
    - Self-Healing Networks  
    - Base and Variable Generation  
    - Predictive Analysis systems |
| Lecture - 3 hrs. | |
| 5.2 Increasing Utility Grid System Reliability | The student will be able to:  
  - Explain the way that efficiency methods affect grid system reliability in terms of  
    - Decreases in Event Frequency  
    - Increases Power Quality  
    - Extended Life of Assets (Organic and External)  
    - Reductions in system Redundancy |
| Lecture - 3 hrs. | |
| 5.3 Increasing Utility Grid System Security | The student will be able to:  
  - Explain the current threats to utility security  
  - Describe the methods that can be used to reduce the threat to disruption of utility service |
| Lecture - 3 hrs. | |
| 5.4 Increasing Utility Grid System Responsiveness | The student will be able to:  
  - Assess the impact that improvements, modifications, or changes have on the Responsiveness of a utility grid system for each of the following:  
    - Self-Healing networks  
    - Micro-Grid interconnections |
| Lecture - 3 hrs. | |
| 5.5 Increasing Utility Grid System Sustainability | The student will be able to:  
  - Evaluate and explain the implementation of "smart" modifications on the sustainability of a utility grid system  
  - Describe specific changes in the hierarchy grid that will enhance overall sustainability in relation to:  
    - Generation  
    - Fuel Sources, Fuel Types and Equipment efficiencies  
    - Continuous reduction in demand  
    - Consumer equipment upgrades, advanced Metering, and alternate sources at the load  
    - Transmission Network Efficiencies  
    - Substation improvements, reduced thermal losses refined control networks |
| Lecture - 3 hrs. | |

Notes:
INTELLIGENT ENERGY SYSTEMS - ARCHITECTURE

COURSE DESIGN GUIDE

COURSE TITLE
Intelligent Systems-Architecture

CATALOG DESCRIPTION
This course introduces the student to the structural elements of a power transmission and distribution system with intelligent energy system enhancements. A detailed analysis of distributed generation, communication and measuring systems, and Information Integration Solutions hardware, software, and capabilities are addressed.

CREDITS
4 credits, 96 hours

COURSE FORMAT
This course is a lecture/lab format that incorporates industry-related lab exercises and activities during in-class, instructor-supervised labs. Course topics may be enhanced with the addition of research assignments.

COURSE NUMBER
Material for this course is presented to meet the requirements for a 200-level undergraduate course in an Applied Science or Career Technical Education Program.

PREREQUISITES
Intelligent Energy Systems-Fundamentals, College Algebra, Applied Math, Power Transmission and Distribution, or equivalent courses.

INSTRUCTOR INFORMATION
Recommended Qualifications: Master’s degree in electrical engineering, control systems engineering, information systems, or related field; experience in systems management.

TEACHING METHODS AND ASSIGNMENTS FOR ACHIEVING LEARNING OUTCOMES
The course material is presented in a lecture-lab format that divides material into logical topics with both learning and performance objectives. Each topic lists suggested time allocation. Total time allocated includes a 1-hour course introduction, a 2-hour review, a 2-hour practical exam, and a 2-hour written exam.

STUDENT TEXTS, READING AND OTHER MATERIALS
BIBLIOGRAPHY


STUDENT LEARNING OUTCOMES

Upon successful completion of this course students will be able to:

- Develop an understanding of Intelligent Energy Systems sources and loads
- Develop an understanding of Intelligent Energy Systems equipment systems
- Examine and explain the architecture of Intelligent Energy Systems working environment
- Design, program, and operate an integrated Intelligent Energy System
- Manage device hardware and software to optimize power systems
## ASSESSMENT RUBRIC

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>EXEMPLARY 4</th>
<th>SATISFACTORY 3</th>
<th>DEVELOPING 2</th>
<th>BEGINNING 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power System Sources and Loads</td>
<td>Explanation shows complete understanding of the Intelligent Energy Systems as it applies to sources and loads</td>
<td>Explanation shows substantial understanding of the Intelligent Energy Systems as it applies to sources and loads</td>
<td>Explanation shows some understanding of the Intelligent Energy Systems as it applies to sources and loads</td>
<td>Explanation minimal understanding of the Intelligent Energy Systems as it applies to sources and loads</td>
</tr>
<tr>
<td>IES Equipment</td>
<td>Explanation shows complete understanding of the Intelligent Energy Systems as it applies to equipment</td>
<td>Explanation shows substantial understanding of the Intelligent Energy Systems as it applies to equipment</td>
<td>Explanation shows some understanding of the Intelligent Energy Systems as it applies to equipment</td>
<td>Explanation shows minimal understanding of the Intelligent Energy Systems as it applies to equipment</td>
</tr>
<tr>
<td>Architecture</td>
<td>Accurately describes several dominant elements and principles used in an Intelligent Energy Systems and accurately relates how they are used in a working environment</td>
<td>Accurately describes a couple of dominant elements and principles used in an Intelligent Energy Systems and accurately relates how these are used in a working environment</td>
<td>Describes some dominant elements and principles used in an Intelligent Energy Systems, but has difficulty describing how these relate a working environment</td>
<td>Has trouble picking out the dominant elements</td>
</tr>
<tr>
<td>Design, Program, and Operate Power System</td>
<td>Design shows complete understanding of an integrated Intelligent Energy System and all information is well-organized</td>
<td>Design shows substantial understanding of an integrated Intelligent Energy System and most information is well-organized</td>
<td>Design shows some understanding of an integrated Intelligent Energy System and information shows some organization</td>
<td>Design shows minimal understanding of an integrated Intelligent Energy System, and organization of material is confusing</td>
</tr>
<tr>
<td>Hardware Management</td>
<td>Student efficiently and effectively manages all device hardware</td>
<td>Student effectively manages all device hardware</td>
<td>Student is capable of managing device hardware</td>
<td>Student is not able to manage device hardware</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 1: DISTRIBUTED GENERATION

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.1 Base and Variable Generation</strong> Lecture - 2 hrs.</td>
<td><strong>The student will be able to:</strong></td>
</tr>
<tr>
<td></td>
<td>• Classify power system generation sources and uses (base and variable generation).</td>
</tr>
<tr>
<td></td>
<td>• Compare the practicality of base and variable generation sources.</td>
</tr>
<tr>
<td></td>
<td>• Analyze the cost effectiveness of base and variable generation sources.</td>
</tr>
<tr>
<td></td>
<td>• Compare alternative energy and fossil fuel output variables effect on grid.</td>
</tr>
<tr>
<td><strong>1.2 Power Sources</strong> Lecture - 6 hrs.</td>
<td><strong>The student will be able to:</strong></td>
</tr>
<tr>
<td></td>
<td>• Demonstrate an understanding of the sources of base-load electrical power, including efficiency, ramp rate, heat rate.</td>
</tr>
<tr>
<td></td>
<td>• Describe nuclear power generation equipment and systems, including availability, efficiency, ramp rate, heat rate.</td>
</tr>
<tr>
<td></td>
<td>• Describe ocean-thermal power generation equipment and systems, including availability, efficiency, ramp rate, heat rate.</td>
</tr>
<tr>
<td></td>
<td>• Describe Rankin cycle power generation equipment and systems, including availability, efficiency, ramp rate, heat rate.</td>
</tr>
<tr>
<td></td>
<td>• Describe gas turbine power generation equipment and systems, including availability, efficiency, ramp rate, heat rate.</td>
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<tr>
<td></td>
<td>• Examine and discuss the sources of variable-load electrical power.</td>
</tr>
<tr>
<td></td>
<td>• Describe photovoltaic (PV) power generation equipment and systems, including availability, efficiency, ramp rate, heat rate.</td>
</tr>
<tr>
<td></td>
<td>• Describe solar power generation equipment and systems, including availability, efficiency, ramp rate, heat rate.</td>
</tr>
<tr>
<td></td>
<td>• Describe hydroelectricity power generation equipment and systems, including availability, efficiency, ramp rate, heat rate.</td>
</tr>
<tr>
<td></td>
<td>• Describe wind power generation equipment and systems, including availability, efficiency, ramp rate, heat rate.</td>
</tr>
<tr>
<td></td>
<td>• Describe Wave Generation equipment and systems, including availability, efficiency, ramp rate, heat rate.</td>
</tr>
</tbody>
</table>

Notes:
**UNIT 1: DISTRIBUTED GENERATION**

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>**1.3 Direct Energy Regulated Services,</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Power Storage Systems</td>
<td>- Describe energy storage technology types to include characteristics capabilities and limitations of</td>
</tr>
<tr>
<td></td>
<td>- Flow Batteries</td>
</tr>
<tr>
<td></td>
<td>- Advanced Batteries (UPS)</td>
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<tr>
<td></td>
<td>- Super Capacitors</td>
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<td></td>
<td>- Superconducting Magnetic Energy Storage</td>
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<td></td>
<td>- Pumped Hydro</td>
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<td></td>
<td>- Compressed Air</td>
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<td></td>
<td>- Flywheels</td>
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<tr>
<td></td>
<td>- Explain the operational capabilities and limitations of storage systems in terms of both efficiency and reliability.</td>
</tr>
<tr>
<td></td>
<td>- Describe the storage topology as it relates to a distributed generation system.</td>
</tr>
<tr>
<td><strong>1.4 Combined Load Curve</strong></td>
<td><strong>The student will be able to:</strong></td>
</tr>
<tr>
<td></td>
<td>- Describe the demand load curve for a typical grid architecture.</td>
</tr>
<tr>
<td></td>
<td>- Describe the variable supply curve of distributed generation systems.</td>
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<tr>
<td></td>
<td>- Explain the effects of the combined supply/demand curve.</td>
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<tr>
<td></td>
<td>- Explain methods to mitigate the effects of variable generation including summation formulas, visualization, and Self Organizing Maps (Kohonen maps).</td>
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<tr>
<td></td>
<td><strong>Performance Objectives, the student will:</strong></td>
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<tr>
<td></td>
<td>- Construct combined load curve charts for a given set of parameters, clustering data for optimum visualization.</td>
</tr>
<tr>
<td></td>
<td>- Solve load curve optimization problems using independent and hierarchical clustering methods.</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 1.4-1 Combined Load Curve</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 2: COMMUNICATION MEASURING

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 AMI Lecture - 1 hr.</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Explain the use and function of Advanced Metering Infrastructure equipment and systems.</td>
</tr>
<tr>
<td></td>
<td>• Describe the placement of AMI systems at various levels of a distribution system.</td>
</tr>
<tr>
<td></td>
<td>• Describe the uses of AMI data for both supplier and consumer.</td>
</tr>
<tr>
<td>2.2 Power Metering Lecture - 1 hr.</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Explain the use and function of power metering (PM) equipment and systems.</td>
</tr>
<tr>
<td>2.3 Weather Lecture - 1 hr.</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Explain the use and function of weather measuring systems as an aid to power system optimization.</td>
</tr>
<tr>
<td></td>
<td>• Describe the metrics typically collected by meteorological systems.</td>
</tr>
<tr>
<td></td>
<td>• Examine and discuss the ways that the data collected may be used to integrate a power management system.</td>
</tr>
<tr>
<td>2.4 GIS Lecture - 1 hr.</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Explain the use and function of Geographic Information Systems (GIS).</td>
</tr>
<tr>
<td></td>
<td>• Describe the integration of GIS with power system architecture and functionality.</td>
</tr>
<tr>
<td>2.5 Power Management Unit Lecture - 3 hrs.</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Explain the use and function of power management units (PMUs) to monitor power quality.</td>
</tr>
<tr>
<td></td>
<td>• Examine and discuss PMU configurations in a grid system at both transmission and distribution levels.</td>
</tr>
<tr>
<td></td>
<td>• Describe PMU output, raw and calculated.</td>
</tr>
<tr>
<td></td>
<td>• Understand PMU input sensors CT/PT.</td>
</tr>
<tr>
<td>2.6 Load Leveling Lecture - 1 hr.</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Explain the use and function of load leveling, at power source, distribution, and load centers.</td>
</tr>
<tr>
<td>2.7 Instrument Level Communication Lecture - 3 hrs.</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Understand the various methods that instruments, sensors, and intermediate controls communicate information to a central repository.</td>
</tr>
<tr>
<td>2.8 Utility Power Management Systems Lecture - 2 hrs. Lab - 6 hrs.</td>
<td>The student will be able to:</td>
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<tr>
<td></td>
<td>• Combine multiple communications and measuring devices and systems to determine the health of a power system.</td>
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<tr>
<td></td>
<td><strong>Performance Objectives, the student will:</strong></td>
</tr>
<tr>
<td></td>
<td>• Develop a dynamic system proposal for a power management system that utilizes multiple communication paths and instrumentation/measurement devices.</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 2.8-1 Power Management System Blueprint (Team)</td>
</tr>
</tbody>
</table>
# UNIT 3: INFORMATION INTEGRATION SOLUTIONS (IIS)

<table>
<thead>
<tr>
<th>TOPICS</th>
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</tr>
</thead>
<tbody>
<tr>
<td>3.1 Energy Management Systems and Distribution Management Systems&lt;br&gt;Lecture - 3 hrs.</td>
<td>The student will be able to:&lt;br&gt;• Describe the function of real time energy management and distribution management system technology.</td>
</tr>
<tr>
<td>3.2 Monitoring and Control&lt;br&gt;Lecture - 3 hrs.</td>
<td>The student will be able to:&lt;br&gt;• Describe utility transmission and distribution system monitoring and control device interoperability including HAN, WAN, SCADA, utility instruments.&lt;br&gt;• Apply IEC 61850 standard to EMS/DMS Architecture.</td>
</tr>
<tr>
<td>3.3 Fault Location, Isolation and System Restoration (FLISR)&lt;br&gt;Lecture - 3 hrs.&lt;br&gt;Lab - 9 hrs.</td>
<td>The student will be able to:&lt;br&gt;• Explain the integration of EMS/DMS with control to recognize and isolate system faults as a function.</td>
</tr>
<tr>
<td>3.4 IES Powerflow Modeling&lt;br&gt;Lecture - 8 hrs.&lt;br&gt;Lab - 30 hrs.</td>
<td>The student will be able to:&lt;br&gt;• Describe the physical and electrical relationship of Power System Components.&lt;br&gt;• Describe the placement of plants, busses, generators, transformers, lines, loads, and shunts.&lt;br&gt;&lt;strong&gt;Performance Objectives, the student will:&lt;/strong&gt;&lt;br&gt;• Using a software simulation program, generate a EMS one-line diagram with a control overlay, including a minimum of three generations, two primary load buses and three substation nodes.&lt;br&gt;  - Lab Exercise: 3.4-1 EMS One Line Diagram&lt;br&gt;• Develop an EMS overlay on a two feed distribution system topology diagram, and given parameters for temporary faults, such as insulator flashover, lightning strikes, and line failure, determine the route used to restore service.&lt;br&gt;  - Lab Exercise: 3.4-2 EMS Overlay Basic&lt;br&gt;  - Lab Exercise: 3.4-3 EMS Overlay Intermediate&lt;br&gt;• Determine routing and recloser positions for the restoration of permanent faults that de-energize the area surrounding the faulted section of the substation or the feeder.&lt;br&gt;  - Lab Exercise: 3.4-4 EMS Overlay Advanced</td>
</tr>
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Notes:
### UNIT 4: MICROGRID

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
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<tbody>
<tr>
<td>4.1 Microgrid</td>
<td><strong>The student will be able to:</strong></td>
</tr>
<tr>
<td></td>
<td>• Develop an understanding of distributed energy resources and microgrid topology.</td>
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<tr>
<td></td>
<td>• Describe how microgrid networks interact with utility grid systems.</td>
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<td></td>
<td><strong>Performance Objectives, the student will:</strong></td>
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<tr>
<td></td>
<td>• Assess a substation area topology that includes 50% variable generation,</td>
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<tr>
<td></td>
<td>double feed macrogrid tiepoints, and medium quality loads.</td>
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<tr>
<td></td>
<td>• Develop an isolation plan to operate the system as a microgrid topology.</td>
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<tr>
<td></td>
<td>• Apply stable load parameters to a microgrid topology, apply event faults to</td>
</tr>
<tr>
<td></td>
<td>determine the capabilities, limitations and vulnerabilities of the system, and write</td>
</tr>
<tr>
<td></td>
<td>an operational assessment using industry standard reporting format.</td>
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<tr>
<td></td>
<td>- Lab Exercise: 4.4-1 Microgrid Assessment plan</td>
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<tr>
<td></td>
<td>- Lab Exercise: 4.4-2 Microgrid Isolation Plan</td>
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<tr>
<td></td>
<td>- Lab Exercise: 4.4-3 Microgrid Operational Assessment</td>
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</tbody>
</table>

**Notes:**
INTELLIGENT ENERGY SYSTEMS - ARCHITECTURE
LAB 1.4-1 VARIABLE LOAD CURVE

PERFORMANCE OBJECTIVE

- Construct a combined load curve chart for a given set of parameters, clustering data for optimum visualization.
- Solve load curve optimization problems using independent and hierarchical clustering methods.

LAB TYPE

Individual

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

The instructor will provide students with grid system load curve parametric data and variable generation data for a 24-hour period on a given grid topology. The information can be tabular or electronic.

BACKGROUND

The load on a power station is never constant; it can be plotted using several time bases. These plots can be used to make predictions regarding usage. The introduction of Solar, Wind, PV, and other variable generation sources increases uncertainty of power system operation and management. This exercise is designed to introduce the student to the representation of load and source power available to a power system over a specified time period. The foundation of load flow analysis is probabilistic. In order to understand and interpret data, the student must develop a base understanding of data collection and plotting.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range that may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material.

An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical, or otherwise, from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on the lesson. Students tend to momentarily neglect safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.
TEST EQUIPMENT
None

MATERIALS NEEDED

• Software to calculate and plot load and generation variables:
  - Microsoft Excel
  - Mathmatecia
  - Matlab
  - Paladin Power system Simulator
  - Siemens PSS-E

CRITICAL TASKS STUDENTS MUST COMPLETE

• Plot system demand variables using a time base of 1 hour for a duration of 24 hours.
• Plot system generation variable using a time base of .25 hours for a duration of 24 hours.
• Develop a base load and peak load demand schedule (Exclude Variable Generation).
• Develop a base load and peak load demand schedule (Include Variable Generation).
• Modify the schedule based on a changing generation variable.

FINDINGS

• Determine the additional load demand on a base load plant with a diminished variable load. Distinguish between solar source and wind source variable loads. Discuss the differences in the reliability and availability of solar and wind power by region, and how that will affect the combined load curve.

ADDITIONAL INFORMATION

None
INTELLIGENT ENERGY SYSTEMS - ARCHITECTURE
LAB 2.8-1 POWER MANAGEMENT SYSTEM BLUEPRINT

PERFORMANCE OBJECTIVE

● Develop a dynamic system proposal for a power management system that utilizes multiple communication paths and instrumentation/measurement devices.

LAB TYPE

Team

TIME REQUIRED

6 hours

INSTRUCTOR PREPARATION

The instructor should develop a traditional Power T&D system using line drawn system diagrams, a small-scale model, or simulation software. The students will put the system into motion by assigning load curve data to the system. The instructor can either assign the parameters or have the teams develop their own.

Determine the appropriate variable load sources for the region and have the students integrate the variable load into the system. The instruction will guide the student teams to add appropriate instruments, communications, and controls to begin to automate the system. This exercise is not intended to have the student fully automate the system; it is intended to have the students use available resources to consider the many ways that a system could be automated. The final segment of the exercise will have the students evaluate the other projects, and provide comments and suggestions for improvement.

BACKGROUND

This team exercise will illustrate the integration of communication and measuring devices, communications, and management systems with power distribution systems.

SAFETY REQUIREMENTS

Proper classroom and lab safety are the minimum requirement for this lab exercise.

TEST EQUIPMENT

None

MATERIALS NEEDED

● Microsoft Visio or other visualization Software
● Power System Simulation Software
CRITICAL TASKS STUDENTS MUST COMPLETE

- Review and understand the objectives and outcomes of the exercise.
- Assign team roles and responsibilities, and elect a team leader.
- Review the power system narrative and develop block diagram.
- Using proper graphical symbology, develop a print layout of the system.
- Using instructor provided parameters, assign working values to the system.
- Using instructor provided variable generation source data, re-draw the system to include the sources.
- Recalculate the system parameters.
- Using instructor provided instruments, insert instrumentation, communications, and control elements.
  Use proper graphical symbology.
- Evaluate the system blueprint for efficiency and effectiveness.

FINDINGS

- The student teams will draft a written report providing a basic narrative overview of the system and justification for the placement and purpose of instruments and controls. Additionally the team will develop a 5-10 minute presentation highlighting the system.

- The student teams will evaluate at least one other team project, critiquing the system, and suggesting improvements.

ADDITIONAL INFORMATION

None

RECOMMENDED MATERIALS

- Local utility companies may be able to provide system diagrams of real world power systems located in the vicinity of the school.
- Power control system manufacturers provide simulation software for use by colleges and universities as well as training on proper use of the software in an academic environment.
INTELLIGENT ENERGY SYSTEMS - ARCHITECTURE
LAB 3.4-1 EMS ONE LINE

PERFORMANCE OBJECTIVE

● Using a software simulation program, generate a EMS one-line diagram with a control overlay. Include a minimum of three generations, two primary load buses, and three substation nodes.

LAB TYPE

Individual

TIME REQUIRED

8 hours

INSTRUCTOR PREPARATION

Develop a brief narrative description of the transmission and distribution topology. The narrative should include descriptions of regional geographic conditions, types, and density of load consumers on the network, as well as the relative age of the existing infrastructure.

Incorporate industry standard equipment and system parameters into the overall diagram. Include both legacy and new equipment standards.

Develop the topology in multiple phases, save, print, and prepare completed examples of each phase in final operational condition. This will be used as a standard basis for the students’ development of the topology.

Incorporate realistic load parameters based on the previously developed narrative. Depending upon the complexity of the software simulation suite, develop fault scenarios that may be inserted into the students’ design schemes.

BACKGROUND

The purpose of this exercise is to have the student develop a fully functional electrical system topology using simulation software that will show function. This method is used by engineers to develop, test, and modify existing electrical systems. At the technical level, the student technician will gain a holistic understanding of existing systems. Through the process of “building” the system using functional simulation, the student technician takes ownership of the system under construction and will be able to use the system for further experimentation in a series of more complex structures as well as the introduction of control system communications and equipment.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range that may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material. An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment. Always disconnect the electrical power source before isolating any component, electrical, or otherwise, from
the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on the lesson. Students tend to momentarily neglect safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.

Specific to this exercise: Both student and instructor must maintain situational awareness while working in a computer lab environment.

