LABORATORY EXPERIMENTS IN DISTANCE LEARNING

Ingvar Gustavsson[1]

Abstract *— In engineering education, laboratory experiments are indispensable, but they do require instruments and experimental equipment to be performed. Instruments are expensive and mostly located in laboratories. Experiments in circuit theory and other similar courses are easy to control. You use electronic instruments to see what is happening. Instruments are easy to control from a PC and so are switch units used to form test circuits and connect test probes and sources. Anyone can now do experiments over the Internet, from anywhere, using a client PC connected to a lab server at the Blekinge Institute of Technology, BTH, in Sweden. On the client screen you will see virtual front panels of the real instruments located in the lab at BTH. You may use the mouse to set the control knobs. The appearance of the virtual front panel and the real one is almost the same so later it should be easy to use a real instrument. The server supports several clients simultaneously.*

Index Terms — Circuit theory, distance learning, Internet, laboratory, on-line laboratory.

INTRODUCTION

In engineering education written exercises are necessary for a student to master mathematical tools while virtual experimentation done by simulation serves to reinforce the understanding of the subject. Real experiments are indispensable for developing skills to deal with instrumentation and physical processes. Practical projects provide the framework for a group of students to learn to cope with real world problems.

There is no doubt that nothing will replace synchronous learning through face to face interaction but it is not always feasible for students to attend conventional classes. Models for using information technology to enhance learning experience for conventional on-campus students, as well as for students asynchronous in time or space have been presented [1], [2]. Interesting proposals for the use of the Internet for various educational purposes including virtual laboratory web sites have been advanced [3], [4].

In this paper a virtual laboratory in circuit theory is described. Earlier this laboratory was one of four traditional laboratories in a circuit theory course at the Blekinge Institute of Technology. All but one are now replaced by simulations. Our reason to keep the fourth is that it contains experiments where Kirchhoff's voltage law is tested. Physical laws must be verified by real experiments. Simulations will not do.

For most circuit theory experiments instruments must be used to notice what is happening. You cannot see the electrons. Instrument data are easy to send over the Internet using only limited bandwidth. Test circuits can be formed using remotely controllable switch units. These devices may also be used to connect the instrument probes to test points.

VIRTUAL LABORATORY EXPERIMENTS

Electrical laboratory experiments, where controllable switch units or robots could be used to form the circuits and connect instruments to test desired points, are easy to modify for remote operation. Nowadays computer-based instruments can often replace ordinary instruments for non-demanding applications. Computer-based instruments have only connectors on the front panel. The knobs and keys or displays are missing. A software package containing a virtual front panel is delivered with the instruments. Figure 1 shows five computer-based instruments in a PXI box.

FIGURE. 1
COMPUTER-BASED INSTRUMENTS.

In the figure the modules are from left to right:

- PXI/PCI bridge, which is connected to a host PC using optical fibers
- Digital multimeter
- Switch unit with ordinary relays
- Function generator
- Oscilloscope
- Multifunction board used as controllable DC supply

[1] Ingvar Gustavsson, Blekinge Institute of Technology, Sweden, ingvar.gustavsson@bth.se

PXI stands for “PCI Extensions for Instrumentation” and is a standard proposed by National Instruments. Virtual front panels with the missing knobs and displays, but without connectors, are shown on the PC screen. The operator can use the mouse to do the settings. Thus there is almost no difference whether the operator is in the lab near the setup or is using a remote PC to show the virtual front panel. However, there may be a longer response time in remote operation.

When doing experiments remotely, the student cannot assemble the circuits or connect the test probes to test points wanted. At BTH we have found that project courses offer better possibilities for the student to get practical experience of electrical circuits. In such courses better tools for circuit assembly are offered. During a traditional laboratory the student may spend four hours in the lab and sometimes use a significant part of that time to troubleshoot connecting failures due to equipment earlier misused.

