# Intranet-Based Real-Time Laboratory
# A Case Study in Electrical Engineering

Saoud H Al-Shoaili and Halit Eren
Curtin University of Technology
School of Electrical and Computer Engineering
Kent Street, Bentley, WA, 6102, AUSTRALIA
Tel: 61-8-9266 7903, Fax: 61-8-9266 2584, e-mail: shoailis@ece.curtin.edu.au, h.eren@ece.curtin.edu.au

***Abstract –*** *The goal of this paper is to design, develop and demonstrate virtual instrumentation (VI) system that can be used to monitor and remotely control a real-time laboratory experiment. The system has b een interfaced with a computer, also used as a server, and the virtual instrumentation has been developed in LabVIEW environment. An important feature of this study is that, the virtual instruments operate on real-time basis collecting, processing, analyzing and displaying data as the events take place. Furthermore, this stu dy concentrates on the problem encounter on the system-computer interface by using a host of interfacing techniques including data acquisition card and parallel and serial interface techniques operating simultaneously. It has been shown that the laboratory experiment can be conducted by the intranet of the enterprise from any location. The problems related with the use of internet due to firewall and others are under investigation*

***Keywords –****Intranet, Internet, Virtual Instrument, Virtu al Laboratory, Computer Interface, LabVIEW.*

## I. INTRODUCTION

The invention of the internet makes the world appears as a small village in which people can communicate with each other face to face from anywhere and at anytime. Apart from using internet for the traditional applications such as reading the latest news of the world, chatting, making buisness, etc, academic organizations have made use of this technology to enhance the education process by developing virtual education systems. This education system run through the internet environment in which the teaching materials are delivered to students via the internet eliminating the need to attend and sit in classical classrooms; conversely the students organize their own suitable places and times. Likely to the virtual education system, experiments and classes run over the internet are called virtual experiments or virtual laboratory. Virtual Laboratory (VL) or Remote Accessible Laboratory (REAL) ,as some researchers call it [1], means that an experiment can be performed remotely without the need for the physical attendance in its real place or laboratory. With the Virtual Laboratories users can plan and conduct experiments or proc-esses, collect live data, analyze, study the data and present the results in the required format as if they were physically in the experiments or the process places.

Instruments that are used in building the virtual laboratory are called virtual instruments (VI). They are designed and built by using software. These instruments emulate the appearance and the function of the real one. They are a result of the combination of a general purpose computer with a generic data acquisition system in order to emulate several traditional measurement instruments . VI's are a knowledge area that integrates several others areas. These are instrumentation system, concurrent programming, graphical user interface (GUI), real-time system, object oriented program and object oriented technology . Recently there are several systems for developing the virtual instrument such as LabVIEW, Look-Out, BridgeVIEW and LabWindows/CVI [2].

The computer package has been used in this study to build the virtual laboratory is LabVIEW7 from National Instrument. LabVIEW is a graphical development environment for test, measurement and control applications. It is an object oriented program in which different blocks are connected together to perform a job instead of writing a textual programming language. LabVIEW has built-in capabilities for direct I/O communication through interfaces including VISA, GPIB, Serial, and Ethernet. LabVIEW delivers extensive acquisition, analysis, and presentation capabilities in a single environment toseamlessly develop a complete solution on a selected platform. LabVIEW delivers what engineers and scientists need to build test and measurement, data acquisition, embedded control, scientific research, and process monitoring systems [3].

As a program, LabVIEW has two different desktops; a front panel and a block diagram. The front panel provides the user interface with the experiment instruments and devices through a Graphical User Interface (GUI). It contains adjusting knobs, indicators, reading meters, controllers, graphs or charts and all other facilities that help the user to realize the required tasks. By the front panel, users interact with experiments or processes. The block diagram is where the program

designer wired the function blocks together to execute jobs. In this paper, a case study for undergraduate students in Electrical Engineering Department is reported. The objective behind is that to provide virtual or remote laboratory managers, teachers and learners with an easy-access work environment.

## II.   RELATED WORK

Utilizing computers and Internet in education process provides a low cost, easy and flexible access distributed teaching institutes that are not controlled by any geographical boundaries. The internet is expected to be the base for the distance learning system [4]. Nowadays some researchers try to bring different types of instruments and devices into the internet server [5] and [6]. Despite the development in the internet communication, till now only few didactic experiments have been made with students access to laboratory equipment [7]. The first networked device appeared over the internet was the Cambridge Coffeepot at Cambridge University [8] and the first time bi-directional communication has been used via the Web to control an instrument remotely was to control the Scanning Probe Microscopes (SPM) at Arizona State University [9].

