ASPECTS CONCERNING THE IMPLEMENTATION OF A VIRTUAL LABORATORY FOR DC SERVOMOTORS USING THE INTERNET

Gheorghe BĂLUȚĂ

”Gh. Asachi“ Technical University, Faculty of Electrical Engineering, Iasi, Romania, e-mail: gbaluta@tuiasi.ro

Abstract. *The e-learning has introduced new opportunities in teaching and learning electrical engineering subjects. This paper presents the architecture of a virtual engineering laboratory, designed to allow remote training in the control of DC, brushless DC, and stepper servomotors. An example of DC servomotor control on virtual laboratory is also presented.*

Keywords: *education tool, DC servomotor, electrical drive, and motion control.*

1. Introduction

Traditionally, the main objective of education consisted in acquiring knowledge by the students. The assessment was based on testing whether students could reproduce the acquired knowledge. By the end of last century engineering educators began to realize that the demands from industry changed. There should be more emphasis in skill and deep understanding rather than knowledge [1]. A general problem in electrical engineering is the fact that it deals with rather abstract notions such as current, voltage, resistance, capacitance, etc. These electrical quantities and phenomena are not directly observable and can only be made observable by means of measurements. Using new media and IT-technologies in classroom enables not only make studying more attractive to the student, but also might make teaching much easier. Complex technical problems have to be presented in a way that is easy to follow and understand. However, even if computer animations are used, student cannot grasp the details in a short time, since the teacher only once or twice shows examples or animations. There remains a need for repetition and exercises.

E-learning courses offer user-controlled elements that just aren't feasible in regular training classes. This self-paced element is one of the things that make e-learning so effective. It can lead to increased retention and a stronger grasp on the subject. This is because there is the ability to revisit or replay sections of the training that might not have been clear the first time around. Another element that an e-learning offers is the fact that it can work from any location and any time.

E-learning has introduced a new access to engineering subject learning; by using interactive animation and simulation it enable to create interactive training environment helping partly to replace laboratories [2]. Software simulations exercises are certainly helpful. But it is an absolute necessity that hardware-based laboratory experiments be performed concurrently by the students. It is a dangerous trend in many universities to move away from hardware to purely software-based laboratories; such an approach fails to excite students and also does not prepare them for the "real word" where they will design, build, test or use real hardware [3], [8].

It is important to give to the students a real world experience. However, to build an experiment is expensive and it is impossible for an educational institute to have the complete scale of experiments. The hardware experiments should therefore be redesigned in such a way that they also can be accessed in the Web and possibly integrated in e-learning. It must be a real electrotechnical experiment conducted in the laboratory but remotely controlled and monitored by e-learning Web-based tools.

A Virtual Laboratory (VL) is an electronic workspace for distance collaboration and experimentation in research or other creative activity, to generate and deliver results using distributed information and communication technologies [4]. A VL is not viewed as a replacement for, or a competitor with, a Real Laboratory (RL). Instead, VLs are possible extensions to RLs and open new opportunities not realizable entirely within a RL at an affordable cost. They will probably have an important role in the future because they integrate the technical, financial and human resources by sharing data, information, documents, multimedia means, etc., that is, the knowledge base.

This paper presents the architecture of a virtual engineering laboratory, designed to allow remote training in the control of separately-excited DC, brushless DC, and stepper servomotors. An example of separately-excited DC servomotor control on virtual laboratory is also presented.

2. The Architecture of the VL for Training in the DC, Brushless DC, and Stepper Servomotor

Using mechanical actuators based on electric servomotors is one of the most widely used options in industrial and consumer applications. This growing demand, together with the call for better performance in systems using electric motors, explain why more and more electronic devices (controllers, drivers, etc.) are marketed, designed to facilitate and improve the control of electric servomotors [5].

2.1 The Architecture of VL

The VL for Training in the DC, Brushless DC and Stepper Servomotors is an Internet-based Virtual Learning and Training Environment where learners can interact with lab equipment, regardless of geographical constraints. Fig. 1 illustrates the concept of a virtual engineering laboratory on a network that allows for geographically separated users to have access to real devices at different sites.

The training equipment aims to make easier the task of instruction on methods and devices for the control and driving of servomotor, offering in a single environment, the possibility of testing different types of servomotor and different means of controlling each one.