**TEST EQUIPMENT**

- Calculator
- Spreadsheet software suite with installed analytical tools

**MATERIALS NEEDED**

- Interactive Electrical distribution system simulation software suite
- (Optional) Reactive Power distribution system modeling trainer with control system

**CRITICAL TASKS STUDENTS MUST COMPLETE**

- Read and understand the narrative description of the system to be modeled.
- List the major block components of the system under construction.
- Categorize the block components according to function.
- Identify interconnection components required for the system.
- Identify protective devices required for the system.
- Using simulation software or modeling hardware, place and connect the generation, transmission, and distribution components in the simulation.
- Using interconnection components, develop a basic one-line diagram that schematically represents the system, including all load centers and protective devices.
- Place the system under load and the test the components for proper function.

**FINDINGS**

- Upon successful completion of this exercise, the student will compare the “as built” simulated electrical environment to the standard provided by the instructor. The comparative analysis may be used as a learning tool to reinforce the performance objective, or alternately used as an assessment tool to measure the performance objective. The student may be required to provide a written acknowledgment of the discovery encountered in the performance of the exercise. In the case of higher-level delivery of the curriculum, the student may be required to complete worksheets based upon mathematical data derived from the simulation.
ADDITIONAL INFORMATION

Bibliography:
  • EDSA Micro Corporation, Paladin Design Base 2.0

Recommended materials:
  • ETAP Software Suite
  • Paladin Designbase 2.0 Simulation software
  • Siemens- Power Systems Simulation- Engineering PSS-E
  • Milsoft Windmil simulation software
  • Microsoft Excel with analytical tools
INTELLIGENT ENERGY SYSTEMS - ARCHITECTURE
LAB 3.4-2 EMS OVERLAY BASIC

PERFORMANCE OBJECTIVE

- Develop an EMS overlay on a two-feed distribution system topology diagram.

LAB TYPE

Individual

TIME REQUIRED

8 hours

INSTRUCTOR PREPARATION

Develop a brief narrative description of the transmission and distribution topology. The narrative should include descriptions of regional geographic conditions, types, and density of load consumers on the network, as well as the relative age of the existing infrastructure.

Incorporate industry standard equipment and system parameters into the overall diagram. Include both legacy and new equipment standards.

Develop the topology in multiple phases, save, print, and prepare completed examples of each phase in final operational condition. This will be used as a standard basis for the students’ development of the topology.

Incorporate realistic load parameters based on the previously developed narrative. Depending upon the complexity of the software simulation suite, develop fault scenarios that may be inserted into the students’ design schemes.

BACKGROUND

The purpose of this exercise is to have the student develop a fully functional electrical system topology using simulation software that will show function. This method is used by engineers to develop, test, and modify existing electrical systems. At the technical level, the student technician will gain a holistic understanding of existing systems. Through the process of “building” the system using functional simulation, the student technician takes ownership of the system under construction and will be able to use the system for further experimentation in a series of more complex structures as well as the introduction of control system communications and equipment.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range that may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.
Keep the floor clean of debris—oil, water, or other slippery material. An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment. Always disconnect the electrical power source before isolating any component, electrical, or otherwise, from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on the lesson. Students tend to momentarily neglect safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.

Specific to this exercise: Both student and instructor must maintain situational awareness while working in a computer lab environment.

**TEST EQUIPMENT**

- Calculator
- Spreadsheet software suite with installed analytical tools

**MATERIALS NEEDED**

- Interactive Electrical distribution system simulation software suite
- (Optional) Reactive Power distribution system modeling trainer with control system

**CRITICAL TASKS STUDENTS MUST COMPLETE**

- Open and bring to full function a working system simulation.
- Read and understand the narrative description of the system to be modeled.
- List the major block components of the system under construction that can be controlled and/or monitored using an EMS.
- Determine the function and expected outcome for the EMS.
- Insert EMS.
- Using simulation software or modeling hardware, place and connect the generation, transmission, and distribution components in the simulation.
- Using interconnection components, develop a basic one-line diagram that schematically represents the system, including all load centers and protective devices.
- Place the system under load and the test the components for proper function.

**FINDINGS**

- Upon successful completion of this exercise, the student will compare the “as built” simulated electrical environment to the standard provided by the instructor. The comparative analysis may be used as a learning tool to reinforce the performance objective or alternately used as an assessment tool to measure the performance objective. The student may be required to provide a written acknowledgment of the discovery encountered in the performance of the exercise. In the case of higher-level delivery of the curriculum, the student may be required to complete worksheets based upon mathematical data derived from the simulation.
ADDITIONAL INFORMATION

Bibliography:
- EDSA Micro Corporation, Paladin Design Base 2.0
- Siemens PSSE

Recommended materials:
- ETAP Software Suite
- Paladin Designbase 2.0 Simulation software
- Siemens- Power Systems Simulation- Engineering PSS-E
- Milsoft Windmil simulation software
INTELLIGENT ENERGY SYSTEMS - ARCHITECTURE
LAB 3.4-3 EMS OVERLAY INTERMEDIATE

PERFORMANCE OBJECTIVE

- With a functioning EMS overlay on a two-feed distribution system topology diagram and parameters for temporary faults such as insulator flashover, lightning strikes, and line failure, determine the route used to restore service.

LAB TYPE

Individual

TIME REQUIRED

8 hours

INSTRUCTOR PREPARATION

Develop a brief narrative description of the transmission and distribution topology. The narrative should include descriptions of regional geographic conditions, types, and density of load consumers on the network, as well as the relative age of the existing infrastructure.

Incorporate industry standard equipment and system parameters into the overall diagram. Include both legacy and new equipment standards.

Develop the topology in multiple phases, save, print, and prepare completed examples of each phase in final operational condition. This will be used as a standard basis for the students’ development of the topology.

Incorporate realistic load parameters based on the previously developed narrative. Depending upon the complexity of the software simulation suite, develop fault scenarios that may be inserted into the students’ design schemes.

BACKGROUND

The purpose of this exercise is to have the student develop a fully functional electrical system topology using simulation software that will show function. This method is used by engineers to develop, test, and modify existing electrical systems. At the technical level, the student technician will gain a holistic understanding of existing systems. Through the process of “building” the system using functional simulation, the student technician takes ownership of the system under construction and will be able to use the system for further experimentation in a series of more complex structures as well as the introduction of control system communications and equipment.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range that may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.
Keep the floor clean of debris—oil, water, or other slippery material. An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical or otherwise, from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on the lesson. Students tend to momentarily neglect safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.

Specific to this exercise: Both student and instructor must maintain situational awareness while working in a computer lab environment.

**TEST EQUIPMENT**

- Calculator
- Spreadsheet software suite with installed analytical tools

**MATERIALS NEEDED**

- Interactive Electrical distribution system simulation software suite
- (Optional) Reactive Power distribution system modeling trainer with control system

**CRITICAL TASKS STUDENTS MUST COMPLETE**

- Open and bring to full function a working system simulation.
- Read and understand the narrative description/problem statement of the system to be modeled.
- Ensure the basic EMS/Grid system provided is functioning normally.
- Develop a project list of components and systems that could be incorporated into the functioning system that will satisfy the requirements of the narrative problem statement.
- List the major block components of the system under construction that can be controlled and/or monitored using an additional control elements of an EMS.
- Determine the function and expected outcome for the EMS.
- Using the simulation software tools, insert EMS.
- Using simulation software, or modeling hardware, place and connect additional transmission and distribution components in the simulation as necessary to satisfy the requirements of the problem statement.
- Using interconnection components, develop a basic one-line diagram that schematically represents the system, including all load centers and protective devices.
- Place the system under load and the test the components for proper function and to ensure that the EMS satisfies the requirements to overcome the problem.
FINDINGS

- Upon successful completion of this exercise, the student will compare the “as built” simulated electrical environment to the standard provided by the instructor. The comparative analysis may be used as a learning tool to reinforce the performance objective or alternately used as an assessment tool to measure the performance objective. The student may be required to provide a written acknowledgment of the discovery encountered in the performance of the exercise. In the case of higher-level delivery of the curriculum, the student may be required to complete worksheets based upon mathematical data derived from the simulation.

ADDITIONAL INFORMATION

Bibliography:
- EDSA Micro Corporation, Paladin Design Base 2.0

Recommended materials:
- ETAP Software Suite
- Paladin Designbase 2.0 Simulation software
- Siemens- Power Systems Simulation- Engineering PSS-E
- Milsoft Windmil simulation software
- Microsoft Excel with analytical tools
INTELLIGENT ENERGY SYSTEMS - ARCHITECTURE
LAB 3.4-4 EMS OVERLAY ADVANCED

PERFORMANCE OBJECTIVE

- With a functioning EMS overlay on a two-feed distribution system topology diagram and parameters for
temporary faults such as insulator flashover, lightning strikes, and line failure, determine routing and
re-closer positions for the restoration of permanent faults that de-energize the area surrounding
the faulted section of the substation or the feeder.

LAB TYPE

Individual

TIME REQUIRED

6 hours

INSTRUCTOR PREPARATION

Develop a brief narrative description of the transmission and distribution topology. The narrative should include
descriptions of regional geographic conditions, types, and density of load consumers on the network, as well as
the relative age of the existing infrastructure.

Incorporate industry standard equipment and system parameters into the overall diagram. Include both legacy
and new equipment standards.

Develop the topology in multiple phases, save, print, and prepare completed examples of each phase in final
operational condition. This will be used as a standard basis for the students’ development of the topology.

Incorporate realistic load parameters based on the previously developed narrative. Depending upon the
complexity of the software simulation suite, develop fault scenarios that may be inserted into the students’
design schemes.

BACKGROUND

The purpose of this exercise is to have the student develop a fully functional electrical system topology using
simulation software that will show function. This method is used by engineers to develop, test, and modify existing
electrical systems. At the technical level, the student technician will gain a holistic understanding of existing
systems. Through the process of “building” the system using functional simulation, the student technician takes
ownership of the system under construction and will be able to use the system for further experimentation in a
series of more complex structures as well as the introduction of control system communications and equipment.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting
an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and
current range that may be applied to the instrument. This will protect the demonstrator, the instrument,
and the operator.
Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris—oil, water, or other slippery material.

An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical or otherwise, from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on the lesson. Students tend to momentarily neglect safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.

Specific to this exercise: Both student and instructor must maintain situational awareness while working in a computer lab environment.

**TEST EQUIPMENT**

- Calculator
- Spreadsheet software suite with installed analytical tools

**MATERIALS NEEDED**

- Interactive Electrical distribution system simulation software suite
- (Optional) Reactive Power distribution system modeling trainer with control system

**CRITICAL TASKS STUDENTS MUST COMPLETE**

- Open and bring to full function a working system simulation.
- Read and understand the narrative description/problem statement of the system to be modeled.
- Ensure the basic EMS/Grid system provided is functioning normally.
- Develop a project list of components and systems that could be incorporated into the functioning system that will satisfy the requirements of the narrative problem statement.
- List the major block components of the system under construction that can be controlled and/or monitored using an additional control elements of an EMS.
- Determine the function and expected outcome for the EMS.
- Using the simulation software tools, insert EMS.
- Using simulation software or modeling hardware, place and connect additional transmission and distribution components in the simulation as necessary to satisfy the requirements of the problem statement.
- Using interconnection components, develop a basic one-line diagram that schematically represents the system, including all load centers and protective devices.
- Place the system under load and the test the components for proper function and to ensure that the EMS satisfies the requirements to overcome the problem.
FINDINGS

- Upon successful completion of this exercise, the student will compare the “as built” simulated electrical environment to the standard provided by the instructor. The comparative analysis may be used as a learning tool to reinforce the performance objective or alternately used as an assessment tool to measure the performance objective. The student may be required to provide a written acknowledgment of the discovery encountered in the performance of the exercise. In the case of higher-level delivery of the curriculum, the student may be required to complete worksheets based upon mathematical data derived from the simulation.

ADDITIONAL INFORMATION

Bibliography:
- EDSA Micro Corporation, Paladin Design Base 2.0

Recommended materials:
- ETAP Software Suite
- Paladin Designbase 2.0 Simulation software
- Siemens- Power Systems Simulation- Engineering PSS-E
- Milsoft Windmil simulation software
- Microsoft Excel with analytical tools
LAB 4.4-1 MICROGRID ASSESSMENT PLAN

PERFORMANCE OBJECTIVE

- Conduct an operational assessment of a substation area topology that includes 50% variable generation, double feed macrogrid tie-points, and medium quality loads to function as a microgrid. Use industry standard criteria (CERT) to conduct the assessment.

LAB TYPE

Team or Individual

TIME REQUIRED

2 hours

INSTRUCTOR PREPARATION

Develop a brief narrative description of the transmission and distribution topology with a CERT microgrid functioning as part of the system. The narrative should include descriptions of regional geographic conditions, types, and density of load consumers on the network, as well as the relative age of the existing infrastructure. Additionally the microgrid topology should include the controls in place as tie-points to the overall system.

Incorporate industry standard equipment and system parameters into the overall diagram. Include both legacy and new equipment standards for the system, and describe the microgrid input and load limitations.

Incorporate realistic load parameters based on the previously developed narrative. Depending upon the complexity of the software simulation suite, develop fault scenarios that may be inserted into the students’ design schemes.

BACKGROUND

The microgrid, or islanded distributed resource, is an evolving element of the new grid architecture. Microgrids operate both as an independent system and as functional element of a larger system. In order to understand the relationship between and among a microgrid topology and the parent grid, technicians must be able to conduct an operational assessment that parallels the findings of an engineering study. The operational assessment will become increasingly more useful as more microgrid resources are developed. The purpose of this exercise is to have the student assess a functional electrical system topology with a functioning microgrid using simulation software that will show function. This method is used by engineers to develop, test, and modify existing electrical systems. At the technical level, the student technician will gain a holistic understanding of existing systems.

Through the process of “building” the system using functional simulation, the student technician takes ownership of the system under construction and will be able to use the system for further experimentation in a series of more complex structures as well as the introduction of control system communications and equipment.
SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range that may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material.

An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component electrical or otherwise from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on the lesson. Students tend to momentarily neglect safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.

Specific to this exercise: Both student and instructor must maintain situational awareness while working in a computer lab environment.

TEST EQUIPMENT

- Calculator
- Spreadsheet software suite with installed analytical tools

MATERIALS NEEDED

- Interactive Electrical distribution system simulation software suite
- (Optional) Reactive Power distribution system modeling trainer with control system

CRITICAL TASKS STUDENTS MUST COMPLETE

- Read and understand the problem statement.
- Develop situational awareness of the area to be assessed.
- Determine the boundaries of the microgrid.
- Develop a complete matrix of all variable and distributed generation in the bounded microgrid.
- Develop a complete matrix of load centers.
- Using simulation methodologies, translate the load and distributed energy resources into the simulation.
FINDINGS

- Upon successful completion of this exercise, the student will compare the “as built” simulated electrical environment to the standard provided by the instructor. The comparative analysis may be used as a learning tool to reinforce the performance objective or alternately used as an assessment tool to measure the performance objective. The student may be required to provide a written acknowledgment of the discovery encountered in the performance of the exercise. In the case of higher-level delivery of the curriculum, the student may be required to complete worksheets based upon mathematical data derived from the simulation.

ADDITIONAL INFORMATION

Bibliography:
- EDSA Micro Corporation, Paladin Design Base 2.0
- Feasibility and Guidelines for the Development of Microgrids in Campus-Type Facilities
- SERDP Project EW-1710

Recommended materials:
- ETAP Software Suite
- Paladin Designbase 2.0 Simulation software
- Siemens- Power Systems Simulation- Engineering PSS-E
- Milsoft Windmil simulation software
- Microsoft Excel with analytical tools
INTELLIGENT ENERGY SYSTEMS - ARCHITECTURE
LAB 4.4-2 MICROGRID ISOLATION PLAN

PERFORMANCE OBJECTIVE

- Develop an isolation plan to operate a microgrid system that will support generation and load requirements.
- Determine the capabilities and limitations of the microgrid.

LAB TYPE

Individual

TIME REQUIRED

2 hours

INSTRUCTOR PREPARATION

Develop a brief narrative description of the transmission and distribution topology with a CERT microgrid functioning as part of the system. The narrative should include descriptions of regional geographic conditions, types, and density of load consumers on the network, as well as the relative age of the existing infrastructure. Additionally the microgrid topology should include the controls in place as tie-points to the overall system.

Incorporate industry standard equipment and system parameters into the overall diagram. Include both legacy and new equipment standards for the system, and describe the microgrid input and load limitations. Include typical disturbance triggers for the microgrid.

Develop the topology in multiple phases, save, print, and prepare completed examples of each phase in final operational condition. This will be used as a standard basis for the students’ development of the topology.

Incorporate realistic load parameters based on the previously developed narrative. Depending upon the complexity of the software simulation suite, develop fault scenarios that may be inserted into the students’ design schemes.

BACKGROUND

The microgrid, or islanded distributed resource, is an evolving element of the new grid architecture. Microgrids operate both as an independent system and as functional element of a larger system. In order to understand the relationship between and among a microgrid topology and the parent grid, technicians must be able to conduct an operational assessment that parallels the findings of an engineering study. The operational assessment will become increasingly more useful as more microgrid resources are developed. The purpose of this exercise is to have the student assess a functional electrical system topology with a functioning microgrid using simulation software that will show function. This method is used by engineers to develop, test, and modify existing electrical systems. At the technical level, the student technician will gain a holistic understanding of existing systems. Through the process of “building” the system using functional simulation, the student technician takes ownership of the system under construction and will be able to use the system for further experimentation in a series of more complex structures as well as the introduction of control system communications and equipment.
SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range that may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material.

An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component electrical or otherwise from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on the lesson. Students tend to momentarily neglect safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.

Specific to this exercise: Both student and instructor must maintain situational awareness while working in a computer lab environment.

TEST EQUIPMENT

- Calculator
- Spreadsheet software suite with installed analytical tools

MATERIALS NEEDED

- Interactive Electrical distribution system simulation software suite
- (Optional) Reactive Power distribution system modeling trainer with control system

CRITICAL TASKS STUDENTS MUST COMPLETE

- Read and understand the problem statement.
- Develop situational awareness of the area to be assessed.
- Review the results from lab exercise 3.4-1.
- Using the predetermined boundaries DER and load profiles, develop a block isolation plan that includes isolation points and thresholds.
- Apply the plan to the microgrid scenario using the simulation.
- Conduct dynamic testing of the microgrid to island and sustain the load.
- Record the results and suggest modifications to the original plan.
FINDINGS

• Upon successful completion of this exercise, the student will compare the “as built” simulated electrical environment to the standard provided by the instructor. The comparative analysis may be used as a learning tool to reinforce the performance objective or alternately used as an assessment tool to measure the performance objective. The student may be required to provide a written acknowledgment of the discovery encountered in the performance of the exercise. In the case of higher-level delivery of the curriculum, the student may be required to complete worksheets based upon mathematical data derived from the simulation.

ADDITIONAL INFORMATION

Bibliography:
• EDSA Micro Corporation, Paladin Design Base 2.0

Recommended materials:
• ETAP Software Suite
• Paladin Designbase 2.0 Simulation software
• Siemens- Power Systems Simulation- Engineering PSS-E
• Milsoft Windmil simulation software
• Microsoft Excel with analytical tools
INTELLIGENT ENERGY SYSTEMS - ARCHITECTURE
LAB 4.4-3 MICROGRID OPERATIONAL ASSESSMENT

PERFORMANCE OBJECTIVE

- Apply stable load parameters to a microgrid topology, insert event faults to determine the capabilities, limitations, and vulnerabilities of the microgrid system to react, isolate, and reconnect.
- Write an operational assessment using industry standard reporting format.

LAB TYPE

Individual

TIME REQUIRED

2 hours

INSTRUCTOR PREPARATION

Develop a brief narrative description of the transmission and distribution topology with a CERT microgrid functioning as part of the system. The narrative should include descriptions of regional geographic conditions, types and density of load consumers on the network, and the relative age of the existing infrastructure. Additionally, the microgrid topology should include the controls in place as tie-points to the overall system.

Incorporate industry standard equipment and system parameters into the overall diagram. Include both legacy and new equipment standards for the system, and describe the microgrid input and load limitations. Include typical disturbance triggers for the microgrid.

Develop the topology in multiple phases, save, print, and prepare completed examples of each phase in a final operational condition. This will be used as a standard basis for the students’ development of the microgrid.

Incorporate realistic load parameters based on the previously developed narrative. Depending upon the complexity of the software simulation suite, develop multiple fault scenarios that may be inserted into the design scheme to test the microgrid’s ability to respond.

BACKGROUND

The microgrid, or islanded distributed resource, is an evolving element of the new grid architecture. Microgrids operate both as an independent system and as a functional element of a larger system. In order to understand the relationship between and among a microgrid topology and the parent grid, technicians must be able to conduct an operational assessment that parallels the findings of an engineering study. The operational assessment will become increasingly more useful as more microgrid resources are developed. The purpose of this exercise is to have the student assess a functional electrical system topology with a functioning microgrid using simulation software that will show function. This method is used by engineers to develop, test, and modify existing electrical systems. At the technical level, the student technician will gain a holistic understanding of existing systems. Through the process of “building” the system using functional simulation, the student technician takes ownership of the system under construction and will be able to use the system for further experimentation in a series of more complex structures as well as the introduction of control system communications and equipment.
SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range that may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris—oil, water, or other slippery material.

An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical or otherwise, from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on the lesson. Students tend to momentarily neglect safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.

Specific to this exercise: Both student and instructor must maintain situational awareness while working in a computer lab environment.

TEST EQUIPMENT

- Calculator
- Spreadsheet software suite with installed analytical tools

MATERIALS NEEDED

- Interactive Electrical distribution system simulation software suite
- (Optional) Reactive Power distribution system modeling trainer with control system

CRITICAL TASKS STUDENTS MUST COMPLETE

- Read and understand the problem statement.
- Develop situational awareness of the area to be assessed.
- Determine the boundaries of the microgrid.
- Review the results of lab exercise 3.4-2.
- Apply the modifications from the previous exercise to the simulated microgrid.
- Test the modifications for proper operation.
- Modify the simulation until the system is able to sustain normal operation.
- Insert a single, external event into the system and rerun the scenario, observe the results.
- Insert two, unrelated external events in a sub-cycle time block, observe the results.
- Develop a matrix of physical, parametric, and scope (size) modifications to the original microgrid plan.
- OPTIONAL EXERCISE: Implement the above changes and test for effectiveness.
FINDINGS

- Upon successful completion of this exercise, the student will compare the “as built” simulated electrical environment to the standard provided by the instructor. The comparative analysis may be used as a learning tool to reinforce the performance objective or alternately used as an assessment tool to measure the performance objective. The student may be required to provide a written acknowledgment of the discovery encountered in the performance of the exercise. In the case of higher-level delivery of the curriculum, the student may be required to complete worksheets based upon mathematical data derived from the simulation.

