Aspects Concerning the Implementation of a Virtual Laboratory for Brushless DC Servomotors Using the Internet

Gheorghe BALUTA, Vasile HORGA

"Gh. Asachi" Technical University of Iasi, bd. D. Mangeron, no. 53, RO-700050 Iasi
gbaluta@tuiasi.ro, horga@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 Brushless DC servomotor control on virtual laboratory is also presented.**

Index Terms—**Brushless DC motors, motion control**

I. 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.

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 [3]. 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, multimedia means, etc.

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 brushless DC servomotor control on VL is also presented.

II. THE ARCHITECTURE OF THE 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 [4], [5], [7], [8].

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.

In the first stage the VL include 3 representative types of electrical drives. Each one of these VL components has own specific actuator, controlled loading device as well as transducers for electrical and mechanical quantities and protection devices.
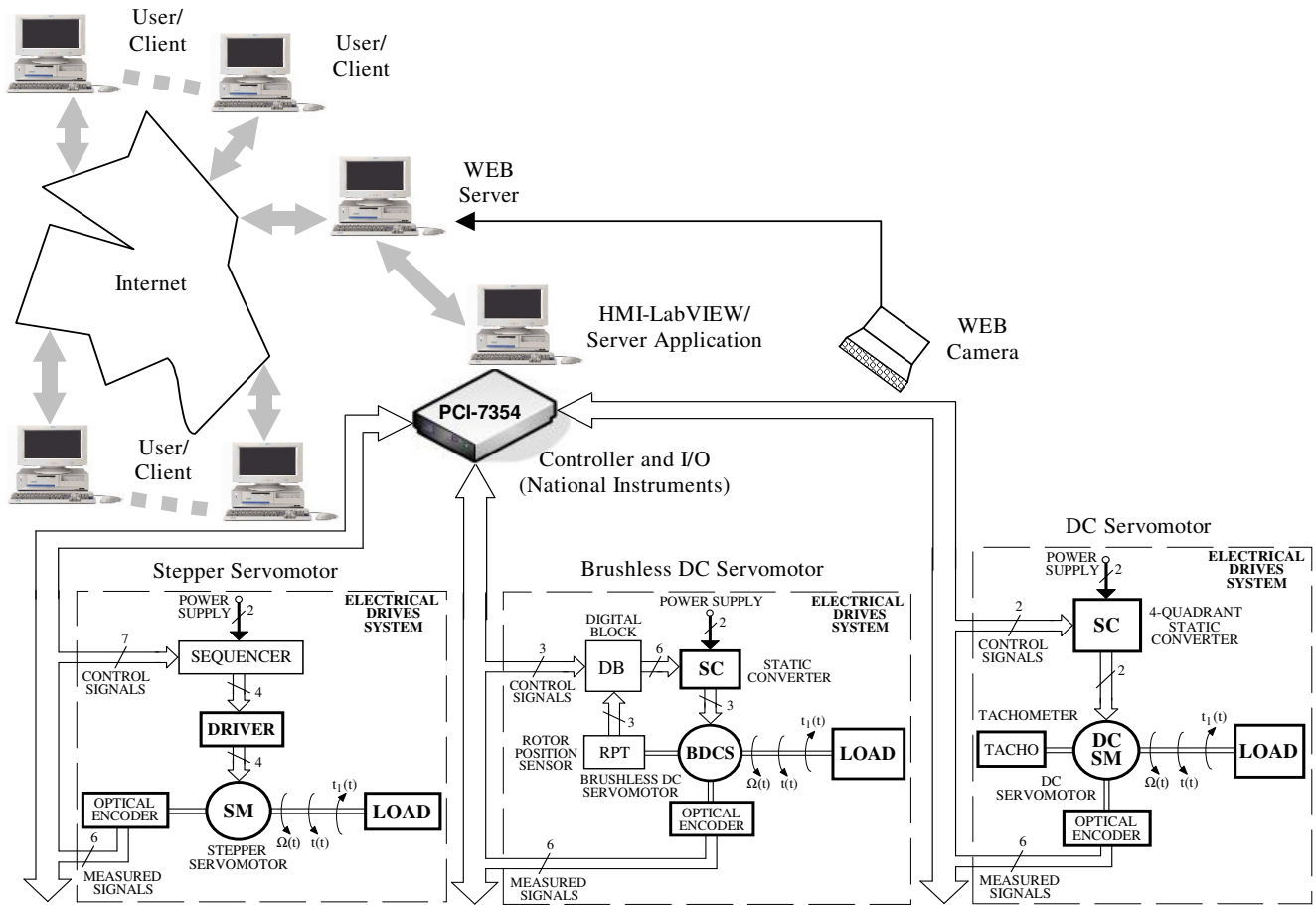
Fig. 1 The virtual electrical engineering laboratory concept

