A Remote Laboratory for Electrical Experiments

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Abstract

Many laboratory experiments in electrical engineering courses can be performed remotely using real equipment. Conventional electrical circuit experiments have been conducted over the Internet at BTH (Blekinge Tekniska Högskola: The Blekinge Institute of Technology) in Sweden from different locations simultaneously using an experimental hardware setup in a closed room at BTH. This is neither a simulation nor a SCADA (Supervisory Control and Data Acquisition) application. The students control the instruments in the same way as they would in the local laboratory. The only difference is that they do not form the circuits and connect the test probes manually. Not only the experiment itself is important but also the measurement procedure and the handling of the instruments.

Introduction

Real experiments are indispensable in engineering education for developing skills to deal with physical processes and instrumentation. Laboratory exercises are integrated into many courses in electrical engineering. The traditional way of conducting an experiment is to go to a university laboratory. Students work in teams at a laboratory and receive tutorial help from teachers.

During the last decades the author and others have noted a trend towards increased use of virtual labs, i.e. simulations in electrical engineering education[1]. One obvious reason is the fact that physical experiments are expensive to maintain, and rooms with special arrangements are needed to accommodate a number of identical lab stations. Such premises can hardly be used for other purposes. Another possible reason is the persistence of the belief that virtual labs can replace physical experiments.

Virtual labs are software simulations of physical processes and devices. They can help to illustrate complex phenomena during classroom teaching as well as in individual training. The ability to simulate a process is clearly helpful in finding solutions to many real-world problems. Thus, knowledge of modeling and simulation are important skills for engineers working in industry or elsewhere.

There is no doubt that nothing can replace synchronous learning through face-to-face interaction; it is not always feasible, however, for students to attend conventional classes. Models for using information technology to enhance the learning experience for students who are asynchronous in time or/and space and which are also suitable for on-campus students have been presented earlier[2]. The Word Wide Web will allow new developments in the way in which knowledge is transferred. Remote experimentation is a relatively new phenomenon in distance learning. A number of so-called remote laboratories have been set up by some universities around the world. These offer remote access to laboratory equipment and experimental setups via the Internet[3].

There are different types of remote access. Some are SCADA (Supervisory Control and Data Acquisition) applications. These have been around for many years and are used by utility and manufacturing companies to control large processes. The goal of this type of remote operation is to put the user 'in the control room' with full and immediate access to all important system parameters. The test points are fixed, as are the settings of most of the sensors and instruments.

This paper presents the remote laboratory at the Blekinge Institute of Technology in Sweden (BTH). The three main objectives of the laboratory are: (1) to offer remote laboratory experiments to on-campus students as well as to distance learning students as part of courses in electrical engineering; (2) to design remote laboratories which are almost identical to local ones; and (3) to use the equipment and the premises more efficiently. The address of the home page of the laboratory is http://www.its.bth.se/distancelab/english/index.htm.

Electrical laboratories

A survey of types of laboratories and remote lab scenarios has been presented earlier[4]. In local labs there are normally a number of lab stations. The same number of student teams can do identical experiments supervised simultaneously by one teacher. The cost of the equipment and its maintenance can be cut down if the number of lab stations is reduced and/or the laboratories are used outside ordinary working hours. However, most teachers wish to work during the day. Is it possible with the aid of remote access for a number of students to conduct electrical experiments on one experimental setup simultaneously around the clock? The answer is 'yes' if manual handling which cannot be taken care of by remotely controlled switch matrices or robots is not required. The switch matrices can be used to form electrical circuits; additional cabling will then in most cases be needed, however. This may limit the frequency range.

In most laboratories today there are desktop instruments fitted with real front panels. One can guess that computer-based instruments with virtual front panels gradually will replace these. It then makes no difference if you handle instruments in local labs or by remote control. Nevertheless, students need a great deal of hands-on practice. At BTH students gain this experience in practical projects, which provide the right methodology to cope with real-world problems such as EMC issues, finding bad connections etc. However, the experience of sitting in the laboratory together with other students and with a teacher cannot be recreated by remote access with current technology.

