AC 2007-473: INTRODUCTION OF NEW AND COST EFFECTIVE TECHNOLOGIES IN THE ENT POWER LABORATORY

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Introduction of New and Cost Effective Technologies in the ENT Power Laboratory

Abstract

Power systems is an important component of a well-rounded electrical engineering technology program. However, since power systems tends to be a rather complex topic, students react positively to hands-on experiments that assist them visualize power systems in practical situations, and, in today's technology, utilizing and integrating computers within loop is essential. Electrical power engineering has for many years been taught in a rather traditional manner. Laboratory equipment is based on large test sets using analogue instrumentation. Computerization of these teaching laboratories that allows data acquisition and display of data has not been widely used. It should be noted that developing a fully functional high voltage Power Systems Lab that would cover all the various areas of power and their control systems would require a large facility and hundreds of thousands of dollars and possibly into the millions dollars[1]. A number of Universities work in conjunction with large power companies to subsidize the cost of these larger laboratories[2].

An innovative power system laboratory has been developed in our department of engineering technology to fill this need. The **UNItrain-I® Training Platform** is the new standard for State-of-the-Art instruction and experimentation. Captivating Computer Aided Instruction (CAI) provides a basic overview of theory under study, complementing the eLearning Courseware, and includes animated instructions on experimental procedures, incorporates UNItrain-I Courseware into Learning Management System or use LabSOFT to edit, manage, and deliver content & control student access. The system includes a diverse collection of experimental and theoretical courses. Students can choose between a wide range of turnkey experiment cards with patching cords, or breadboard packages that include all necessary components. The extensive suite of PC Based Virtual Instruments allows students to conduct real-time measurements with Data Acquisition via computer's USB or RS232 port. The system is WEB COMPATIBLE; **it u**ses LabSOFT to manage Courses over the Internet or link with your School IMS for web-based content. Furthermore, it can be used as Distance Learning Lab that includes Robust Platform Engaging CAI Virtual Instruments, Optional Breadboard and Design Software. The Virtual Instruments Include: Analog & Digital Multimeters, Oscilloscope, Spectrum Analyzer, Function Generator, Logic Analyzer, AC/DC Power Supplies, Relay Control, Digital I/O Monitors, Frequency Analyzer, Frequency Counter, Power Vector Display, Bode Plots, Step Response and more . . .

The Trainer is complete with the necessary power supplies, loading and testing devices and PC virtual instrumentation for the metering of all system values.
Detailed laboratory notes are provided, which cover experimental operation and practical training on**:** Electrical Technology, Single Phase Transformers, Three Phase Transformers, DC Machines, AC Single Phase and Three Phase Machines, Machine Loading Systems, Instrumentation, Electromagnetic Motor Control. It allows the investigation of various starting and controlling techniques. A low power, industrial motor system is used in demonstrating the

minimum control functions for speed control of a three-phase induction motor as well as control of DC motors.

This State-of-the-Art technology allowed our department to develop a power laboratory for less than 5% cost of traditional laboratory that does not require an oversized space. Furthermore, it is portable and will be very suitable for underdeveloped countries where they have limited resources.

Introduction

The Department of Engineering Technology at the University of Central Florida has been involved in teaching power systems concepts since its inception. Over the years, this commitment has evolved into a four-credit upper division course, EET4548.

This course introduces the following areas of study[3]:

- Various types of energy sources and the conversion methods of electrical energy
- Electrical, Magnetic, Electromagnetic Circuits and Power Concepts
- Single and Three-Phase Transmission
- Rotating Machines, Generators, Motors, DC Machines and their operational characteristics
- Signal and Three Phase induction motors.

This course originally was taught the traditional lecture only fashion due to the lack of laboratory equipment. The traditional approach of teaching power systems without the use of laboratory experiments ignores the student's needs of applying their theoretical knowledge to real world situations. Using only examples from textbooks or lectures the students are only utilizing equations, block diagrams and schematics to gain an understanding of a very important and complex subject.