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).
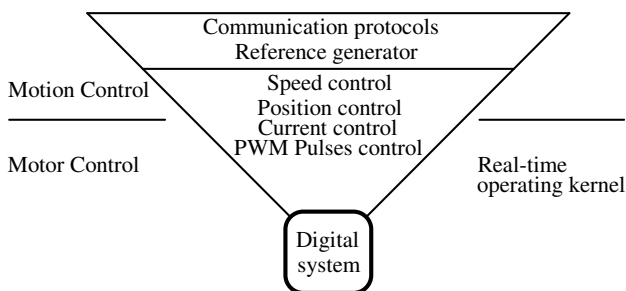

Fig. 2 Motion system structure hierarchy

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.
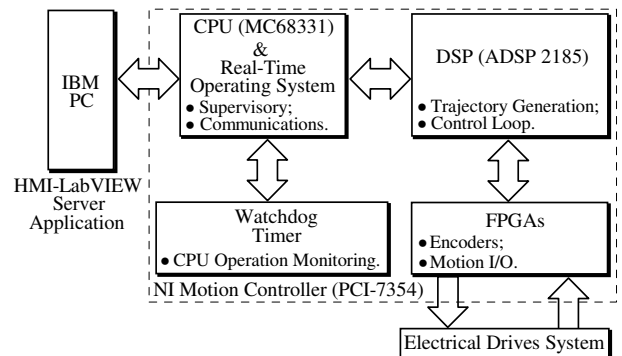

Fig. 3 Motion controller board structure

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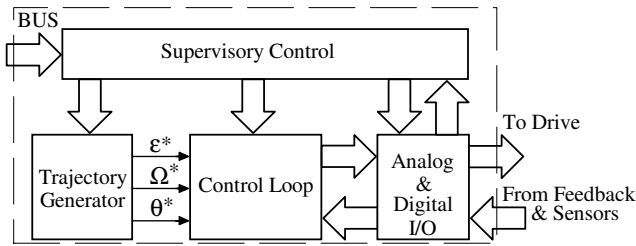

Fig. 4 Functional architecture of the NI PCI-7354

SCADA software enables programmers to create distributed control applications having supervisory facilities and a Human-Machine Interface. 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 brushless DC servomotor.

III. SET-UP BRUSHLESS DC SERVOMOTOR ELECTRICAL DRIVES SYSTEM

The detailed layout is presented in Fig. 5 and the set-up for three-phase brushless DC servomotor (BDCS) control can be inspected in Fig. 6. The rated parameters of the BDCS with three "delta" connected windings (manufactured by the MINIMOTOR S.A. Company, 2444 S 024 BL 1 type, permanent magnet rotor with one pole-pair, built-in gear reducer-ratio 3.7:1) are presented in Table I.

TABLE I. RATED PARAMETERS OF THE BDCS

Rated parameters	Symbol	Value	Unit
Output power (at 30000 RPM)	P_{2max}	36	W
Voltage	U_n	24	V
Maximum current (at 30000 RPM)	I_{max}	1.37	A
Terminal resistance	R	2.1	Ω
Maximum torque (at 30000 RPM)	M_{max}	11.8	mN·m
Maximum speed	n_{max}	38000	RPM
Back-EMF constant	k_E	1.026	mV/RPM
Torque constant	k_M	9.8	mN·m/A
Mechanical time constant	T_m	14	ms
Rotor inertia	J_r	6.5	g·cm^2
Friction torque (static)	C_o	1	mN·m
Friction torque (dynamic)	C_v	$3.5·10^{-5}$	mN·m/ RPM
Efficiency	η_{max}	77	%

The BDCS has the rotor position transducer composed of three Hall-effect sensors located at the periphery of the stator and geometrically spaced at the 120˚, generating TTL logical signals. The servomotor's shaft is connected with an incremental optical encoder that gives 2500 pulses/rev.