The first test setup for remote access at BTH is an example of a remote lab[5]. The configuration is shown in figure 1. The Internet provides the communication infrastructure between the client and the lab server. A number of clients can access the setup simultaneously, and each client can choose to conduct any one of five experiments in basic circuit theory. One of the five circuits is shown in figure 2. The student at the client PC selects an experiment and connects test probes using the mouse. He or she then makes the instrument settings using the virtual front panels offered by the client program, concluding by sending the data to the lab server. The virtual front panel of the oscilloscope is shown in figure 3. Most of the functions of the 54600B oscilloscope from Agilent Technologies are implemented. The lab server forms the required circuit and connects the test probes using a switch matrix. Then the lab server makes the settings requested and reads the instruments. Finally, the lab server returns the results obtained.

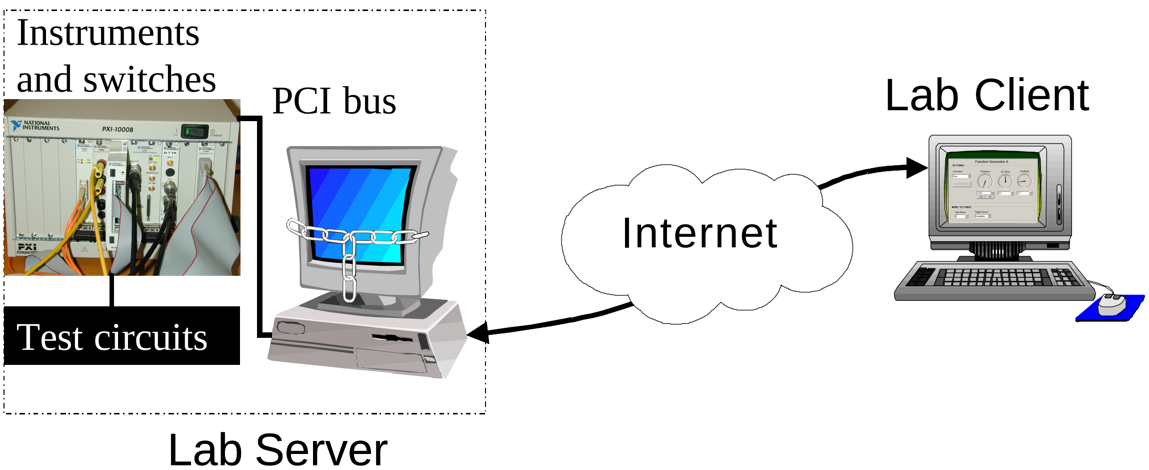

Figure 1: Structure of the first remote lab at BTH.

To cope with requests from more than one client simultaneously the server must have a queue manager and a short response time. When the circuit requested is formed the server must wait until the switch transients have faded away and then read the instruments to obtain the static quantities wanted. By selecting proper values for the components in the circuits to be formed by the students the time constants involved can be short - below 0.1 second - without causing any inconvenience; their contribution to the response time will then not be significant. Instrument delay will be low when computer-based instruments are used[6]. Proper coding of the oscilloscope trace data is essential to minimize the length of the data strings to be sent from the server. The normal way of reading data from the oscilloscope is to read scaled data, 64 bits per sample. However, the two A/D converters of the oscilloscope provide only eight bits per sample. To reduce the amount of data to be transferred, only one byte per sample is sent together with some bytes of scaling information.

