Integrated Electrical Laboratory with Internet-based Distance Learning Capabilities

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1. Introduction

Students of electric power technology and electric machines traditionally perform hands-on activities in a physical laboratory. Using Lab-Volt's standard electrical power training system (EMS), students are guided by instructional manuals to set up modular components, make electrical connections among various components, and perform measurements and experiments on the actual, physical equipment. An enhancement was made by integrating existing Lab-Volt's electromechanical modules, Lab-Volt simulation software (LVSIM), and additional modules to create a state-of the art laboratory.
This additional equipment includes:

- Data Acquisition and Management System (consists of Data Acquisition Interface, or DAI, Advantech PCL 711b data acquisition card, cable, and software);
- Prime Mover/Dynamometer(Digital)

Students are able to power up the equipment and set the operating levels of parameters such as voltage, current, torque and speed. A built-in link with Lab-Volt's Data Acquisition and Management system (LVDAM) enables students to obtain real-time measurements on all operating parameters. In other words, LVDAM allows substituting analog meters on the physical panels by more accurate digital meters on the computer screen. Moreover, such parameters, as speed, torque, power factor, apparent power, and a number of programmable meters, which were not readily available before, can be easily displayed.
Excellent recording and graphing capabilities, virtual four-channel oscilloscope, and phasor analyzer allow time allocated for typical experiments in Electric Machines course to be reduced twice, e.g. twice as many laboratory exercises can be done during the coursework.

Typically, electromechanical equipment that can operate separately from an array of other devices and installations does not exist. This includes motor control apparatus (electromechanical and digital), programmable logic controllers (PLC), and power electronics devices among others. Obviously, it is necessary to integrate and coordinate curricula and laboratory exercises in various electrical engineering disciplines.
A block diagram of the possible integration is shown in Figure 1. This integration allows utilization of existing equipment more effectively, reducing costs for laboratory enhancement, as well as demonstrating integration and coordination of real-life engineering processes. It also allows instructions on the processes to take place at the junction of disciplines.