The idea of the virtual laboratory has drawn the attention and time of many researchers [10, 11], and [7]. Several internet-based experiments or virtual laboratories have been studied and developed so far. In 1999 Overstreet & Tzes described the design of generic virtual instruments used for real time experimentation in a remote access environment in which a remote user can access the laboratory facility from anywhere at any time [12]. Durate & Butz have designed virtual laboratories by using virtual components & instruments. Their design targeting mostly disabled students. Elhajj *et al* has studied a real-time control of internet-based teleoperation with force feedback. Their approach is based on an event-based control and was implemented on a mobile robot over the internet [13]. Gomez *et al* have proposed a solution that allows a remote access to equipments in such a way that hardly differentiates from using the same equipments at laboratory [14]. Seet and Ling have developed and demonstrated a real time remotely accessible control laboratory [6]. A continuous control of a closed loop control system of an internet-based virtual-wire that uses virtual instrumentation have been investigated by Eren *et al* [15].

The work presented in this paper goes in parallel with the others effort in the virtual laboratory and virtual instrumentation and thus  a virtual laboratory for a common experiment in electrical engineering study. It is to monitor and control remotely the behavior of a 3-phase squirrel cage induction motor mechanically coupled with a DC-Dynamometer.

## III.   THE EXPERIMENT STRUCTURE AND METHOD

To achieve the goals of this study a common electrical engineering experiment has been taken as a case study. The student should be able to conduct the experiment on or off campus from any location and at anytime. The apparatus that have been used for this experiment are:

1.  A 3-phase squirrel cage induction motor, 440V, 4.6A, 50HZ, 2.2K.W and rotates at a rated speed of 1420RPM.
2.  A DC-Dynamometer, 220V, 12A, 2.24K.W and rotates at a rated speed of 1200RPM. This acts as a various load to the system.
3.  A NANOVIP Plus measuring instrument from elcontrol. This instrument to measures the phase voltage, line current, power and the power factor from the induction motor side.
4.  A digital load cell from Interface to measure the system developed torque. It is physically hooked with the motor shaft. A Personal computer (Intel Pantium4, 2.6GHZ, 530MB RAM, MS Windows2000). A LabVIEW program is installed in the computer.
5.  A data acquisition card (NI BNC-2110) to interface the motor shaft with the computer, via a Bayonet Neill Concelman (BNC) connector, to measure the motor rotating speed.
6.  An in-house designed and developed control box to interface and control the system load with the computer.

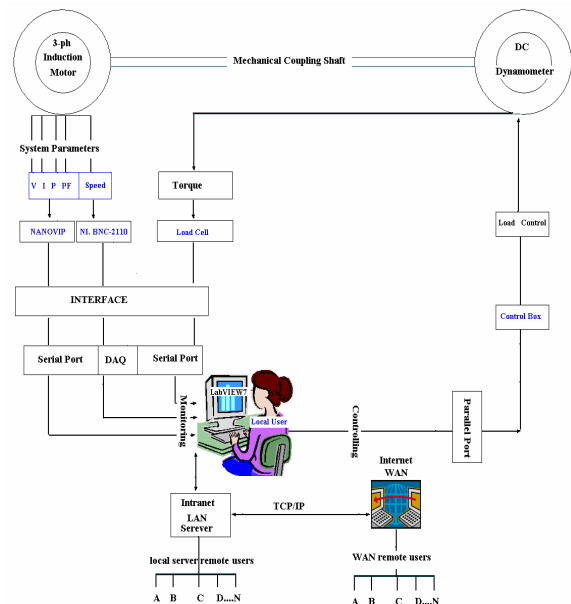The setup structure of the system is shown in Figure 1



Figure 1 the system setup structure.

## IV. LABVIEW PROGRAM AND INSTRUMENTS CONTROL

LabVIEW is a graphical programming language that uses icons instead of lines of text to create applications. In contrast to text-based programming languages, where instructions determine program execution, LabVIEW uses dataflow programming, where the flow of data determines execution. LabVIEW interacts with the programmer into two separate desktops:

1. Front panels, in which switches, counters, controls, knobs, graphs, tables and other formats of data can be displayed here.
2. Block diagram where the data flow and control function can be designed.

