Intelligent Energy Conversion Laboratory for Undergraduate Power Engineering Education

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Abstract
This paper describes the development of the Intelligent Data-Acquisition and Control (IDAC) system -- a virtual instrumentation-based system for conducting experiments in the electrical machinery laboratory at Penn State - Harrisburg. The system as developed departs from the traditional approach in a power laboratory environment where measurements are manually logged from several meters, and followed by hours of calculations and plotting of results. Introduction of the IDAC system has offered the typical power engineering undergraduate a unique opportunity to learn the principles of real-time data acquisition, and to apply it in the study of electric machines.

1. Introduction

A downward trend in enrollment in graduate and undergraduate electrical power engineering programs has been observed over the last decade or two [1-2]. The causes have been attributed to shifting interests among the student population and stalling electrical load-growth dynamics, among others. Efforts to remedy the decline in interest have resulted in the wider use of computer simulation tools. This has significantly aided students in gaining a better understanding of power system devices and operations. Latest innovations in simulation systems revolve around improvements in man-machine interfaces, and reduction in the level of high level programming [3-5].

Another factor that is seldom cited as a probable cause of reduction in enrollment is the apparent lack of innovation in how the subject is presented to power engineering students. The range of experiments that a typical undergraduate energy conversion laboratory facility can support does not adequately prepare power engineering students for the digital-computer oriented 1990's power system industry. For instance, experiments on derivation of performance characteristics and equivalent circuits of a motor normally involve manually reading, recording, and tabulating measurements of voltage, current, power, speed, and torque as the energy conversion devices are subjected to loading or other test conditions. Data is later correlated, processed, and plotted on graph paper to determine parameters of interest. This approach to problem-solving and power engineering laboratory experience has been in place for decades and certainly has proven very useful. However, advances in digital computer technology have engendered a new generation of hardware and software concepts that enable routine and mundane tasks such as "meter-reading" and data logging to be automated, processed and presented in useful and desired formats. This frees the student to focus on intellectual aspects of the project. Furthermore, it ensures a significantly higher degree of accuracy in data analysis.

The application of data acquisition and control in undergraduate engineering projects usually requires high level or assembly level programming skills, as well as knowledge of computer interfacing systems. This makes it impractical to integrate an adequate amount of computer application in the power engineering curriculum.

With the goal of addressing the issue, an Intelligent Data-Acquisition and Control (IDAC) system is implemented for the energy conversion laboratory at Penn State University - Harrisburg. Four lab-stations in the energy conversion laboratory are equipped with a self-contained IDAC system. It is comprised of a PC-computation base, a number of sensors, a data-acquisition and presentation software system, high-level language compilers, a fuzzy-logic development system, and an adjustable frequency drive. Basic data such as current, voltage, and speed are acquired from several sensors. Information that is unavailable by direct measurement is then derived by computer processing as sensor data are combined. Processed data is then transmitted to output transducers (or actuators) and/or displayed for observation. The intelligent sensor system thus performs the routine activity of data measurement and synthesis of measurements that could not be determined from the output of a single sensor. The system as implemented would necessitate a revision of AC and DC machinery experiments.

The IDAC system is described in the sections that follow. A sample application on determination of performance characteristics of an induction motor is discussed.

2. The IDAC system hardware

Figure 1 illustrates the typical IDAC laboratory unit setup for an experiment on electric machinery. The laboratory machinery used in the illustration is a 3-phase induction motor coupled with a mechanical load system. Experimental data may be acquired from the setup, and feedback data from the IDAC may be returned to the machine.

Table I provide a summary data on the sensors, computer I/O board, and output device utilized in the IDAC system. The hardware data range is adequate for typical AC and DC machinery experimentation. To make provisions for experiments involving symmetrical components, one of the IDAC stations is equipped with a CIO-SSH16 board which provides simultaneous sample and hold capability for four channels.

3. Software (hardware interface and data analysis)

The level and mode of interaction with physical data and manipulation of acquired data is very critical in achieving the stated objectives of the IDAC system. The interface platform needs to be very simple in order to be learned and applied by an average student. Text-based protocols or assembly level programming are to be totally avoided as this will unduly get the student sidetracked. A number of Graphic User Interface (GUI) based systems that would provide such an environment are widely available. They include: National Instruments - LabView, DSP Development Corporation - DADiSP, etc.

