

Control of Stepper Motors on Virtual Laboratory

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Abstract-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 stepper servomotor control on virtual laboratory is also presented.

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 [3].

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.

II. The Architecture of the VL for Training in the DC, Brushless DC and Stepper Servomotors

Using mechanical actuators based on electric motors 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 motors [5].

A. The Architecture of VL

The VL for Training in the DC, Brushless DC and Stepper Servomotors will be an Internet-based Virtual Learning and Training Environment where learners and teachers can interact with one another as well as with computer-based simulators or 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.

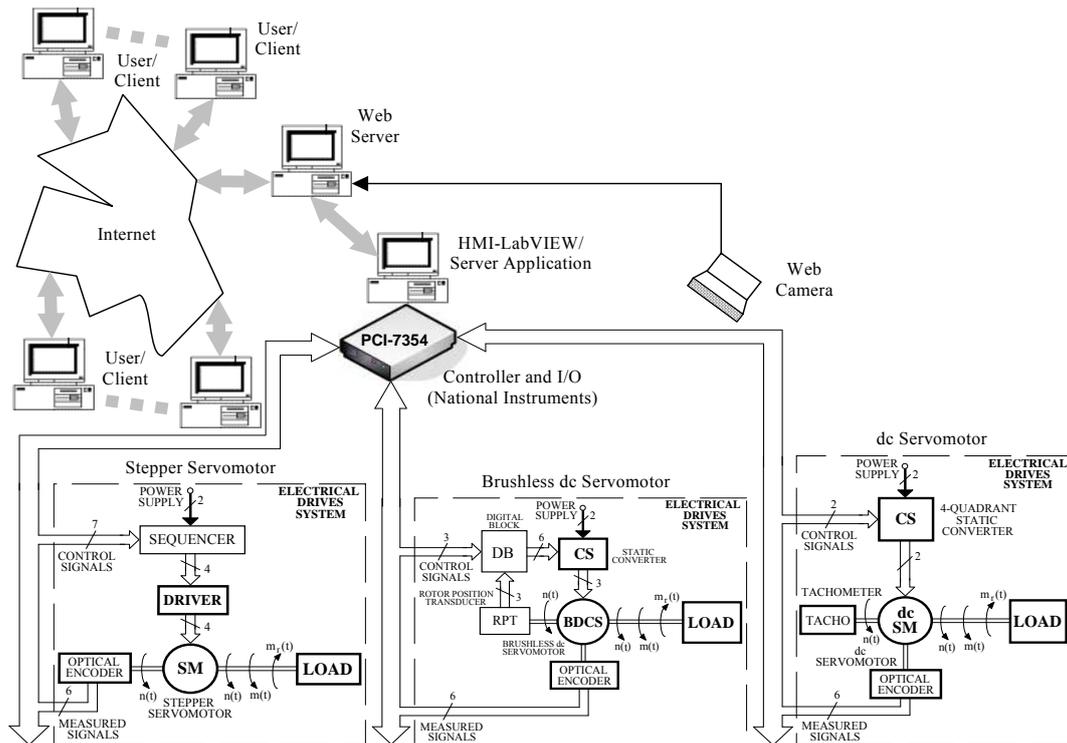


Figure 1. The virtual electrical engineering laboratory concept.

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

B. Hardware and Software Resources of Server Application

In a first stage the VL include three representative types of electrical drives (stepper/dc/brushless dc servomotors). 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. 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 (Fig. 2).

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 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 (Fig. 3). These board resources assure a high computational power, needed for such real-time control.

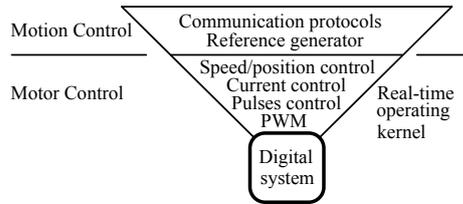


Figure 2. Motion system structure hierarchy.

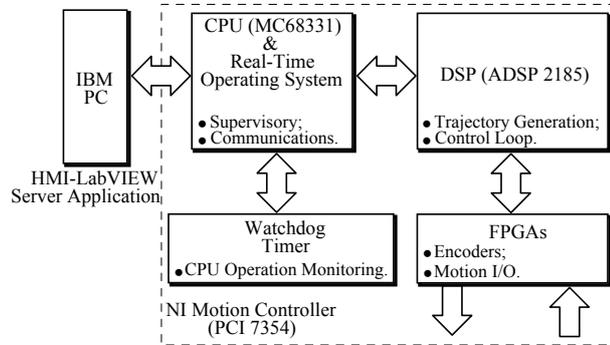


Figure 3. Motion controller board structure.