ADDITIONAL INFORMATION

Bibliography:
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Recommended materials:
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- Siemens- Power Systems Simulation- Engineering PSS-E
- Milsoft Windmil simulation software
- Microsoft Excel with analytical tools
INTELLIGENT ENERGY SYSTEMS - INTEROPERABILITY

COURSE DESIGN GUIDE

COURSE TITLE
Intelligent Energy Management Systems-Interoperability

CATALOG DESCRIPTION
The Smart Grid Intelligent Energy Systems course is the capstone course for students pursuing an Associate’s Degree, or advanced certificate in Smart Grid Technology. The course is designed to incorporate the fundamental concepts of power generation and smart grid technology equipment and systems to help the student develop a deeper understanding of the emerging technology of intelligent energy management. The course is designed to provide the student with direct experience in the design, implementation, and operation of a power management system. The course incorporates the fundamental principles of scientific experimentation with an emphasis on measurement, data collection, and feedback.

CREDITS
4.0 credits, 96 hours

COURSE FORMAT
This course is a lecture/lab format that incorporates industry-related lab exercises and activities during in-class, instructor-supervised labs. The students will participate in a learning team project that incorporates multiple layers of power system, communications, control, and data analysis technologies to develop an interactive Smart Grid energy management system.

COURSE NUMBER
Material for this course is presented to meet the requirements for a 200-level undergraduate course in an Applied Science or Career Technical Education program.

PREREQUISITES
Intelligent Energy Systems-Architecture

INSTRUCTOR INFORMATION
Recommended Qualifications: Master’s Degree in Electronics, Information Systems or related field; experience in systems management; working knowledge and background in subject/topic area; experience teaching secondary, or post-secondary/adult students.

TEACHING METHODS AND ASSIGNMENTS FOR ACHIEVING LEARNING OUTCOMES
The course material is presented in a lecture/lab format that divides material into logical topics with both learning and performance objectives. Each topic lists suggested time allocation. Total time allocated includes: 1-hour course introduction, 2-hour course review, and 2-hour written exam.
STUDENT TEXTS, READING AND OTHER MATERIALS


BIBLIOGRAPHY


STUDENT LEARNING OUTCOMES

Upon successful completion of this course students will be able to:

- Examine and discuss the performance characteristics of a grid power system
- Survey and explain a grid rate system on core factors of reliability, stability, security, and quality
- Develop and provide a framework to optimize the power flow of a utility system
- Demonstrate how to weigh performance factors in a grid system to balance power quality
- Develop and provide an integrated Intelligent Energy System that incorporates distributed generation and Information Integration Solutions to produce an optimized grid system
- Write a clear, complete, and correct report based upon the finding of laboratory exercises, describing the systems, integration methods, results, and conclusions
## ASSESSMENT RUBRIC

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>EXEMPLARY 4</th>
<th>SATISFACTORY 3</th>
<th>DEVELOPING 2</th>
<th>BEGINNING 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem Framework</td>
<td>Independently identified the framework of the problem</td>
<td>Identified the framework of the problem with help from instructor</td>
<td>Struggled to identify the framework of the problem with help from instructor</td>
<td>Unable to identify the framework of the problem, with help from instructor</td>
</tr>
<tr>
<td>Grid System Variables</td>
<td>Independently identified and clearly defined which variables were going to be changed (independent variables) and which were going to be measured (dependent variables)</td>
<td>Independently identified which variables were going to be changed (independent variables) and which were going to be measured (dependent variables), but some feedback was needed to clearly define the variables</td>
<td>With Instructor help, identified and clearly defined which variables were going to be changed (independent variables) and which were going to be measured (dependent variables)</td>
<td>Instructor assistance was needed to identify and define almost all the variables</td>
</tr>
<tr>
<td>Integrated Data Collection Techniques</td>
<td>Data was collected using all available resources, and the resources were optimized to streamline collection, so that data was stored and retrieved properly</td>
<td>Data was collected using all available resources, and the resources were mostly optimized to streamline collection, so that data was stored and retrieved properly</td>
<td>Most data was collected using most available resources, and the resources were somewhat optimized to streamline collection, so that data was stored and retrieved</td>
<td>Not all data was collected and the data that was collected did not use all available resources, so that the data was not properly stored and retrieved</td>
</tr>
<tr>
<td>Project Procedures</td>
<td>Procedures were outlined in a step-by-step fashion that could be followed by anyone without additional explanations</td>
<td>Procedures were outlined in a step-by-step fashion that could be followed by anyone without additional explanations, but some instructor feedback needed to accomplish this</td>
<td>Procedures were outlined in a step-by-step fashion, but had gaps that required explanation even after instructor feedback was incorporated into the procedures</td>
<td>Procedures that were outlined were incomplete or not sequential, and instructor feedback was not incorporated into the document</td>
</tr>
<tr>
<td>Grid &amp; Control System Layout</td>
<td>Provided an accurate, easy-to-follow diagram with labels to illustrate the procedure and the process</td>
<td>Provided an accurate diagram with labels to illustrate the procedure and process</td>
<td>Provided an easy-to-follow diagram with labels to illustrate the procedure but process key steps were left out or out of sequence</td>
<td>Did not provide a diagram OR the diagram was incomplete</td>
</tr>
<tr>
<td>Project Written Report</td>
<td>Student provided a detailed conclusion clearly based on the data and related the project outcomes to an optimized system</td>
<td>Student provided a somewhat detailed conclusion clearly based on the data and related the project outcomes to an optimized system</td>
<td>Student provided a conclusion with some reference to the data, but the relationship to the system was weak and difficult to link</td>
<td>No conclusion was apparent OR important details were overlooked</td>
</tr>
</tbody>
</table>
## UNIT 1: ENERGY SYSTEM PERFORMANCE

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.1 System Reliability</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Describe the integration of generation transmission and distribution reliability to rate and predict the continuity of service.</td>
</tr>
<tr>
<td></td>
<td>• Understand measures of system reliability, loss of load probability reverse margin, loss of load expectation, expected un-served (undelivered) energy.</td>
</tr>
<tr>
<td></td>
<td>• Factor outage frequency and duration into reliability.</td>
</tr>
<tr>
<td><strong>1.2 System Security</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Describe utility security as it applies to system performance.</td>
</tr>
<tr>
<td></td>
<td>• Explain the operating envelope, transient stability, and the effect of contingencies on system security.</td>
</tr>
<tr>
<td></td>
<td>• Describe “system reserve.”</td>
</tr>
<tr>
<td></td>
<td>• Explain how contingency analysis drives system reserve for a given system.</td>
</tr>
<tr>
<td><strong>1.3 System Stability</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Describe “stability” as it applies to utility system performance.</td>
</tr>
<tr>
<td></td>
<td>• Define angle stability, frequency stability, voltage stability.</td>
</tr>
<tr>
<td></td>
<td>• Distinguish between steady state and dynamic stability.</td>
</tr>
<tr>
<td></td>
<td>• Describe synchronism.</td>
</tr>
<tr>
<td></td>
<td>• Calculate power angle.</td>
</tr>
<tr>
<td></td>
<td>• Calculate power balance using swing equation.</td>
</tr>
<tr>
<td></td>
<td>• Measure dynamic stability of an unstable power source.</td>
</tr>
<tr>
<td><strong>1.4 System Quality</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Describe power quality as a function of system performance.</td>
</tr>
<tr>
<td></td>
<td>• Relate how voltage, frequency, and waveform affect power quality.</td>
</tr>
<tr>
<td></td>
<td>• Measure power quality.</td>
</tr>
<tr>
<td><strong>1.5 System Scaling Characteristics</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Understand power system scaling.</td>
</tr>
<tr>
<td></td>
<td>• Describe power system equalization.</td>
</tr>
<tr>
<td></td>
<td>• Describe how to balance energy input and output within the time scale.</td>
</tr>
<tr>
<td></td>
<td>• Describe the primary power system scales (cycle scale, real time operation, scheduling, planning).</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 2: GRID OPTIMIZATION

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2.1 Optimization Methodologies</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 4 hrs.</td>
<td>• Understand the basic concept of optimization.</td>
</tr>
<tr>
<td>Lab - 4 hrs.</td>
<td>• List various mathematical methods that can be employed to optimize existing</td>
</tr>
<tr>
<td></td>
<td>power systems, including</td>
</tr>
<tr>
<td></td>
<td>- Proportional-Integral-Derivative Loop</td>
</tr>
<tr>
<td></td>
<td>- Linear Programming</td>
</tr>
<tr>
<td></td>
<td>- Stochastic Algorithms</td>
</tr>
<tr>
<td></td>
<td>- Heuristics</td>
</tr>
<tr>
<td></td>
<td>• Understand the relationship between input variables and the computed</td>
</tr>
<tr>
<td></td>
<td>output optimization.</td>
</tr>
<tr>
<td></td>
<td>Performance Objectives, the student will:</td>
</tr>
<tr>
<td></td>
<td>• Apply PID Loop programing functions to solve a power distribution</td>
</tr>
<tr>
<td></td>
<td>optimization problem.</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 2.1-1 PID Loop Optimization</td>
</tr>
<tr>
<td></td>
<td>• Apply Linear programing functions to solve a power distribution</td>
</tr>
<tr>
<td></td>
<td>optimization problem.</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 2.1-2 Linear Program Optimization</td>
</tr>
<tr>
<td></td>
<td>• Apply Stochastic Algorithms to solve a power distribution</td>
</tr>
<tr>
<td></td>
<td>optimization problem.</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 2.1-3 Stochastic Algorithm Optimization</td>
</tr>
<tr>
<td></td>
<td>• Apply Heuristic functions to solve a power distribution</td>
</tr>
<tr>
<td></td>
<td>optimization problem.</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 2.1-4 Heuristic Algorithm Optimization</td>
</tr>
<tr>
<td><strong>2.2 Power Flow Solution Methodologies</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 4 hrs.</td>
<td>• Understand the concept of iterative algorithms.</td>
</tr>
<tr>
<td></td>
<td>• Describe the advantages and disadvantages of different iterative</td>
</tr>
<tr>
<td></td>
<td>methods.</td>
</tr>
<tr>
<td></td>
<td>• Derive Newton-Ralphson.</td>
</tr>
<tr>
<td></td>
<td>• Solve basic problems using Newton-Ralphson formula.</td>
</tr>
<tr>
<td></td>
<td>• Derive Gauss-Seidel.</td>
</tr>
<tr>
<td></td>
<td>• Solve basic problems using Gauss-Seidel formula.</td>
</tr>
<tr>
<td></td>
<td>• Compare Newton-Ralphson and Gauss-Seidel.</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 3: EXPLORING POWER FLOW SOLUTIONS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
</table>
| 3.1 Interpret Power Flow Reports for Solved Cases | The student will be able to:  
• Identify branch, bus, transformer and machine load rates.  
• Understand rate limit as a function of time.  
• Apply capability curve from load data. |
| Lecture - 2 hrs. | |
| 3.2 Interpret Limit Check Reports | The student will be able to:  
• Distinguish between full system and selected bus reporting criteria.  
• Describe the circumstances and reasons for out-of-limit loading.  
• Distinguish between overcurrent and fault current. |
| Lecture - 2 hrs. | |
| 3.3 Interpret Branch Loading Reports | The student will be able to:  
• Use power flow solutions report data to calculate branch rating, branch flow, and percent loading.  
• Calculate current loading and transformer loading. |
| Lecture - 2 hrs. | |
| 3.4 Interpret Generator Limit Reports | The student will be able to:  
• Determine single plant and multi-plant loading.  
• Understand implicit and explicit transformer modeling at the bus.  
• Model generator bus and machine terminal step up transformer and loads. |
| Lecture - 2 hrs. | |
| 3.5 Understand and Interpret Contingency Analysis Reports | The student will be able to:  
• Understand contingency isolation, rate limits and monitoring branch.  
• Distinguish single and multiple contingency.  
• Define DC contingency checking. |
| Lecture - 2 hrs. | |
| 3.6 Understand and Interpret Fault Analysis Reports | The student will be able to:  
• Graph transfer limit for normal and contingency flow.  
• Interpret contingency report data. |
| Lecture - 2 hrs. | |
| 3.7 Grid System Performance Measurement | Performance Objectives, the student will:  
• Conduct a Power Flow Study to interpret grid system parametric values to evaluate system performance.  
• Lab Exercise: 3.7-1 Generation Bus and Branch  
• Lab Exercise: 3.7-1 Transformer Substation and Load  
• Lab Exercise: 3.7-1 Power Flow Study with Contingencies |
| Lab - 9 hrs. | |
| Notes: | |
## UNIT 4: DISTRIBUTION SYSTEMS AND GRID PERFORMANCE

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4.1 Describe System Elements and Operations</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Model a 3-phase radial distribution network with 3-phase and 2-phase taps.</td>
</tr>
<tr>
<td></td>
<td>• Model primary loop systems with single and multiple substation feeds.</td>
</tr>
<tr>
<td></td>
<td>• Model multi-substation loop closures.</td>
</tr>
<tr>
<td></td>
<td>• Describe the limitations on transformers and feeder to transfer load.</td>
</tr>
<tr>
<td></td>
<td>• Describe fault isolation using primary selective/dual radial and secondary selective configurations.</td>
</tr>
<tr>
<td></td>
<td>• Describe matrix secondary networks.</td>
</tr>
<tr>
<td><strong>4.2 Understand Performance Measurement</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Define the reliability contingencies of outage, planned outage, momentary interruption, and major event.</td>
</tr>
<tr>
<td></td>
<td>• Understand the reason for and relationship between SAIFI, SAIDI, and CAIDI.</td>
</tr>
<tr>
<td><strong>4.3 Calculate System Reliability Using the Performance Indices of SAIFI, SAIDI, CAIDI</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Define limits of time and number of affected customers that constrain SAIFI, SAIDI and CAIDI indices.</td>
</tr>
<tr>
<td></td>
<td>• Calculate system reliability.</td>
</tr>
<tr>
<td><strong>4.4 Describe Measures that are Used to Improve System Performance</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Discuss the implications of changes in reliability indices.</td>
</tr>
<tr>
<td></td>
<td>• Describe improvement measures that impact one or more indices.</td>
</tr>
<tr>
<td></td>
<td>• Evaluate cost and benefit of improvement (diminishing return).</td>
</tr>
</tbody>
</table>

Notes:
# UNIT 5: INCORPORATING SMART GRID SOLUTIONS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1 Describe the Technical Problems the Current Grid Infrastructure</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Experiences</td>
<td>• Underground vs. overhead systems.</td>
</tr>
<tr>
<td></td>
<td>• PQ alignment in mixed industrial areas.</td>
</tr>
<tr>
<td></td>
<td>• Limitations on control, visibility and configuration.</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td></td>
</tr>
<tr>
<td>5.2 Describe the Challenges and Limitations of Increasing Distributed</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Generation and EV</td>
<td>• Downstream power flow.</td>
</tr>
<tr>
<td></td>
<td>• Cap bank anomalies.</td>
</tr>
<tr>
<td></td>
<td>• Describe the reasons that DG disrupts frequency stability.</td>
</tr>
<tr>
<td></td>
<td>• Challenges of grid connected EV.</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td></td>
</tr>
<tr>
<td>5.3 FLISR and Optimal Branching Methods</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Describe the technical solutions to DG.</td>
</tr>
<tr>
<td></td>
<td>• Model FLISR, VVC, DR, MG.</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td></td>
</tr>
<tr>
<td>5.4 Volt/Var Optimization and Voltage Regulation Methods</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Model the current manual and automated methods to optimize volt/VAR.</td>
</tr>
<tr>
<td></td>
<td>• Discuss the tradeoff of VVO to optimal DG.</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
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<tr>
<td>5.5 Distributed Generation</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Understand the effect that optimizing measures have on system performance.</td>
</tr>
<tr>
<td></td>
<td>• Calculate loss reductions as a function of power factor optimization.</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td></td>
</tr>
<tr>
<td>5.6 Energy Storage</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Understand the purposes and methods of energy storage.</td>
</tr>
<tr>
<td></td>
<td>• Describe the relationship between energy storage timing and peak demand.</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td></td>
</tr>
<tr>
<td>5.7 Optimizing</td>
<td>Performance Objectives, the student will:</td>
</tr>
<tr>
<td></td>
<td>• Incorporate an optimization engine onto an existing control system to determine optimal operating characteristics.</td>
</tr>
<tr>
<td></td>
<td>• Create a simple control optimization engine to stabilize recurring contingencies.</td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 5.7-1 Equipment and Communications</td>
</tr>
<tr>
<td></td>
<td>• Lab Exercise: 5.7-2 Control Systems</td>
</tr>
<tr>
<td>Lab - 9 hrs.</td>
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</tr>
</tbody>
</table>

Notes:
### UNIT 6: DEMAND RESPONSE

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
</table>
| 6.1 Understand the Types of Demand Response  
Lecture - 2 hrs. | The student will be able to:  
• Define and describe demand response.  
• Identify the 3 types of demand responses.  
• Define the limit of demand response technology.  
• FERC Ruling 745 effect on retail DR.  
• Base interruptible vs. capacity bidding. |
| 6.2 Describe Peak Shifting  
Lecture - 2 hrs. | The student will be able to:  
• Define time of use to peak shift.  
• Discuss technology solutions TOU enforce peak shifting. |
| 6.3 Sketch Common DR Schemes  
Lecture - 2 hrs. | The student will be able to:  
• Using typical distribution network parameters.  
• Draw DR schemes to impact the TOU curve. |
| 6.4 Compare Base Interruptable and Capacity Bidding  
Lecture - 2 hrs. | The student will be able to:  
• Develop a comparison between BI and CB DR methods.  
• Discuss the technical and social limiting factors. |
| 6.5 Describe Time of Use and Dynamic Time of Use Programs  
Lecture - 2 hrs. | The student will be able to:  
• Describe how AMI and consumer level smart products will begin to influence TOU curves. |

Notes:
### UNIT 7: SYSTEM INTEGRATION PROJECT

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.1 Project</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Integrate equipment (physical and control systems technology).</td>
</tr>
<tr>
<td></td>
<td>• Assess the capabilities and limitations of integrated power distribution systems (Power Flow Study database).</td>
</tr>
<tr>
<td></td>
<td>Performance Objectives, the student will:</td>
</tr>
<tr>
<td></td>
<td>• Develop an integrated Intelligent Energy Management System that incorporates distributed generation and Information Integration Solutions to produce an optimized grid system.</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 7.1-1 Optimizing the Smart Grid</td>
</tr>
</tbody>
</table>

Notes:
INTELLIGENT ENERGY SYSTEMS - INTEROPERABILITY
LAB 2.1-1 PROPORTIONAL INTEGRAL AND DERIVATIVE LOOPS

PERFORMANCE OBJECTIVE
- Integrate control loops into a power control scheme and tune the control loop to achieve optimum performance.

LAB TYPE
Individual

TIME REQUIRED
1.5 hours

INSTRUCTOR PREPARATION
Using all available resources and materials, the instructor will write a problem-based scenario that describes a power distribution system (substation and end user) that will encounter excessive power outages that result from events.

BACKGROUND
This laboratory exercise is the capstone performance exam for the smart grid program. The exercise incorporates all of the elements of basic electronics and power distribution to show a complete understanding of the optimizing a smart electrical grid.

SAFETY REQUIREMENTS
Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range, which may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material.

An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical, or otherwise from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on the lesson. Students tend to momentarily neglect safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.
TEST EQUIPMENT
- Meter, Volt and Amp multimeter

MATERIALS NEEDED
- Control system simulator, or actual control system
- Programmable Logic Controller, or Remote Terminal Unit

CRITICAL TASKS STUDENTS MUST COMPLETE
- Read and understand the project problem statement. Conduct secondary research and write a project proposal and submit for approval.
- Develop a tuned control loop to bring an unstable process into stability.
- Introduce a destabilizing event to test the recovery of the control loop.
- Tune the PID Terms to optimize the control and retest.

FINDINGS
- Students will record initial and subsequent parameters of the loop, analyze the results, and write a short statement on the value of heuristic control systems.

ADDITIONAL INFORMATION
Recommended materials:
- Simtronics SPM 2400 or equivalent
- CMH Software PLC Trainer
- PSSE Power system simulator
INTELLIGENT ENERGY SYSTEMS - INTEROPERABILITY
LAB 2.1-2 LINEAR PROGRAM OPTIMIZATION

PERFORMANCE OBJECTIVE

- Provide an optimization algorithm that utilizes linear inequalities as constraints.

LAB TYPE

Individual

TIME REQUIRED

1.5 hours

INSTRUCTOR PREPARATION

Using all available resources and materials, the instructor will write a problem-based scenario that can be solved using a linear program.

BACKGROUND

This laboratory exercise is a simple linear programing example of optimization. The exercise is not designed to have the students derive complex formulas. It is designed to have the student understand the application of existing formulas.

SAFETY REQUIREMENTS

Standard Computer Lab safety is the minimum requirement for this lab.

MATERIALS NEEDED

- Instructor developed linear parameters based on an RTU control loop or other simple power utility based problem
- Formula diagram for linear program development (Solver)

CRITICAL TASKS STUDENTS MUST COMPLETE

- Read and understand the project problem statement. Conduct secondary research and write a project proposal and submit for approval.
- Complete a step by step optimization problem formula through the development of a linear program (Solver) formula.
- Adapt the given formula to a new set of parameters.
- Evaluate the optimized answer.
- Write a solution statement.
- Suggest an alternate problem that can be solved with linear programing.
FINDINGS

- The student will write a short solution based statement on the linear programing method of optimization, and include an alternate problem that may be solved or optimized using this method.

ADDITIONAL INFORMATION

Recommended materials:
- Microsoft Excel
INTELLIGENT ENERGY SYSTEMS - INTEROPERABILITY
LAB 2.1-3 STOCHASTIC ALGORITHMS

PERFORMANCE OBJECTIVE
• Provide an optimization algorithm that utilizes stochastic programming.

LAB TYPE
Individual

TIME REQUIRED
1.5 hours

INSTRUCTOR PREPARATION
Using all available resources and materials, the instructor will write a problem-based scenario that can be solved using a stochastic programming.

BACKGROUND
This laboratory exercise is a simple stochastic programming example of optimization. The exercise is not designed to have the students derive complex formulas. It is designed to have the student understand the application of existing formulas.

SAFETY REQUIREMENTS
Standard Computer Lab safety is the minimum requirement for this lab.

MATERIALS NEEDED
• Instructor developed stochastic parameters based on an RTU control loop or other simple power utility based problem
• Formula diagram for stochastic program development (Matlab)

CRITICAL TASKS STUDENTS MUST COMPLETE
• Read and understand the project problem statement. Conduct secondary research and write a project proposal and submit for approval.
• Complete a step by step optimization problem formula through the development of a stochastic program (Matlab) formula.
• Adapt the given formula to a new set of parameters.
• Evaluate the optimized answer.
• Write a solution statement.
• Suggest an alternate problem that can be solved with stochastic programming.
FINDINGS

- The student will write a short solution based statement on the stochastic programming method of optimization, and include an alternate problem that may be solved or optimized using this method.