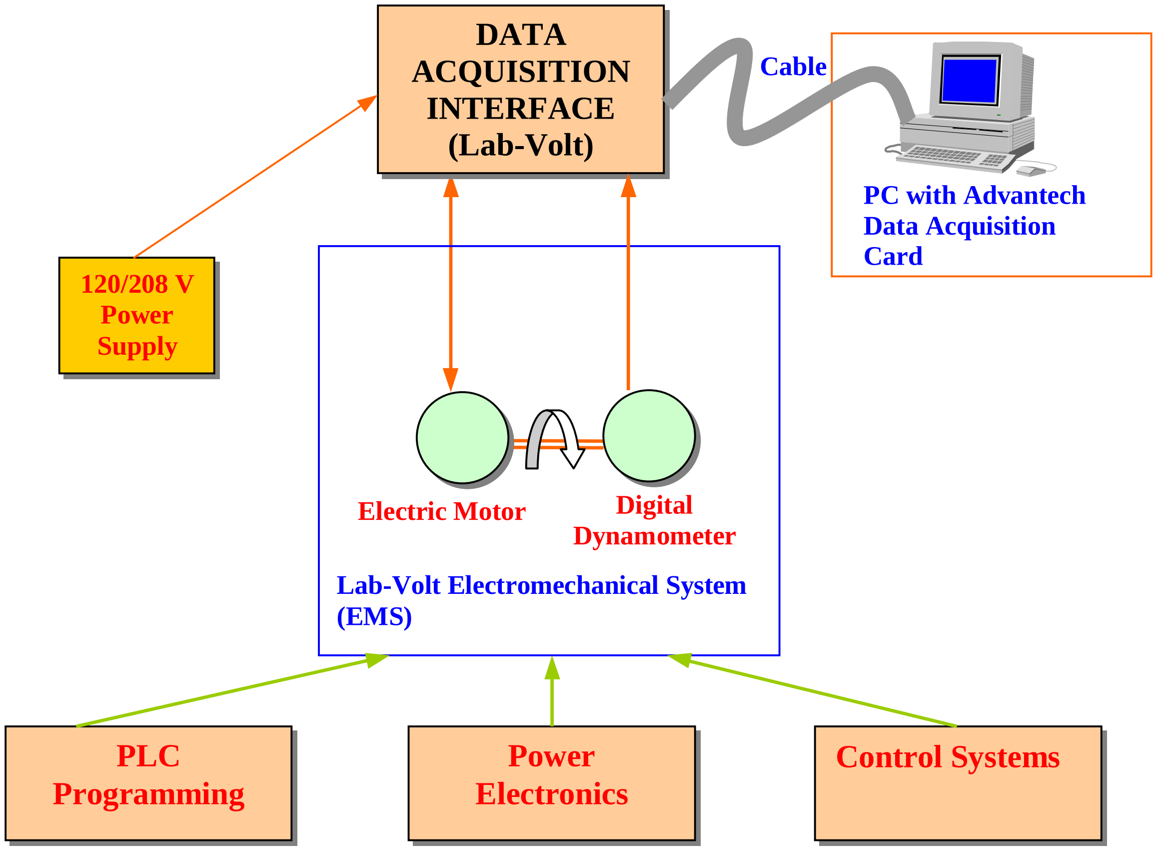

Figure 1. Integration of Lab-Volt® Electromechanical System with Various Disciplines (Variant)

The capabilities of the LVDAM to establish a dialog with the host computer and to display results of measurements in real time are great but are limited to a display of information for a small group of students performing a laboratory exercise. The information flows from the electromechanical equipment to the data acquisition card to the data acquisition interface to the computer screen.

Several challenging questions arose: How can this process be made more interactive? How can the equipment be controlled from the host computer? How can the number of system's users be increased?

Currently the Lab-Volt EMS equipment has manual control of the following parameters:

- voltage with the help of variable power supply (variac)
- motor load with the help of a dynamometer

The master switch on the variac panel supplies the entire EMS system with power and also operates manually. For example, to start an induction motor students should connect the power supply through the meters to the motor, turn on the power supply, and than gradually increase voltage on the variac to bring the motor to desired speed.

The Lab-Volt LVDAM system has a provision to control the load remotely through the input of the digital dynamometer. Therefore, it was necessary to modify the variac for the remote operations as well as to develop a motor power control panel for local and remote operations.

2. Variac Remote Control

It was decided to use a stepper motor drive to operate the variac. This unit was modified by installing a stepper motor, gearing, and motor driver to control the variac from the host computer. At this time the LabView® AT-MIO-16E-10 data acquisition card and software is used to drive the circuit. Four digital lines are used to energize the stepper motor coils in a specific sequence to cause the stepper motor to rotate at a specified rate and through a specified angle. A micro-switch is used to indicate to the data acquisition card and related software that the variac is at zero volts. Zero volts are interpreted by the software to mean fully counter-clockwise (CCW).

A block-diagram of the driver circuit for variac remote control is presented in Figure 2.

