Experiments with Electrical Motors in Distance Learning Environment: Operating Lab-Volt Electro-Mechanical System Using Web-Based Tools From National Instruments

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Abstract
Recent years gave a significant boost to distance learning (on-line) educational delivery. However, laboratory component was represented by simulation or remote operation of either static or small-size dynamic devices[1, 2]. Few advances have been made in remote control and monitoring of large dynamic electro-mechanical systems, such as electric motors and/or drives. This paper concentrates on remote control of a group of electro-mechanical devices (variable power supply, electric motor, dynamometer, and instrumentation) integrated in one complex as well as visualization of their control parameters (such as voltage, speed, torque, current, and power).
The paper also discusses log-on security procedures, hardware and software development, video streaming to ensure quality video and sound, and teaching methodologies to provide successful laboratory delivery.

Hardware
For electromechanical part of the project it was decided to utilize existing laboratory equipment used in the Technology department of Buffalo State College. It includes Lab-Volt Electromecanical System (EMS) with data acquisition interface (9061-00 or 9062-00) and digital dynamometer (8960-10). Motor load is any available motor, chosen from squirrel cage induction motor (EMS 8221), wound induction motor (EMS 8231), synchronous machine (EMS 8241) or any other available motor.
Power supply/variac (EMS 8821) was modified to allow for remote access.[3]
In order to provide convenient transition from local to remote control and vice-a versa, a motor starter panel was developed.
The Data Acquisition Interface (DAI) consists of isolation and data acquisition units. The isolation unit converts high-level voltages and currents found in electric power systems and power electronics circuits into low-level signals, and routes these signals to the data acquisition unit. The data acquisition unit converts the low-level signals into digital numbers (data) that are sent to the personal computer that runs the LVDAM-EMS software[4].
Data acquisition interface (DAI) is a part of Lab-Volt EMS system and provides interface between electromechanical equipment and data acquisition card provided by Lab-Volt. This card is incompatible with NI series of cards. Software supplied with EMS provides excellent graphic user interface but allows only one local user to operate and/or observe an experiment (a group of students can observe results on one monitor).

The DAI (9061-00) has three inputs for current measurement, three inputs for voltage measurement, inputs for speed and torque measurement and computer inputs/output via D-type connector. When the inputs are properly connected an array of measured and calculated data could be displayed on a computer screen. These data include but are not limited to currents and voltages in all three phases, different varieties of power readings, torque, speed, frequency, and phase angle.

Digital dynamometer/prime mover is also a part of Lab-Volt EMS. In dynamometer mode it acts as a load. The load is controlled manually or externally. A digital display on the module faceplate provides readings either for torque (N/m or Lb-ft) or speed (rpm). In a prime mover mode this module is connected to a DC source and acts as a motor. Selector switches allow changing modes from dynamometer to prime mover and from manual to external control of the load.

Power supply module (Lab-Volt EMS 8821) is a manual device that provides regulated and fixed AC and DC outputs from zero to 208V. Voltage control is provided by a rheostat mounted on a shaft with a dial. In order to exercise remote operation of the rheostat, it was modified by installing a stepper motor and a mechanical gear box coupled with the rheostat shaft on the back of the unit.

A motor control panel was designed and built around a motor starter Telemechanique Integral 18. A start-stop button provides local control of the unit and another button is used to switch the panel for remote operation. An indicator lamp notifies a user what mode is selected.

Motors used in Lab-Volt EMS system are 0.2 kW machines of different types (three- and single phase AC and DC). Coupling between machines and digital dynamometer is achieved with the help of a flexible belt.

As mentioned before, EMS system allows data acquisition and display of measured and calculated data on a local computer directly connected to DAI. The hardware and software do not provide for client-server environment.

Remote control capabilities

In order to control equipment the following procedures are routinely observed:

1. Turn on a power supply and provide a path to a motor
2. Increase voltage from zero to desired value by adjusting a rheostat. In order to reduce voltage the rheostat dial should be moved to an appropriate position up-to zero volt
3. If a mechanical load should be set on a motor pulley, the dynamometer dial (in manual mode) is adjusted to an appropriate position.

In traditional laboratory and/or industrial setting these steps are performed manually by one person at a time. Due to current state of technology all of the above steps could be also performed remotely via computer controlled interface.