ADDITIONAL INFORMATION

Recommended materials:

- Matlab

ADDITIONAL INFORMATION

None
INTELLIGENT ENERGY SYSTEMS - INTEROPERABILITY

LAB 2.1-4 HEURISTIC ALGORITHMS

PERFORMANCE OBJECTIVE

● Provide an optimization algorithm that utilizes Heuristic programming methods.

LAB TYPE

Individual

TIME REQUIRED

1.5 hours

INSTRUCTOR PREPARATION:

Using all available resources and materials, the instructor will write a problem-based scenario that can be solved using a heuristic program.

BACKGROUND

This laboratory exercise is a simple heuristic programing example of optimization. The exercise is not designed to have the students derive complex formulas. It is designed to have the student understand the application of existing formulas.

SAFETY REQUIREMENTS

Standard Computer Lab safety is the minimum requirement for this lab.

MATERIALS NEEDED

● Instructor developed heuristic parameters based on an RTU control loop or other simple power utility based problem
● Formula diagram for heuristic program development (Matlab or Mathematica)

CRITICAL TASKS STUDENTS MUST COMPLETE

● Read and understand the project problem statement. Conduct secondary research and write a project proposal and submit for approval.
● Complete a step by step optimization problem formula through the development of a Heuristic program (Matlab or Mathematica) formula.
● Adapt the given formula to a new set of parameters.
● Evaluate the optimized answer.
● Write a solution statement.
● Suggest an alternate problem that can be solved with heuristic programing.
FINDINGS

• The student will write a short solution based statement on the heuristic programing method of optimization, and include an alternate problem that may be solved or optimized using this method.

ADDITIONAL INFORMATION

Recommended materials:
• Microsoft Excel
• Matlab
• Mathematica
INTELLIGENT ENERGY SYSTEMS - INTEROPERABILITY
LAB 3.7-1 GENERATION, BUS, AND BRANCH TOPOLOGY

PERFORMANCE OBJECTIVE

- Diagram a one-line power grid network that represents a distributed generation topology including multiple types of base-load and variable generation.

LAB TYPE

Individual

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

Using all available resources and materials, the instructor will write a problem-based scenario that describes a power distribution system (substation and end user) that will encounter excessive power outages that result from events.

BACKGROUND

This laboratory exercise is the first foundational exercise for the final performance evaluation. The student is expected to have an understanding of both the systems and the software/simulation that is being utilized to develop the system.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range, which may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material.

An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical, or otherwise from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on the lesson. Students tend to momentarily neglect safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.
TEST EQUIPMENT

- Multimeter
- Oscilloscope
- Multifunction power-meter
- Power grid design and simulation software

MATERIALS NEEDED

- Electrical power distribution trainer
- Grid load monitoring trainer
- PAC controller, PLC or SCADA system

CRITICAL TASKS STUDENTS MUST COMPLETE

- Read and understand project problem statement. Conduct secondary research and write a project proposal and submit for approval.
- Establish a 3-phase base load generation point.
- Monitor a primary node power and program a multifunction power meter.
- Connect transmission line topology at 300 mile 600kv.
- Establish primary node with three branch loads.
- Interconnect multifunction power meter to each branch.
- Test system for normal operation.
- Interconnect node and branch switching network to reroute branch.
- Establish SCADA communications with switch.
- Establish SCADA communications with multifunction meter.
- Use meter input to manipulate switching structure.

FINDINGS

- Students will submit a written analysis of the exercise.

ADDITIONAL INFORMATION

Recommended materials:

- Hampden Model H-190-1 Smart Grid Electrical Distribution Trainer
- Hampden Model H-190-2 Smart Grid Load Monitoring Trainer
INTELLIGENT ENERGY SYSTEMS - INTEROPERABILITY
LAB 3.7-2 TRANSFORMER, SUBSTATION, AND LOAD TOPOLOGY

PERFORMANCE OBJECTIVE
Given a one-line power grid network that represents a distributed generation topology of multiple types of base-load and variable generation, insert high voltage transmission lines, substation, and end-user load nodes that include typical residential, commercial, industrial, and critical infrastructure load models.

LAB TYPE
Team

TIME REQUIRED
3 hours

INSTRUCTOR PREPARATION
Using all available resources and materials, the instructor will write a problem-based scenario that describes a power distribution system (substation and end user) that will encounter excessive power outages that result from events.

BACKGROUND
This laboratory exercise is second level in a series of progressively more complex power transmission systems. The exercise incorporates all of the elements of basic electronics and power distribution to show an understanding of the electrical grid.

SAFETY REQUIREMENTS
Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range, which may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material.

An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical, or otherwise from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on the lesson. Students tend to momentarily neglect safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.
TEST EQUIPMENT

- Multimeter
- Oscilloscope
- Multifunction power-meter
- Power grid design and simulation software

MATERIALS NEEDED

- Electrical power distribution trainer
- Grid load monitoring trainer
- PAC controller, PLC or SCADA system

CRITICAL TASKS STUDENTS MUST COMPLETE

- Read and understand project problem statement. Conduct secondary research and write a project proposal and submit for approval.
- Given a 3-phase base load generation point, monitor a primary node power with three branch loads and program a multifunction power meter.
- Interconnect a transformer substation at each node.
- Interconnect 3 load centers to each substation.
- Configure each load center for residential, industrial, and critical infrastructure.
- Meter each load.
- Configure one substation to include interconnected SCADA control system that monitors and controls loads and sources.

FINDINGS

- Students will submit a written analysis of the project.

ADDITIONAL INFORMATION

Recommended materials:

- Hampden Model H-190-1 Smart Grid Electrical Distribution Trainer
- Hampden Model H-190-2 Smart Grid Load Monitoring Trainer
INTELLIGENT ENERGY SYSTEMS - INTEROPERABILITY
LAB 3.7-3 POWER FLOW STUDY-WITH CONTINGENCIES

PERFORMANCE OBJECTIVE
Given a one-line power grid network that represents a distributed generation topology of multiple types of base-load and variable generation, insert high voltage transmission lines, substation, and end-user load nodes that include typical residential, commercial, industrial and critical infrastructure load models. Utilize a dynamic overlay of parametric values at every system node to include voltage, current, loss, phase angle, and bus phase relationships. Compare the system power flow study with data recorded during a specified period while the system reacts to instructor introduced contingencies. Submit a written analysis of the findings. Use industry standard report format.

LAB TYPE
Team

TIME REQUIRED
3 hours

INSTRUCTOR PREPARATION
Using all available resources and materials, the instructor will write a problem-based scenario that describes a power distribution system (substation and end user) that will encounter excessive power outages that result from events.

BACKGROUND
This laboratory exercise provides the student with the additional practice conducting a system analysis while the system experiences events. In order to understand the engineering principles of power flow, the technician must be familiar with the fluid characteristics of system parametrics. Particular emphasis will be placed on observation of events.

SAFETY REQUIREMENTS
This is a tabletop exercise that does not require the use of energized equipment.

TEST EQUIPMENT
• Calculator
• Spreadsheet software
• Power system simulation software

MATERIALS NEEDED
• None
CRITICAL TASKS STUDENTS MUST COMPLETE

- Read and understand the project problem statement. Conduct secondary research and write a project proposal, and submit for approval.

- Given a one-line power grid network that represents a distributed generation topology of multiple types of base-load and variable generation, insert high voltage transmission lines, substation, and end user load nodes that include typical residential, commercial, industrial and critical infrastructure load models. Utilize a dynamic overlay of parametric values at every system node to include voltage, current, loss, phase angle and bus phase relationships. Conduct a Power Flow Study bus admittance matrix analysis of the topology, and submit a written analysis of the findings. Use industry standard report format.

FINDINGS

- Students will submit a written analysis of the project addressing a solution of the problem statement justifying the solution, and providing other solutions.

ADDITIONAL INFORMATION

Alternate materials:

- Hampden Model H-190-1 Smart Grid Electrical Distribution Trainer
- Hampden Model H-190-2 Smart Grid Load Monitoring Trainer
INTELLIGENT ENERGY SYSTEMS - INTEROPERABILITY
LAB 5.7-1 OPTIMIZING EQUIPMENT AND COMMUNICATIONS

PERFORMANCE OBJECTIVE

- Incorporate instruments, controls, and communications into an operating power distribution system model.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

Using all available resources and materials, the instructor will write a problem-based scenario that is wired into an actual energized model of a power distribution system.

BACKGROUND

This laboratory exercise provides the student with an opportunity to operate an actual working model of an energized power distribution system. The exercise will draw upon previous exercise skills when the student used schematic diagrams to model system behavior. The purpose of the exercise is to have the student predict a behavior and then test the system to determine the accuracy of the model. Specific emphasis is placed on the sensors, instruments, and communications paths that will be used in an optimization scheme. The student will determine the accuracy using local measurements and manual feedback.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range, which may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material.

An electrical short across a ring or wristwatch can cause a severe burn. It is best to remove all watches and jewelry when working on electrical equipment.

Always disconnect the electrical power source before isolating any component, electrical, or otherwise from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.

Most accidents are the result of carelessness when a student is concentrating on the lesson. Students tend to momentarily neglect safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.
TEST EQUIPMENT

- Multimeter
- Oscilloscope
- Multifunction power-meter
- Power grid design and simulation software 208VAC 3-phase

MATERIALS NEEDED

- Electrical power distribution trainer
- Grid load monitoring trainer
- PAC controller, PLC or SCADA system

CRITICAL TASKS STUDENTS MUST COMPLETE

- Read and understand project problem statement. Conduct secondary research and write a project proposal and submit for approval.
- Develop plan of action and milestones. Assign project positions. Determine project needs. Submit report for approval.
- Develop topology and control diagrams.
- Verify sensor and instrument readings.
- Establish communications paths.
- Verify communications protocol.

FINDINGS

- Students will submit a written analysis of the project addressing the accuracy of the findings from test measurements as compared to predicted results.

ADDITIONAL INFORMATION

Recommended materials:
- Hampden Model H-190-1 Smart Grid Electrical Distribution Trainer
- Hampden Model H-190-2 Smart Grid Load Monitoring Trainer
INTELLIGENT ENERGY SYSTEMS - INTEROPERABILITY
LAB 5.7-2 OPTIMIZING CONTROLS AND SYSTEMS

PERFORMANCE OBJECTIVE

- To incorporate Supervisory controls, linked to instruments, controls, and communications that are properly installed into an operating power distribution system model.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

Using all available resources and materials, the instructor will write a problem-based scenario that is wired into an actual energized model of a power distribution system.

BACKGROUND

This laboratory exercise provides the student with an opportunity to operate an actual working model of an energized power distribution system. The exercise will draw upon previous exercise skills when the student used schematic diagrams to model system behavior and build upon previous experience with the installation of sensors, instruments, and communications paths on a system. The purpose of the exercise is to have the student predict a behavior and then test the system to determine the accuracy of the model. Specific emphasis is placed on optimizing controls and systems that will be used in an optimization scheme. The student will determine the accuracy using control system output.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range, which may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material.

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Always disconnect the electrical power source before isolating any component, electrical, or otherwise from the trainer system. Lock the switches open to prevent someone from closing them during demonstration or test procedure.
Most accidents are the result of carelessness when a student is concentrating on the lesson. Students tend to momentarily neglect safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.

**TEST EQUIPMENT**
- Multimeter
- Oscilloscope
- Multifunction power-meter
- Power grid design and simulation software 208VAC 3-phase

**MATERIALS NEEDED**
- Electrical power distribution trainer
- Grid load monitoring trainer
- PAC controller, PLC or SCADA system

**CRITICAL TASKS STUDENTS MUST COMPLETE**
- Read and understand the project problem statement. Conduct secondary research and write a project proposal and submit for approval.
- Develop plan of action and milestones. Assign project positions. Determine project needs. Submit report for approval.
- Connect control system to sensors via established communication path.
- Verify the data receipt.
- Develop a feedback algorithm from input parameters.

**FINDINGS**
- Students will submit a written analysis of the project addressing the accuracy of the data as it is displayed using the control system, and verify the data using local measurements.
- Using an appropriate optimization technique, students will develop a feedback (output) control loop. (PID).

**ADDITIONAL INFORMATION**
Recommended materials:
- Hampden Model H-190-1 Smart Grid Electrical Distribution Trainer
- Hampden Model H-190-2 Smart Grid Load Monitoring Trainer
LAB 7.1-1 OPTIMIZING THE SMART GRID

PERFORMANCE OBJECTIVE

- Develop an integrated Intelligent Energy System that incorporates distributed generation and Information Integration Solutions to produce an optimized grid system.

LAB TYPE

Team

TIME REQUIRED

18 hours

INSTRUCTOR PREPARATION

Using all available resources and materials, the instructor will write a problem-based scenario that describes a power distribution system (substation and end user) that will encounter excessive power outages that result from events.

BACKGROUND

This laboratory exercise is the capstone performance exam for the smart grid program. The exercise incorporates all of the elements of basic electronics and power distribution to show a complete understanding of the optimizing a smart electrical grid.

SAFETY REQUIREMENTS

Instruments and equipment used in testing, while durable, are sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its settings are within the voltage and current range, which may be applied to the instrument. This will protect the demonstrator, the instrument, and the operator.

Use extreme caution when making electrical measurements. Remember, it is too late to learn that a circuit is live after one has touched it. Be certain that the operator knows if the trainer is on or off at all times. Never handle live circuits when in contact with pipes, other wires, or damp floors.

Keep the floor clean of debris-oil, water, or other slippery material.

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Most accidents are the result of carelessness when a student is concentrating on the lesson. Students tend to momentarily neglect safety. Therefore, like the service technician, students must train themselves to do things safely. They must study the job for its safety problems before they start and think about the safety aspects before each step.
TEST EQUIPMENT

- Multimeter
- Oscilloscope
- Multifunction power-meter
- Power grid design and simulation software

MATERIALS NEEDED

- Electrical power distribution trainer
- Grid load monitoring trainer
- PAC controller, PLC or SCADA system

CRITICAL TASKS STUDENTS MUST COMPLETE

- Read and understand project problem statement. Conduct secondary research and write a project proposal and submit for approval.
- Develop plan of action and milestones. Assign project positions. Determine project needs. Submit report for approval.
- Develop topology and control diagrams.
- Program control system and test.
- Integrate control and transmission and development switching.
- Optimize the system and test event recovery.

FINDINGS

- Students will submit a written analysis of the project addressing solution of the problem justifying the solution and other solutions.

ADDITIONAL INFORMATION

Recommended materials:
- Hampden Model H-190-1 Smart Grid Electrical Distribution Trainer
- Hampden Model H-190-2 Smart Grid Load Monitoring Trainer
FUNDAMENTALS OF ADVANCED METERING INFRASTRUCTURE
COURSE DESIGN GUIDE

COURSE TITLE
Fundamentals of Advanced Metering Infrastructure

CATALOG DESCRIPTION
The course will introduce the subject of Advanced Metering Infrastructure (AMI) equipment, systems, and analysis tools as an integral part of the Intelligent Energy Systems Smart Grid architecture.

Topics include characteristics of a power system under load, electrical power as a commodity, metering technology hardware, software, and communications. Other topics include consumer energy displays and controllers that measure, collect, and analyze energy usage as well as systems interoperability with grid and power systems. The student will analyze consumption metrics and develop a set of suggested modifications to lower total energy costs for consumption, conservation, and power quality.

CREDITS
3 credits, 48 hours

COURSE FORMAT
This course is a lecture/lab format that incorporates industry-related lab exercises and activities during in-class, instructor-supervised labs.

COURSE NUMBER
Material for this course is presented to meet the requirements for a 200-level undergraduate course in an Applied Science or Career Technical Education program.

PREREQUISITES
College Algebra or equivalent, SCADA Systems, SCADA Equipment, Power Generation, Transmission and Distribution/Systems, Database Information Systems

INSTRUCTOR INFORMATION
Recommended Qualifications: Master’s Degree in Electrical Engineering, Power Engineering, Information Systems or related field; experience in systems management; working knowledge and background in subject/topic areas; and experience teaching post-secondary/adult students.

TEACHING METHODS AND ASSIGNMENTS FOR ACHIEVING LEARNING OUTCOMES
The course is divided into five learning units; each successive learning unit provides foundational knowledge and understanding of advanced metering infrastructure terminology structure and capabilities. Each topic has a recommended length (topic hours) assigned. Topic hours are a guideline for instruction intended to be adapted to the individual instructor’s teaching style. As a general rule, the ratio of lecture to lab is 1:3. Students are expected to spend additional study/practice time outside of the class time. The generally accepted ratio of class to study time is 1:4 for this course. Each topic lists suggested time allocation. Total time allocated includes a 1-hour course introduction, 2-hour course review, and a 2-hour written exam.
STUDENT TEXTS, READING AND OTHER MATERIALS


STUDENT LEARNING OUTCOMES

Upon successful completion of this course students will be able to:

- Determine the electrical characteristics of a power system under load
- Demonstrate use of measured electrical values to calculate complex energy and demand values
- Plot power and energy factor using phasor and vector diagrams
- Show ability to weigh the supply and demand variables to determine the commodity value energy
- Assess and explain the capabilities, limitations, and vulnerabilities of metering infrastructure systems
- Demonstrate ability to structure timely accurate analysis reports utilizing real-time, historical, and alarm-event metrics
- Show ability to interpret analysis reports to provide feedback to suppliers and consumers of energy regarding optimization techniques to reduce consumption and increase quality
### UNIT 1: ELECTRICAL CHARACTERISTICS OF A POWER SYSTEM UNDER A LOAD

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.1 Fundamental Measured Values of a Power System under Load</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Show understanding of the fundamental values, starting with voltages and currents,</td>
</tr>
<tr>
<td></td>
<td>and calculate other values pertinent to power systems</td>
</tr>
<tr>
<td></td>
<td>• Measure and understand the mathematical relationship of Voltage and Current</td>
</tr>
<tr>
<td></td>
<td>- Peak to peak (Vpp)</td>
</tr>
<tr>
<td></td>
<td>- avg</td>
</tr>
<tr>
<td></td>
<td>- Rms</td>
</tr>
<tr>
<td></td>
<td>- Vmax</td>
</tr>
<tr>
<td></td>
<td>• Calculate VPP average power</td>
</tr>
<tr>
<td></td>
<td>- Impedance</td>
</tr>
<tr>
<td></td>
<td>- Frequency</td>
</tr>
<tr>
<td><strong>1.2 Calculated and Complex Values</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Calculate complex values, energy and demand and power factor (Kw Kva)</td>
</tr>
<tr>
<td></td>
<td>• Use measured electrical values to calculate energy and demand</td>
</tr>
<tr>
<td></td>
<td>• Calculate Total Energy</td>
</tr>
<tr>
<td></td>
<td>• Calculate Load Demand</td>
</tr>
<tr>
<td></td>
<td>• Calculate Power factor</td>
</tr>
<tr>
<td></td>
<td>• Calculate Crest factor</td>
</tr>
<tr>
<td></td>
<td>• Determine Current Flow-DC</td>
</tr>
<tr>
<td></td>
<td>• Determine Current Flow-AC</td>
</tr>
<tr>
<td><strong>1.3 Phase Balance</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Use Phasor Diagrams to graphically represent phase current and voltage balance</td>
</tr>
<tr>
<td></td>
<td>• Use Phasor Diagrams to graphically represent harmonic balance and harmonic distortion</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 2: ELECTRICAL POWER AS A COMMODITY

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
</table>
| 2.1 Power Producer, Distributor, Consumer Relationships | **The student will be able to:**  
  - Demonstrate a depth of understanding regarding the types of classes of customers of a power system  
  - Distinguish between the measures of quality for residential, commercial, retail, industrial, government, and critical infrastructure customers  
  - Describe the measures of energy consumption  
  - Develop an understanding of power as a commodity  
  - Weigh and explain the financial, logistical, and legal questions relevant to implementing a PPA  
  - Examine the technical considerations of a renewable project and develop a fair, legal, and sustainable agreement |
| Lecture - 3 hrs.                             |                                                                                                                                           |
|                                             | **Performance Objectives, the student will:**  
  - Interpret design, distribution and policy/legal constraints to develop a PPA  
  - Lab 2.2-1 Power Producer-Distributor-Consumer PPA Project Team Learning Exercise: three teams will function as system owner, utility, and consumer to develop a power rate structure and negotiate power purchase and power sale agreements |
## UNIT 3: METERING TECHNOLOGY INFRASTRUCTURE

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3.1 Capabilities and Limitations of Meters</strong></td>
<td>The student will be able to:&lt;br&gt;• Compare the capabilities and limitations of basic meters and a advanced meters:&lt;br&gt;- Analog vs. Digital measurement&lt;br&gt;- On-board data storage&lt;br&gt;- Alarm capabilities&lt;br&gt;- Communications protocols&lt;br&gt;- Programing parameters of meters&lt;br&gt;• Use Basic and Real Time measurements, and basic communications&lt;br&gt;• Use Advance metering&lt;br&gt;- Real Time&lt;br&gt;- Historical&lt;br&gt;- Alarms and Events&lt;br&gt;  - All alarms are events, but not all events are alarms&lt;br&gt;• Explain Database Characteristics</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td></td>
</tr>
<tr>
<td><strong>3.2 Metering Connectivity to a Power System</strong></td>
<td>The student will be able to:&lt;br&gt;• Describe the Electrical and Physical connection of a meter to the system:&lt;br&gt;- Direct Connection meters&lt;br&gt;- Indirect connection meters using PT and CT&lt;br&gt;- Parametric delineation for direct and indirect connections&lt;br&gt;- Phasor measurement&lt;br&gt;  - Advanced Metering Infrastructure&lt;br&gt;- Intelligent Device&lt;br&gt;  - Panel meters&lt;br&gt;  - RTU’s, PLC’s&lt;br&gt;- Communications&lt;br&gt;- Analysis Tools (Software)&lt;br&gt;• Identify case wiring&lt;br&gt;• Identify Ethernet attributes for a meter gateway device&lt;br&gt;• Identify serial network attributes for meter gateway device&lt;br&gt;• Add meters to server via the configuration software for meter&lt;br&gt;• Check communication status for all meters on the network via the various communications software for meters&lt;br&gt;<strong>Performance Objectives, the student will:</strong>&lt;br&gt;• Install, configure, and optimize a smart meter:&lt;br&gt;  - Navigate the panels of a smart meter&lt;br&gt;  - Use a meters software configuration tool to configure software&lt;br&gt;  - Use a meters software to assess meter wiring&lt;br&gt;  - Use a meters software to manage programs within the meter&lt;br&gt;• Configure all communication ports for meter:&lt;br&gt;  - Configure Ethernet port for meter with an appropriate IP Address, Subnet Mask, and a Gateway Address&lt;br&gt;  - Configure IP Service protocols&lt;br&gt;  - Configure COM ports for meter&lt;br&gt;• Demonstrate Database capture of power data&lt;br&gt;  - Lab 3.2-1 Meter Physical Connection-Hardware&lt;br&gt;  - Lab 3.2-2 Meter Physical Connection-Software&lt;br&gt;  - Lab 3.2-3 Meter Physical Connection-Communications</td>
</tr>
<tr>
<td>Lecture - 3 hrs. Lab 8 hrs.</td>
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</tbody>
</table>
### UNIT 3: METERING TECHNOLOGY INFRASTRUCTURE