Even simple DC Machines, three phase circuit loads and electromagnetic principles can be very abstract in nature when described only in mathematical terms. Experiments and demonstrations aid the students in their comprehension of theoretical concepts and allow them the ability to study the subject in a realistic situation. In addition, power systems and electromagnetic hardware under operation is a necessary component in a student's educational experience in understanding the subject matter.

To accomplish this objective, the following are essential ingredients for the EET4548 power laboratory:

1. Experiments that cover the different types of three-phase sources and loads
2. Experiments showing the basic theory of magnetism and electromagnetism
3. Transformer theory and operation
4. Relay operation
5. DC Machine principles and operation
6. Armatures and Exciters

7. Motor and Generator Theory and operation
8. Asynchronous Machines Magnetic Fields and Rotation

There are a variety of types of power system experiments that are required to expose the students to a broad range of on-hands knowledge for the subject. Each experiment must provide the student with physical and visual outputs so that they can easily see and understand the performance and effects of varying frequency, voltage levels and loads. In addition, due to budget constraints each lab setup must be economical and relatively easy to develop. Each system needs to be easy and fun to use, while providing sound educational principles for power systems.

Based on aforementioned reasons, a power systems laboratory was established and the course was changed from three-credit to four-credit course.

The following are a few of the commercially available trainers that were reviewed:

- USDiatic
- Lab-Volt Systems Inc.
- RTDS Technologies Inc

The decision was made to equip this laboratory with three UniTrain-1 Training System that utilizes hardware and a computer interface to perform the experiments[4]. Each training system consist of four sets of experimenter cards, single-phase power supply, three-phase power supply and various types of rotors, stators and transformers. The computer interface is via a USB connection and allows the student to change parameters in the experiments and utilize the built in virtual measuring devices such as digital multi-meters, analog meters and oscilloscope. The system also has test points so that actual test equipment can also be used to make measurements.

The training system also allows for expansion in the future to cover other areas of study concerning power as well as digital processes, control systems etc. Therefore, since the initial intention for this laboratory is to illustrate and give students hands-on experience in the power system field, the UniTrain-1 Training System is the best candidate for this purpose.

Overview of Current Laboratory Experiments

The lab manual is divided into four categories of study, Three Phase Technology, Magnetism/Electromagnetism, DC Machines and Asynchronous Machines. The beginning of each major section starts with an overview of the study material and training objectives. Currently, the Power Systems course, EET4548 includes the following experiments in the 172 page-laboratory manual utilizing both hardware and software:

- Introduction
- Safety Notes
- System Overview
- Equipment Handling
- How to utilize the software package and hardware

- Lab #1 - Measurements on a Three-Phase Generator
- Lab #2 - Measurements on a wye circuit
- Lab #3 - Measurements on a delta circuit
- Lab #4 - Measurement of power in wye and delta circuits
- Lab #5 - Electromagnetism Experiments
- Lab #6 - Transformer Operation
- Lab #7 - Transformer under load
- Lab #8 - Relay Switching
- Lab #9 - DC Machines Principles and Construction
- Lab #10 - Shunt Wound Machines
- Lab #11 - Series, Universal and Compound Machines
- Lab #12 - Armatures and Exciters
- Lab #13 - Normal Operation and Starting Resistors
- Lab #14 - Asynchronous Machines Magnetic Fields and Rotation
- Lab #15 - Asynchronous Machines Squirrel Cage Motors
- Lab #16 - Synchronous and Capacitor Machines
- Lab #17 - Variable Transformers

The following is a brief description of the material in each Lab:

Lab 1 – Measurements on a Three-Phase Generator

1. Measure line and phase voltages in a three-phase network utilizing a multi-meter and oscilloscope
2. Determine and identify the relationships between the voltages
3. Explain the phase relationship between the voltages

Lab 2 – Measurements on a wye circuit

1. Demonstrate the relationship in a wye network, 4 wire network and a 3 wire network for symmetric, asymmetric and capacitive loads
2. Determine the influence of an asymmetric load on a wye network
3. Determine the compensating voltages in the neutral line and explain the effects of breaks in the neutral line