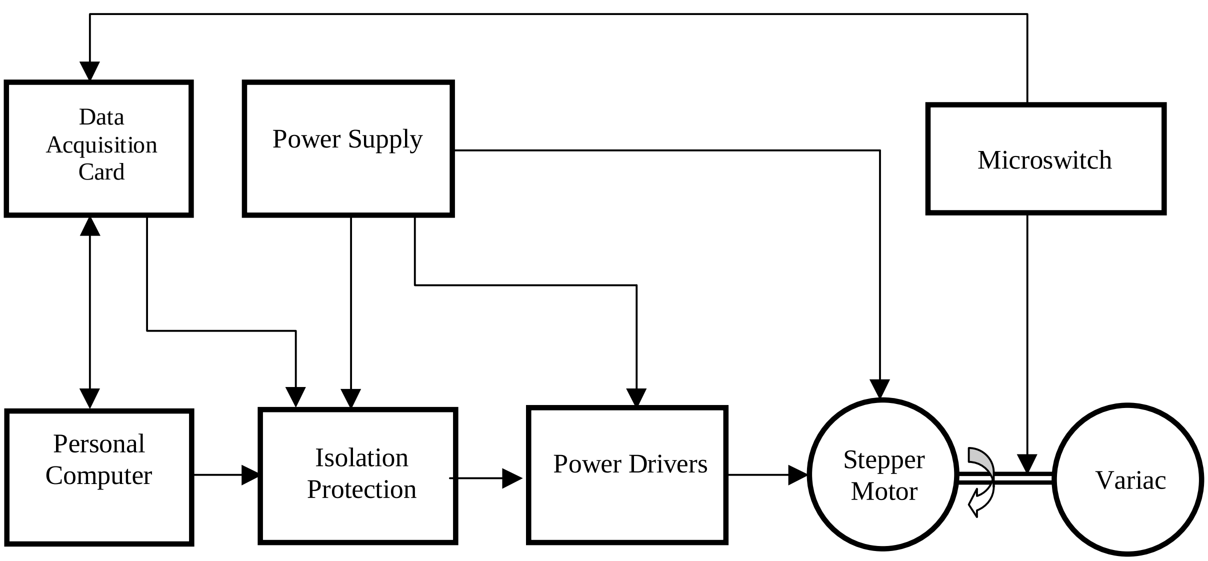

Fig. 2 Block Diagram of the Variac Remote Control

3. Motor Control Panel

The motor control panel is built around a motor starter. The motor starter (Telemechanique®) is installed between the master switch located on the power supply panel and the rest of the power circuit. This provides a safe procedure of turning the power on by depressing the Start button on the motor control panel and turning the power off by depressing the Stop button. The master switch is on all the time during experiments. The motor control panel's circuit is a "seal-in" circuit that allows either local or remote operation of a motor starter. Remote operation is controlled by the LabView® data acquisition card and software. Provisions are made to insure that local start operations would be disabled once a remote user gains control. However, depressing the Stop button locally would terminate the power circuit no matter what type of control (local or remote) had been chosen.

The above modifications allow remote control of the major components of the EMS system via host computer and introduced the elements of interactive dialogue. The next objective was to increase the number of users by bringing this dialogue on to the network.

4. Software Development to Enable Web-based Capabilities

The public's demand for web-based distance delivery has been established. At the closing of the Engineering Technology Leadership Institute (ETLI) Executive Board meeting at Southern Polytechnic University (October 26-28,1997), the following topic was emphasized: distance delivery with an emphasis on laboratories.

The stand-alone use of computers integrated with an electromechanical system through LVDAM allows real time display of all collected data. This feature creates a possibility of innovative on-line instruction via Intranet and/or Internet. However, since the Lab-Volt's LVDAM software is developed for Windows® 3.X/95 only, it allows only single-user operations.

To enable multi-user capability the Linux operating system was chosen as a platform.

The following steps are being developed:

- A Linux kernel level device driver was written to give access to the Advantech PCL-711b data acquisition card under this Operating System
- A graphical user interface to allow full control of the Advantech PCL 711b data acquisition card including modes, IRQs, timer control, block channel scan, and random channel scan. Real-time sampling is fully supported, along with one-shot sampling. Triggering of the virtual oscilloscope is supported as well. This software carries on all the functions of the original factory-supplied package but has higher level of user control. For example, the original program supports only several seconds of real-time sampling of the virtual scope, after which the refresh command is necessary to continue for the next few seconds. The newly developed software allows real-time sampling with no time limitations
- Data Acquisition Daemon software. This program runs on the host computer with the PCL 711b card and manages remote connections, controls the card, formats data for sending, and sends the data to the server upon request
- Server manager software. This program runs on a server computer and manages connections from web-based clients. The main function of this program is to assign priorities to a user who controls the data acquisition cards. It is clear that only one user should be able to control voltage and load levels while the rest of the users would be in the viewing/analyzing mode. Other functions of the server manager software are to send requests to the Daemon software, and to send data back to the viewing clients
- Client software. This is a Java-based program that the end-user (student) will use to connect to the server manager. The server manager will keep track of the clients connected, and send the requested data to appropriate clients. Clients will have graphical views of meters and instruments from the data acquisition card. The controlling client will have access to modify the card's mode, sampling rate, and timers

A block-diagram of the system in the network environment is shown in Figure 3.