As mentioned before, the power supply was modified to provide remote control capabilities for varying voltage levels of the power supply. The motor control panel was designed to provide for remote switching in a feeder line to a motor. And, finally, Lab-Volt module 8960 (digital dynamometer) allows external analog input (up-to 10V DC) to control its output. Therefore, basic manual control operations can be performed remotely from a local computer with an appropriate data acquisition card.

Since the Lab-Volt data acquisition card and DAI do not provide sufficient number of ready to use I/O points, it was decided to use NI card instead. Card PCI-4025E with an interconnect box

SCB-100 was chosen as it provides sufficient number of available entry points and adequate sampling rate.
Please, see Figure 1 for a diagram of the system.

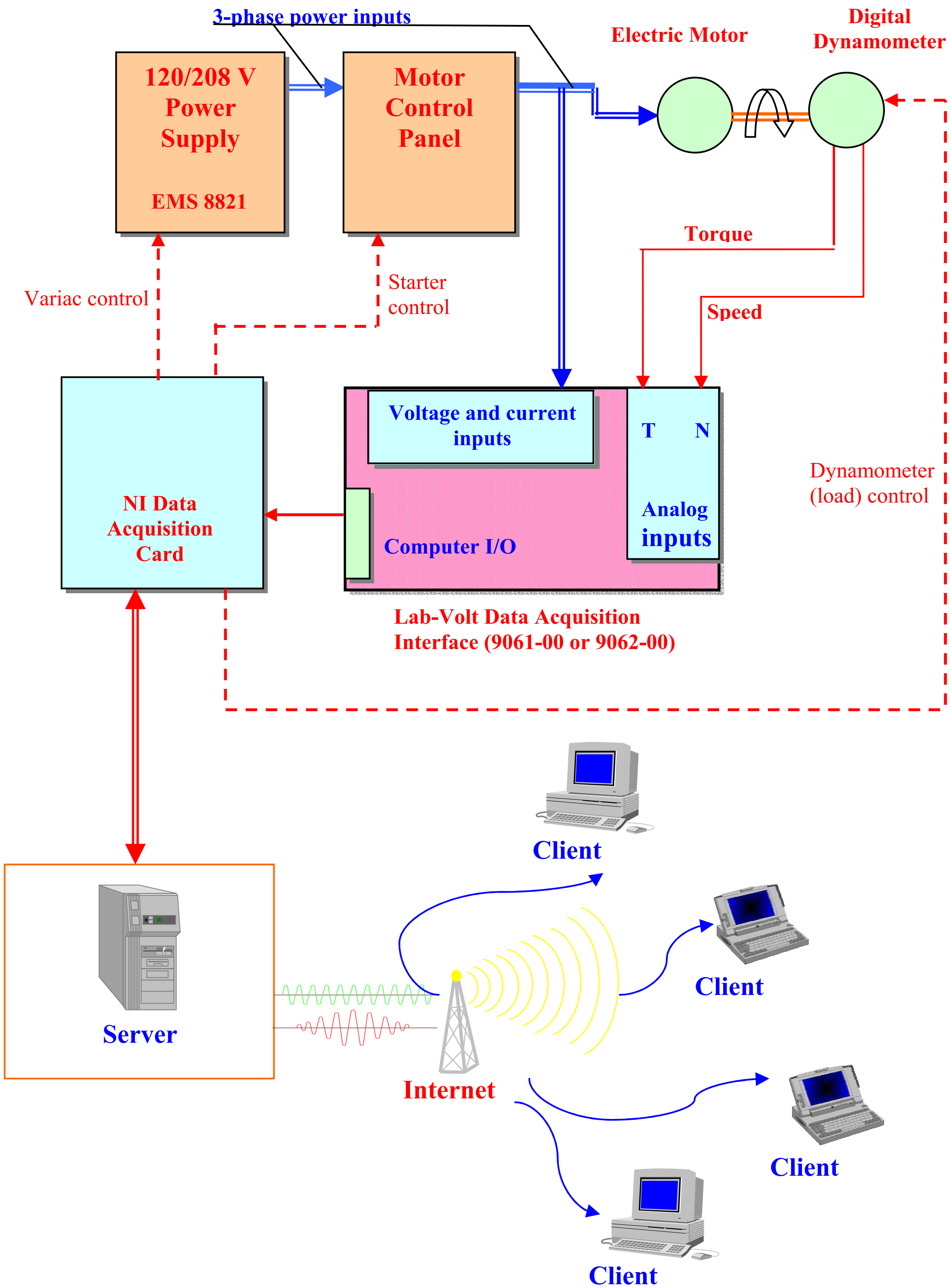
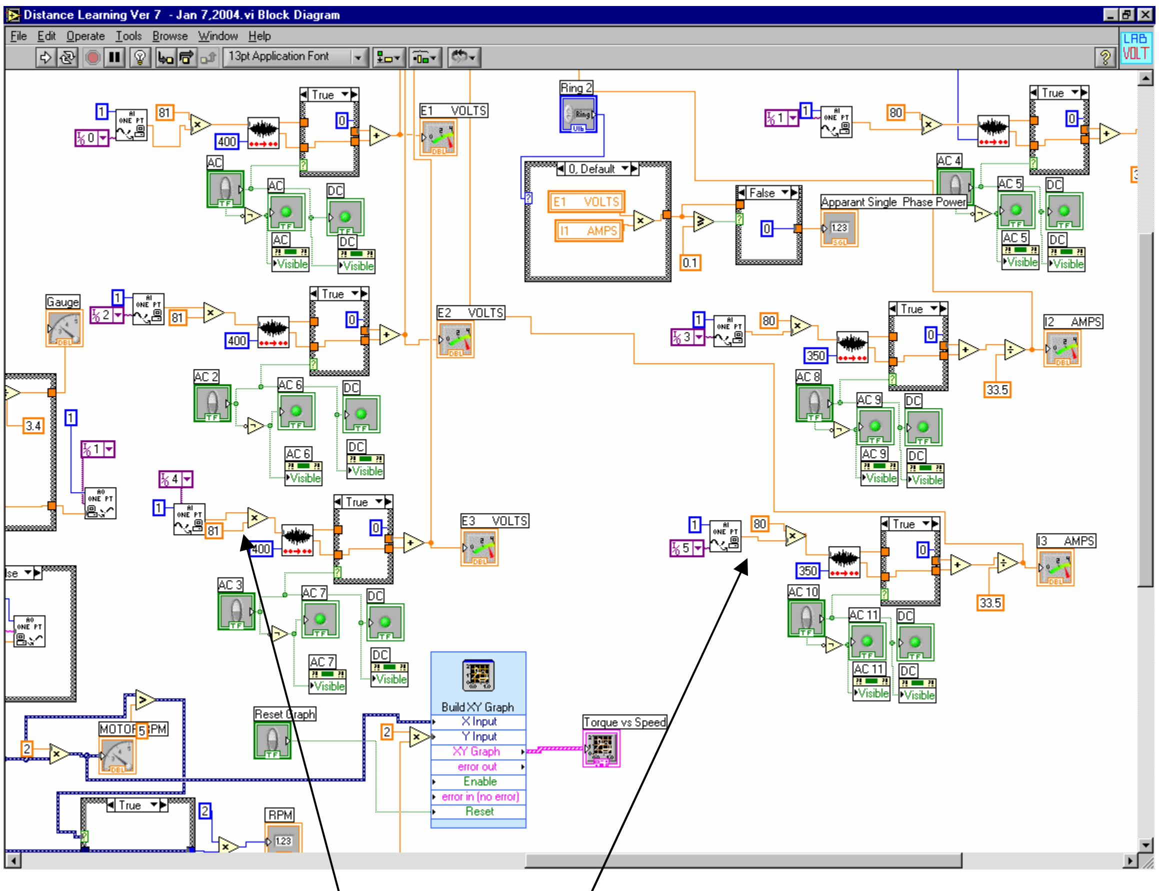


Figure 1. System diagram

Software

LabVIEW version 7software was a natural choice as it delivers a powerful graphical development environment for data acquisition, measurement analysis, and data presentation. LabVIEW is used to communicate with hardware such as data acquisition, vision, and motion control devices and GPIB, PXI, VXI, RS-232, and RS-485 instruments.

LabVIEW programs are called virtual instruments (VI), because their appearance and operation imitate physical instruments. In LabVIEW a user can build a graphic user interface, or front panel, with controls and indicators. Controls are knobs, push buttons, dials, and other input devices. Indicators are graphs, LEDs, and other displays. After the user interface is built, code is added to interface with the front panel objects. The block diagram contains this code. Please, see Figure 2 for a sample of the code.