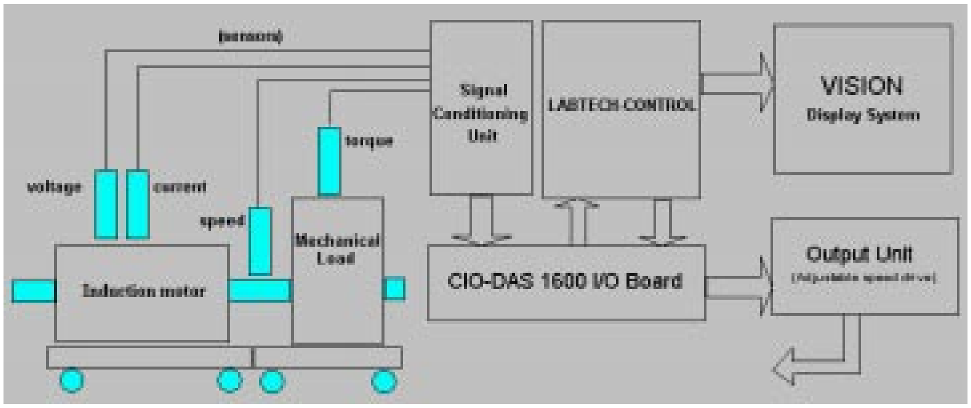

FIGURE I. The Intelligent Data Acquisition and Control (IDAC) system.

TABLE I. IDAC Hardware.

	Type	Signal range
Voltage sensor	Electronic (LEM LV25-P)	500-V AC/DC
Current sensor	Electronic (LEM LA55-P)	70-A AC/DC
Speed sensor	Photo-tachometer	0 - 5V DC (50 - 10,000 RPM)
Torque sensor	Electronic strain force transducer	0.1V DC/N-m (0-17 N-m)
I/O Board	Computer-Boards (CIO-DAS 1600s)	Multifunction Board
PWM Inverter	TB-Woods XFC-micro-inverter (Vector control)	0.1 – 400 Hz

LABTECH (CONTROL) was the data acquisition and process monitoring and control software chosen for the IDAC system. The choice was based on a combination of factors. Among others, it provides support for up to five hundred data acquisition and control boards. LABTECH monitors and performs direct digital process control in real time without a requirement of conventional programming skills. Symbolic icons representing various devices, mathematical and data-control operations are used to accomplish necessary programming. The graphical programming environment is designed to echo windows operating system, therefore requiring no special familiarization.

Data visualization for experimental observation is provided through the Real-time VISION operator interface of LABTECH. It allows the graphical depiction of flows and layouts of the plant or instrument panel, complete with on-screen object graphic animation. Other features of the VISION display system include: trend charts, bar graphs, meters, knobs, switches, and slide bars, multimedia support, and object animation. Instrument customization provides a means for students to visualize data in order to aid understanding of concepts, such as the relationship between real, reactive, and apparent powers. Animation tools likewise could be found valuable for illustration of field concepts that are difficult for power students to visualize, for instance rotating magnetic fields, machine load angle, induction slip, etc.

4. Basic characteristics of a three-phase induction motor -- an application

An application of the IDAC system is illustrated through a typical experiment on a 3-phase induction motor. The objective of this experiment is to collect the set of data indicated on Table I, and then to generate graphs showing: (a) load-torque versus speed, (b) load-torque versus motor current, (c) power input versus motor current, (d) efficiency versus motor current, (e) power factor versus motor current, and (f) torque versus induction slip.

TABLE II. Induction machine performance characteristics data

Torque N-m	Line current Amps (rms)	Line voltage Volts (rms)	Power input Watts	Speed RPM	Power factor	Slip	Efficiency %	Time sec.

The experimental setup in a conventional (or traditional) setting normally requires an ammeter, voltmeter, watt-meter, and torque-meter. Other variables for which there are no instruments available for direct measurement (like slip, or power factor) are analytically obtained, and later plotted. The IDAC system eliminates the need for conventional instruments once calibration is completed. Measurements available from sensors at the computer I/O is limited to instantaneous line voltages, line current, machine speed, and load torque. Virtual instruments must therefore be developed in the IDAC system to supply experimental values for variables that are not directly available from sensors. RMS voltage, RMS current, power factor, real power, reactive power, and efficiency metering systems are therefore synthesized from physical measurements.

The LABTECH build-time program, and VISION setup for virtual instruments in this experiment are shown on Figures III(a) and III(b). As the motor is gradually loaded, students are able to observe the changes in all the variables at once on the VISION instrumentation panel. For data collection, the display icon is replaced with a data-logging icon for direct storage of measurement data on the computer disk.

5. Conclusion

In order to develop more interest in the power engineering program at Penn State-Harrisburg, and to provide students with skills necessary for the modern power engineering environment, laboratory experiments on electric machines are revised to reflect current practices in the industry.

This intelligent data-gathering and processing system offers the students some very significant benefits. They are highlighted as follows.

(a) Creating the instruments that are necessary for completing the experiment gives the student a further insight into the subject, and reinforces basic concepts.
(b) A single student could conduct the same experiment more efficiently and accurately with the IDAC system. Three or more are required in a conventional setup.
(c) The success or failure of the experiment is judged by the student before leaving the laboratory. This gives the student an opportunity to immediately repeat the procedure.