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

-the possibility to load the electric drive servomotor 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.

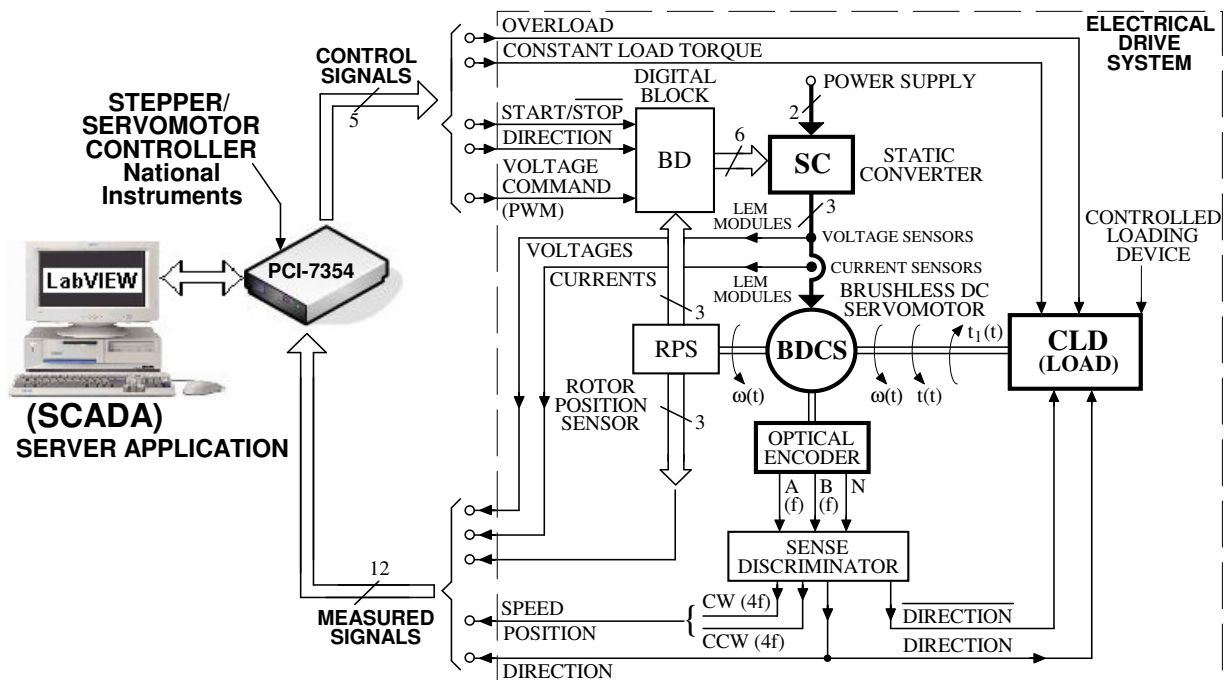The driven axis with BDCS can be controlled in open-loop or closed-loop.