Portion of the program showing the calibration technique for the voltmeters and ammeters. Raw data is acquired, multiplied by 80 and then the RMS value of the result is computed and displayed on the meters.

Figure 2. Fragment of the code

The program runs with a NI data acquisition board PCI-6025E. Other boards may be used depending on budget and application. The program was developed from scratch as no templates or similar programs were available from National Instruments.
The main part of the software was written to control a stepper motor, which is mechanically connected to the shaft of a variac. It rotates the normally manually rotated control knob. Stepper motors require a sequence of motor coil activations to cause rotation and these were implemented using "for loops". Since the front panel knob can be rotated in either the clockwise or counterclockwise direction, the current position of the knob is stored in memory and used to make a decision as to the final end point of the knob. The software writes a series of patterns (bytes) to four digital lines that are applied to a stepper motor driver board. The number of times the "rotation loop" is caused to run depends on the difference between the current position of the knob and the position desired.
A startup routine detects whether the knob is in the zero position (by means of a micro switch) and will rotate the knob to zero if it is not set there. This occurs once and after execution the user may rotate the knob to any position. The motor driver board was designed and fabricated on site.
The PCI-6025E has both inputs and outputs. The software makes use of the outputs by writing an appropriate voltage level to a solid-state relay, which in turn activates the motor starter. The starter then starts the motor. A switch on the front panel accomplishes this task.
Another output is utilized to write an analog voltage level to the dynamometer to alter the torque. The software includes a gauge and a switch to increase or decrease the voltage level and thus alters the applied torque.
The PCI-6025E has 24 analog inputs and channels 0 through 8 are utilized in the following way:
3 channels used acquire the three phase voltages
3 channels used acquire the three phase currents
1 channel to detect Variac position knob zero position
1 channel used to acquire motor RPM
1 channel used to acquire motor torque.
Implementation of metering is straightforward in LabVIEW as meters are available with the included software package. It is only necessary to scale the raw acquired voltage to the actual voltage value. The appearance of the meters is also adjustable (color, size, etc). After scaling, another LabVIEW function was used to convert the data to RMS values for the voltmeters and ammeters. This is also shown on Figure 2.
Similar techniques were used for the speed and torque display. In addition to meters for these two parameters, a graph shows the speed vs. torque characteristic of the motor, a highly desirable motor specification.
The front panel is shown in Figure 3. The graph on the lower portion of the front panel was obtained by setting the torque to 1.38 N-meters and then starting the motor at full voltage.