Lab 3 – Measurements on a delta circuit

1. Demonstrate the effects on a delta network utilizing symmetric, asymmetric and capacitive loads
2. Distinguish the difference between symmetric and asymmetric loads
3. Investigate the effects of phase impedance

Lab 4 – Measurement of power in wye and delta circuits

1. Determine power in a three-phase system utilizing line and phase values for both wye and delta circuits
2. Perform power measurements in a three-phase load
3. Conversion principles from wye to delta circuits

Lab 5 – Electromagnetism Experiments (8 experiments and a test)

1. Determine if the magnetic field of a looped current carrying conductor is greater or less than a straight current carrying conductor
2. Demonstrate magnetic properties and the distribution of magnetic field lines
3. Compare the properties of a coil with and without a ferrite core

4. Properties of a coil with a permanent magnet core

Lab 6 – Transformer Operation (2 experiments)

1. Evaluate the power transmission of a transformer with and without an iron core, and determine if the core has any effect
2. Utilize AC voltage applied to the primary of a transformer; measure the primary and secondary voltages to determine the transformer ratio

Lab 7 – Transformer under load (1 experiment and transformer test)

1. Measure the output voltage of a transformer with varying loads; plot voltages and evaluate the results

Lab 8 – Relay Switching (3 experiments and relay test)

1. Evaluate the operation of relays
2. Monitor induction spikes in the switching of a relay

Lab 9 – DC Machines Principles and Construction (4 experiments)

1. Measure the resulting forces and determine the optimum angle between the rotor and stator magnetic field
2. Utilize voltage and current measurements to determine the resistance of a stator, rotor and carbon brushes

Lab 10 – Shunt Wound Machines (2 experiments)

1. Evaluate the operation of a shunt wound machine
2. Utilize a stroboscope to measure the rotation speed of a DC shunt wound machine
3. Observe the effects in a DC shunt wound machine when the brushes are shifted

Lab 11 – Series, Universal and Compound Machines (4 experiments)

1. Evaluate the operation of series, universal and compound wound machines

Lab 12 – Armatures and Exciters (4 experiments)

1. Evaluate the influence of the armature series resistance on the rotation speed in a DC series wound machine
2. Evaluate the influence of the armature voltage on the rotation speed in a DC shunt wound machine
3. Evaluate the influence of the exciter on the rotation speed in a DC shunt wound machine

Lab 13 – Normal Operation and Starting Resistors (5 experiments)

1. Utilizing relays to demonstrate that the starting current can be reduced by using starting resistors
2. Measure the temperature of the exciter winding

Lab 14 – Asynchronous Machines Magnetic Fields and Rotation (7 experiments)

1. Use a permanent magnet rotor to demonstrate the existence of a magnetic field inside the stator
2. Utilize a permanent magnet rotor to demonstrate a synchronously rotation with a revolving magnetic field
3. Evaluate the difference between delta and star configurations
4. Utilize a permanent magnet rotor to evaluate its use as a three-phase generator

Lab 15 – Asynchronous Machines Squirrel Cage Motors (3 experiments)

1. Measure the response of the stator winding at various frequencies
2. Reverse the rotation direction by interchanging two of the phase windings

Lab 16 –Synchronous and Capacitor Machines (3 experiments)

1. Evaluate some of the problems associated with starting a synchronous machine

2. Utilize a variable three-phase source and demonstrate how the power of a squirrel cage or synchronous machine can be enhanced in a delta configuration
3. Utilize a capacitor an single phase AC in a delta configuration to start a squirrel cage motor

Lab 17 – Variable Transformers (4 experiments)

1. Utilize a three-phase voltage source to demonstrate the secondary winding of a transformer is independent of the rotor's rotation position
2. Evaluate the influence of the stator currents on the winding temperature

UniTrain-1 Training System to perform measurements on a Three-Phase Generator

In this experiment the voltage relationship and phase relationship of a Three-Phase Generator is analyzed. The line and phase voltages will be measured utilizing the virtual digital multi-meter and oscilloscope. The virtual three-phase power supply controller as shown in Figure 1 controls the voltage level and frequency.