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.

III. Setup Stepper Servomotor Electrical Drives System

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 Stepper Motor (SM).

The setup for bipolar SM control is presented in Fig. 4 and the detailed layout can be inspected in Fig. 5. The SM has two phases, 1.8 degrees/step, and is driven by two specialized integrated circuits L297 (controller) and L298N (driver) [10]. The motor's shaft is connected with an incremental optical encoder that gives 1000 pulses/rev.

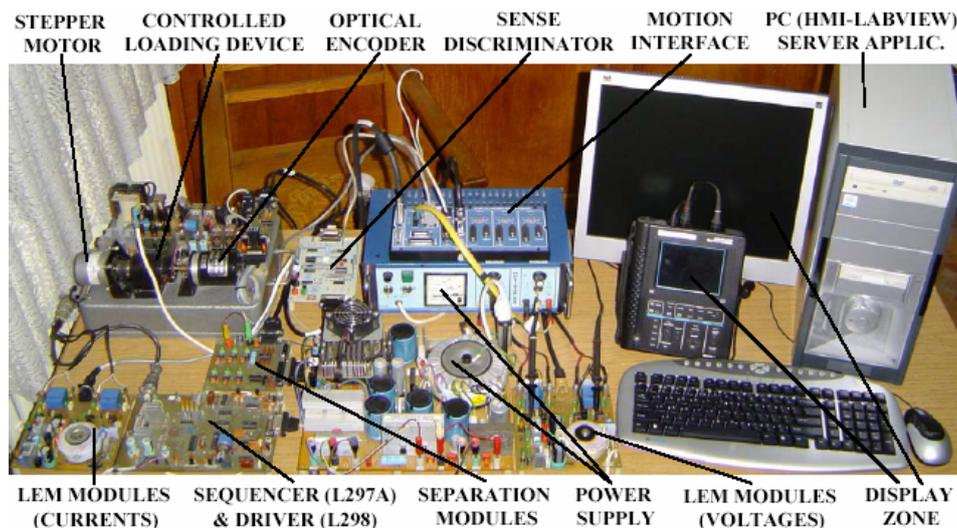


Figure 4. Photograph of the SM electrical drives system.

The SM 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.