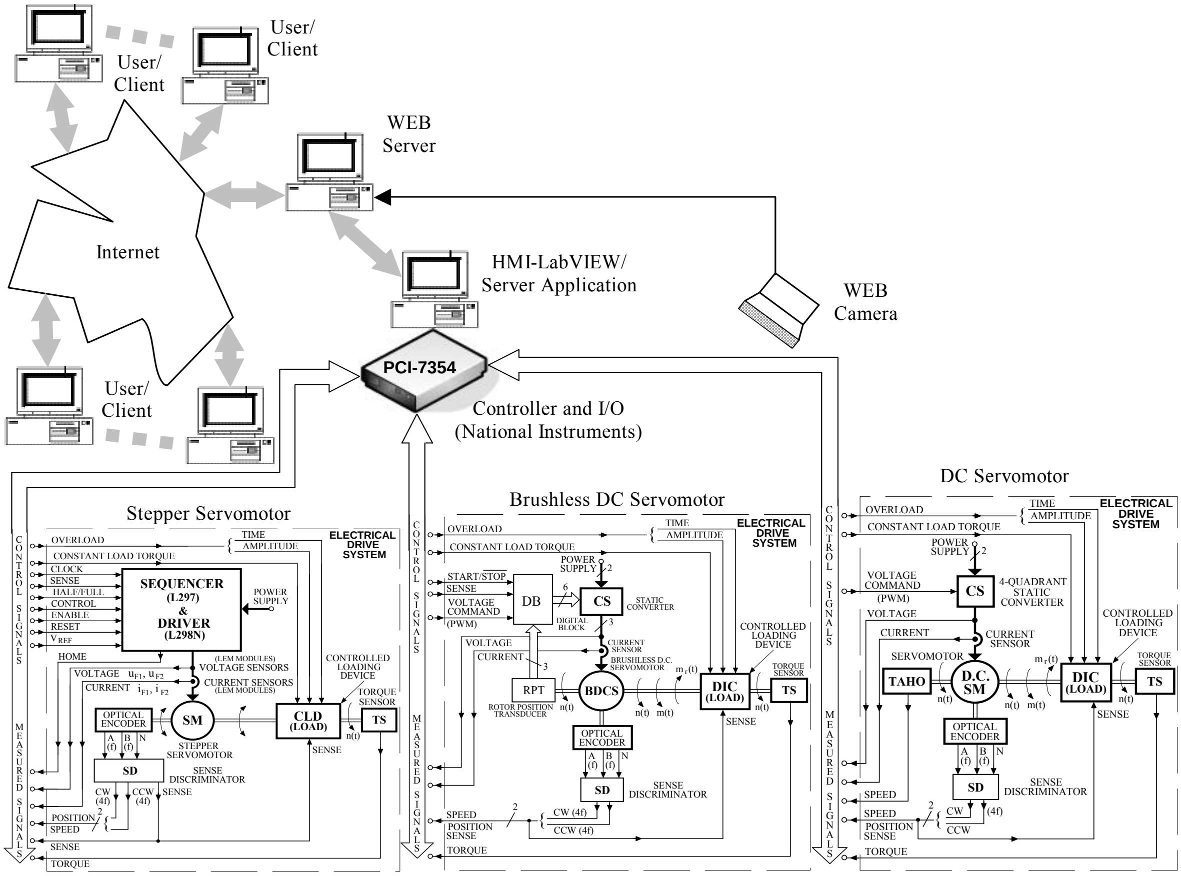

Fig. 1. The virtual electrical engineering laboratory concept.

2.2 Hardware and Software Resources of Server Application

In the first stage the VL include three representative types of electrical drives: stepper servomotors, separately-excited DC servomotors, and brushless DC servomotors. Each one of these VL components has own specific actuator, controlled loading device as well as transducers (analog and digital) for electrical and mechanical quantities and protection devices. In this way all of three types of servomotors can be controlled in open loop or closed loop.

DSP controllers available today are able to perform the computation for high performance digital motion control structures for different motor technologies and motion control configuration. The level of integration is continuously increasing, and the clear trend is towards completely integrated intelligent motion control [6]. Highly flexible solutions, easy parameterized and "ready-to-run", are needed in the existent "time-to-market" pressing environment, and must be available at non-specialist level.

Basically, the digital system component implements through specific hardware interfaces and corresponding software modules, the complete or partial hierarchical motion control structure, i.e., the digital motor control functionality at a low level and the digital motion control functionality at the higher level (see Fig. 2).