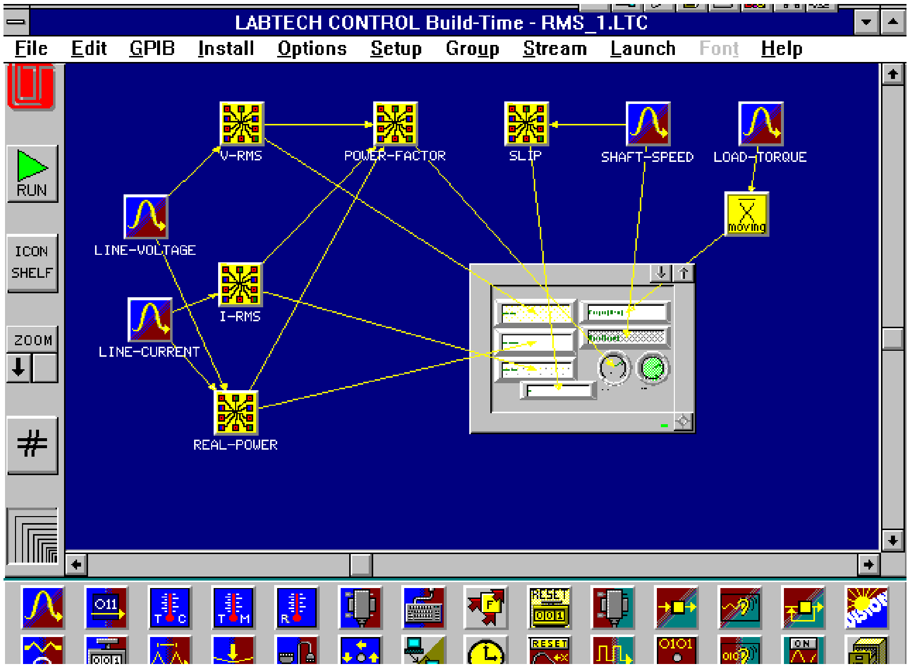

FIGURE III(a) Virtual instrument design and setup in icon-view.

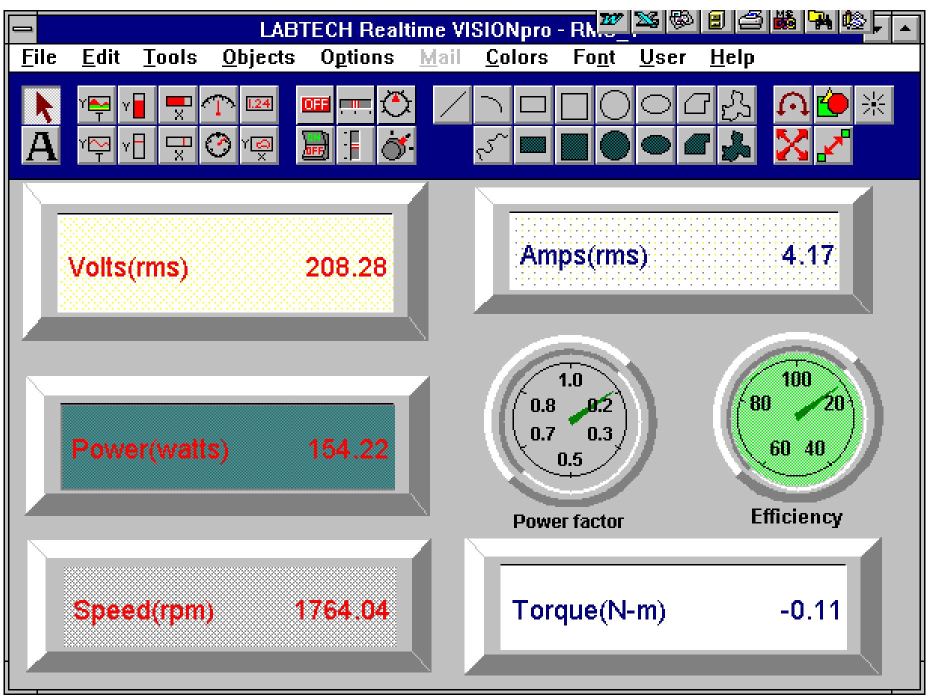

FIGURE III(b) Virtual instrument display (VISION).

(d) The arrangement provides the typical power engineering undergraduate a unique opportunity to learn the principles of real-time data acquisition, and to apply it in the study of electric machines.
(e) The scheme allows for creativity, and offers the animation drawing tools in VISION facility to explain some difficult concepts such as rotating magnetic field, and slip associated with the induction machine.

By a careful selection of training tools, students with minimal backgrounds in computer software and hardware interfacing are able to learn and apply data acquisition methods for electrical machine analysis. This is done within the limited time available in a typical curriculum.

6. Acknowledgments

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8. Biography

Peter Idowu obtained his Ph.D. degree from the University of Toledo, Ohio in 1989, he is a registered professional engineer in the state of Ohio and is currently an assistant professor of engineering at The Pennsylvania State University - Harrisburg, PA.