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
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</thead>
<tbody>
<tr>
<td>3.3 Revenue Logging</td>
<td>Performance Objectives, the student will:</td>
</tr>
<tr>
<td></td>
<td>• Measure and Interpret Energy, Demand curves, and Average demand using static</td>
</tr>
<tr>
<td></td>
<td>and dynamic (rolling) curves</td>
</tr>
<tr>
<td></td>
<td>• Use analysis software to provide both graphical and tabular display of block</td>
</tr>
<tr>
<td></td>
<td>and sliding demand capture to display interval energy vs. cumulative energy.</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 3.3-1 Revenue Logging</td>
</tr>
</tbody>
</table>

Notes:
### UNIT 4: POWER QUALITY

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Power Quality Definitions</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 3 hrs.</td>
<td>● Demonstrate understanding of IEEE Emerald book: Recommended Practice for</td>
</tr>
<tr>
<td></td>
<td>powering and Grounding Electronic Equipment</td>
</tr>
<tr>
<td></td>
<td>● Demonstrate understanding of IEEE 1159: Recommended Practice for Monitoring</td>
</tr>
<tr>
<td></td>
<td>Electric Power Quality</td>
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<td></td>
<td>● Demonstrate understanding of Dranetz Power Quality Handbook</td>
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<td>● Demonstrate understanding of the characteristics of the CBEMA Curve for</td>
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<td>various devices</td>
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</tbody>
</table>

Notes:
<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>5.1 Reports</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Explain the fundamental need for Real Time Reporting, including a detailed understanding of the direct and calculated measurement at:</td>
</tr>
<tr>
<td></td>
<td>- kW, KiloWatts</td>
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<tr>
<td></td>
<td>- kW demand</td>
</tr>
<tr>
<td></td>
<td>- V, Voltage</td>
</tr>
<tr>
<td></td>
<td>- I, Current</td>
</tr>
<tr>
<td></td>
<td>- kVA, Kilovolt-amperes</td>
</tr>
<tr>
<td></td>
<td>- kVAR, Kilovolt-amperes reactive</td>
</tr>
<tr>
<td></td>
<td>- PE or PF, Power Factor</td>
</tr>
<tr>
<td></td>
<td>- Minimum/Maximum values</td>
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<tr>
<td></td>
<td>• Explain the fundamental need for Historical Reporting, including a detailed understanding:</td>
</tr>
<tr>
<td></td>
<td>- Periodic sampling</td>
</tr>
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<td></td>
<td>- Load profile/baseline</td>
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<tr>
<td></td>
<td>- Capacity management</td>
</tr>
<tr>
<td></td>
<td>- Reports</td>
</tr>
<tr>
<td></td>
<td>- Log Entry</td>
</tr>
<tr>
<td></td>
<td>- Waveform capture</td>
</tr>
<tr>
<td></td>
<td>• Explain the fundamental need for Alarms and Events Reporting,</td>
</tr>
<tr>
<td></td>
<td>• Determine the parametric P&amp;Q criteria that triggers an event:</td>
</tr>
<tr>
<td></td>
<td>- Over/Under voltage</td>
</tr>
<tr>
<td></td>
<td>- Sag/Swell</td>
</tr>
<tr>
<td></td>
<td>- Transients</td>
</tr>
<tr>
<td></td>
<td>- Frequency shift</td>
</tr>
<tr>
<td></td>
<td>- Over/under current</td>
</tr>
<tr>
<td></td>
<td>- Fault current</td>
</tr>
<tr>
<td><strong>Performance Objectives, the student will:</strong></td>
<td>• Capture metric data from an operating metering architecture and identify events, alarm thresholds, and waveform capture interpretation</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 5.1-1</td>
</tr>
<tr>
<td></td>
<td>• Interpret metric reports provided by the meter software using software analysis tools provided and third party spreadsheet application software</td>
</tr>
<tr>
<td></td>
<td>- Lab Exercise: 5.1-2</td>
</tr>
<tr>
<td><strong>5.2 Future Trends in AMI</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate an an in-depth understanding of future trends in Intelligent Energy Systems</td>
</tr>
<tr>
<td></td>
<td>• Describe the compatibility of home area networks with utility grade metering devices and equipment</td>
</tr>
<tr>
<td></td>
<td>• Assess the current trends in metering technology to project future technology requirements</td>
</tr>
<tr>
<td></td>
<td>• Describe the interconnection and communication between private AMI systems and provider systems</td>
</tr>
<tr>
<td><strong>Notes:</strong></td>
<td></td>
</tr>
</tbody>
</table>
ADVANCED METERING INFRASTRUCTURE
LAB 2.2-1 POWER PRODUCER-DISTRIBUTOR-CONSUMER PROJECT

PERFORMANCE OBJECTIVE

● Weigh the financial, logistical, and legal questions relevant to implementing a PPA.
● Examine the technical considerations of a renewable project and develop a fair, legal, and sustainable agreement.
● Three teams will function as system owner, utility, and consumer to develop a power rate structure and negotiate power purchase and power sale agreements.

LAB TYPE
Team

TIME REQUIRED
3 hours

INSTRUCTOR PREPARATION

Instructors should have a working knowledge of electrical systems, be familiar with the computer operating system, and have a working knowledge of networked environments, including client/server systems.

Be sure to read the installation and user guide for specific advanced meters to develop procedures so students are able to complete the tasks listed below. Ensure that students are familiar with general electrical terminology, such as amps, volts, watts, power factor (PF), etc.

Using example PPA contracts, develop a scenario-based project that requires each of three teams to research and propose a PPA that meets the requirements of the published Renewable Portfolio Standards RPS for a specified state.

BACKGROUND

The rapid increase of renewable energy power producing platforms demands that a contractual relationship is struck between the system owner, the utility, and the consumer. Each state must set standards based on grid infrastructure, base load capacity, and the quality of renewable power resources.

SAFETY REQUIREMENTS

● This is a team research project. Standard classroom safety and etiquette are required.

TEST EQUIPMENT

● None

MATERIALS NEEDED

● Sample Power Purchase Agreements
● Sample Generation and Distributed Generation Cost analysis
● Distribution Network metric data
CRITICAL TASKS STUDENTS MUST COMPLETE

- Each of the teams must read and understand the requirements of the project.
- Team spokesperson must be identified to the instructor.
- The instructor will brief the spokesperson on time constraints, presentation etiquette, and team control.
- The team will assign roles for each member of the team: legal considerations, physical considerations, pricing, financing, and technical requirements.
- Based on the findings of each role, the team will develop a proposal that is presented to the class.
- Once each team has presented, the team leaders will negotiate the final agreement and present it for review.

FINDINGS

- The final product of this exercise will be either a negotiated and agreed upon PPA or a list of discrepancies that were unresolved in the time frame given to complete the exercise. The final findings depend upon the complexity of the initial conditions and the level of assistance during the project, an appropriate rubric should be developed based on the individual scenarios.

ADDITIONAL INFORMATION

Bibliography:

Recommended materials:
ADVANCED METERING INFRASTRUCTURE
LAB 3.2-1 METER PHYSICAL CONNECTION-HARDWARE

PERFORMANCE OBJECTIVE

- Configure all communication ports for meter:
  - Configure Ethernet port for meter with an appropriate IP Address, Subnet Mask, and a Gateway Address.
  - Configure IP Service protocols.
  - Configure COM ports for meter.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

Instructors should have a working knowledge of electrical systems, be familiar with the computer operating system, and have a working knowledge of networked environments, including client/server systems.

Be sure to read the installation and user guide for specific advanced meters to develop procedures so students are able to complete the tasks listed below. Ensure that students are familiar with general electrical terminology, such as amps, volts, watts, power factor (PF), etc.

BACKGROUND

An advanced meter is usually an electrical meter that records consumption of electric energy in intervals of an hour or less and communicates that information at least daily back to the utility for monitoring and billing purposes. Advanced meters enable two-way communication between the meter and the central system. Unlike home energy monitors, advanced meters can gather data for remote reporting. Such an advanced metering infrastructure (AMI) differs from traditional automatic meter reading (AMR) in that it enables two-way communications with the meter.

SAFETY REQUIREMENTS

Be sure to consult the installation and user guide for the specific Advanced Meter for appropriate safety information.

During normal operation of a power meter, hazardous voltages are present on its terminal strips and throughout the connected potential transformer (PT), current transformer (CT), digital (status) input, control power and external I/O circuits. PT and CT secondary circuits are capable of generating lethal voltages and currents with their primary circuit energized. Follow appropriate safety precautions while performing any installation or service work (i.e. removing PT fuses, shorting CT secondaries, etc.).

Most power meters must be installed with a chassis ground. Ground the device before power is applied. Proper grounding of the meter is necessary for the following reasons:

- Safety of personnel working with the meter
- Protection of the electronic circuitry in the meter
- Proper operation of noise filtering within the meter
- Proper operation of communication ports
- Compliance with all local and national regulations on grounding electrical devices
Be sure to connect appropriate ground equipment including grounding tabs, ground terminals, or ground wires to a protective earth ground before the meter is powered up.

Be sure to install fuses in all voltage measurement inputs and auxiliary power circuits.

All electrical connections on the meter terminals should not be student/user accessible after installation.

**TEST EQUIPMENT**

- Advanced Meter
- Advanced Meter configuration software
- Computer
- Interconnection hardware
- Ohm meter

**MATERIALS NEEDED**

- Wire cutters
- Screw drivers
- Cable ties

**CRITICAL TASKS STUDENTS MUST COMPLETE**

- Configure Ethernet port for meter with an appropriate IP Address, Subnet Mask, and a Gateway Address. Note that students will need to also know how to install a meter behind a router or firewall.
- Configure IP Service protocols for meter, including
  - STMP
  - HTTP
  - Modbus TCP protocol
  - Modbus RTU over TCP/IP
- Ping the Ethernet devices in the meters from a computer terminal.
- If supported by meter use Internet browser to test communication with Ethernet device in meter.
- Set up the COM ports for meter using appropriate protocol, and baud rate.
  - If supported by meter, configure RS-232 Point to point connection.
  - If supported by meter, configure RS-485 Serial Connection.

**FINDINGS**

- This is an appropriate place for a troubleshooting lab. Once the students have the communications fully operational have the instructor introduce a problem, i.e. bug in the software, faulty wiring. The students can then troubleshoot to find the problem and resolve it. The students must carefully document all steps taken and comment on how they were able to resolve the communications.
ADDITIONAL INFORMATION

Bibliography:

Recommended materials:
ADVANCED METERING INFRASTRUCTURE
LAB 3.2-2 METER PHYSICAL CONNECTION-SOFTWARE

PERFORMANCE OBJECTIVE

- Install, configure, and optimize an advanced meter:
  - Navigate the panels of an advanced meter.
  - Use a meter’s software configuration tool to configure software.
  - Use a meter’s software to assess meter wiring.
  - Use a meter’s software to manage programs within the meter.

LAB TYPE

Team

TIME REQUIRED

1 hour

INSTRUCTOR PREPARATION

Instructors should have a working knowledge of electrical systems, be familiar with the computer operating system, and have a working knowledge of networked environments, including client/server systems.

Be sure to read the installation and user guide for specific advanced meters to develop procedures so students are able to complete the tasks listed below. Ensure that students are familiar with general electrical terminology, such as amps, volts, watts, and power factor (PF), etc.

BACKGROUND

An advanced meter is usually an electrical meter that records consumption of electric energy in intervals of an hour or less and communicates that information at least daily back to the utility for monitoring and billing purposes. Advanced meters enable two-way communication between the meter and the central system. Unlike home energy monitors, advanced meters can gather data for remote reporting. Such an advanced metering infrastructure (AMI) differs from traditional automatic meter reading (AMR) in that it enables two-way communications with the meter.

SAFETY REQUIREMENTS

Be sure to consult the installation and user guide for the specific advanced Meter for appropriate safety information.

During normal operation of a power meter, hazardous voltages are present on its terminal strips and throughout the connected potential transformer (PT), current transformer (CT), digital (status) input, control power and external I/O circuits. PT and CT secondary circuits are capable of generating lethal voltages and currents with their primary circuit energized. Follow appropriate safety precautions while performing any installation or service work (i.e. removing PT fuses, shorting CT secondaries, etc.).

Most power meters must be installed with a chassis ground. Ground the device before power is applied. Proper grounding of the meter is necessary for the following reasons:

- Safety of personnel working with the meter
- Protection of the electronic circuitry in the meter
- Proper operation of noise filtering within the meter
• Proper operation of communication ports
• Compliance with all local and national regulations on grounding electrical devices

Be sure to connect appropriate ground equipment including grounding tabs, ground terminals, or ground wires to a protective earth ground before the meter is powered up.

Be sure to install fuses in all voltage measurement inputs and auxiliary power circuits.

All electrical connections on the meter terminals should not be student/user accessible after installation.

TEST EQUIPMENT
• Advanced Meter
• Advanced Meter configuration software
• Computer

MATERIALS NEEDED
None

CRITICAL TASKS STUDENTS MUST COMPLETE
• Navigate through the front panel data screens.
• Use the front panel navigation buttons.
• Identify meter data and status information available on the front panel.
• Enter setup mode through the front panel.
• Change PT and CT ratios.
• View communication port settings.
• Open Meter configuration software.
• Connect directly to an Ethernet meter or Serial meter.
• Properly setup the meters clock, configuring it for both UTC and local time zones.
• Properly synchronize the meters clock.

FINDINGS
• Written lab sheet that verifies the configuration of a meter.
  - What is the kWh delivered value?
  - What is the kWh received value?
  - What is the kW block peak deliver value?
• Test criteria for the meter-under load. Determine if the meter is functioning as configured. Run onboard diagnostic algorithm to determine any faults in the configuration.
ADDITIONAL INFORMATION

Bibliography:


Recommended materials:

ADVANCED METERING INFRASTRUCTURE
LAB 3.2-3 METER PHYSICAL CONNECTION-COMMUNICATIONS

PERFORMANCE OBJECTIVE

- Configure all communication ports for meter.
- Configure Ethernet port for meter with an appropriate IP Address, Subnet Mask, and a Gateway Address.
- Configure IP Service protocols.
- Configure COM ports for meter.

LAB TYPE

Team

TIME REQUIRED

1 hour

INSTRUCTOR PREPARATION

Instructors should have a working knowledge of electrical systems, be familiar with the computer operating system, and have a working knowledge of networked environments, including client/server systems.

Be sure to read the installation and user guide for specific advanced meters to develop procedures so students are able to complete the tasks listed below. Ensure that students are familiar with general electrical terminology, such as amps, volts, watts, power factor (PF), etc.

BACKGROUND

An advanced meter is usually an electrical meter that records consumption of electric energy in intervals of an hour or less and communicates that information at least daily back to the utility for monitoring and billing purposes. Advanced meters enable two-way communication between the meter and the central system. Unlike home energy monitors, advanced meters can gather data for remote reporting. Such an advanced metering infrastructure (AMI) differs from traditional automatic meter reading (AMR) in that it enables two-way communications with the meter.

SAFETY REQUIREMENTS

Be sure to consult the installation and user guide for the specific Advanced Meter for appropriate safety information.

During normal operation of a power meter, hazardous voltages are present on its terminal strips and throughout the connected potential transformer (PT), current transformer (CT), digital (status) input, control power and external I/O circuits. PT and CT secondary circuits are capable of generating lethal voltages and currents with their primary circuit energized. Follow appropriate safety precautions while performing any installation or service work (i.e. removing PT fuses, shorting CT secondaries, etc.).

Most power meters must be installed with a chassis ground. Ground the device before power is applied. Proper grounding of the meter is necessary for the following reasons:

- Safety of personnel working with the meter
- Protection of the electronic circuitry in the meter
- Proper operation of noise filtering within the meter
- Proper operation of communication ports
- Compliance with all local and national regulations on grounding electrical devices
Be sure to connect appropriate ground equipment including grounding tabs, ground terminals, or ground wires to a protective earth ground before the meter is powered up.

Be sure to install fuses in all voltage measurement inputs and auxiliary power circuits.

All electrical connections on the meter terminals should not be student/user accessible after installation.

**TEST EQUIPMENT**

- Advanced Meter
- Advanced Meter configuration software
- Computer

**MATERIALS NEEDED**

None

**CRITICAL TASKS STUDENTS MUST COMPLETE**

- Configure Ethernet port for meter with an appropriate IP Address, Subnet Mask, and a Gateway Address. Note that students will need to also know how to install a meter behind a router or firewall.
- Configure IP Service protocols for meter, including (if supported by meter):
  - STMP
  - HTTP
  - Modbus TCP protocol
  - Modbus RTU over TCP/IP
- Ping the Ethernet devices in the meters from a computer terminal.
- If supported by meter, use Internet browser to test communication with Ethernet device in meter.
- Set up the COM ports for meter using appropriate protocol, and baud rate.
  - If supported by meter, configure RS-232 Point to point connection.
  - If supported by meter, configure RS-485 Serial Connection.

**FINDINGS**

- This is an appropriate place for a troubleshooting lab. Once the students have the communications fully operational, have the instructor introduce a problem, i.e. bug in the software, faulty wiring. The students can then troubleshoot to find the problem and resolve it. The students must carefully document all steps taken and comment on how they were able to resolve the communications.

**ADDITIONAL INFORMATION**

Bibliography:


Recommended materials:

FUNDAMENTALS OF ADVANCED METERING INFRASTRUCTURE

LAB 3.3-1 REVENUE LOGGING

PERFORMANCE OBJECTIVE

• Measure and interpret energy, demand curves, and average demand using static and dynamic (rolling) curves. Use analysis software to provide both graphical and tabular display of block and sliding demand captures. Display interval energy vs. cumulative energy.

LAB TYPE

Individual

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

Instructors should have a working knowledge of electrical systems, be familiar with the computer operating system, and have a working knowledge of networked environments, including client/server systems.

Be sure to read the installation and user guide for specific advanced meters to develop procedures so students are able to complete the tasks listed below. Ensure that students are familiar with general electrical terminology, such as amps, volts, watts, power factor (PF), etc.

BACKGROUND

An advanced meter is usually an electrical meter that records consumption of electric energy in intervals of an hour or less and communicates that information at least daily back to the utility for monitoring and billing purposes. Advanced meters enable two-way communication between the meter and the central system. Unlike home energy monitors, advanced meters can gather data for remote reporting. Such an advanced metering infrastructure (AMI) differs from traditional automatic meter reading (AMR) in that it enables two-way communications with the meter.

SAFETY REQUIREMENTS

Be sure to consult the installation and user guide for the specific Advanced Meter for appropriate safety information.

During normal operation of a power meter, hazardous voltages are present on its terminal strips and throughout the connected potential transformer (PT), current transformer (CT), digital (status) input, control power and external I/O circuits. PT and CT secondary circuits are capable of generating lethal voltages and currents with their primary circuit energized. Follow appropriate safety precautions while performing any installation or service work (i.e. removing PT fuses, shorting CT secondaries, etc.).

Most power meters must be installed with chassis ground. Ground the device before power is applied. Proper grounding of the meter is necessary for the following reasons:

• Safety of personnel working with the meter
• Protection of the electronic circuitry in the meter
• Proper operation of noise filtering within the meter
• Proper operation of communication ports
• Compliance with all local and national regulations on grounding electrical devices
Be sure to connect appropriate ground equipment including grounding tabs, ground terminals, or ground wires to a protective earth ground before the meter is powered up.

Be sure to install fuses in all voltage measurement inputs and auxiliary power circuits.

All electrical connections on the meter terminals should not be student/user accessible after installation.

**TEST EQUIPMENT**
- Advanced Meter
- Advanced Meter configuration software
- Computer

**MATERIALS NEEDED**
- None

**CRITICAL TASKS STUDENTS MUST COMPLETE**
- Open a multiple meter site configuration using meter configuration software.
- Establish a timeframe for data capture.
- Create database with appropriate fields for revenue data capture and analysis.
- Capture revenue data metrics from each meter and save to database.
- Query data to create a raw demand curve using revenue data.
- Apply a smoothing constant to demand curves and compare with raw data.
- Write analysis report using tabular and graphical display.
- Capture power data using the same periodicity.
- Compare power capture vs. revenue capture data.
- Apply per-unit pricing based on total demand- sliding scale demand- power quality.
- Compare the pricing basis and draft a report with the benefits and limitations of pricing baselines.

**FINDINGS**
- The student will understand the delivery and sale of power as a commodity. The analysis will emphasize the various methods that the same quantity of power can be consumed, why there is a variable cost basis and how to best configure metering equipment to measure power consumption for the purpose of revenue logging.

**ADDITIONAL INFORMATION**

Bibliography:

Recommended materials:
ADVANCED METERING INFRASTRUCTURE
LAB 5.1-1 EVENT REPORTING

PERFORMANCE OBJECTIVE

- Using advanced metering infrastructure architecture with data logging software and a fully configured system collecting data from advanced metering architecture, the team will
  - Establish Event threshold and configure system to capture events for reporting.
  - Create a comprehensive daily, weekly, and monthly data log views for energy and demand.
  - Create a “Sags and Swells” Data Log from multiple sources.
  - Create and view a data log viewer for alarm statuses with present values.
- The team will interpret event reports generated from a system, analyze data, and determine the source, cause, magnitude, and duration of the event, based solely on the reports.

LAB TYPE

Team

TIME REQUIRED

3 hours

INSTRUCTOR PREPARATION

Instructors should have a working knowledge of electrical systems, be familiar with the computer operating system, and have a working knowledge of networked environments, including client/server systems.

Be sure to read the installation and user guide for specific advanced meters to develop procedures so students are able to complete the tasks listed below. Ensure that students are familiar with general electrical terminology, such as amps, volts, watts, power factor (PF), etc.

BACKGROUND

An advanced meter is usually an electrical meter that records consumption of electric energy in intervals of an hour or less and communicates that information at least daily back to the utility for monitoring and billing purposes. Advanced meters enable two-way communication between the meter and the central system. Unlike home energy monitors, advanced meters can gather data for remote reporting. Such an advanced metering infrastructure (AMI) differs from traditional automatic meter reading (AMR) in that it enables two-way communications with the meter.