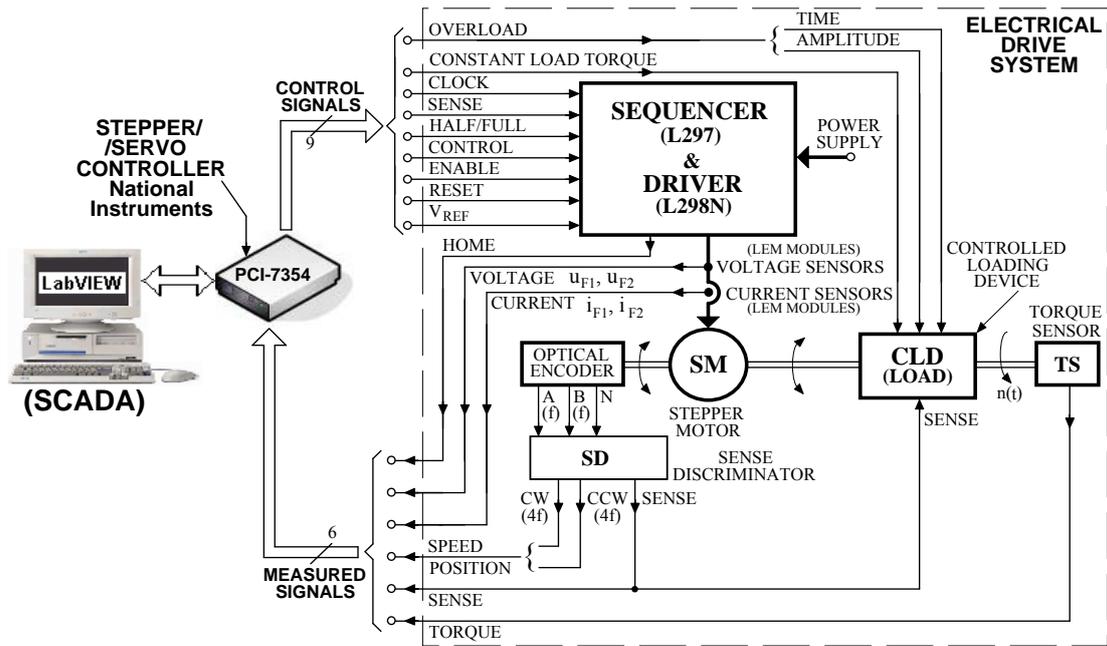


Figure 5. The block diagram of the SM electrical drives system.

The driven axis with SM can be controlled in open loop using constant frequency or prescribed profile (trapezoidal or S-curve move profile) or closed loop. In the second case, the user has to initialise the feedback for position and speed variables and to adequately set the control block of the pulse generation for SM command. The operating mode of the SM can be with full step, half step or microstepping mode.

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 (Fig. 7).

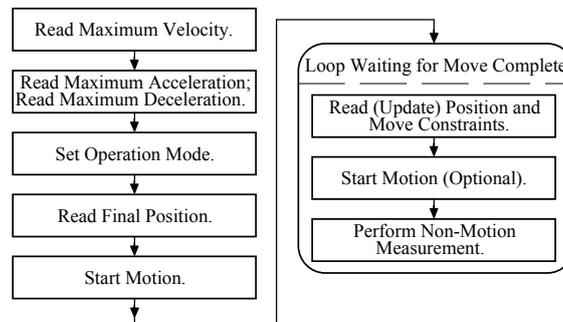


Figure 6. Position-based straight-line move algorithm.

To introduce a student to motor command, the SM setup will provide 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 such as oscilloscope, voltmeters etc, and since the majority of students do not have prior technical experience, this remote setup is very economical and offers students a great tool for learning about the servomechanism and data acquisition.

In order to build a positioning application, the developer has to follow the stages shown in Fig. 8, which represent the steps required to design a motion application.

The fourth and fifth stages can be also performed by the learner. Motion constraints are the maximum velocity, acceleration, deceleration and jerk that the system can handle. Trajectory parameters are expressed as a function of steps numbers. In this case the number of steps depends on the type of the stepper drive and the motor that is used.

The trajectory generator takes into account the type and the constraints of motion and generates points or instantaneous position in real-time.

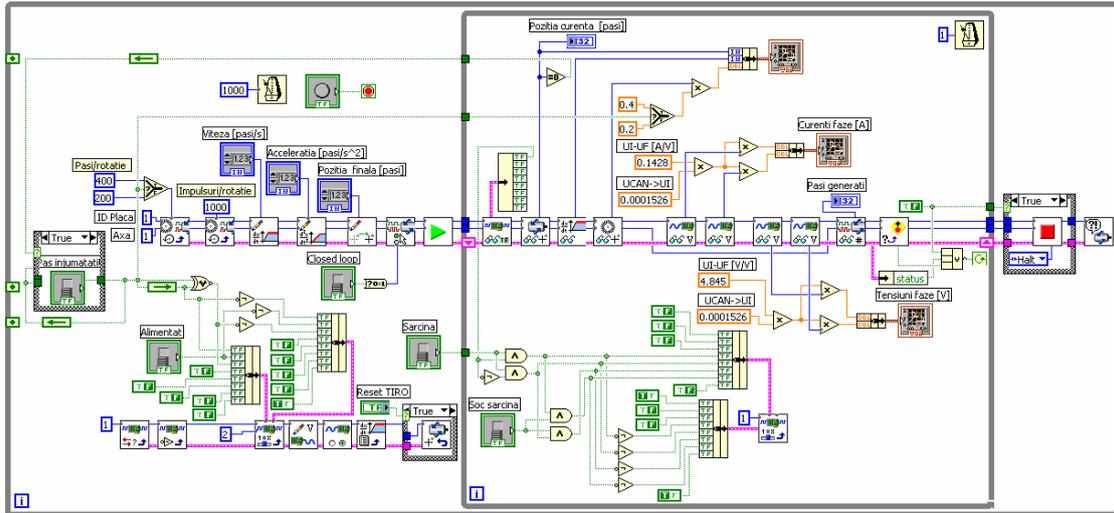


Figure 7. LabVIEW diagram for single axes positioning system.