LabVIEW controls instrument by sending control commands from the computer to programmable instrument and are supported with a computer interface (serial, parallel, DAQ). The measurement and test instrument used in this study are interfaced with the computer in different methods.

### Serial Port Interface

Serial port communication is a very common protocol for device communication that is standard on almost every computer. Most computers include two RS232 based serial ports. In this communication protocol the serial port sends and receives bytes of information one bit at a time. For LabVIEW program to communicate with any external instrument or devices using serial port, the port needs to be initialized and other parameters specified and be identical between the two sides of communication. The main parameters for the serial port are: Port number, Baud rate, number of data bit and number of stop bit [16]. Furthermore, some instruments come with an American Standard Commands for Information Interchange (ASCII) string and that need to be specified as well.

The NANOVIP Plus and the digital Load Cell are interfaced using the serial port. The port parameters has been specified as follow: (0, 9600, 8, 1). The ASCII of the NANOVIP for request for the main measurement and it is: (: 010302020015E3) [17] while the load cell doesn't have. Normally computers have two serial ports only which is the case with the computer used in this study. Both ports are being used by the computer screen and the NANOVIP plus instrument. To add one more serial port to the computer a serial to Universal Serial Bus (USB) adaptor have been used. This adaptor adds one more serial port to the computer through the USB connector and as a result the load cell was interfaced with the computer.

For LabVIEW program to start interchanging data from an external instrument by the serial port, it performs four steps:

1.  Initializes the serial port specified in the port address.
2.  Write the instrument ASCII in the specified port for request of the measurement data available in that instrument.
3.  Read the instrument reply with the readings data it collected from the system.
4.  Close the communication.

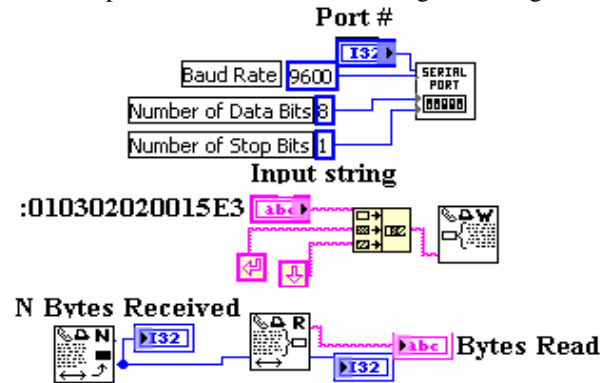These steps are shown in the block diagram of Figure 2.



Figure 2 block diagram o f the steps of sub-VI designed to communicate with the NANOVIP through the serial port

The measurement data collected from the system is in a string format, jumbled and difficult to understand.
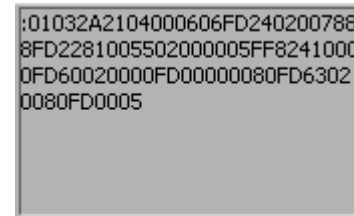


Figure 3 the data for mat as it comes out of the NANOVIP and enters the co mputer

The measurement data collected from the system is in a string format, jumbled and difficult to understand. The complex string needs to be reformatted into useful Form by following the manufacturer recommendations. Figure 3 illustrates the format of the data when it comes out of the NANOVIP.

### Standard Parallel Port (SPP) Interface

Normally the standard parallel port is used for output to a printer or other device. It sends data 8-bits or one byte at a time. In this study, the computer communicates with the load control box via the parallel port.

In contrast to the use of LabVIEW for the serial communication method, using the SPP is easier in term of number of steps. Instead of 4-steps to interchange data by the serial port communication, it is only 2-steps by using SPP. LabVIEW communicates with external instruments or devices by the use of SPP in two different methods. The method used in this study for SPP communication was input/output digital port. These two ports perform their job as follow:

1. Output Port: It writes the control commands/data onto the

specified port address. The port transmits data from the computer to an external instrument or device. Figure 4.

2. Input Port:  It reads the assigned value or data available in the specified port address. The port acquires data from an external instrument or device to the computer. Figure 5.
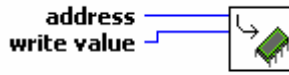


Figure 4 digital out-p ut port



Figure 5 digital input port

The digital output port has been used in this study since it is required to transmit the control commands from the computer to the load control box.