SAFETY REQUIREMENTS

Be sure to consult the installation and user guide for the specific advanced Meter for appropriate safety information.

During normal operation of a power meter, hazardous voltages are present on its terminal strips and throughout the connected potential transformer (PT), current transformer (CT), digital (status) input, control power and external I/O circuits. PT and CT secondary circuits are capable of generating lethal voltages and currents with their primary circuit energized. Follow appropriate safety precautions while performing any installation or service work (i.e. removing PT fuses, shorting CT secondaries, etc.).

Most power meters must be installed with a chassis ground. Ground the device before power is applied. Proper grounding of the meter is necessary for the following reasons:
• Safety of personnel working with the meter
• Protection of the electronic circuitry in the meter
• Proper operation of noise filtering within the meter
• Proper operation of communication ports
• Compliance with all local and national regulations on grounding electrical devices

Be sure to connect appropriate ground equipment including grounding tabs, ground terminals, or ground wires to a protective earth ground before the meter is powered up.

Be sure to install fuses in all voltage measurement inputs and auxiliary power circuits.

All electrical connections on the meter terminals should not be student/user accessible after installation.

**TEST EQUIPMENT**

- Advanced Meter
- Advanced Meter configuration software
- Computer

**MATERIALS NEEDED**

None

**CRITICAL TASKS STUDENTS MUST COMPLETE**

- Establish a multiple meter architecture including but not limited to the physical configuration of meters, provide communications with the SCADA, and configure the SCADA to database to capture data for a given set of parameters.
- Set alarm and event thresholds to provide indications when a specific events occur.
- Monitor normal operations of the system.
- Once the system is operating normally and is stabilized, the instructor will trigger a series of events.
- Create a comprehensive daily, weekly, and monthly data log views for energy and demand.
- Create a “Sags and Swells” Data Log from a single source.
- Create and view a data log viewer for alarm statuses with present values.
- The completed event report will then be submitted for analysis by the opposite team.
- Each team with draft a final report outlining the report analysis and the suspected source, cause, magnitude, and duration of the event.
- The team will review the actual event data and draft a report outlining suggested modifications to the alarms, thresholds, and data logging parameters used to create the report.
FINDINGS

- In this lab, the instructor will simulate an anomaly that will cause a drop in the power quality such as a sag/swell or a transient. The students will use an advanced meter to analyze the power quality to identify the problem. They will then re-establish a database link and optimize the system.

ADDITIONAL INFORMATION

Bibliography:

Recommended materials:
APPLIED MATHEMATICS
COURSE DESIGN GUIDE

COURSE TITLE
Applied Mathematics

CATALOG DESCRIPTION
Applied Mathematics for Technology is a comprehensive study of mathematical skills used in a variety of technical occupations. This course will provide a strong mathematical foundation for further study in Career Technical Education (CTE) programs such as Process Technology, Energy Technology, or Mechatronics. Topics include principles and applications of decimals, fractions, percentages, ratios and proportions, order of operations, geometry, measurement, and elements of algebra and statistics. Upon completion, students should be able to perform basic computations and solve relevant, multi-step mathematical problems using industry relevant examples and technology.

CREDITS
4.0 credits, 96 hours

COURSE FORMAT
This course is a lecture/exercise format that incorporates industry related exercises and activities during in-class, instructor supervised labs.

COURSE NUMBER
Material for this course is presented to meet the requirements for a 100-level course.

PREREQUISITES
The recommended prerequisite for this course is the successful completion of a developmental math course or placement.

INSTRUCTOR INFORMATION
Recommended Qualifications: A Master’s Degree in Mathematics and three to five years of experience teaching secondary or post-secondary mathematics, working knowledge of content, curriculum, methods, materials, and equipment in the career technical specialty that the course will be used, including Process Technology, Energy Technology, Advanced Manufacturing; experience and ability to develop and implement lessons based on objectives for career technical programs; experience working in a related vocational trade.

TEACHING METHODS AND ASSIGNMENTS FOR ACHIEVING LEARNING OUTCOMES
The course is divided into twelve learning units; each learning unit addresses a specific mathematical concept and topic with direct application to further study in a technical degree or certificate program. Each topic has a recommended length (topic hours) assigned; topic hours are a guideline for instruction intended to be adapted to the individual instructor’s teaching style. As a general rule, the ratio of lecture to lab is 1:3. Students are expected to spend additional study/practice time outside of the class time. The generally accepted ratio of class to study time is 1:4 for this course.
STUDENT TEXTS, READING AND OTHER MATERIALS


• Instructor developed student worksheets

• Scientific Calculator: Casio ES300fx or equivalent

APPLICATION GUIDELINES

This course is not intended to be a terminal study of mathematical principles. It provides a practical framework that allows students to apply basic principles to specific applications. As they progress through CTE programs, they will use these principles as a foundation for the theoretical study of Algebra, Geometry, Trigonometry, and Calculus.

STUDENT LEARNING OUTCOMES

Upon successful completion the student will have the ability to:

• Apply mathematical concepts and principles to perform computations

• Apply mathematical reasoning to solve technical problems

• Create, use, and analyze diagrams, sketches, and graphical representations of mathematical relationships

• Communicate mathematical knowledge and understanding using mathematical terminology and notation

• Apply mathematical strategies and procedures to solve mathematical problems

• Show ability to learn independently
## ASSESSMENT RUBRIC

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>EXEMPLARY 4</th>
<th>SATISFACTORY 3</th>
<th>DEVELOPING 2</th>
<th>BEGINNING 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematical Concepts</td>
<td>Shows complete understanding of the mathematical concepts used to solve the problem(s)</td>
<td>Shows substantial understanding of the mathematical concepts used to solve the problem(s)</td>
<td>Shows some understanding of the mathematical concepts needed to solve the problem(s)</td>
<td>Shows very limited understanding of the underlying concepts needed to solve the problem(s) OR shows no written work</td>
</tr>
<tr>
<td>Mathematical Reasoning</td>
<td>Uses complex and refined mathematical reasoning</td>
<td>Uses effective mathematical reasoning</td>
<td>Provides some evidence of mathematical reasoning</td>
<td>Shows little evidence of mathematical reasoning</td>
</tr>
<tr>
<td>Diagrams and Sketches</td>
<td>Diagrams and/or sketches are clear and greatly add to the reader’s understanding of the procedure(s)</td>
<td>Diagrams and/or sketches are clear and easy to understand</td>
<td>Diagrams and/or sketches are somewhat difficult to understand</td>
<td>Diagrams and/or sketches are difficult to understand or are not used</td>
</tr>
<tr>
<td>Mathematical Terminology and Notation</td>
<td>Correct terminology and notation are always used, making it easy to understand what was done</td>
<td>Correct terminology and notation are usually used, making it fairly easy to understand what was done</td>
<td>Correct terminology and notation are used, but not easy to understand what was done</td>
<td>There is little use, or a lot of inappropriate use, of terminology and notation</td>
</tr>
<tr>
<td>Strategy/Procedures</td>
<td>Typically uses an efficient and effective strategy to solve the problem(s)</td>
<td>Typically uses an effective strategy to solve the problem(s)</td>
<td>Sometimes uses an effective strategy to solve problems, but not consistently</td>
<td>Rarely uses an effective strategy to solve problems</td>
</tr>
</tbody>
</table>

Assessment: Assignments, testing, and student participation should be taken into consideration when instructors develop individual grading policies. The above assessment rubric specifically addresses the learning outcomes for the course. This is intended to be a tool to assess and assign a value to gauge the achievement of the stated learning outcomes.

Notes:
## UNIT 1: INTRODUCTION

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Introduction</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td>• Explain the course objectives</td>
</tr>
<tr>
<td></td>
<td>• Describe what materials are needed</td>
</tr>
<tr>
<td></td>
<td>• Explain the importance of regular attendance, timely homework preparation,</td>
</tr>
<tr>
<td></td>
<td>class participation, and asking questions when in doubt</td>
</tr>
<tr>
<td></td>
<td>• Describe that mathematics is a tool made by man to help him manage his world</td>
</tr>
</tbody>
</table>

Notes:
# UNIT 2: WHOLE NUMBERS, FRACTIONS, AND DECIMALS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
</table>
| **2.1 Whole Numbers and the Base-Ten Place Value System**  
Lecture - 5 hrs. | The student will be able to:  
- Demonstrate an appreciation for early use of numbers and different number bases  
- Define the set of counting numbers  
- Explain the value of having and using a symbol for zero in a number system  
- Explain what numbers comprise the set of whole numbers and how this differs from the set of counting numbers  
- Show understanding of the base-ten place value system to be able to expand numbers using their place value, be able to read large numbers, be able to add, subtract, multiply and divide whole numbers without a calculator using proper notation and language, i.e. addend, sum, subtrahend, minuend, difference, etc.  
- Demonstrate understanding that addition and multiplication are commutative and associative while subtraction and division are not  
- Explain the order of operations (PEMDAS) and use that information to evaluate an expression  
- Identify the operations needed to solve a word problem  
- Translate problems written in English into mathematical sentences  
- Perform arithmetic to solve word problems  
- Ascertain whether or not the answer to a problem seems reasonable |
| **2.2 Fractions**  
Lecture - 9 hrs. | The student will be able to:  
- Explain what the numerator and denominator mean and what each represents  
- Distinguish between the various types of fractions: proper, improper, and mixed  
- Show recognition of equivalent fractions  
- Change fractions to higher terms  
- Change a fraction to lower terms  
- Explain when a fraction is in its lowest terms  
- Order fractions from least to greatest or vice-versa  
- Explain why a common denominator is needed to add and subtract common fractions  
- Find the least common denominator using prime factors if necessary  
- Add and subtract all types of fractions: proper, improper and mixed  
- Demonstrate when there is a need to borrow in subtraction and be able to execute the procedure  
- Multiply and divide fractions  
- Show understanding that mixed fractions must be changed to improper for multiplication and division  
- Show how to reduce before multiplying or dividing to simplify computation  
- Translate and solve word problems involving fractions |

Notes:
## UNIT 2: WHOLE NUMBERS, FRACTIONS, AND DECIMALS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.3 Decimal Fractions, Significant Digits and Scientific Notation</td>
<td><strong>The student will be able to:</strong></td>
</tr>
<tr>
<td>Lecture - 6 hrs.</td>
<td>• Explain and exhibit understanding of basic terminology</td>
</tr>
<tr>
<td></td>
<td>• Read decimal numbers correctly</td>
</tr>
<tr>
<td></td>
<td>• Convert fractions to decimals</td>
</tr>
<tr>
<td></td>
<td>• Convert decimals to fractions</td>
</tr>
<tr>
<td></td>
<td>• Identify the significant digits of a number</td>
</tr>
<tr>
<td></td>
<td>• Round off to the required degree of accuracy, i.e. the specified number of significant figures</td>
</tr>
<tr>
<td></td>
<td>• Perform the operations of arithmetic with decimal numbers without the aid of a calculator</td>
</tr>
<tr>
<td></td>
<td>• Determine and explain how many digits in a reported measurement are significant</td>
</tr>
<tr>
<td></td>
<td>• Show understanding of the difference in accuracy between a reported measurement with more or less significant digits</td>
</tr>
<tr>
<td></td>
<td>• Round off to a specific decimal place</td>
</tr>
<tr>
<td></td>
<td>• Show understanding that the final answer in a problem with measurement cannot be any more accurate than the least accurate piece of information used to find it</td>
</tr>
<tr>
<td></td>
<td>• Determine the maximum allowable number of significant digits in a final answer for a word problem involving measurement</td>
</tr>
<tr>
<td></td>
<td>• Write decimal numbers in scientific notation</td>
</tr>
<tr>
<td></td>
<td>• Expand numbers written in scientific notation into decimal form</td>
</tr>
</tbody>
</table>

Notes:
# UNIT 3: CALCULATOR AND SPREADSHEET USE

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Use of a Scientific calculator</td>
<td>The student will be able to:&lt;br&gt;• Explain the difference between the math mode and the linear mode&lt;br&gt;• Show understanding of the functions of the various calculator keys&lt;br&gt;• Demonstrate when to use each of the keys&lt;br&gt;• Explain how a DAL calculator knows and uses the correct order of operations&lt;br&gt;• Show understanding that, if using the linear mode, when parenthesis must be inserted to insure that the problem is evaluated correctly&lt;br&gt;• Perform complex calculations with the calculator&lt;br&gt;• Determine whether or not the answer obtained using the calculator seems reasonable&lt;br&gt;• Use the calculator to perform operations with numbers written in scientific notation</td>
</tr>
<tr>
<td>Lecture - 4 hrs.</td>
<td></td>
</tr>
<tr>
<td>3.2 Use of a Spreadsheet for Calculation</td>
<td>The student will be able to:&lt;br&gt;• Enter information into cells on a spreadsheet&lt;br&gt;• Show understanding of the basic arithmetic functions of the spreadsheet&lt;br&gt;• Demonstrate how to sum, autosum, multiply, and divide&lt;br&gt;• Explain that a spreadsheet formula must be given precise order of operations&lt;br&gt;• Perform complex calculation with the calculator&lt;br&gt;• Determine whether or not the answer obtained using the spreadsheet seems reasonable&lt;br&gt;• Use the spreadsheet to perform operations with numbers written in scientific notation</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td></td>
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</tbody>
</table>

Notes:
# UNIT 4: RATIO PROPORTION AND PERCENTAGE

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4.1 Ratios</strong>&lt;br&gt;Lecture – 1.5 hrs.</td>
<td>The student will be able to:&lt;br&gt;• Show understanding that numbers can be compared by either subtraction or division&lt;br&gt;• Define what is meant by a ratio&lt;br&gt;• Write a ratio in two ways&lt;br&gt;• Demonstrate when a ratio requires a label and when one is not used</td>
</tr>
<tr>
<td><strong>4.2 Proportions</strong>&lt;br&gt;Lecture – 1.5 hrs.</td>
<td>The student will be able to:&lt;br&gt;• Define a proportion&lt;br&gt;• Name the parts of a proportion&lt;br&gt;• State the cross-product property&lt;br&gt;• Use the cross-product property to solve a proportion&lt;br&gt;• Set up the proportion required to solve a word problem</td>
</tr>
<tr>
<td><strong>4.3 Percentages</strong>&lt;br&gt;Lecture - 3 hrs.</td>
<td>The student will be able to:&lt;br&gt;• Explain the derivation of the percent sign (%)&lt;br&gt;• Explain the basic terminology of percents&lt;br&gt;• Convert between fraction forms, decimal forms, and percent forms&lt;br&gt;• Perform calculations with percentages&lt;br&gt;• Use the percent key on the scientific calculator&lt;br&gt;• Solve word problems involving percentages&lt;br&gt;• Determine maximum and minimum measurements using percent tolerance</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 5: UNITS OF MEASURE AND DIMENSIONAL ANALYSIS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>5.1 Units of Measure</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 3 hrs.</td>
<td>• Explain the difference between the English and metric systems of measure</td>
</tr>
<tr>
<td></td>
<td>• Explain common conversion factors for the English system</td>
</tr>
<tr>
<td></td>
<td>• Use the tables in the text to find necessary conversion factors for less commonly known units of measure</td>
</tr>
<tr>
<td><strong>5.2 Dimensional Analysis</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 3 hrs</td>
<td>• Determine with certainty when to multiply by the conversion factor and when to divide by it</td>
</tr>
<tr>
<td></td>
<td>• Convert compound units, i.e. miles per hour to feet per second, using a conversion bar</td>
</tr>
<tr>
<td></td>
<td>• Perform operation of arithmetic on denominate numbers</td>
</tr>
</tbody>
</table>

Notes:
# UNIT 6: SIGNED NUMBERS AND COMBINING LIKE TERMS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1 Signed Numbers</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 4 hrs.</td>
<td>• Use the correct terminology with regard to signed numbers</td>
</tr>
<tr>
<td></td>
<td>• Diagram the set of real numbers on the number line</td>
</tr>
<tr>
<td></td>
<td>• Show understanding of the difference between the magnitude of a number</td>
</tr>
<tr>
<td></td>
<td>and its direction</td>
</tr>
<tr>
<td></td>
<td>• Find the absolute value of a number and explain what that means in</td>
</tr>
<tr>
<td></td>
<td>terms of the number line</td>
</tr>
<tr>
<td></td>
<td>• Insert the proper order symbol between any two signed numbers</td>
</tr>
<tr>
<td></td>
<td>• Determine the sign of a fraction</td>
</tr>
<tr>
<td></td>
<td>• Perform the four basic operations with signed numbers</td>
</tr>
<tr>
<td></td>
<td>• Simplify a complex expression involving signed numbers</td>
</tr>
</tbody>
</table>

| 6.2 Combining Like Terms | The student will be able to:                                               |
| Lecture - 6 hrs.         | • Explain what “like terms” are                                           |
|                         | • Demonstrate an understanding of the basic terminology of algebra, i.e.   |
|                         |   expression, equation, variable, constant, term, factor, numerical       |
|                         |   coefficient, like terms, monomial, and polynomial                       |
|                         | • Perform basic operation of addition and subtraction on monomials and     |
|                         |   polynomials                                                             |
|                         | • Use the distributive property effectively                              |

Notes:
# UNIT 7: EXPONENTS, ROOTS AND SOLVING LITERAL EQUATIONS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>7.1 Exponents</strong></td>
<td>The student will be able to:</td>
</tr>
</tbody>
</table>
| Lecture - 3 hrs.     | • Use the proper terminology associated with exponentiation  
                      • Show understanding that an exponent affects ONLY what is directly to the left of it unless otherwise indicated by parenthesis  
                      • Show that exponentiation takes precedence over all other operations unless otherwise indicated by parenthesis  
                      • Calculate, with and without the calculator, the value of a rational number raised to an integral power                                                                 |
| **7.2 Exponents and Roots** | The student will be able to:                                                                                                                                                                               |
| Lecture - 5 hrs.     | • Extract roots using the scientific calculator  
                      • Understand the rule for multiplying powers of the same base and use it effectively  
                      • Understand the rule for dividing powers of the same base and use it effectively  
                      • Develop a definition for the zero exponent and for negative exponents as a result of their understanding of the rule for dividing powers of the same base  
                      • Understand and effectively use the rule for raising a power to a power  
                      • Understand and effectively use the rule for taking the root of a power  
                      • Develop an understanding of the meaning of a fractional exponent as it result of the rule for taking roots of powers  
                      • Perform complex operations using the rules for operating with exponents and will leave the answer in simplest form, i.e. no negative exponents and all fractions reduced  
                      • Demonstrate an understanding of the laws of exponents when simplifying expressions                                                                 |
| **7.3 Solving Literal Equations** | The student will be able to:                                                                                                                                                                               |
| Lecture - 4 hrs.     | • Solve an algebraic equation with one variable  
                      • Solve a literal equation or formula for a designated variable  
                      • Translate word problems into algebraic equations  
                      • Solve word problems using algebra                                                                                                                                            |

Notes:
# UNIT 8: GEOMETRY

## TOPICS

### 8.1: Terminology and Classification of Shapes

Lecture - 6 hrs.

<table>
<thead>
<tr>
<th>The student will be able to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Explain the original meaning of the word “geometry” from its Latin roots</td>
</tr>
<tr>
<td>• Use the proper terminology when discussing, lines, segments, rays, and planes</td>
</tr>
<tr>
<td>• Use the proper notation and symbols for the terminology above</td>
</tr>
<tr>
<td>• Demonstrate the ways in which two lines can be related: coinciding, parallel, skew, or intersecting</td>
</tr>
<tr>
<td>• Define a circle</td>
</tr>
<tr>
<td>• Explain what is meant by one degree</td>
</tr>
<tr>
<td>• Define an angle in a plane</td>
</tr>
<tr>
<td>• Show why the measure of an angle is between inclusive</td>
</tr>
<tr>
<td>• Classify angles by measure</td>
</tr>
<tr>
<td>• Define a polygon</td>
</tr>
<tr>
<td>• Classify polygons by the number of their sides</td>
</tr>
<tr>
<td>• Classify triangles by the lengths of their sides</td>
</tr>
<tr>
<td>• Classify triangles by the measure of their angles</td>
</tr>
<tr>
<td>• State the interior angle sum for a triangle</td>
</tr>
<tr>
<td>• Explain when a polygon is regular</td>
</tr>
<tr>
<td>• Explain when a figure is rigid</td>
</tr>
<tr>
<td>• Define a quadrilateral</td>
</tr>
<tr>
<td>• Distinguish between the types of quadrilaterals, i.e. quadrilateral, parallelogram, rectangle, rhombus, square, and trapezoid</td>
</tr>
<tr>
<td>• Use a Venn diagram to depict the relationships between the various sets of quadrilaterals</td>
</tr>
<tr>
<td>• State the interior angle sum of a quadrilateral</td>
</tr>
<tr>
<td>• Compare and contrast the various types of parallelograms</td>
</tr>
</tbody>
</table>

### 8.2: Plane Shapes and Solids

Lecture - 3 hrs.