Figure 1

This experiment shows how to:

- Measure and distinguish voltages in a three-phase network.
- Determine and identify the relationships between the voltages.
- Measure and explain the phase displacement angle between the voltages.

Figure 2 is an example of the virtual oscilloscope with a single-phase signal input.

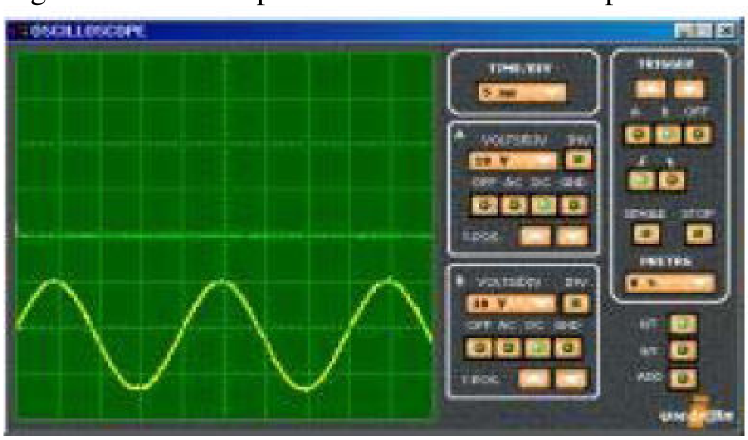
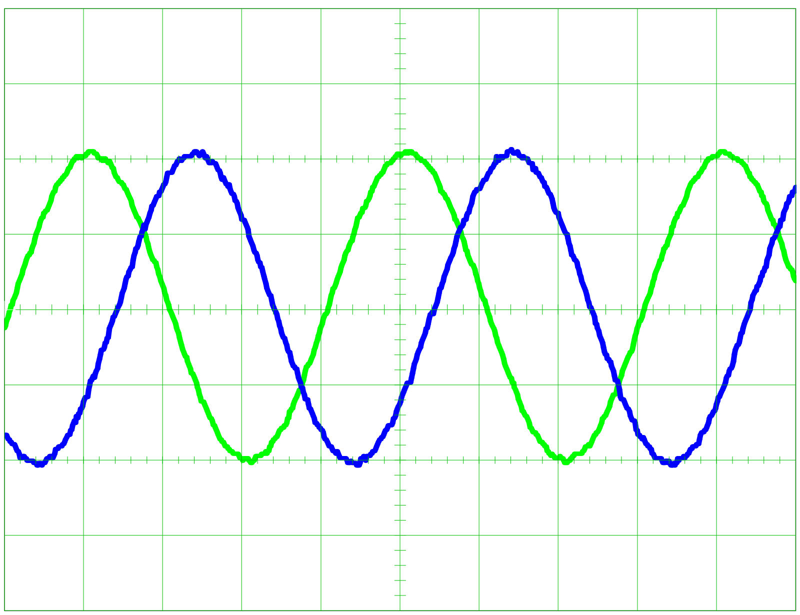


Figure 2

The student connects the equipment per the instructions in the lab manual using the appropriate experimenter card. Then they turn on the power supply and set the voltage and frequency levels following the lab instructions. After the scope is connected and the signals are displayed on the oscilloscope, the student then is able to drag it on to a plot. Figure 3 shows the voltage and phase relationship between $\mathbf{V_{1N}}$ and $\mathbf{V_{2N}}$ of the three-phase generator. Then the student can draw a sketch in their lab manual for future reference.

After performing the voltage and frequency measurements between $\mathbf{V_{1N}}$ and $\mathbf{V_{2N}}$, the same measurements are made between $\mathbf{V_{1N}}$ and $\mathbf{V_{3N}}$, so that the student is able to see the relationship between the three phases.