In order to interface and control the system load by the computer, the load control box has been designed and developed. It consists of numbers of solid state relays (SSR) equal to the number of the system loads to be controlled. These SSR are computer controlled and able to sustain the current and the voltage of the system load. Beside the SSR, the control box has a buffer connected between the computer and the SSR to amplify the computer signal. The internal structure and connection of the load control box is shown in Figure 6.
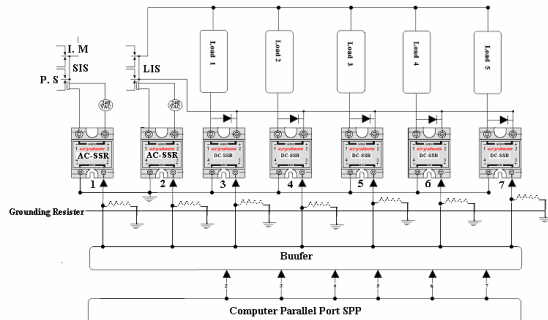


Figure 6 the internal structure and connectio n of the load control box.

To protect the system from the transient voltage may produced by the load, diodes of fast recovery type with peak inverse voltage (PIV) rated greater than supply voltage are connected across the relays output.

### Data Acquisition Card Interface.

It is a device that is used to acquire and convert physical signals such as voltage, current, pressure, temperature, level and force, into digital format and transmit them into the computer. In many applications it is used as plug-in devices to acquire data and transfer it directly to computer memory. The

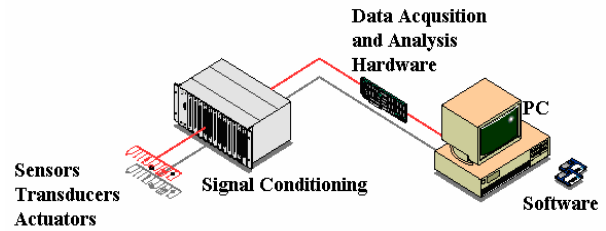typical computer-based data acquisition is shown in Figure 7.



Figure 7 computer -based data acquisitio n [18]

To measure the speed of the induction motor, the motor shaft is interfaced with the computer by the use of the national instrument BNC-2110 which, in turn, is connected to the data acquisition card.

In order for the LabVIEW program to communicate with the acquisition card, some parameters of the card have to be specified and configured. These are the device number, the type of measurement, the time base and the counter used for the measurement. The LabVIEW function (VI) used for the motor speed measurement is Measure Pulse- Width or Period shown in Figure 8.
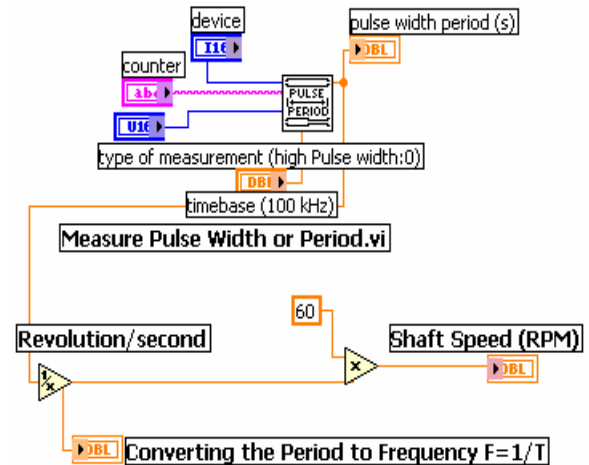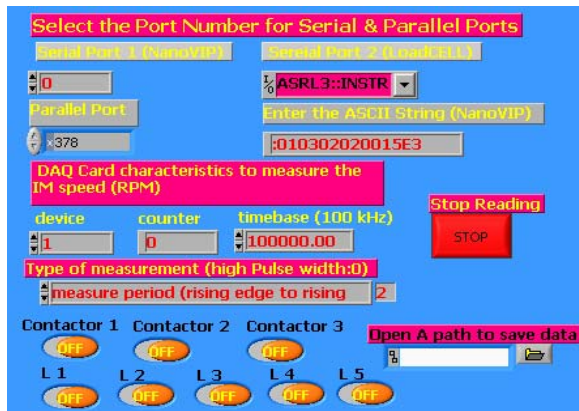


Figure 8 block diagram o f sub-VI illustrates the measurements of the motor speed

 This function measures the motor speed indirectly by measuring the period, which is the time in second, of two consecutive rising edge or falling edge of one revolution. The program is designed to convert the reading of the period to show the reading of the speed. The reading of the period is converted first into frequency by taking its inverse since the frequency is the reciprocal of the time (Frequency=1/Time). By that we have the number of the revolutions per second which if we multiply it by sixty we end up with the number of the revolutions per each minutethe and this is the motor rotation speed. Figure 8 illustrates the sub-VI and the steps of measuring the motor speed by the data acquisition card.