<table>
<thead>
<tr>
<th>The student will be able to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Calculate the perimeter of a plane shape and show that it is a linear measure</td>
</tr>
<tr>
<td>• Calculate the area of a plane shape and show that it is square measure</td>
</tr>
<tr>
<td>• Identify various types of solid figures: prisms, pyramids, right circular cylinders, right circular cones, and spheres</td>
</tr>
<tr>
<td>• Demonstrate understanding that the concept of volume of a prism or cylinder as the area of the base times the height</td>
</tr>
<tr>
<td>• Demonstrate understanding that the concept of volume of a right pyramid or right circular cone as one-third the area of the base times the height</td>
</tr>
<tr>
<td>• Calculate volumes of geometric solids given the necessary formulas and show that is its cubic measure</td>
</tr>
</tbody>
</table>

## Notes:
# APPLIED MATHEMATICS

## UNIT 9: TRIGONOMETRY

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.1 Right Triangle Trigonometry</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 5 hrs.</td>
<td>• Explain important facts about triangles such as interior angle sum,</td>
</tr>
<tr>
<td></td>
<td>types of triangles, sum of acute angles in a right triangle, Pythagorean</td>
</tr>
<tr>
<td></td>
<td>Theorem, area formulas</td>
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<tr>
<td></td>
<td>• Label the vertices of a right triangle using capital letters and the</td>
</tr>
<tr>
<td></td>
<td>sides opposite, using the corresponding lower case letter</td>
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<tr>
<td></td>
<td>• Define similar triangles and state their properties</td>
</tr>
<tr>
<td></td>
<td>• Explain that the ratio of corresponding sides of similar triangles is a</td>
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<tr>
<td></td>
<td>function of the angle measure, not the lengths of the sides</td>
</tr>
<tr>
<td></td>
<td>• Explain the use of the words opposite, adjacent, and hypotenuse in</td>
</tr>
<tr>
<td></td>
<td>relation to a particular acute angle of a right triangle</td>
</tr>
<tr>
<td></td>
<td>• State the definitions of the three basic trig ratios, sine, cosine, and</td>
</tr>
<tr>
<td></td>
<td>tangent, using the words opposite, adjacent, and hypotenuse</td>
</tr>
<tr>
<td></td>
<td>• Show, using similar triangles, that the value of a trig ratio is a function of the angle measure</td>
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<tr>
<td></td>
<td>• Write the three trig ratios for a specified acute angle of a right</td>
</tr>
<tr>
<td></td>
<td>triangle given the measures of the sides</td>
</tr>
<tr>
<td></td>
<td>• Use the scientific calculator to find the value of the sin, cos, or tan</td>
</tr>
<tr>
<td></td>
<td>of a given angle whose measure is expressed in decimal degrees or in</td>
</tr>
<tr>
<td></td>
<td>degrees, minutes, and seconds</td>
</tr>
<tr>
<td></td>
<td>• Use the scientific calculator to find the measure of an angle given the</td>
</tr>
<tr>
<td></td>
<td>value of its sin, cosine, or tangent</td>
</tr>
<tr>
<td></td>
<td>• Explain what it means to solve a right triangle</td>
</tr>
<tr>
<td></td>
<td>• Solve any right triangle given two additional pieces of information</td>
</tr>
<tr>
<td></td>
<td>• Differentiate between angles of elevation and angles of depression</td>
</tr>
<tr>
<td></td>
<td>• Explain how the angle of elevation is related to the angle of depression</td>
</tr>
<tr>
<td></td>
<td>in a given problem</td>
</tr>
<tr>
<td>9.2 Trigonometric Word Problems</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1 hrs.</td>
<td>• Solve word problems involving applied trigonometry</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 10: TRIGONOMETRIC FUNCTIONS OF THE UNIT CIRCLE

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.1 Definitions of a Unit Circle</td>
<td>The student will be able to:  &lt;br&gt; - Define an angle of rotation  &lt;br&gt; - Identify the initial and terminal sides of an angle of rotation  &lt;br&gt; - Explain why angle measure can now range from negative infinity to positive infinity  &lt;br&gt; - Draw an angle in standard position in the x-y plane  &lt;br&gt; - Classify angles in standard position depending on the quadrant in which their terminal side falls  &lt;br&gt; - Define a quadrantal angle  &lt;br&gt; - Demonstrate a basic knowledge of graphing in the x-y plane  &lt;br&gt; - Explain a unit circle on the x-y plane  &lt;br&gt; - Explain, by using the definition of the trig ratios, that the radius (hypotenuse) is one, the coordinates of the point where the terminal side of an angle in standard position crosses the circle are cos, sin  &lt;br&gt; - Mark, on the unit circle, the degree measures of the special angles between inclusive.  &lt;br&gt; - Use the scientific calculator to write, to the nearest tenth, the coordinates where the aforementioned angles cross the unit circle</td>
</tr>
<tr>
<td>10.2 Graphing the Unit Circle</td>
<td>The student will be able to:  &lt;br&gt; - Construct the graph of $y = \sin x$ using the information on the unit circle  &lt;br&gt; (The x-axis will be labeled in degrees from and the y-axis in tenths from -1 to 1)  &lt;br&gt; - Demonstrate that the sin wave is a periodic function with an amplitude of 1 and a period of 2π  &lt;br&gt; - Draw one period of the sine wave with a phase shift of  &lt;br&gt; - Demonstrate an understanding of the period nature and shape of the sine wave by drawing one period given a specific starting and ending point</td>
</tr>
</tbody>
</table>

Notes:
# UNIT 11: APPLIED STATISTICS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>11.1 Measures of Central Tendency</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 4 hrs.</td>
<td>• Define statistics as the collection, organization, and interpretation of data</td>
</tr>
<tr>
<td></td>
<td>• Define the measures of central tendency: mean, median, and mode</td>
</tr>
<tr>
<td></td>
<td>• Calculate the mean and median of a set of data</td>
</tr>
<tr>
<td></td>
<td>• Explain that exactly half of the data is greater than the median and half is less</td>
</tr>
<tr>
<td></td>
<td>• Use a frequency distribution to identify the mode(s), if any</td>
</tr>
<tr>
<td></td>
<td>• Explain what is meant by an outlier in a set of data</td>
</tr>
<tr>
<td></td>
<td>• Explain which measure of central tendency is most affected by an outlier</td>
</tr>
<tr>
<td></td>
<td>• Find measures of central tendency on various sets of data and demonstrate the effect of the outlier by removing it and recalculating</td>
</tr>
<tr>
<td></td>
<td>• Define the range of a set of data as a single number</td>
</tr>
<tr>
<td><strong>11.2 Distribution and Standard Deviation</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 4 hrs.</td>
<td>• Explain that the standard deviation is a measure of the spread of the data</td>
</tr>
<tr>
<td></td>
<td>• Show understanding that the standard deviation represents the average distance that a piece of data is from the mean</td>
</tr>
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<td></td>
<td>• Calculate the standard deviation for smaller sets of data</td>
</tr>
<tr>
<td></td>
<td>• Explain how an outlier affects the standard deviation</td>
</tr>
<tr>
<td></td>
<td>• Construct a histogram of a set of data</td>
</tr>
<tr>
<td></td>
<td>• Interpret a histogram of a set of data</td>
</tr>
<tr>
<td></td>
<td>• Show understanding of the shape of the bell or normal curve</td>
</tr>
<tr>
<td></td>
<td>• Show that as the number of pieces of data increases, the histogram begins to assume the shape of the normal distribution</td>
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<td></td>
<td>• Label the horizontal axis of a normal distribution given the mean and standard deviation</td>
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<td></td>
<td>• Explain, when the data is normally distributed, what percent lies within one standard deviation of the mean, within two standard deviation, and within three standard deviations</td>
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<td></td>
<td>• Use the bell curve to answer questions about a set of data that is normally distributed</td>
</tr>
</tbody>
</table>

Notes:
GEOGRAPHY AND THE NATURAL ENVIRONMENT
COURSE DESIGN GUIDELINES

COURSE TITLE
Geography and the Natural Environment

CATALOG DESCRIPTION
This course is designed to provide the student with an understanding of the major eco and environmental systems as they relate to the use of natural resources to provide energy for mankind. It introduces the elements and interactions of the earth’s major ecosystems, discusses the human population, and the impact of human population growth on the earth’s resources and ecosystems from a geographic perspective. The course covers the historical, contemporary, and emerging use of the earth’s natural resources to provide energy for machines and devices that save human labor.

CREDITS
3 credits, 48 hours

COURSE FORMAT
This course is presented in a lecture format that addresses both global and regional subjects that relate to the development of the modern power system.

COURSE NUMBER
Material for this course is presented to meet the requirements for a 100-level course.

PREREQUISITES
Completion of English Composition or Technical Writing

INSTRUCTOR INFORMATION
Recommended Qualifications: A Master’s Degree or higher in environmental science, or related field; 3-5 years working experience in topic area/academic discipline; experience teaching post-secondary/adult students.

TEACHING METHODS AND ASSIGNMENTS FOR ACHIEVING LEARNING OUTCOMES
Instructor lectures, class discussions, and student research or independent learning are recommended teaching methods. To emphasize specific areas that are pertinent to the energy industry, problem-based group scenarios are recommended to be incorporated

COURSE DEVELOPMENT AND CONTEXT
This is foundational course covering topics in geography and environmental science. Courses in this academic discipline are commonplace in community college and junior college course offerings, as either a general education requirement or introductory course for a specific discipline. In order to provide a framework and context for further study in the technical area of Smart Grid, courses should consider placing emphasis on the historical, contemporary, and emerging use of the earth’s natural resources to provide energy for machines and devices that save human labor. In order to accomplish this objective, the course design should address the scientific principles and natural functions that contribute to the dynamic nature of the earth, and its environment.
TECHNICAL WRITING
COURSE DESIGN GUIDE

COURSE TITLE
Technical Writing

CATALOG DESCRIPTION
This course is an introduction to writing used in business and industry for communication, planning, and reporting. In this course, students learn methods of communication, effective ways to convey technical information and writing styles common to commercial and industrial environments.

CREDITS
3.0 credits, 48 hours

COURSE FORMAT
The content for this course is lecture-style and writing intensive. Students will have assigned projects designed to demonstrate and reinforce the knowledge, principles, and formats covered during the course.

COURSE NUMBER
Material for this course is presented to meet the requirements for an ENG 100-level course.

PREREQUISITES
Students entering this course are expected to possess basic reading and writing skills that place them beyond developmental curriculum. Additionally students should possess critical thinking tools, personal behaviors, and attitudes necessary to complete the writing and research assignments required for successful completion. Computer application skills are recommended for word processing.

INSTRUCTOR INFORMATION
Recommended Qualifications: A Master’s Degree in English, Communications, Business Management/Administration, or related field; 3-5 years working experience in higher education, private company, power utility, or related industry; working knowledge and background in subject/topic area; experience teaching post-secondary/adult students.

TEACHING METHODS AND ASSIGNMENTS FOR ACHIEVING LEARNING OUTCOMES
The course is divided into five learning units; each learning unit addresses a specific writing concept and topic with direct application to further study in technology. Each topic has a recommended length (topic hours) assigned. Topic hours are a guideline for instruction that is intended to be adapted to the individual instructor’s teaching style. Included in the instructional materials are example worksheets, homework assignments, and quizzes. Students are expected to spend additional study/practice time outside of the class time. The generally accepted ratio of class to study time is 3:1 for this course. Each topic lists suggested time allocation. Total time allocated includes an hour course introduction, a 2-hour review, and a 2-hour written exam.
The better knowledge that a student has of the formats and approaches commonly used in the technical working environment, the more likely the ideas will have a positive impact. Students will work with many forms of business writing, learning how to structure comments, suggestions, and arguments to seek agreement with the presented ideas. The course has 10 writing assignments. The assignments should focus on technical issues and graded on format of presentation, adequate discussion, appropriate content, logical connection of ideas, and smooth sentence flow as well as technical accuracy.

**STUDENT TEXTS, READING AND OTHER MATERIALS**


**ADDITIONAL REQUIREMENTS**

- Word processing software
- Reference management software
- Access to a library

**STUDENT LEARNING OUTCOMES**

Upon successful completion the student will have the ability to:

- Use a computer as a tool to research information
- Compose, edit, and proofread written documents
- Write through a process of generating ideas, developing details, providing support, organizing, revising, editing, and proofreading
- Write cohesive paragraphs that contain topic sentences, supporting ideas, transitions, and conclusions
- Write correct, complete sentences, using a variety of sentence patterns
- Write with the correct use of grammar and diction appropriate to college-level writing
- Research topics and cite sources in reports using proper format
- Think logically, plan, organize, and write reports at an appropriate level of detail
- Apply technical writing skills to projects
## ASSESSMENT RUBRIC

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>EXEMPLARY 4</th>
<th>SATISFACTORY 3</th>
<th>DEVELOPING 2</th>
<th>BEGINNING 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer research; assignment composition</td>
<td>Demonstrates excellent research techniques, writing, editing, and proofing skills</td>
<td>Demonstrates adequate research techniques, writing, editing, and proofing skills</td>
<td>Demonstrates essential research techniques, writing, editing, and proofing skills</td>
<td>Demonstrates limited or no research techniques, writing, editing, and proofing skills</td>
</tr>
<tr>
<td>Writing process</td>
<td>Illustrative application of all areas and concepts of the writing process</td>
<td>Average application of some areas and concepts of the writing process</td>
<td>Shows basic application of some areas and concepts of the writing process</td>
<td>Shows fundamental use of limited areas and concepts of the writing process</td>
</tr>
<tr>
<td>Effective writing approaches and formats</td>
<td>Effectively puts to use the various approaches and forms of technical writing formats</td>
<td>Competently puts to use the various approaches and forms of technical writing formats</td>
<td>Low-level usage of the various approaches and forms of technical writing formats</td>
<td>Rudimentary use of the various approaches and forms of technical writing formats</td>
</tr>
<tr>
<td>Diverse writing structures and patterns</td>
<td>Demonstrates clear comprehension and application of writing structures and patterns</td>
<td>Demonstrates fair comprehension and application of writing structures and patterns</td>
<td>Demonstrates basic comprehension and application of writing structures and patterns</td>
<td>Demonstrates limited or no comprehension and application of writing structures and patterns</td>
</tr>
<tr>
<td>Proper use of grammar and citations</td>
<td>Shows mastery of grammar and proper use of citations in writing</td>
<td>Shows sound use of grammar and proper use of citations in writing</td>
<td>Shows essential use of grammar and proper use of citations in writing</td>
<td>Shows fundamental use of grammar and proper use of citations in writing</td>
</tr>
</tbody>
</table>

Notes:
# UNIT 1: INTRODUCTION TO WRITING

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Course Introduction</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td>• Identify and explain strategies of the course.</td>
</tr>
<tr>
<td></td>
<td>• Demonstrate baseline for content</td>
</tr>
<tr>
<td></td>
<td>• Use writing labs for course content application</td>
</tr>
<tr>
<td>1.2 Five Steps to Writing</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Use 5 steps to writing</td>
</tr>
<tr>
<td></td>
<td>• Preparation</td>
</tr>
<tr>
<td></td>
<td>• Research</td>
</tr>
<tr>
<td></td>
<td>• Organization</td>
</tr>
<tr>
<td></td>
<td>• Writing</td>
</tr>
<tr>
<td></td>
<td>• Revision</td>
</tr>
<tr>
<td></td>
<td>• Apply 5 steps of writing</td>
</tr>
<tr>
<td>1.3 Paragraph Structure</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1.5 hrs.</td>
<td>• Explain and apply paragraph structure in reports</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 2: BASIC WRITTEN COMMUNICATION

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2.1 Review of Memo Format</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td>• Identify key concepts for effective communication using memos</td>
</tr>
<tr>
<td></td>
<td>• Apply concepts of communication in writing of brief memos</td>
</tr>
<tr>
<td><strong>2.2 Effective Communication for Positive Letters</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Identify and explain key concepts in effective communication</td>
</tr>
<tr>
<td></td>
<td>• Apply concepts of communication to writing letters</td>
</tr>
<tr>
<td></td>
<td>• Discuss role and concept of positive letters in business writing</td>
</tr>
<tr>
<td></td>
<td>• Apply positive letter writing concepts - assignment</td>
</tr>
<tr>
<td><strong>2.3 Negative Letters</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Identify and explain key concepts in writing negative letters</td>
</tr>
<tr>
<td></td>
<td>• Apply concepts of negative letter writing - assignment</td>
</tr>
</tbody>
</table>

Notes:
**UNIT 3:**

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
</table>
| 3.1 Job Letters/Cover Letters | The student will be able to:  
  - Discuss the purpose, objective, and format to writing a job letter/cover letter  
  - Apply concepts of job letters/cover letters - assignment |
| Lecture - 2 hrs.        |                                                                             |
| 3.2 Resumes             | The student will be able to:  
  - Identify and explain the purpose, objective, and format of resumes  
  - Evaluate necessary information to input into resumes  
  - Apply concepts of resume writing - assignment |
| Lecture - 4 hrs.        |                                                                             |
| 3.3 Employment Communication | The student will be able to:  
  - Prepare a letter of acceptance  
  - Communicate workplace issues to supervisors  
  - Understand format and purpose of periodic evaluations  
  - Writing change order reports or technical problem reports  
  - Identify and explain concept, purpose, and format of evaluation reports  
  - Apply evaluation report concepts in a writing assignments |
| Lecture - 2 hrs.        |                                                                             |

Notes:
# TECHNICAL WRITING

## UNIT 4: WRITING FORMATS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Business Letters</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Identify and explain writing strategies for business letters</td>
</tr>
<tr>
<td></td>
<td>• Apply appropriate writing for business letters</td>
</tr>
<tr>
<td></td>
<td>• Apply concepts of business letter writing towards assignment/writing lab</td>
</tr>
<tr>
<td></td>
<td>Performance Objectives, the student will:</td>
</tr>
<tr>
<td></td>
<td>• Assignments: Writing - Business Letters</td>
</tr>
<tr>
<td>4.2 Thesis Statements, Essay Structure, Problem Analysis</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 5 hrs.</td>
<td>• Identify and explain essay structure</td>
</tr>
<tr>
<td></td>
<td>• Discuss purpose and format of thesis statements</td>
</tr>
<tr>
<td></td>
<td>• Develop thesis statements</td>
</tr>
<tr>
<td></td>
<td>• Develop supporting topics and content</td>
</tr>
<tr>
<td></td>
<td>• Explore and document research channels</td>
</tr>
<tr>
<td></td>
<td>• Apply problem analysis, essay, and thesis statement concepts - assignment</td>
</tr>
<tr>
<td></td>
<td>Performance Objectives, the student will:</td>
</tr>
<tr>
<td></td>
<td>• Assignment: Writing - Complete problem-based essay</td>
</tr>
<tr>
<td>4.3 Run-On Sentences, Comma Splices, Fragments, Irregular Verbs, Subject-Verb Agreement</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 3 hrs.</td>
<td>• Identify and correct concepts of run-on sentences, comma splices, and sentence fragments</td>
</tr>
<tr>
<td></td>
<td>• Evaluate and correct irregular verbs and subject-verb agreement</td>
</tr>
<tr>
<td></td>
<td>• Apply concepts taught in the writing lab</td>
</tr>
<tr>
<td></td>
<td>Performance Objectives, the student will:</td>
</tr>
<tr>
<td></td>
<td>• Assignment: Writing Lab</td>
</tr>
<tr>
<td>4.4 Memos and Emails</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td>• Identify and apply formats for writing memos and emails</td>
</tr>
<tr>
<td></td>
<td>• Employ appropriate writing for memos and emails</td>
</tr>
<tr>
<td></td>
<td>• Apply concepts of business memos and emails using assignments/writing lab</td>
</tr>
<tr>
<td></td>
<td>Performance Objectives, the student will:</td>
</tr>
<tr>
<td></td>
<td>• Assignments: Writing effective memos and emails</td>
</tr>
</tbody>
</table>

Notes:
# UNIT 4: WRITING FORMATS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4.6 Effective Visuals</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 3 hrs.</td>
<td>• Identify and use effective visuals as a supplemental resource for communication</td>
</tr>
<tr>
<td></td>
<td>• Discuss appropriate uses for visuals</td>
</tr>
<tr>
<td></td>
<td>• Apply concepts of effective visuals for assignments</td>
</tr>
<tr>
<td></td>
<td><strong>Performance Objectives, the student will:</strong></td>
</tr>
<tr>
<td></td>
<td>• Assignment: Creating and using effective visuals for communication</td>
</tr>
<tr>
<td><strong>4.7 Tense, Subject-Verb-Pronoun Agreement, Focus/Tone, Pronoun Cases</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Identify and correct concepts of tense, s-v-p agreement, focus/tone, pronoun cases</td>
</tr>
</tbody>
</table>

Notes:
## TECHNICAL WRITING

### UNIT 5: SHORT REPORTS, SUMMARIES, FORMAL REPORTS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
</table>
| **5.1 Short Reports, Progress Reports** Lecture - 2 hrs. | The student will be able to:  
• Examine and explain concept, purpose, and format of short reports and progress reports  
• Apply appropriate writing strategies for short reports and progress reports  
• Apply concepts of short reports in assignments/writing lab |
| **5.2 Summaries, Who/whom** Lecture - 1 hr. | The student will be able to:  
• Evaluate the writing concepts and strategies of summaries  
• Explain the difference between using who/whom  
• Apply concepts of who/whom, and summaries using the writing lab |
| **5.3 Punctuation** Lecture - 1 hr. | The student will be able to:  
• Identify and use proper punctuation  
• Analyze past work to identify grammar/punctuation errors and correct them  
• Apply strategies of punctuation using the writing lab |
| **5.4 Parallelism, Shift in Tense, Dangling Modifiers, Grammar Review** Lecture - 2 hrs. | The student will be able to:  
• Identify and use concepts of parallelism, shift in tense, and dangling modifiers  
• Evaluate and explain grammar concepts  
• Apply grammar concepts in writing of formal reports  
• Apply concepts using the writing lab |
| **5.5 Formal Reports** Lecture - 4 hrs. | The student will be able to:  
• Examine and explain concept, purpose, and format of formal reports  
• Employ appropriate writing strategies for formal reports  
• Apply concepts of formal reports in assignments/writing lab |
| **5.6 Final Essay/Report** Lecture - 4 hrs. | The student will be able to:  
• Apply all writing strategies and concepts of effective writing  
• Apply the use of proper grammar  
• Evaluate and apply thesis statements, report content, paragraph structure  
• Analyze problem and use appropriate research  

Notes:
ENGLISH COMPOSITION

COURSE SELECTION GUIDELINES

COURSE TITLE
English Composition

CATALOG DESCRIPTION
This course is designed to provide the student with background in the conceptual and stylistic structures of written composition as well as substantial practice in producing compositions that meet the requirements of college level courses across multiple disciplines.

CREDITS
3 credits, 48 hours

COURSE FORMAT
This course is a presented in a lecture format that includes student engagement in research activities in sustainable and energy-related subjects. Following a recursive writing process, the students will analyze the rhetorical, conceptual, and stylistic demands of writing for a wide spectrum of purposes and audiences.

COURSE NUMBER
Material for this course is presented to meet the requirements for a 100-level course.

PREREQUISITES
Students should possess an appropriate level of reading, writing, and critical thinking skills necessary to complete the assigned projects in the course. Local requirements regarding placement testing and/or developmental education should be considered.

INSTRUCTOR INFORMATION
Recommended Qualifications: A Master’s Degree or higher in English or related field; 3-5 years teaching experience in topic area/academic discipline; experience teaching post-secondary/adult students.

TEACHING METHODS AND ASSIGNMENTS FOR ACHIEVING LEARNING OUTCOMES
Instructor lectures, class discussions, student research, and independent learning are recommended teaching methods. Recursive writing assignments based on research in specific areas that are pertinent to the energy industry are recommended.

COURSE DEVELOPMENT AND CONTEXT
This is foundational course covering English Composition. Courses in this academic discipline are common in community college and junior college course offerings as a general education requirement. In order to provide a framework and context for further study in the technical area of Smart Grid, both research and writing assignments should be founded in subjects that are pertinent to energy, sustainable practices, and or the interaction of man and the environment.
COLLEGE ALGEBRA FOR TECHNOLOGY
COURSE SELECTION GUIDELINES

COURSE TITLE
College Algebra for Technology

CATALOG DESCRIPTION
College Algebra for Technology is a comprehensive study of mathematical skills that have direct application to a variety of technical occupations. This course is part of a logical progression in quantitative reasoning courses; the student should be prepared to apply the material to a pre-calculus or equivalent course. Topics include functions, graphing, and derivation of the elementary properties of linear, quadratic, rational, exponential, and logarithmic functions. Upon completion, students should be able to perform basic computations and solve relevant, multi-step mathematical problems using industry relevant examples and technology.