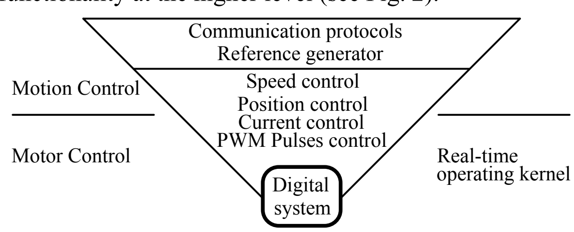

Fig. 2. Motion system structure hierarchy.

The National Instruments PCI-7354 controller is a high-performance 4-axis-stepper / DC / brushless DC controller. This controller can be used for a wide variety of both simple and complex motion applications. It also includes a built-in data acquisition system with eight 16-bit analog inputs as well as a host of advanced motion trajectory generator and triggering features. Through four axes, individually programmable, the board can control independently or in a coordinated mode the motion. The board architecture, which is build around of a dual-processors core, has own real-time operating system (see Fig. 3). These board resources assure a high computational power, needed for such real-time control.

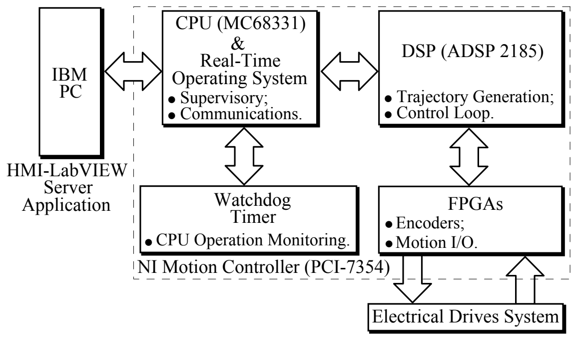

Fig. 3. Motion controller board structure.

Functionally, the architecture of the NI PCI-7354 controller is generally divided into four components (Fig. 4): supervisory control, trajectory generator, control loop, and motion I/O.

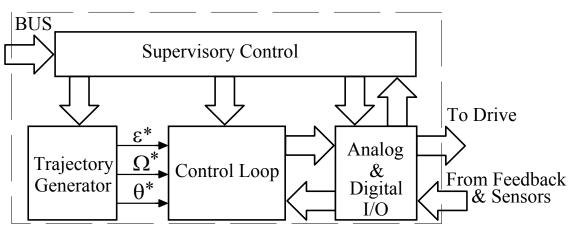

Fig. 4. Functional architecture of the NI PCI-7354.

Supervisory control performs all the command sequencing and coordination required to carry out the specified operation. Trajectory generator provides path planning based on the profile specified by the user, and control loop block performs fast, closed-loop control with simultaneous position, velocity, and trajectory maintenance on one or more axes, based on feedback signals.

SCADA software enables programmers to create distributed control applications having supervisory facilities and a Human-Machine Interface (HMI). As SCADA software, LabVIEW is used. The development environment used to complete the applications is LabVIEW 7.0, which beside the graphic implementation that gives easy use and understanding takes full advantage of the networking resources.

In the following an example is presented to illustrate the manipulation of instruments and real devices for low power electrical drives education on the Web. It illustrates the laboratory works dedicated to control an electrical drives system with separately-excited DC servomotor.

3. Setup DC Servomotor Electrical Drives System

The detailed layout is presented in Fig. 1 and the setup for DC servomotor control can be inspected in Fig. 5.

The rated parameters of the used separately-excited DC servomotor are presented in Tab. 1. It is driven by a reversible chopper with the L292 specialized integrated circuit [9]. The servomotor's shaft is connected with an incremental optical encoder that gives 1000 pulses/rev.

Tab. 1. The rated parameters of the DC servomotor.

Rated parameters	Symbol	Value	Unit
Armature voltage	U_n	20	V
Armature current	I_n	2	A
Speed	n_n	2400	rpm
Armature winding resistance	R_a	1.31	Ω
Armature winding inductance	L_a	7.58	mH
Electrical time constant	T_e	5.78	ms