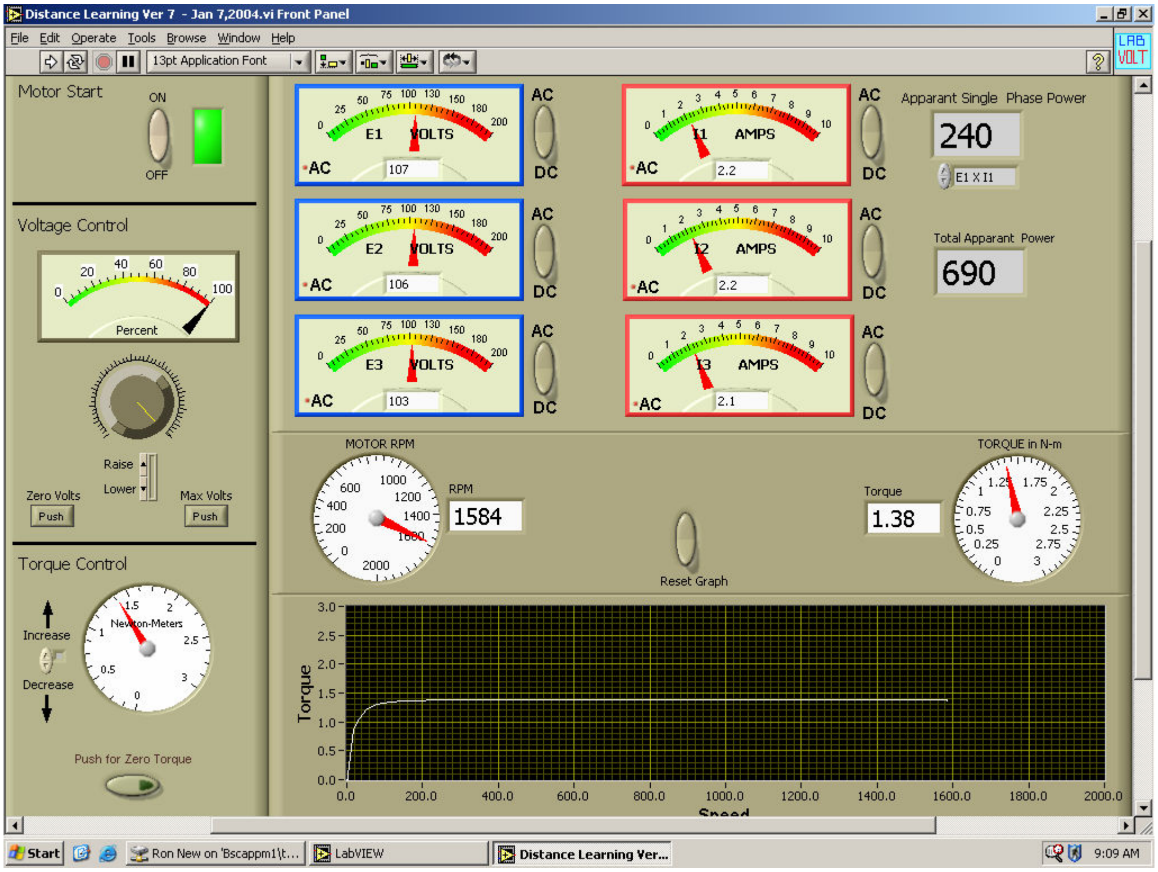


Figure 3. Screenshot of the front panel showing actual acquired data for voltmeters, ammeters, torque meter, motor RPM, Phase 1 apparent power, total apparent power and a graph of torque (N-Meters) vs. speed (RPM).

Web-publishing

LabVIEW makes it easy to publish the VI on the web and several tools enable the user to easily get on the Internet. To run the VI on the web, a real time engine is required. Any user logging on to a web enabled VI without the engine will be directed to a site for downloading.

Starting the Distance Learning Equipment

Sequence of Events

1) Connect equipment as shown in the diagram
2) Attach the National Instruments interface/PC
3) Start the PC
4) Power up the Variac, Motor Control Panel, Dynamometer and Variac Control Power Supply
5) Start the Virtual Instrument
6) Test local operation of motor starter control, Variac voltage variation control, torque control.
7) Verify that readings on voltage, current, speed and torque are within specifications.
8) On the PC, from the "Tools" menu, select "Web Publishing Tool" (see Figure 4)
9) Fill in the appropriate boxes and click "Save to Disk"

10) Enter a Web name and click OK.
11) The Document URL window appears and shows the URL of the base station, which is the server by which all clients will connect. Record the URL address. This address is then made known to the clients intended to use the Distance Learning feature.
12) Click "Close" to finish or you may select "Connect to Browser" if you wish to view the Control Panel of the VI in your browser and check its operation.
13) Others may now log on to the above website and either operate or view the activity. Instructor and/or lab administrator can set permissions and monitor activities. Figure 5 illustrates the case that all users may log on.
14) Users, after connecting to the website, may request control of the VI by right clicking in an open area of the VI and selecting "Request Control". If it is granted, a message appears informing the user that he or she has control. Similarly, the user can relinquish control at any time. Only one user, or the base station, can control the VI at one time.