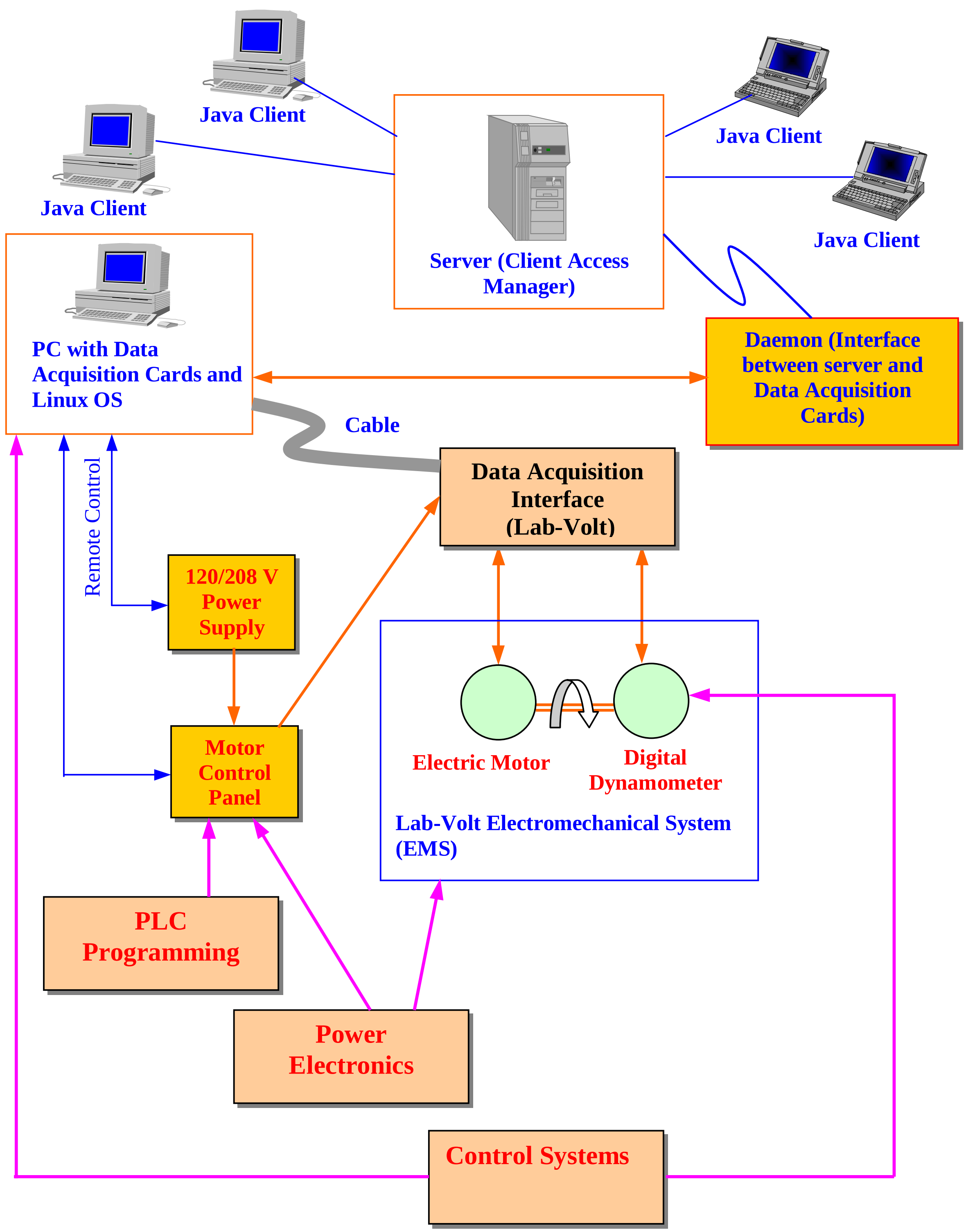

Figure 3. Enhanced Multi-user Electromechanical System Block-diagram

5. Internet Video as an Element of Interactive Distance Learning Laboratory

The ability to offer voice, video and data communications over the Internet and other TCP/IP-based networks is now a technological reality. These developments are fundamentally changing the role of the Internet from a purely data centered service network to a video and audio enabled information service. Internet video is also encouraging the development of innovative video based services, audio broadcasts and other programs. Several universities are already using Internet video as a source of distance learning presentations mostly in a multimedia lecture format.