SYSTEM ARCHITECTURE

Two different experimental setups are available. The cable arrangement and the switching hardware support low frequency applications only. Both setups consist of sources, circuits, electronic instruments and switch units connected to a PC. The first uses ordinary instruments and they are connected to a PC using the instrument bus, GPIB, figure 2. In the second setup, the computer-based PXI modules in figure 1 are used. Both setups are connected to the same PC.

The software system is based on the client/server paradigm. There are two server programs written in LabVIEW – one for the GPIB devices and one for the PXI modules. The client sends commands to one of the servers and reads measurement results. The server programs send commands to and receive data from the two experimental setups. The same client software written in Visual Basic and Component Works is used for both servers, figure 3.

FIGURE. 3
CLIENT/SERVER SYSTEM.

The author started together with senior students to design the server connected to GPIB devices. This equipment was already present in our laboratories for undergraduate education and our students would use them in other experiments or project courses, therefore the authorthought it would be nice if the appearance of the virtual front panels were the same as the real ones. It should be easy to recognize the knobs and buttons on the real front panel if you have used the virtual one, figure 4.

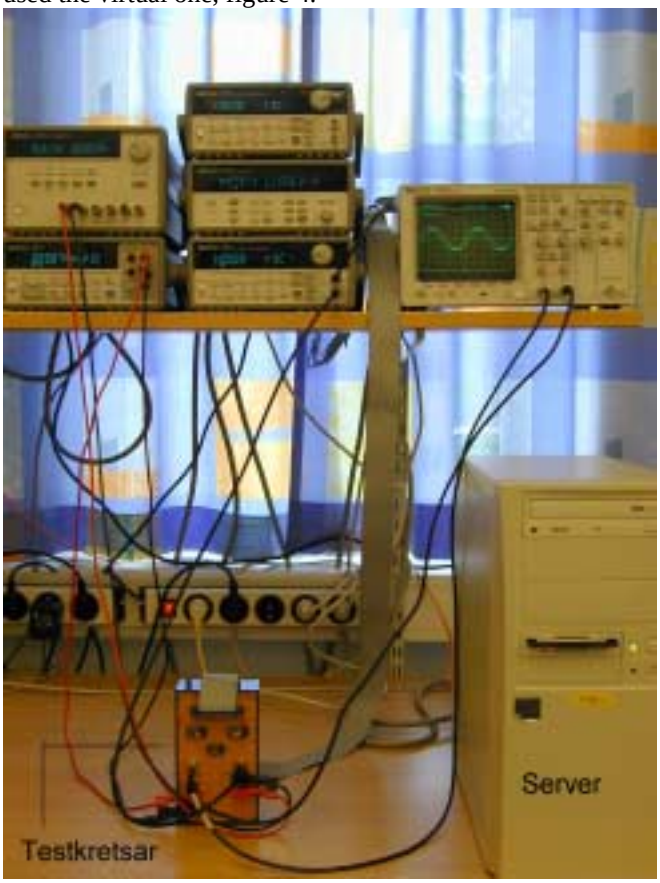

FIGURE. 2
GPIB BASED SETUP.

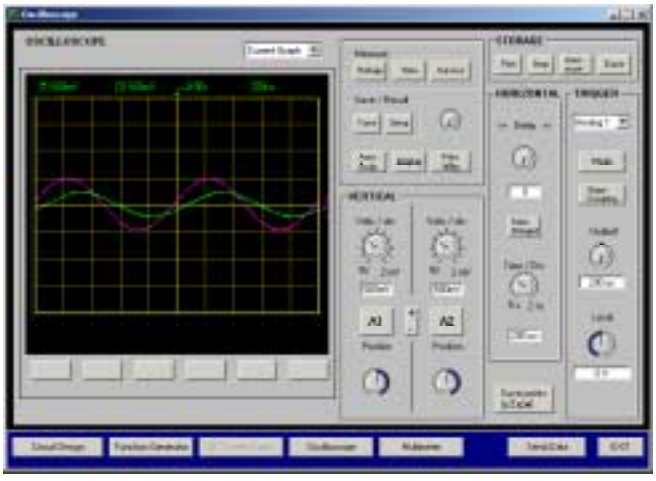

FIGURE. 4
VIRTUAL FRONT PANEL OF THE OSCILLOSCOPE.