Fig. 5 The block diagram of the brushless DC electrical drives system
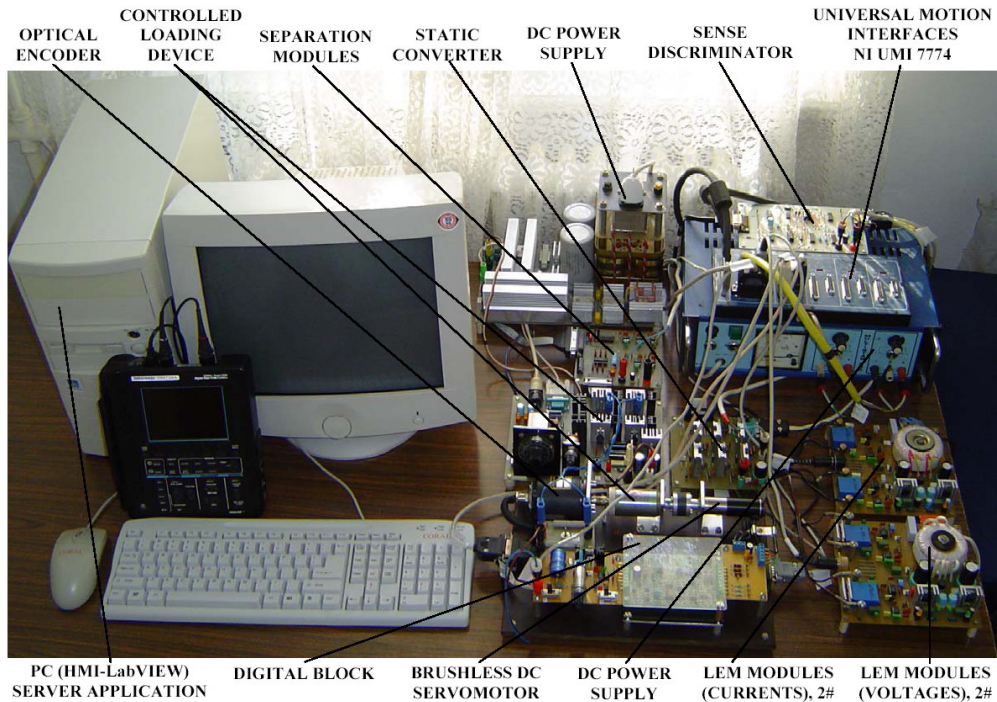
Fig. 6 Photograph of the BDCS electrical drives system

The implemented control system uses the algorithm from Fig. 7, 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 (see Fig. 8).

In order to build a positioning application, the developer has to follow the stages shown in Fig. 9, which represent the steps required to design a motion application.

To introduce a student to servomotor control, the BDCS 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.
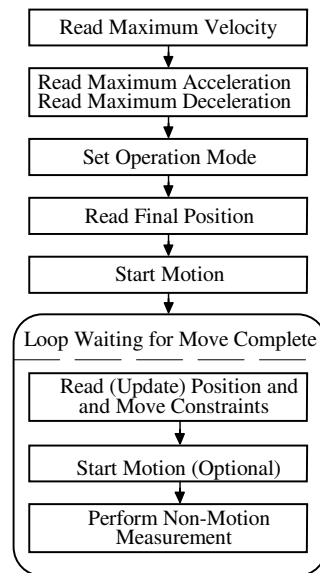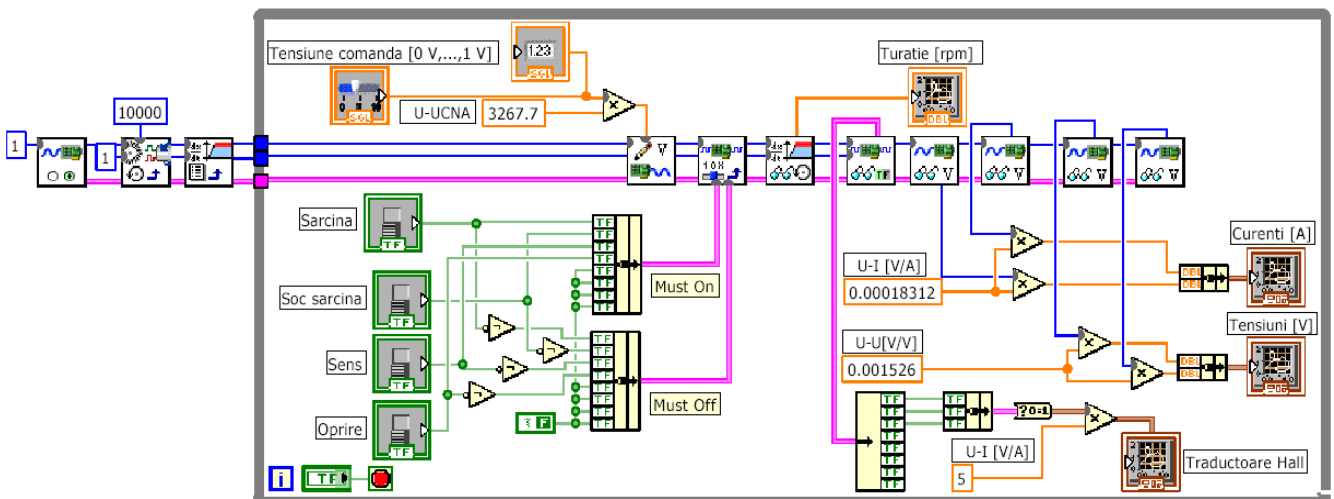