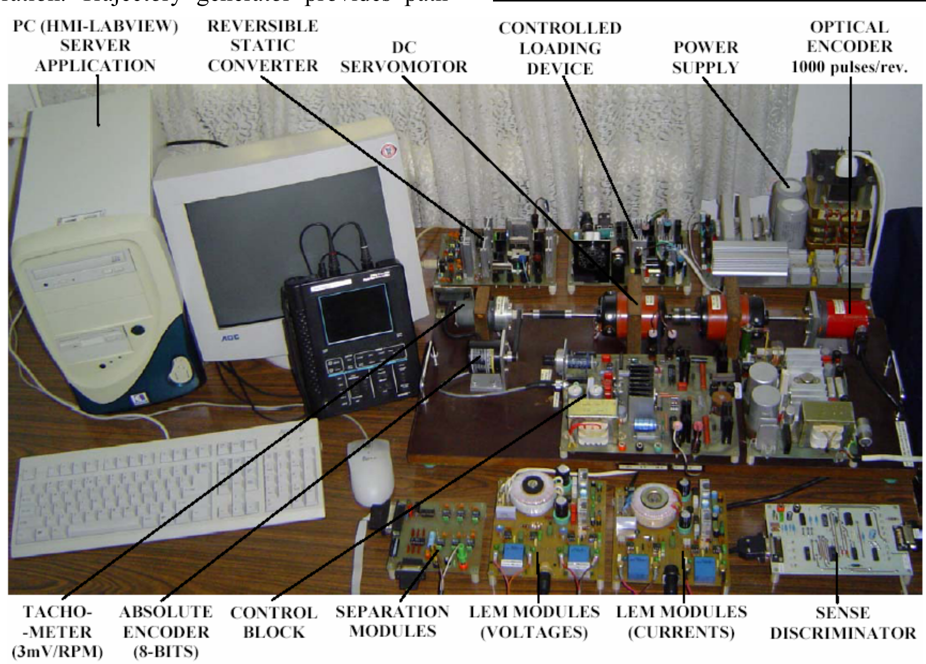

Fig. 5. General view of the DC electrical drives system.

The DC servomotor is loaded using a controlled loading device. Among the features of the loading system, the authors emphasize:

-the possibility to load the electric drive motor with a reactive load torque in a wide range of speed, including very low speeds;

-the possibility to impose a constant load torque operation mode or an overload operation mode.

The driven axis with DC servomotor can be controlled in open loop or closed loop.

The implemented control system uses the algorithm from Fig. 6, which allows to generate in real-time the move trajectory and to change the motion parameters. In order to program the motion control system, the developer employs LabVIEW environment with specific virtual instruments for motion control from the FlexMotion library. For closed-loop operating mode, the associated graphic program is shown in Fig. 7.

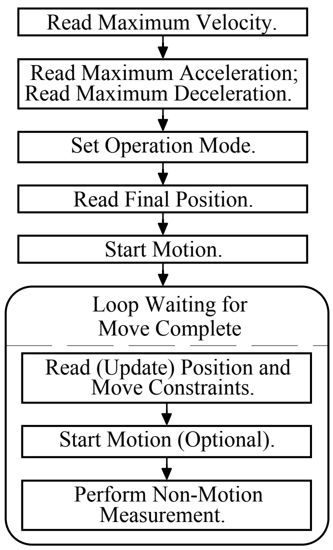

Fig. 6. Position-based straight-line move algorithm.

The vast majority of motion control algorithms employed in industrial applications are of two forms [7]:

-the well-known PID position loop (see Fig. 8);

-an average velocity loop cascaded with a position loop (see Fig. 9).

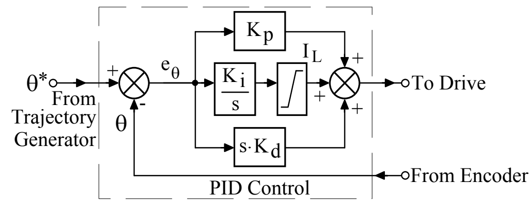

Fig. 8. PID Servocontrol topology.

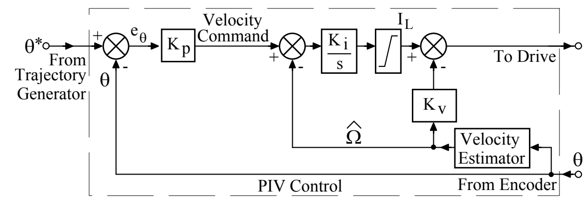

Fig. 9. PIV. Servocontrol topology.

On the other hand, in order to achieve near zero following or tracking error, feedforward control is often employed. An example of how feedforward control is used in addition to the second servocontrol topology is shown in Fig. 10. A requirement for feedforward control is the availability of both the velocity, $\Omega^*(t)$, and acceleration, $\varepsilon^*(t)$, commands synchronized with the position commands, $\theta^*(t)$. The NI PCI-7354 controller can be configured for any of the above servocontrol topologies.