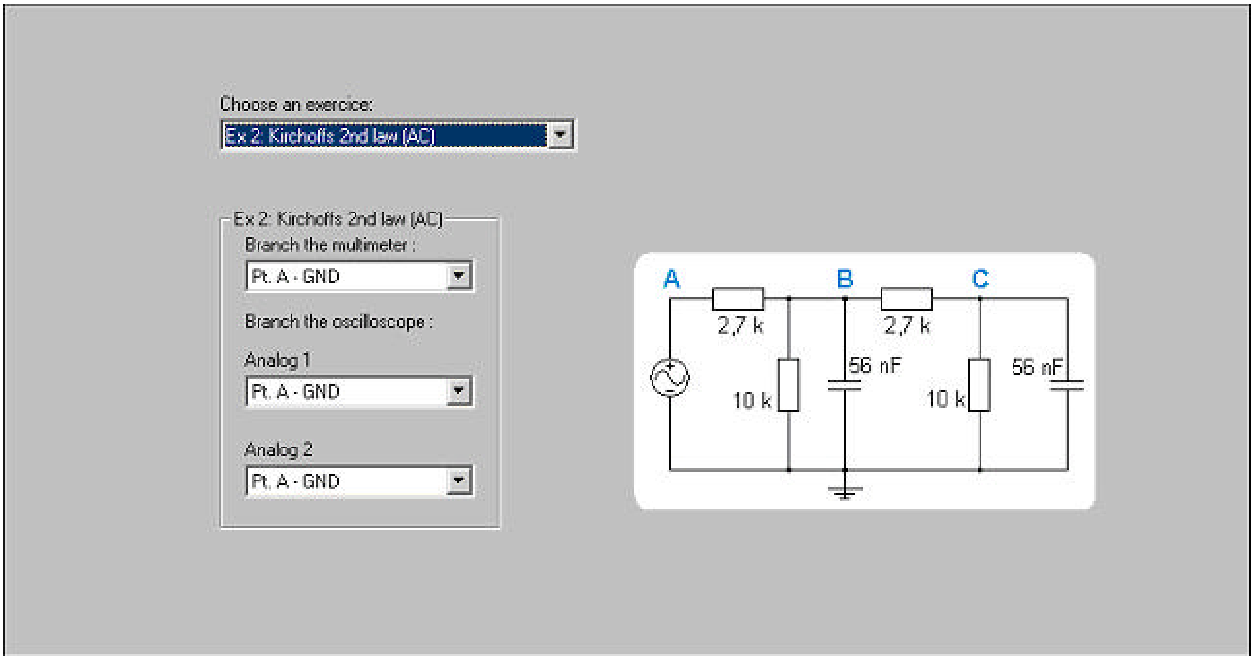

Figure 2: Experiment 2. Test of Kirchhoff's voltage law. Physical laws must be tested with real experiments. Simulations will not do.

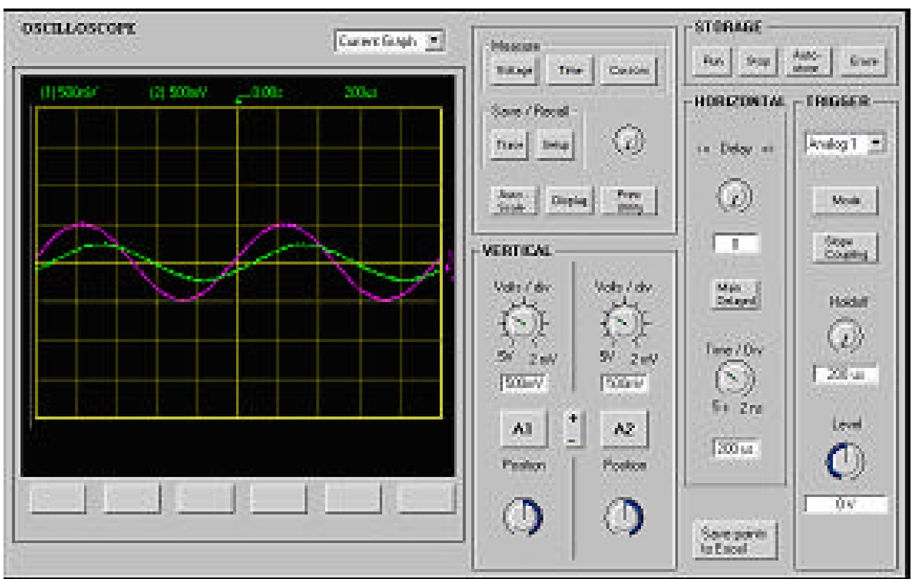

Figure 3: The virtual front panel of the oscilloscope.