The oscilloscope used is HP 54600B. The row of keys in the lower part of the figure is not a part of the virtual front panel but action keys for the client. With them, you can show different windows or start sending data to the server or exit from the client. The windows are the different front panels or the window shown in figure 5 where the experiment desired can be selected and the probes can be connected to the test points. First you can make the settings you want. They are transferred to the server when you press the key "Send Data". If you for example change the sensitivity of channel 1 of the oscilloscope you can see the sensitivity value set in the white box beneath the sensitivity knob. The trace and the green sensitivity value in the upper part of the oscilloscope display will not change until the server has returned a new trace from the oscilloscope. Thus there is an important difference between the real and the virtual front panel of the oscilloscope. The small white boxes with text cannot be found on the real front panel.

The HP 54600B display is monochrome but traces in different colors are used for the virtual panel and are supposed to be easier to read. Some uncommon functions of the devices are not implemented. Most of them are not supported in the software drivers.

The second server connected to the PXI modules has two main advantages. The drivers support all functions. The PCI bus transfer speed is much higher than that of the instrumentation bus.

The system is made for applications with short time constant. Simultaneous calls to the server are queued.

APPLICATION

If you download the client software and install it you can do five experiments in circuit theory. These experiments could also be made traditionally in our laboratory using the same instruction manual. However, for remote operation there is an additional short manual describing the client.

The first two experiments are tests of Kirchhoff's voltage law first with both DC and AC. The three other experiments are filter measurements. From the client startup window you can select one of the five experiments, figure 5. The default experiment is the DC test. There you can use the voltmeter only and connect the probes to test points indicated with letters in the schematic. You also have to select the DC source and set the voltage, figure 6. In the window describing the AC test you can also use the oscilloscope, figure 7. With the voltmeter, floating measurements can be made but with the oscilloscope only measurements referenced to ground are allowed for each input channel in this version of the client software. For the AC test the source is automatically changed to the function generator and there are default values set for the voltage and frequency, figure 8.

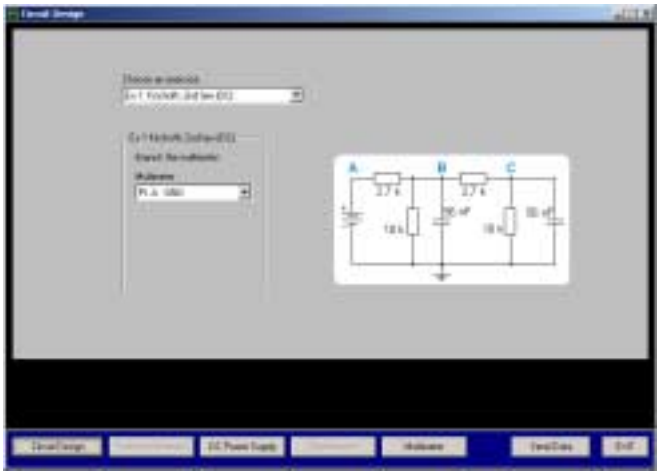

FIGURE. 5
STARTUP WINDOW.

FIGURE. 6
DC SOURCE.