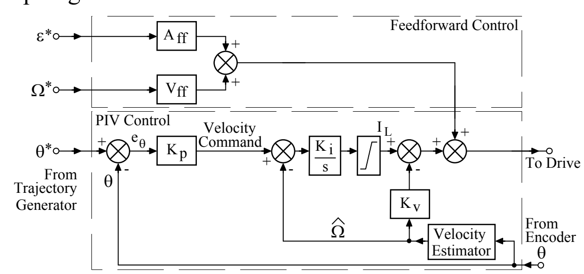

Fig. 10. Basic feedforward and PIV control topology.

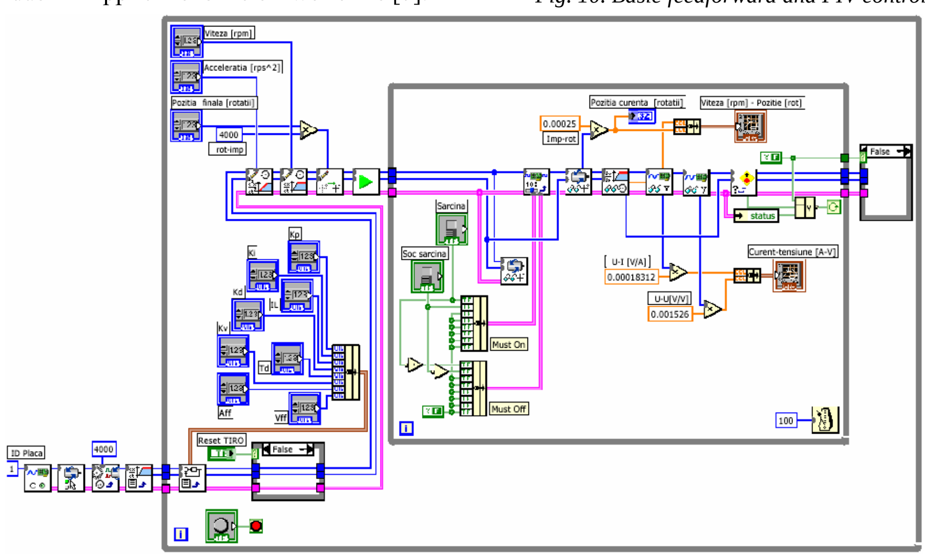

Fig. 7. LabVIEW diagram for single axes positioning system with DC servomotor.

In order to build a positioning application, the developer has to follow the stages shown in Fig. 11, which represent the steps required to design a motion application.

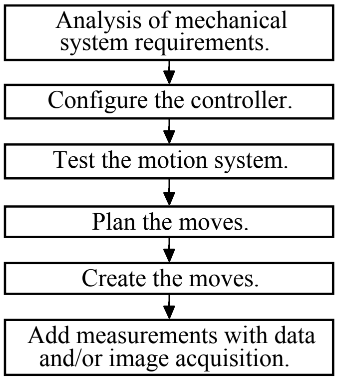

Fig. 11. Generic steps for designing a motion application.

To introduce a student to motor control, the DC servomotor set-up provides the opportunity to learn about this motor without ever attending a laboratory session at their institution. Since most engineering students cannot procure expensive electronic instruments (oscilloscope, voltmeters, etc.) and since the majority of students do not have prior technical experience, this remote set-up is very economical and offers students a great tool for learning about the servomechanism and data acquisition.

The learner can also perform the second to fifth stages of motion application design (see Fig. 11). To ensure proper performance for servomechanism the motion control system must be tuned and tested. Then the type of move profile is planed. Motion constraints are the maximum velocity, acceleration, deceleration and jerk that the system can handle. Trajectory parameters are expressed as a function of motor shaft revolutions. The trajectory generator takes into account the type and the constraints of motion and generates values of instantaneous trajectory parameters in real-time.

Basically, the student can learn about the parameters of the DC servomechanism by tuning the control loop parameters and setting the motion constrains to make execute the operations, i.e. change the rotation direction, position and speed. Also during the experiment, the student can visualize critical input and output points in the DC servomotor electronic interface using virtual oscilloscopes. Since this system is in real-time mode, the learner observes changes in position, direction, and velocity as the motor rotates after being commanded.

The graphical user interfaces specific to this application are shown in Fig. 12 (for open-loop operating mode) and Fig 13 (for closed-loop operating mode). The first one reveals the experimental results being obtained for the open-loop control of the electrical drives system when the user applies a load torque disturbance to the controlled servomotor shaft. The variations of the armature current and modulated voltage applied to its terminals are presented by means of the first virtual oscilloscope. The speed drop caused by the load torque disturbance can be noticed on the second virtual oscilloscope. Thus the user can deduce the causal link between the disturbance acting over the system and its effects over the output measure.