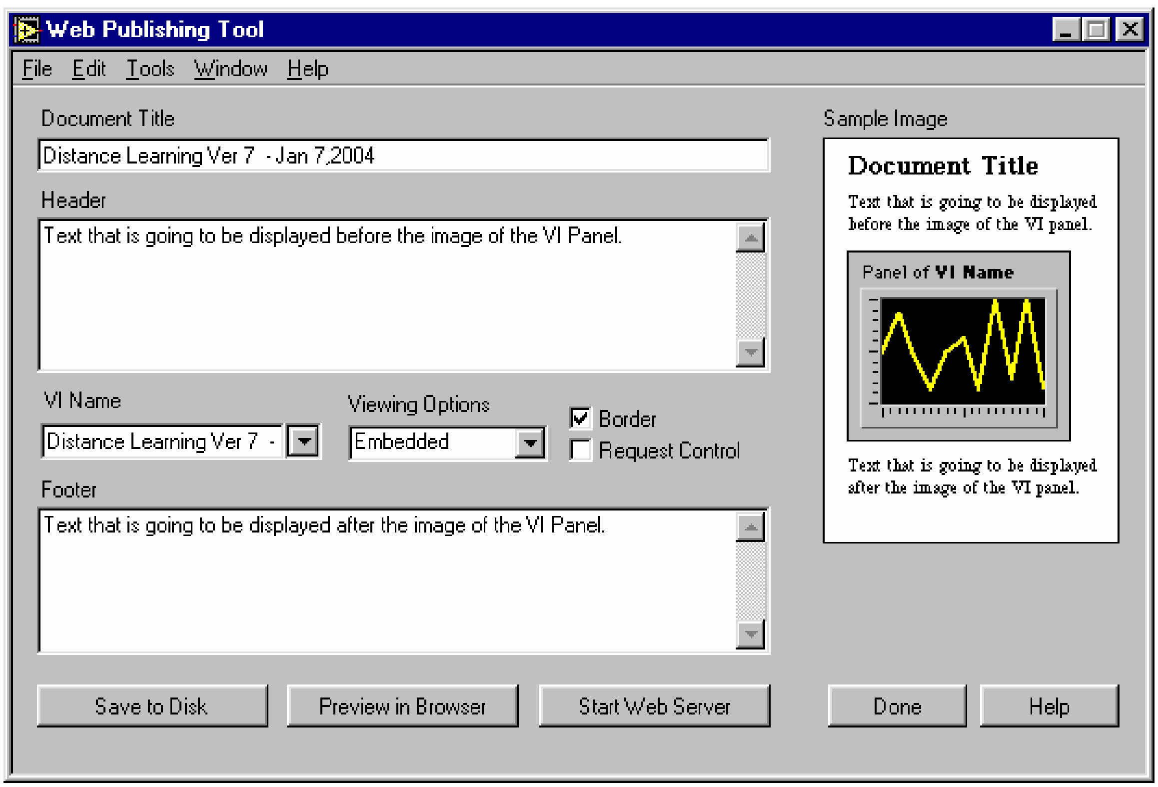


Figure 4. Web-publishing tool screenshot

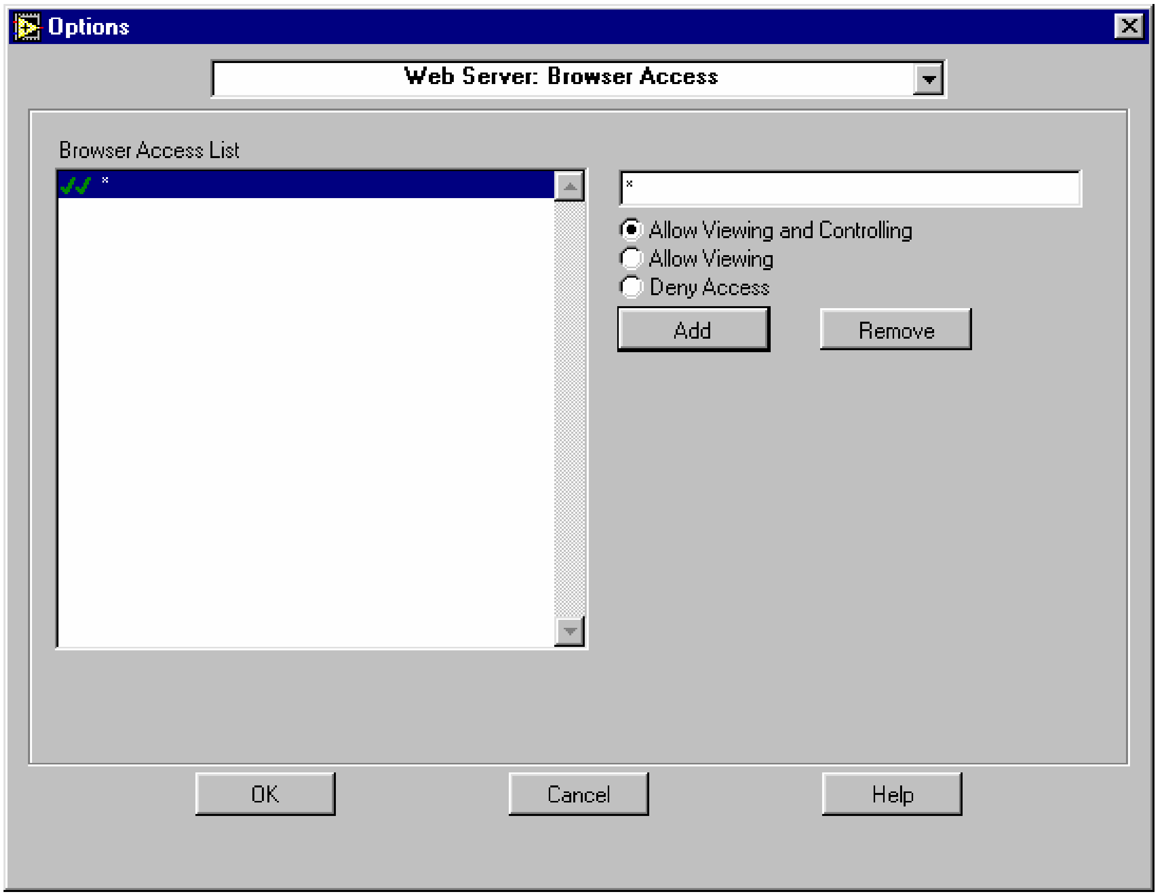


Figure 5. Web-server browser access control screenshot

Video streaming

Advances in processing speed and later versions of the encoding software enabled successful implementation of video streaming for this project. Pentium III 800 MHz PC is used to ensure the high quality available at the time of development (video streaming part of the project was accomplished in 2001). Video capture cards were purchased as well as digital-8 Sony camcorder. Video capture cards were selected to provide performance, reliability, and compatibility with hardware and software solutions chosen. Digital-8 camcorder proved to be an excellent choice: it provides much better quality of the images captured compared to analog devices. The above mentioned PC is being used as a video server for the project. Linux operating system was chosen for the video server as being more reliable and crash-proof for this application. To provide video encoding (to digitize video inputs) Real Producer® for Linux from Real Networks™ was used. The authors experimented with the version for Windows as well. However, reliable results with this operating system were not achieved. On the clients end the latest version of the Real Player® is used. End users should have this program to be installed on their computers in order to receive video feedback.

Teaching Methodology

The proposed development reflects authors' vision of laboratory experiments to be conducted in interactive manner under supervision of a person on site.

Certain limitations have to be observed:

1. Due to high voltage application actual physical set up should be monitored constantly
2. A large variety of experiments with different types of motors and/or connection diagrams require frequent change of wiring configurations, which should only be done physically on the site. A student or a group of students should request configuration changes to continue with another experiment