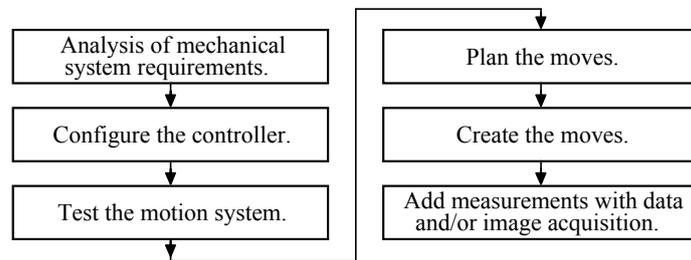


Figure 8. Generic steps for designing a motion application.

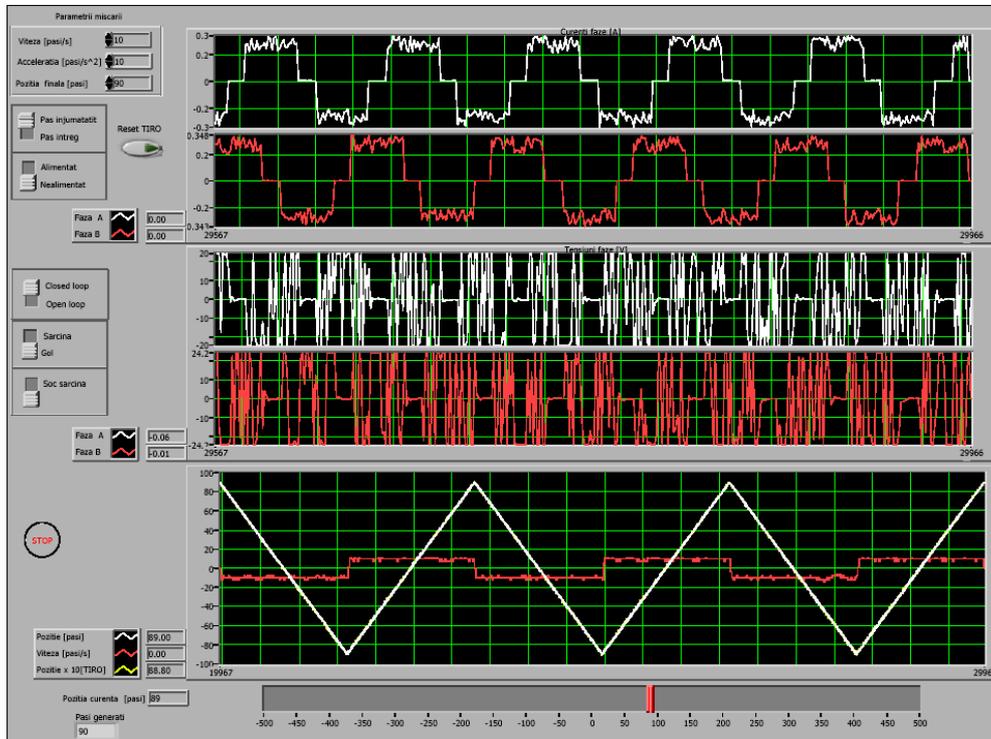


Figure 9. Main panel for SM electrical drives system.

Basically, the student can learn about the parameters of the SM, by changing modes and input settings 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 SM 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 stepped through with various frequencies corresponding to increasing or decreasing variations of steps/sec. (see Fig. 7: closed-loop operating mode).

Through the user interface, the students acquire the following abilities [7]:

- calibrating a SM system;
- controlling the rotation direction of the SM;
- enabling the motor and resetting the control system;
- understanding the relationship between a step and the number of steps required making one complete 360-degree revolution;
- moving the motor shaft from one arbitrary position to another;
- accelerating the motor and maintaining a constant velocity as well as decelerating and bringing it to a complete stop;
- visualizing intermediate motor control and encoder signals.

IV. 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. This type of laboratory has some advantages compared to RL, such as [10], [11]:

- 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 system real-time control is assured by the hardware and software resources of the NI PCI-7354 board. On the other hand, the remote monitoring and parameterisation is depended on the speed of telecommunication network.

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