The hardware necessary to provide internet video includes 28.8 modem or TCP/IP connection, camera or other input source, capture card if required by camera or other input source.

One of the variants of video/audio conferencing connections is presented in Figure 4.

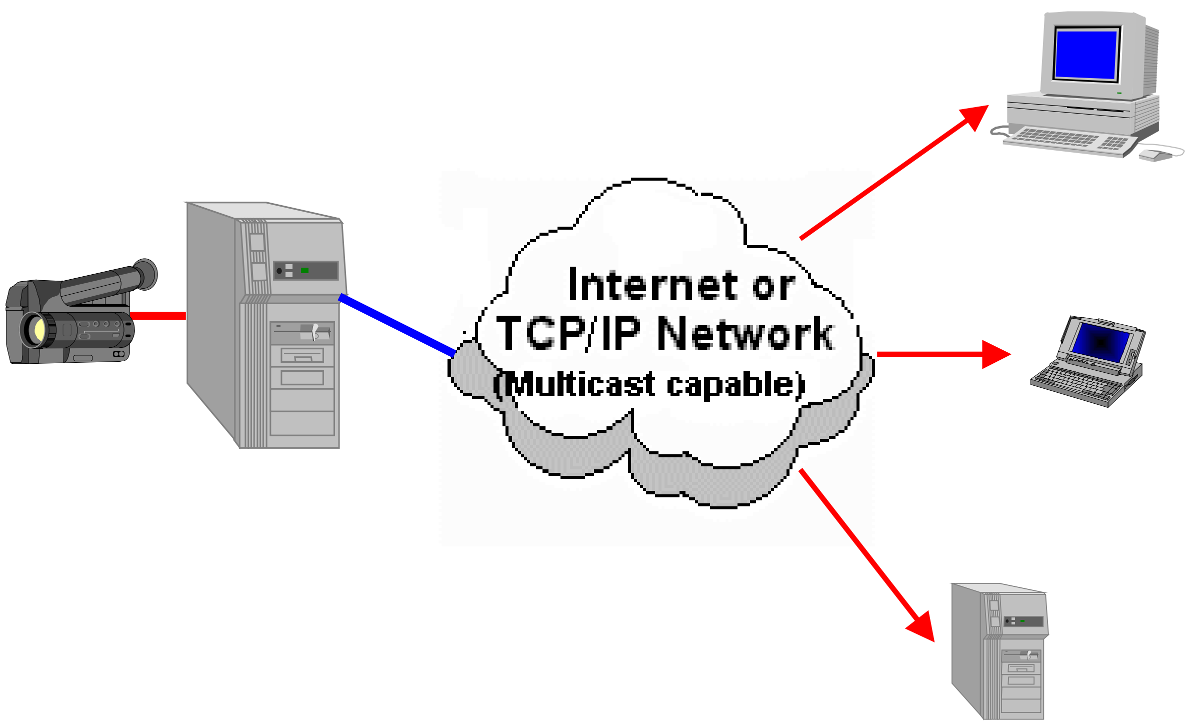

Figure 4. Video/Audio Conference Connections

6. Conclusion

Implementation of the above innovations creates the following educational benefits:

- emphasis on the analysis of gathered data rather than on connecting equipment and following laboratory guides
- exposure to state-of the-art equipment such as power electronics, data acquisition, and real-time data technology
- distance learning delivery with interactive “hands-on” laboratory exercises
- remote access to data and the ability to analyze them from a different location

Companies hiring prospective candidates require them to possess skills in machine/system installation and maintenance, selection and programming of AC/DC drive systems, and data acquisition and analysis techniques. In addition, they must be capable in the areas of documentation, proposal preparation, and specification writing.
The proposed methodology would prepare our students for the multi-skills demanded by the power/electronics industry and for the challenging careers in the next century.

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