3. As with traditional manual experiment only one person can physically operate equipment while others observe and record data
4. Video feedback has several seconds delay so actual response of equipment to control inputs is much faster than the observed one
5. Due to scheduling and monitoring concerns proposed methodology calls for scheduled sessions for on-line students
6. Although more control functions are possible with more complicated experiments (synchronous machines, for example), where even more circuits should be controlled (excitation circuit), the authors feel that at present time remote control of such circuits is not feasible. It could be easily achieved by a person on site following users' request.

Several interactive tools are utilized to communicate between students and instructor and/or lab personnel. One of these tools is video feedback; another is achieved via Internet communication set of tools, such as Windows Messenger® or similar means.

Developed system is flexible as it allows adjusting to specific needs of the learning outcomes. If an objective is to develop skills of data collection and presentation then students can do it manually after each change in operational parameters (voltage, speed, and torque among others) or it could be recorded by a computer and analyzed using various tools. This is utilized in original Lab-Volt procedure. On another hand, if other skills are to be developed, for example, simple comparison of a sample speed/torque graph with an actual one after motor repairs, relevant information could be gathered and displayed automatically for visual analysis.

Conclusions

Proposed system verified feasibility of remotely controlled experiments with larger size electromechanical equipment (standard Lab-Volt 0.2 kW motors were used). Latest advances in software development by National Instruments allow secure, effective and efficient use of LabVIEW-based front panel in server-client environment. The portions of the system described in this paper are built and tested but were not yet used in actual on-line learning.

Bibliography

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