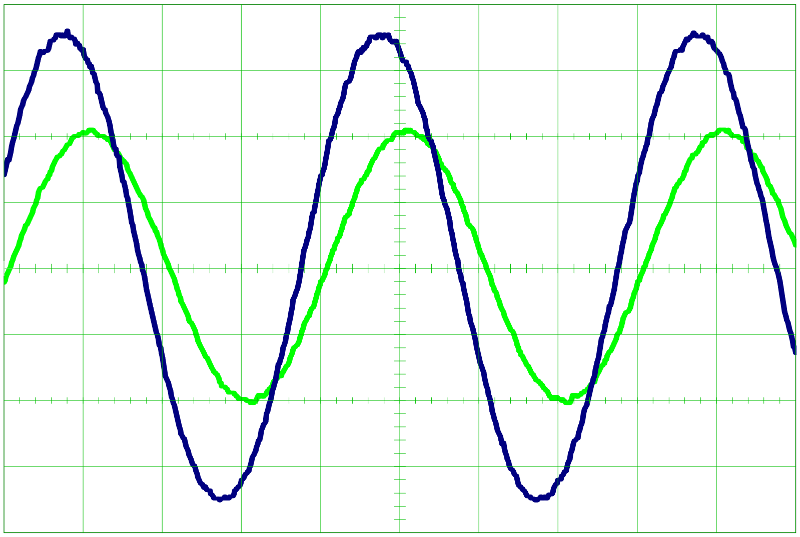
Time/Div: 5mS

Chan A/Div: 5V

Chan B/Div: 5V

Figure 3

Then measurements are made between each phase $\mathbf{V_{12}}$, $\mathbf{V_{23}}$, $\mathbf{V_{31}}$, Figure 4 shows the relationship between $\mathbf{V_{12}}$ and $\mathbf{V_{23}}$.



Time/Div: 5mS

Chan A/Div: 5V

Chan B/Div: 5V

Figure 4

Using the measurements made by the student's they are then able to answer questions as part of the experiment and also verify their theoretical calculations. Figure 5 shows the set up for three phase measurement. Figure 6 shows the Stator measurements of Asynchronous Machines (Squirrel Cage Motor)