Fig. 7 Position-based straight-line move algorithm

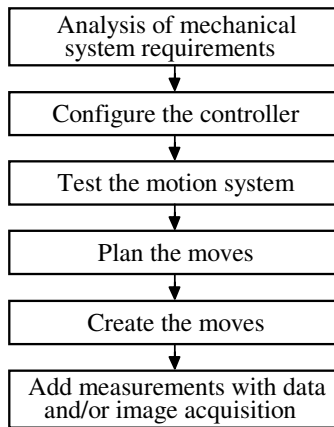Fig. 8 Associated graphic program for closed-loop operating mode

146

Fig. 9 Associated graphic program for closed-loop operating mode

The learner can also perform the second to fifth stages of motion application design (see Fig. 9). 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 brushless 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 visualise critical input and output points in the brushless 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 servomotor rotates after being commanded.

In this application the user has the possibility to study the command regime in speed closed-loop. The control elements of the loop create the possibility that the user could modify the command signal of the speed servomotor and/or to establish the servomotor loading degree. The measures acquired in view of their graphical representation are line currents and phase voltages supply, the Hall-effect sensors digital signals and also the speed of the electrical drive system.

The user graphical interface specific to this application is shown in Fig. 10. The user graphical interface shows the experimental results being obtained for the closed-loop control of the electrical drives system when the user applies a load torque disturbance to the controlled servomotor shaft (for clock-wise direction and counterclock-wise direction). The variations of the line currents and the voltages supply of the phase's servomotor are presented by means of the first and second virtual oscilloscope. The digital signals acquired from Hall-effect sensors are presented by means of the third virtual oscilloscope. The speed drop caused by the load torque disturbance can be noticed on the fourth virtual oscilloscope. Thus the user can deduce the causal link between the disturbance acting over the system and its effects over the output measure.

IV. 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 (see Fig. 11) allows the users to remote control the applications of RL. But, in order to access the current configured application, the user has to sign up for an account and has to be authorized by site administrator. If the access is granted, the user has the possibility to read the breviary related to the applications of the RL and/or to test.
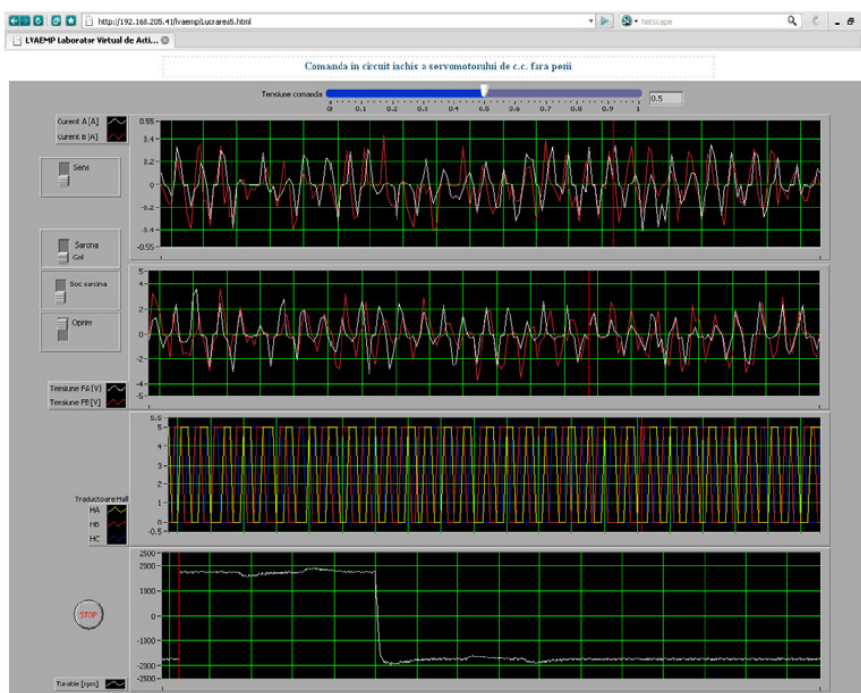