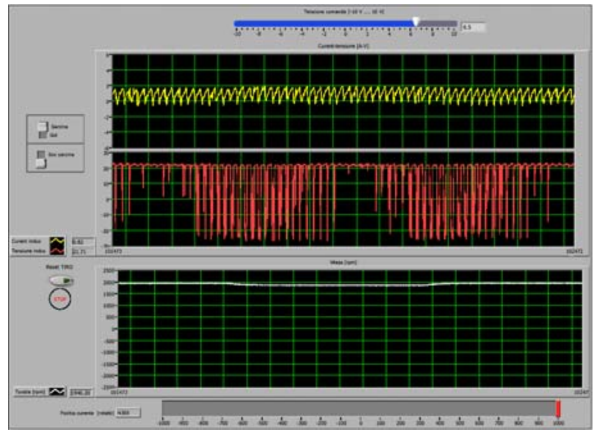

Fig. 12. Main panel for DC servomotor electrical drives system: open-loop operating mode.

The user graphical interface presented in Fig. 13 shows the experimental results obtained for a classical position control structured by using a PID controller. The tuning parameters of the control law are presented in the bottom-left area reserved for the controller settings and those related to the motion in the top-left part. The review of the results certifies the fact that the positioning within the range [0÷1000] rev. is completed in full accordance with the requirements imposed by the motion constraints and with optimal dynamic behavior performances.

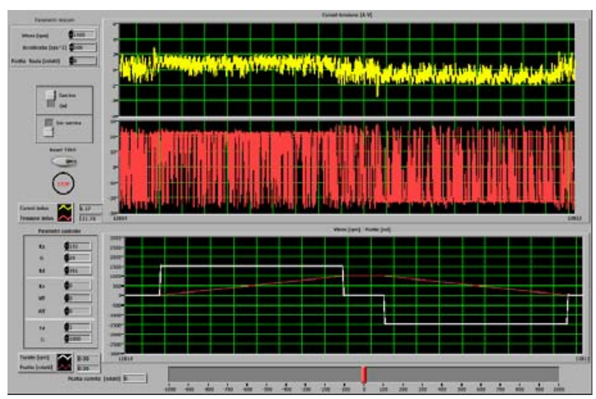

Fig. 13. Main panel for DC servomotor electrical drives system: closed-loop operating mode.

4. The Web Page

The WEB Server shown in Fig. 1 and accessed to the address http://www.lvaemp.tuiasi.ro, hosts the WEB pages created for this VL. The WEB page (Fig. 14) allows the users to remote control the applications of RL. But in order to access the current configured application the user must to register an account and to be authorized by the site administrator. If the access is granted the user has the possibility to red the breviary related to the applications of the RL and/or to test. On the other hand, if the experimental set-up is accessing by another user then the last in user can only to assist at the remote control of the application and to the experimental data analyzing, waiting in a queue the release of the application in order to have full access.

Fig. 14. The WEB page of virtual laboratory.

The design of WEB pages is based on PHP and AJAX programming languages and their publishing is made using the CGI scripts. In this way, the potential user can access the VL from any location without other supplementary software resources.

Even the used browser can be Internet Explorer we strongly recommend Netscape Navigator because this support the *.monitor* mode, which permits the images update periodically irrespective of users.

5. Conclusions

This paper focuses on the use of a VL concept to show that it is now possible to bring remote access instrumentation and control techniques within an educational framework.

Through the user interfaces, the students acquire the following abilities:

-enabling the servomotor and resetting the control system;

-calibrating a DC servomotor system;

-controlling the rotation direction of the DC servomotor;

-moving the servomotor shaft from one arbitrary position to another;

-accelerating the servomotor and maintaining a constant velocity as well as decelerating and bringing it to a complete stop;

-visualizing intermediate servomotor control and encoder signals;

-understanding the relationship between the external loads and command effort.

This type of laboratory has some advantages compared to RL, such as:

-it is not limited in time, as students can exercise at any hour;

-if a university has just one expensive equipment it could share it with other universities and so students can practice on different equipment;

-students can review the laboratory session that has been made earlier as many times they want and in a relaxed environment;

-VL can be a good alternative in distance learning system because it can fill the absence of practical session.

In the case of electrical drives the hardware and software resources of the NI PCI-7354 board assure system real-time control. On the other hand, the remote monitoring and parameterization is depended on the speed of telecommunication network.

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