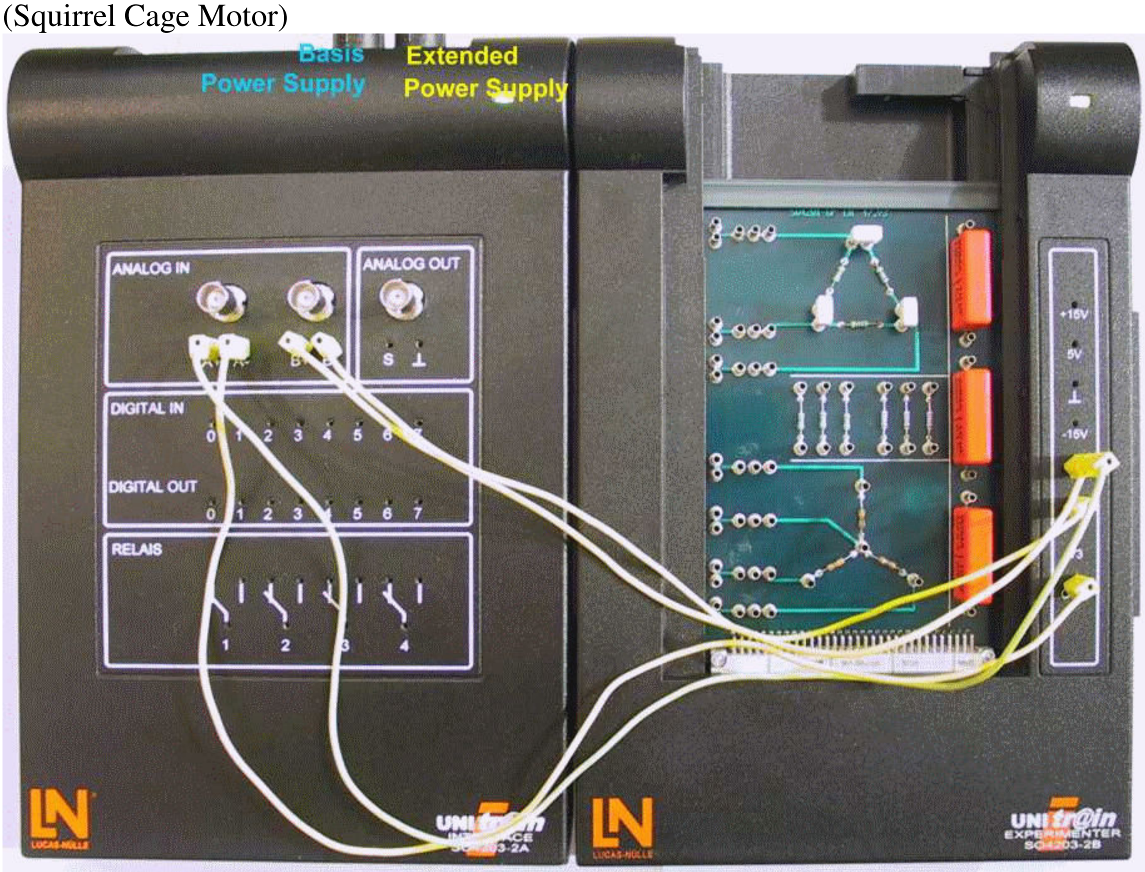


Figure 5. Set up for Measurements on a Three-Phase Generator

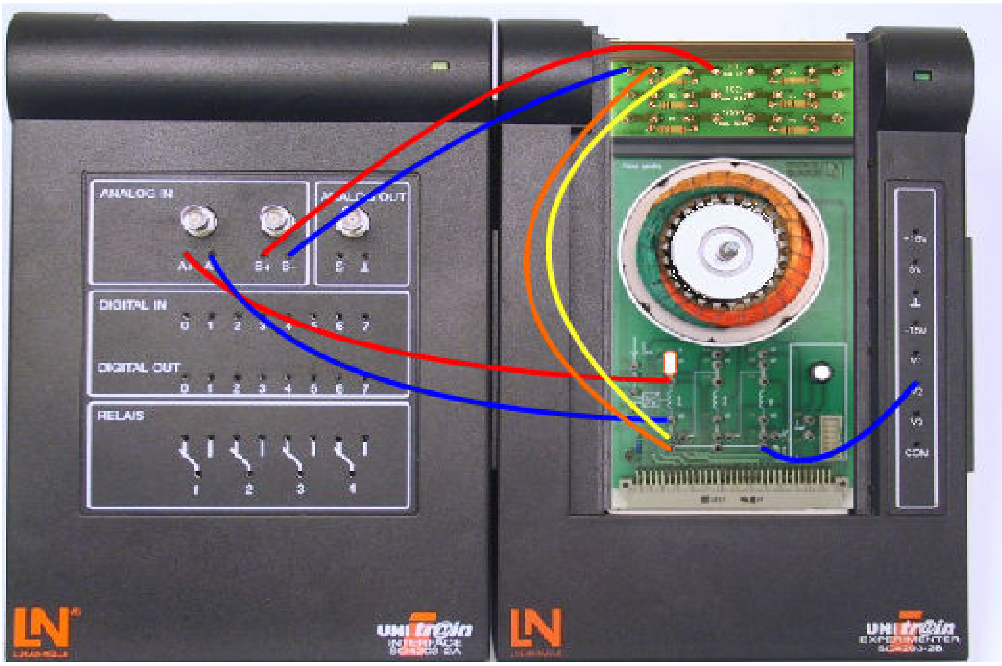


Figure 6. Stator measurements Asynchronous Machines (Squirrel Cage Motor)

References

[1] <u>Power Systems</u>, by David Salvia, appears on the Penn State Electrical Engineering *Areas of Specialization Within EE, http://www.ee.psu.edu/undergradareas.asp#power%20systems Web page*, June 2001

[2] <u>Power Systems Laboratory,</u> by Dr. A. Gole, P.E., appears on the University of Manitoba Electrical and Computer Engineering, Web Page http://www.ee.umanitoba.ca/research/power.html

[3] Juan L. Bala Jr., Zia A. Yamayee, *Electromechanical Energy Devices and Power Systems,* Gonzaga University: John Wiley & Sons Inc., Copyright, 1994.

[4] USDidactic home page http://www.usdidactic.com/