CREDITS
4.0 credits, 96 hours

COURSE FORMAT
This course is a lecture/exercise format. Industry related exercises and activities pertinent to the energy industry are recommended during in-class, instructor supervised labs.

COURSE NUMBER
Material for this course is presented to meet the requirements for a 100-level course.

PREREQUISITES
Students should possess an appropriate level of quantitative reasoning and critical thinking skills necessary to complete the assigned coursework. Local requirements regarding placement testing and/or developmental education should be considered.

INSTRUCTOR INFORMATION
Recommended Qualifications: A Master’s and/or Bachelor’s Degree in Mathematics, and three to five years of experience teaching post-secondary mathematics; a working knowledge of content, curriculum, methods, materials, and equipment in the career technical specialty that the course will be used, such as Process Technology, Energy Technology, Advanced Manufacturing; experience and ability to develop and implement lessons based on objectives for career technical programs; experience working in a related vocational trade.

COURSE DEVELOPMENT AND CONTEXT
This is foundational course covering topics in College Algebra. Courses in this academic discipline are common in community college and junior college course offerings as a general education, and/or degree specific requirement. In order to provide a framework and context for further study in the technical area of Smart Grid, assignments and exercises should be founded in mathematical concepts that are pertinent to the program.
HISTORY ELECTIVE
COURSE SELECTION GUIDELINES

COURSE DEVELOPMENT AND CONTEXT
Courses that satisfy the history elective generally satisfy the foundational requirement for global, multicultural perspectives. Courses in this academic discipline are common in community college and junior college course offerings as a general education requirement. In order to provide a framework and context for further study in the technical area of Smart Grid, both research and writing assignments should be included in subjects pertinent to the historical perspective of man and the use of energy and sustainable practices.

CREDITS
3 credits, 48 hours

COURSE FORMAT
This course is presented in a lecture format that includes student engagement in research activities in sustainable and energy related subjects.

COURSE NUMBER
Material for these courses is presented to meet the requirements for a 100-level course.

PREREQUISITES
Students should possess an appropriate level of reading, writing, and critical thinking skills necessary to complete the assigned projects in the course. Local requirements regarding placement testing and/or developmental education should be considered.

COURSES THAT MAY BE ADAPTED TO MEET THIS REQUIREMENT
Western Civilization
World History
Global Art
Anthropology
Modern Civilization
SOCIAL SCIENCE
COURSE SELECTION GUIDELINES

COURSE DEVELOPMENT AND CONTEXT
Courses that satisfy the social science elective generally satisfy the foundational requirement for social science, and/or diversification. Courses in this academic discipline are common in community college and junior college course offerings as a general education requirement. In order to provide a framework and context for further study in the technical area of Smart Grid, both research and writing assignments should be included in subjects pertinent to the historical perspective of man and the use of energy and sustainable practices.

CREDITS
3 credits, 48 hours

COURSE FORMAT
The course is presented in a lecture format that includes student engagement in research activities in sustainable and energy-related subjects.

COURSE NUMBER
Material for these courses is presented to meet the requirements for a 100-level course.

PREREQUISITES
Students should possess an appropriate level of reading, writing, and critical thinking skills necessary to complete the assigned projects in the course. Local requirements regarding placement testing and/or developmental education should be considered.

COURSES THAT MAY BE ADAPTED TO MEET THIS REQUIREMENT
Cultural Anthropology
Micro Economics
Macro Economics
Introduction to Political Science
Introduction to Psychology
Workplace Psychology
Introduction to Sociology
American Studies
Cultural Studies
Women’s Studies
ARTS/HUMANITIES/LITERATURE ELECTIVE
COURSE SELECTION GUIDELINES

COURSE DEVELOPMENT AND CONTEXT
Courses that satisfy the arts, humanities, or literature elective generally satisfy the foundational requirement for diversification. Courses in these academic disciplines are common in community college and junior college course offerings as a general education requirement. In order to provide a framework and context for further study in the technical area of Smart Grid, both research and writing assignments should be included in subjects pertinent to the historical perspective of man, and the use of energy and sustainable practices.

CREDITS
3 credits, 48 hours

COURSE FORMAT
The course is presented in a lecture format that includes student engagement in research activities in sustainable and energy-related subjects.

COURSE NUMBER
Material for is presented to meet the requirements for a 100-level course.

PREREQUISITES
Students should possess an appropriate level of reading, writing, and critical thinking skills necessary to complete the assigned projects in the course. Local requirements regarding placement testing and/or developmental education should be considered.

COURSES THAT MAY BE ADAPTED TO MEET THIS REQUIREMENT:

<table>
<thead>
<tr>
<th>ART</th>
<th>HUMANITIES</th>
<th>LITERATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two or Three dimensional Art</td>
<td>Philosophy</td>
<td>American Literature</td>
</tr>
<tr>
<td>Introduction to Design</td>
<td>American Studies</td>
<td>World Literature</td>
</tr>
<tr>
<td>Drafting</td>
<td>Religion</td>
<td>Film Studies</td>
</tr>
<tr>
<td>Photography</td>
<td>Western Civilizations</td>
<td>Regional Literature</td>
</tr>
<tr>
<td>Computer Aided Design CAD</td>
<td>Eastern Civilizations</td>
<td>Classical Literature</td>
</tr>
<tr>
<td>Dance</td>
<td></td>
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<tr>
<td>Acting</td>
<td></td>
<td></td>
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<tr>
<td>Music</td>
<td></td>
<td></td>
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<tr>
<td>Drama</td>
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</tr>
</tbody>
</table>
INTRODUCTION TO SMART GRID

COURSE GUIDE

COURSE TITLE
Introduction to Smart Grid

CATALOG DESCRIPTION
This abbreviated, presentation style course is designed to give the student a broad, non-technical overview of the Smart Grid concept as it applies to utility grid systems. The course will familiarize the student with what the basic features and capabilities and current topics related to the development and deployment of smart grid technologies.

CREDITS
1.0 credit, 15 hours

COURSE FORMAT
This course provides informational lectures on various topics related to the power grid as it exists today, and describes the features, systems, and functions of a Smart Grid.

COURSE NUMBER
Material for this course is presented to meet the requirements for a single credit, introductory course.

PREREQUISITES
Basic English Comprehension

INSTRUCTOR INFORMATION
Recommended Qualifications: Master’s Degree in Electronics, Information Systems, or related field; experience in systems management; 3-5 years working experience in related industry; working knowledge and background in subject/topic area; experience teaching secondary, or post-secondary/adult students.

STUDENT LEARNING OUTCOMES
Upon successful completion of this course students will be able to:

● Explain the basic concept of the electrical power grid architecture
● Describe basic features of Smart Grid
● Describe the need for, and advantages of modernizing the present electrical power grid
● Explain the basic functionality and capabilities of Smart Grid technologies
● Describe current Smart Grid deployment projects
TEACHING METHODS AND ASSIGNMENTS FOR ACHIEVING LEARNING OUTCOMES

Each topic has a recommended length (topic hours) assigned. Topic hours are a guideline for instruction that is intended to be adapted to the individual instructor’s teaching style. Students are expected to spend additional study/practice time outside of the class time. The generally accepted ratio of class to study time is 1:1 for this course.

The student may be assigned a short research paper on an assigned topic relating to Smart Grid. Additionally, the student may be assigned to provide an in-class presentation on the research topic.
# ASSESSMENT RUBRIC

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>EXEMPLARY 4</th>
<th>SATISFACTORY 3</th>
<th>DEVELOPING 2</th>
<th>BEGINNING 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Grid Concepts and Components</td>
<td>Demonstrates thorough and complete understanding of electrical grid concept/components</td>
<td>Demonstrates adequate amount understanding of electrical grid concept/components</td>
<td>Demonstrates some understanding of electrical grid concept/components</td>
<td>Demonstrates limited understanding of electrical grid concept/components</td>
</tr>
<tr>
<td>Features of Smart Grids</td>
<td>Accurately describes the features of Smart Grids</td>
<td>Satisfactorily describes the features of Smart Grids</td>
<td>Describes some, or a few features of Smart Grids</td>
<td>Limited ability to describe features of Smart Grids or unable to describe any Smart Grid features.</td>
</tr>
<tr>
<td>Advantages of Smart Grids</td>
<td>Explains clearly and accurately the positive and negative attributes of Smart Grid Technology</td>
<td>Explains the general positive and negative attributes of Smart Grid Technology</td>
<td>Explains some of the positive and negative attributes of Smart Grid Technology</td>
<td>Explains limited information of the positive and negative attributes of Smart Grid Technology</td>
</tr>
<tr>
<td>Operation of Smart Grids</td>
<td>Able to explain and expand on all the functions and capabilities of Smart Grids</td>
<td>Explains the general functions and capabilities of Smart Grids</td>
<td>Explains some of the general functions and capabilities of Smart Grids</td>
<td>Has limited ideas about the functions and capabilities of Smart Grids</td>
</tr>
<tr>
<td>Features of Current Smart Grid Developments</td>
<td>Accurately outlines the features of current Smart Grid projects</td>
<td>Generally outlines the features of current Smart Grid projects</td>
<td>Outlines some of the features of current Smart Grid projects</td>
<td>Expresses limited information about current Smart Grid projects</td>
</tr>
</tbody>
</table>

Notes:
## UNIT 1: INTRODUCTION TO SMART GRID

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Electrical Grid, History of the Grid</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 1 hr.</td>
<td>1. Explain the history of a traditional electric grid 2. Explain basic power generation, transmission, and distribution 3. Compare and discuss the challenges that the current grid presents</td>
</tr>
<tr>
<td>1.2 Defining a Smart Grid</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>1. Describe features of the smart grid 2. Identify smart grid characteristics</td>
</tr>
<tr>
<td>1.3 Smart Grid Basics, Electric Grid – Supply and Demand</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>1. Explain the supply and demand needs of a traditional utility grid system 2. Identify the components of a smart grid 3. Discuss how the concept of smart grids will evolve 4. Identify the issues presented in smart grids</td>
</tr>
<tr>
<td>1.4 Smart Meters, Purpose of Smart Meters</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>1. Explain the purpose of smart meters 2. Discuss the use of AMI (Advanced Metering Infrastructure) 3. Demonstrate understanding of the fundamentals of a HAN (home area network)</td>
</tr>
<tr>
<td>1.5 SCADA Systems</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>1. Explain basic functions of a SCADA system 2. Explain the system components of a SCADA system</td>
</tr>
<tr>
<td>1.6 Distributed Generation (DG)</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>1. Explain renewable Distributed Generation technologies 2. Explain the benefits of Distributed Generation</td>
</tr>
<tr>
<td>1.7 Current Smart Grid Deployments</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>1. Explain the current deployments of a Smart Grid</td>
</tr>
<tr>
<td>1.8 Student Presentations</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>2 hrs.</td>
<td>1. Provide a 5 minute presentation on a selected topic related to a Smart Grid</td>
</tr>
</tbody>
</table>

Notes:
SMART GRID COOPERATIVE EDUCATION
COURSE DESIGN GUIDE

COURSE TITLE
Cooperative Education/Externship

CATALOG DESCRIPTION
This course provides students with instruction and hands-on work experience in an industry setting. Participating students will have an opportunity to apply the knowledge and skills gained in the classroom to real work experience in a related industrial environment.

CREDITS
3.0 credits, 48 hours

COURSE FORMAT
This course is a lecture/lab format that incorporates actual work performed on-site at the location of an industry partner.

COURSE NUMBER
Material for this course is presented to meet the requirements for a 200-level course.

PREREQUISITES
Successful completion of an approved certificate or degree program course of study.

Pre-requisite course material for the externship will vary depending upon the degree or certificate program.

It is recommended to develop and implement an application process for acceptance into an externship. The application should address, background information, ability to gain access to controlled industrial areas, transportation to and from the off-site location and other logistic issues. Applicants should include a recommendation for program participation from faculty or instructional program advisors.

INSTRUCTOR INFORMATION
Recommended Qualifications: Post-secondary workforce development program coordinator or cooperative education coordinator with three to five years of experience. A pre-established relationship with industry partners who participate in an advisory group or other forum that links the program with industry. The coordinator should act as a liaison and have input on and ability to guide the teaching faculty on matters that pertain to advances in the industry.
TEACHING METHODS AND ASSIGNMENTS FOR ACHIEVING LEARNING OUTCOMES

The course is divided into four units. The initial application and acceptance process will be assessed. Students will attend lectures, safety briefings, and fulfill acceptance/employment requirements according to the work site assigned.

While the students are working, they attend weekly/bi-weekly conferences with their cooperative education coordinator. Students will keep periodic logs of work performed and specific tasks completed using a qualification standard format.

A final project and written report will be due at the conclusion of the on-site work.

The better knowledge that a student has of the formats and approaches commonly used in the technical working environment, the more likely the ideas will have a positive impact. Students will work with many forms of business writing, learning how to structure comments, suggestions, and arguments to seek agreement with the presented ideas. The course has 10 writing assignments. The assignments should focus on technical issues and graded on format of presentation, adequate discussion, appropriate content, logical connection of ideas, smooth sentence flow, and technical accuracy. Grammar assignments may be assigned using Pearson’s MyWritingLab.

STUDENT TEXTS, READING AND OTHER MATERIALS

- Industry provided safety and emergency procedures manuals
- Personal Protective Equipment PPE instruction and use manuals
- Rules of professional conduct

BIBLIOGRAPHY

None

STUDENT LEARNING OUTCOMES

Upon successful completion the student will have the ability to:

- Demonstrate the ability to assess individual skills and capabilities
- Demonstrate the ability to communicate individual skill and capabilities in written and oral format
- Demonstrate job performance skills in an industrial environment, including but not limited to positive work habits, understand and follow written and oral directions, adhere to appropriate normal operating procedures, recognize hazards and respond to appropriate emergency procedures, and apply the use of industry related tools and equipment
- Demonstrate the ability to complete and submit a work performance evaluation
FUNDAMENTALS OF DISTRIBUTION AUTOMATION
COURSE DESIGN GUIDE

COURSE TITLE
Fundamentals of Distribution Automation

CATALOG DESCRIPTION
This course expands upon the integration of intelligent energy systems to explore advanced topics in distribution automation. By examining a conceptual model of distribution automation as well as the equipment, systems and processes involved, students will gain an understanding of the social, cultural, and economic impact of implementing disruptive innovation. Throughout the course, students will examine case studies of DA application projects, finishing with the development of a project business case for implementing the technology.

CREDITS
3.0 credits, 48 hours

COURSE FORMAT
This course is a lecture/case study format that incorporates the examination of project examples to provide context to the challenges of implementing disruptive innovation. The students will participate in a team-based final project to develop a business case, cost benefit analysis, and project plan for a distribution automation project.

COURSE NUMBER
Material for this course is presented to meet the requirements for a 200-level undergraduate course.

PREREQUISITES
Intelligent Energy Systems Interoperability, Macro Economics, Managerial Economics or Equivalent

INSTRUCTOR INFORMATION
Recommended Qualifications: Master’s degree or higher in power engineering or related field.
TEACHING METHODS AND ASSIGNMENTS FOR ACHIEVING Learning Outcomes

Lecture/case study format

STUDENT TEXTS, READING AND OTHER MATERIALS

Microgrids and Active Distribution Networks

BIBLIOGRAPHY


STUDENT LEARNING OUTCOMES

Upon successful completion the student will have the ability to:

• Evaluate the properties of legacy and intelligent grid systems
• Integrate a conceptual model of a distribution automation system
• Outline the equipment and systems of a distribution automation system
• Develop the methodology and process for data handling and collection in a distribution automation system
• Evaluate the characteristics of a distribution automation system
• Implement a distribution automation system
• Develop a business case for the implementation of a distribution automation system
## ASSESSMENT RUBRIC

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>EXEMPLARY 4</th>
<th>SATISFACTORY 3</th>
<th>DEVELOPING 2</th>
<th>BEGINNING 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluate Legacy Systems</td>
<td>Demonstrates excellent research techniques, writing, editing, and proofing skills</td>
<td>Demonstrates adequate research techniques, writing, editing, and proofing skills</td>
<td>Demonstrates essential research techniques, writing, editing, and proofing skills</td>
<td>Demonstrates limited or no research techniques, writing, editing, and proofing skills</td>
</tr>
<tr>
<td>Integrate Conceptual Model</td>
<td>Illustrative application of all areas and concepts of the writing process</td>
<td>Average application of some areas and concepts of the writing process</td>
<td>Shows basic application of some areas and concepts of the writing process</td>
<td>Shows fundamental use of limited areas and concepts of the writing process</td>
</tr>
<tr>
<td>Equipment and Systems</td>
<td>Effectively puts to use the various approaches and forms of technical writing formats</td>
<td>Competently puts to use the various approaches and forms of technical writing formats</td>
<td>Low-level use of the various approaches and forms of technical writing formats</td>
<td>Rudimentary use of the various approaches and forms of technical writing formats</td>
</tr>
<tr>
<td>Develop DA Methodologies</td>
<td>Demonstrates clear comprehension and application of writing structures and patterns</td>
<td>Demonstrates fair comprehension and application of writing structures and patterns</td>
<td>Demonstrates basic comprehension and application of writing structures and patterns</td>
<td>Demonstrates limited or no comprehension and application of writing structures and patterns</td>
</tr>
<tr>
<td>Business Case</td>
<td>Shows mastery of grammar and proper use of citations in writing</td>
<td>Shows sound use of grammar and proper use of citations in writing</td>
<td>Shows essential use of grammar and proper use of citations in writing</td>
<td>Shows fundamental use of grammar and proper use of citations in writing</td>
</tr>
</tbody>
</table>

Notes:
### UNIT 1: OVERVIEW OF DISTRIBUTION AUTOMATION

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.1 Smart Grid Model</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Name and describe the three major components of the smart grid.</td>
</tr>
<tr>
<td></td>
<td>• Describe the properties of the smart grid.</td>
</tr>
<tr>
<td><strong>1.2 Properties of Incorporated Systems</strong></td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Explain the benefit of configuring and controlling a power system to be self-healing.</td>
</tr>
<tr>
<td></td>
<td>• Describe the increasing role of distributed generation.</td>
</tr>
<tr>
<td></td>
<td>• Describe the limitations on the current distribution system to handle distributed generation.</td>
</tr>
<tr>
<td></td>
<td>• Distinguish between traditional and renewable generation sources.</td>
</tr>
<tr>
<td></td>
<td>• Understand the need for consumer engagement in the implementation of distributed generation.</td>
</tr>
<tr>
<td></td>
<td>• Define energy efficiency.</td>
</tr>
</tbody>
</table>

Notes:
# UNIT 2: POWER SYSTEMS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Power System – Grid System</td>
<td>The student will be able to:                                                                                      • Describe capabilities and limitations of the current power system.</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Explain the relationship that generation transmission and distribution system have as part of a functioning power system.</td>
</tr>
<tr>
<td></td>
<td>The student will be able to:                                                                                      • Describe the current process or methodology used to provide reliability controls in the power system.</td>
</tr>
<tr>
<td></td>
<td>• Explain current methods for controlling the voltage in a power system.</td>
</tr>
</tbody>
</table>

Notes:
<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Functional Block Diagram</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>• Explain the processes required for distribution automation.</td>
</tr>
<tr>
<td></td>
<td>• Build a functional block diagram of a DA System.</td>
</tr>
<tr>
<td>3.2 Overview and Overlay on a</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Legacy System</td>
<td>• Explain the changes required to implement distribution automation in the</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td>power system</td>
</tr>
<tr>
<td>3.3 Distribution Automation</td>
<td>The student will be able to:</td>
</tr>
<tr>
<td>Outcomes</td>
<td>• Describe self-healing (for reliability)</td>
</tr>
<tr>
<td>Lecture - 3 hrs.</td>
<td>• Describe Voltr/VAR Optimization</td>
</tr>
</tbody>
</table>

Notes:
# UNIT 4: DISTRIBUTION AUTOMATION EQUIPMENT AND SYSTEMS

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Physical</td>
<td>The student will be able to:&lt;br&gt;• Describe the physical equipment/devices used to provide self healing for distribution automation.&lt;br&gt;• Describe the physical equipment/devices used to provide volt/var optimization for distribution automation.</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td></td>
</tr>
<tr>
<td>4.2 Communications</td>
<td>The student will be able to:&lt;br&gt;• Describe the media available for providing communication between the equipment/devices and the central control station.&lt;br&gt;• Describe the methods available for providing communication between the equipment/devices and the central control station.</td>
</tr>
<tr>
<td>Lecture - 3 hrs.</td>
<td></td>
</tr>
<tr>
<td>4.3 Controls</td>
<td>The student will be able to:&lt;br&gt;• Describe the automated control methods used to provide self healing.&lt;br&gt;• Describe the automated control methods used to provide volt/var optimization.</td>
</tr>
<tr>
<td>Lecture - 2 hrs.</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
## UNIT 5: DATA HANDLING AND COLLECTION

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
</tr>
</thead>
</table>
| **5.1 Collection Methodology**  
Lecture - 3 hrs. | The student will be able to:  
- Identify the major system components for data handling and collection.  
- Explain the function of each component for data handling and collection. |
| **5.2 Collection Process**  
Lecture - 3 hrs. | The student will be able to:  
- Describe the role of the DMS.  
- Describe the control functions that the DMS can provide. |
| **5.3 Data Handling and Collection Outcomes**  
Lecture - 3 hrs. | The student will be able to:  
- Describe the indexes used to measure effectiveness of distribution automation controls.  
- Explain the differences between the indexes: SAIDI, SAIFI, and CAIDI. |

Notes:
### UNIT 6: DYNAMIC MODELING AND IMPLEMENTATION OF DISTRIBUTION AUTOMATION

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES</th>
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| **6.1 Dynamic Modeling of Distribution Automation** | The student will be able to:  
  • Describe the processes to implement to achieve reliability controls in the smart grid.  
  • Describe the processes to implement to achieve efficient voltage level control. |
| Lecture - 5 hrs.                             |                                                                            |
| **6.2 Implementation of Distribution Automation** | The student will be able to:  
  • Describe the operation of self-healing properties of the smart grid.  
  • Address the issues that arise in the implementation of a distribution automation system. |
| Lecture - 4 hrs.                             |                                                                            |
| **6.3 Business Case**                       | The student will be able to:  
  • Describe the benefits of distribution automation for the utilities.  
  • Describe the benefits of distribution automation for the consumer.  
  • Understand how to implement a distribution automation project. |
| Lecture - 8 hrs.                             |                                                                            |

Notes:
PART IV

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