The other side of LabVIEW program is the front panel which is for the user interface. From the program designed for this

study, different images were captured from the front panel as it can be seen in Figure 9.a, and b.

Figure 9.a shows a part from the front panel. It contains controllers, indicators, switches and a path to open a new file where users can save the data. The first three controllers are to address the serial port number for the NANOVIP and the load cell and to specify the parallel port address for controlling the load. There is a string controller to enter the ASCII for the NANOVIP. There are four controllers to address the data acquisition card. The image contains also eight sliding switches to control the load. To save the acquired data in a file, there is a controller to open a file so the program will save the data in the specified file. To end the experiment or the process, there a STOP switch and that will quit the program safely. To simplify the understanding of the acquired data, the program is incorporated with a table. The table arranges the reading of the voltage, the current, the power and the torque in sequence with the time and the date at which the reading is acquired as it can be seen in Figure 9.b.



**(a)**

**(b)**



Figure 9 images (a and b) been captured fro m the program front panel

For a better understand of the relationship between the different parameters of the system, a waveform graph has been incorporated in the design as can be seen in Figure 10. In this design the graph shows the relationship between the current and the torque. However, the waveform graph can be redes-

igned to show the relationship between any different parameters in the experiment. In this image, there are two lines; bolded line and thin line; as they can be seen. The bolded line stands for the current reading while the thin line is for the developed torque. From the graph, the lines drop to zero points abruptly. These sudden drops can be attributed to the communication cut off between the measuring instruments, of both the current and the torque, and the computer.
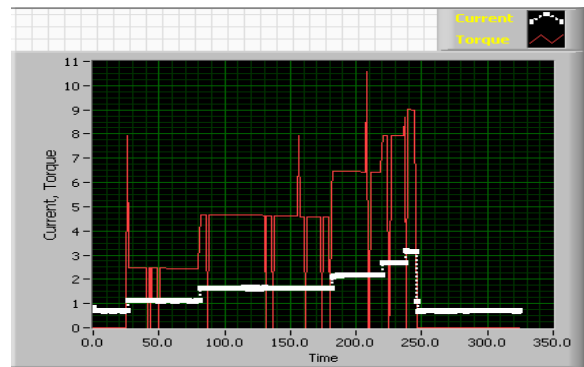


Figure 10 wave graph plotting of system parameter s

## V. THE VIRTUAL LAB EXPERIMENT EXECUTION

At the end of this study, the laboratory experiment has been interfaced with the computer. With the use of LabVIEW program, the experiment was conducted and the data was collected. The system has been tested by other intranet users in different locations. The experiment is performed remotely through number of steps:

1. Type the URL address of the experiment. The program front panel will appear to the user.
2. Specify and configure the parameters of the ports and instruments as it is shown in Figure 9.a.
3. Open a new file to save the collected data for the off-line or future analysis and reference.
4. Press on the continuous run icon, which is located on the top left corner of the program front panel, for the experiment will run continuously.
5. Use the controllers provided in the bottom of the Figure 11.a to send the control commands in order to control the system.
6. The collected data will be presented in a tabular format.
7. To stop running the experiment the user has to press the STOP switch which will quit the experiment safely without loosing of data and the gathered data will be saved in the opened path file.

The experiment was run locally from the computer in the laboratory and remotely through the local area network.

There are some more modifications that can take place in this design postponed for the future work. Theses are like incor-

porating the design with a web camera to capture live images from the experiment setup. Beside that it is intended to add a discussion forum as a communication channel between users and supervisor in charge.

## VI. CONCLUSION AND FUTURE WORKS

The objectives of this study have been achieved. The possibility of conducting a laboratory experiment remotely has been proven. The local area network (intranet) was used to control and monitor the experiment at different locations. Using the LabVIEW program to design a virtual laboratory has been achieved. Interfacing different instruments with the computer through the serial port, parallel port or data acquisition card has been realized. The proposed virtual laboratory has been testified in the electrical machine laboratory, school of Electrical and Computer engineering, Curtin University of technology. The experiment runs successfully locally on the computer inside the laboratory and remotely through the local network by the other users.

## ACKNOWLEDGMENT

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