Fig. 10 Main panel for BDCS electrical drives system (closed-loop operating mode)

Fig. 11 The WEB page of the VL

On the other hand, if the experimental set-up is accessed by another user, then the last user can only assist by remote control towards application and experimental data analyzing, waiting in a queue way the release of application, in order of having full access.

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.

If the used browser might be Internet Explorer, we strongly recommend Netscape Navigator, because this supports the *.monitor* mode, which allows periodically images' update, independently of users.

V. CONCLUSION

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 can acquire the following abilities:

-enabling the servomotor and resetting the control system;

-calibrating a BDCS system;

-controlling the rotation direction of the 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, therefore students can practice anytime;

-if a university has just expensive equipment, it might share that with other universities, and in this way, the students can practice on different equipments;

-students could review the laboratory session, which might be performed earlier, as many times they want and in a relaxed environment;

-VL might represent a good alternative for distance learning system, because is able of filling the absence of practical session.

Considering the electrical drives system, the real-time control is assured by hardware and software resources of the NI PCI-7354 board. On the other hand, the remote monitoring and parameterization depend upon the speed of telecommunication network.

REFERENCES

[1] V. Fedok, and P. Bauer, "E-learning in Education of Electrical Drives and Power Electronics: Opportunities and Challenges", Proc. of the 15-th Int. Conf. on Electrical Drives and Power Electronics, pp. 1-9, Dubrovnik, Croatia, September 2005.

[2] P. Bauer, and V. Fedak, "E-learning for Power Electronics and Electrical Drives", Proc. of the 13-th Int. Conf. on Electrical Drives and Power Electronics, pp. 567-572, High Tatras, Slovak Republic, September 2003.

[3] P. V. James, "Report of the Expert Meeting on Virtual Laboratories", International Institute of Theoretical and Applied Physics, Ames, Iowa, 1999.

[4] M. Mazo, J. Urena, F. J. Rodriguez, J. J. Garcia, J. L. Lazaro, E. Santiso, F. Espinosa, R. Garcia, P. Revenga, J. C. Garcia, E. Bueno, and R. Mateos, "Teaching Equipment for Training in the Control of DC, Brushless and Stepper Servomotors", IEEE Trans. on Education, Vol. 41, No. 2, pp. 146-158, May 1998.

[5] H. H. Saliah, E. Nurse, and A. Abecassis, "Design of a Generic, Interactive, Virtual and Remote Electrical Engineering Laboratory", Proc. of the 29-th ASEE/IEEE Frontiers in Education Conference, Session 12c6, pp. 18-23, San Juan, Puerto Rico, November 1999.

[6] L. Kreindler, "DSP Solution for Digital Motion Control", Journal of Electrical Engineering, Vol. 2, pp. 1-9, June 2002.

[7] Gh. Baluta, and C. Lazar, "Remote Control Laboratory Development for Electrical Drive Systems", Proc. of the 13-th IEEE/IFAC Int. Conf. on Methods and Models in Automation and Robotics, pp. 393–398, Szczecin, Poland, August 2007.

[8] Gh. Baluta, V. Horga, and C. Lazar, "Implementation of a Virtual Laboratory for Low Power Electrical Drives", Proc. of the 13-th Int. Conf. on Power Electronics and Motion Control, pp. 2066-2071, Poznan, Poland, September 2008.