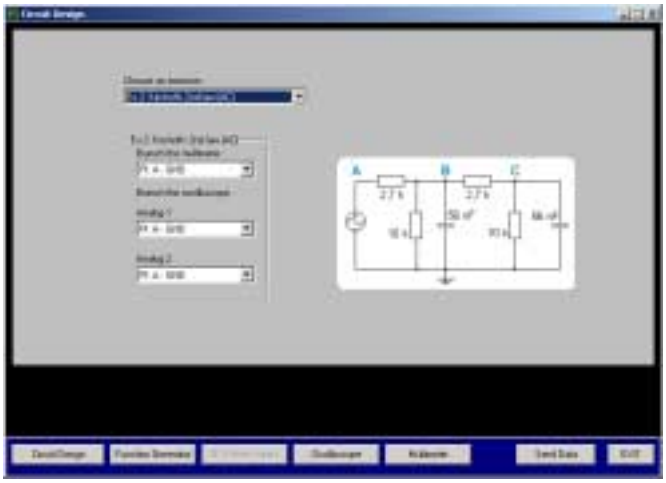

FIGURE. 7
TEST OF KIRCHHOFF'S VOLTAGE LAW WITH AC.

FIGURE. 8
FUNCTION GENERATOR.

With the PXI based server the response time is acceptable even if a number of students are using the server simultaneously. A test has been made by 14 students in a computer room at the Technical University in Luleå in the northern part of Sweden. Ronneby, where the server is located, is in the southern part of Sweden. After the test they answered a questionnaire. The main questions were:

1. Have you used a function generator earlier?
2. Have you used an oscilloscope earlier?
3. Is the response time acceptable?
4. Should these experiments be replaced by PSPICE simulations?
5. Is there any advantage of these experiments over PSPICE simulations?
6. Here you need not assemble the circuits yourself. Is that an advantage?
7. Would it be possible for you to become an expert in using the oscilloscope using these experiments and appropriate written instructions?
8. Should it be more evident that these experiments are performed on a real circuit and with real instruments?

The same test has been made in Ronneby. On both occasions a teacher was present but he was told to let the students work by themselves as much as possible, table I and II. One of the students wrote a comment "This was a nice and a different way of working. Can well be compared with traditional real experiments and you need less time to do them. The instruction manual could be improved. It was not evident what voltage levels we were supposed to use."

How do you know that these experiments are not simulations only? The answer is you do not. If the instruments are computer-based you would not know even if you were close to the experimental setup and the server. You can only see what is happening on the client PC screen. However you might hear the noise from relays in the PXI box when you for example change experiment if your ears are good and you are close to the switch unit. People with electronics experience realize that such simulation programs do not yet exist.

The response time is small but still significant compared to traditional experiments. If for example you change the vertical sensitivity of one the oscilloscope channels then you have to wait a few seconds before you see the new trace.

People testing the application from remote locations find the response time acceptable even if they are using a 56 kbit modem. The oscilloscope traces are only some kB so only a limited amount of data is transferred. The virtual front panels are a part of the client and are not transferred.

TABLE I
ANSWERS FROM RONNEBY STUDENTS

Question number	Yes	No	No answer
1	5	8	
2	8	5	
3	10	2	1
4	6	3	4
5	7	5	1
6	3	10	
7	9	2	2
8	7	5	1

TABLE II
ANSWERS FROM LULEÅ STUDENTS

Question number	Yes	No	No answer
1	8	6	
2	12	2	
3	14		
4	3	7	4
5	9	5	
6	3	10	1
7	4	10	
8	9	5	

CONCLUSION

A methodology to create certain web-based remote experiments in circuit theory has been presented. These are experiments with short time constants but without phenomena you can perceive with your five senses. There is no need for image or sound transmission.

Two of five experiments are tests of KVL (Kirchhoff's voltage law). KVL is a physical law and must be tested using physical experiments.

Two or more clients may access the server simultaneously. Two groups of students have tested the response time and found it is acceptable even if they send commands almost simultaneously.

Client software for PC only and manuals to be used to access the circuit theory experiments at BTH can be downloaded from: http://www.its.bth.se/courses/skt106/distanslabbar/english/.

ACKNOWLEDGMENT

The author gratefully acknowledges the support of the former vice chancellor Per Eriksson and the Board of BTH and the DAL/MAL project with funding from DISTUM, the Swedish Agency for Distance Education. He also acknowledges the equipment grant from National Instruments Sweden AB.

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