Certainly, neither video nor sound transmission from the remote lab is required because it is not possible to see the electrical current with the naked eye or hear the electrons moving, thereby reducing the data transfer bandwidth needed. Only instruments are required to observe what is happening and these produce only a small amount of data. There are, of course, exceptions such as the electrical stove, incandescent lamp or lightning where you can actually feel the heat or see the light. Most types of electrical instruments can be controlled and read remotely. The total amount of data to be transferred over the Internet is small; a 56-kbit/second modem will do.

The laboratory described is used in regular courses in circuit theory for electrical engineering students and in a course in basic electricity at the Department of Mechanical Engineering. Here not only the experiment itself is important but also the measurement procedures and the handling of the instruments. The concept should also be applicable to experiments in low-frequency electronics. For RF applications, other switches and other instruments will be considered.

This example represents one of the least demanding experiments in terms of equipment, data transfer speed etc. In the remote lab today we also have experiments with long time constants and physical sensations. In the example below, there is a mixture of short and long time constants and phenomena with and without physical sensations.

New laboratories with video transmission

BTH offers a project course where teams of students are expected to design and implement control systems for small vehicles[7]. At the end of the course there is a contest where their vehicles must navigate autonomously through a racetrack filled with obstacles in the direction of a guiding light . The vehicle is fitted with transducers, a line scan camera and two ultra sound transducers. It should find its bearing to the light source with the aid of the line scan camera and detect the obstacles in its way using the ultra sound transducers. The exercise requires that students produce some electronics and software. In the camera box there is only one linear sensor chip; the sensor array is mounted horizontally in the focal plane.

The students are invited to conduct remote experiments to determine how the transducers can be used to help the vehicle find its way to the light source and avoid obstacles. In the experimental setup the transducers are attached to a stepper motor shaft as in figure 4. The experiments are arranged in a closed room without windows but with a network connector and a mains outlet, as shown in figure 5. In the room there are four light sources and one obstacle, a plank. Two of the walls can also be used as obstacles. The transducers and the stepper motor are fed via cables from the ceiling.

There are three servers. The experiment server controls the transducer fixture and the light sources. The students are only permitted to rotate the fixture 360º. There is a rotation limit in the server software. If that limitation fails then the author may encounter a hardware problem. The instrument server controls the two function generators, the oscilloscope and two relay switch matrices. The function generators are to generate the pulses needed to feed the transducers. Students are permitted to switch the function generator outputs from the oscilloscope to the camera chip only when the voltage level output from the generators is acceptable to the chip. The third server controls the web camera.

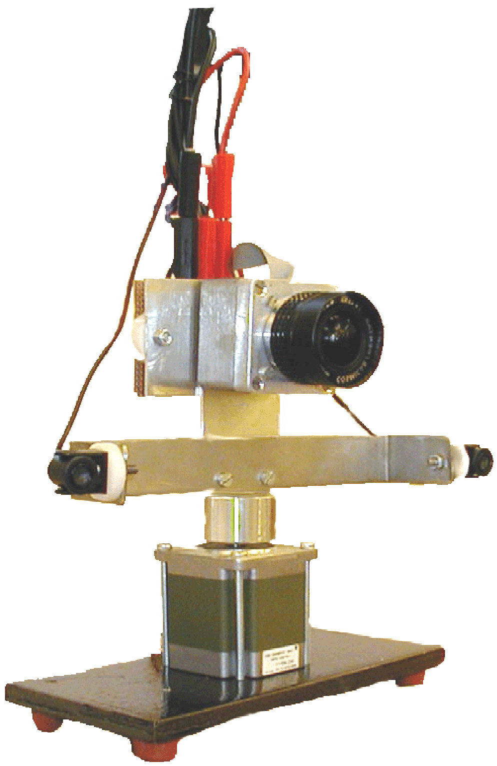

Figure 4: Transducer fixture.

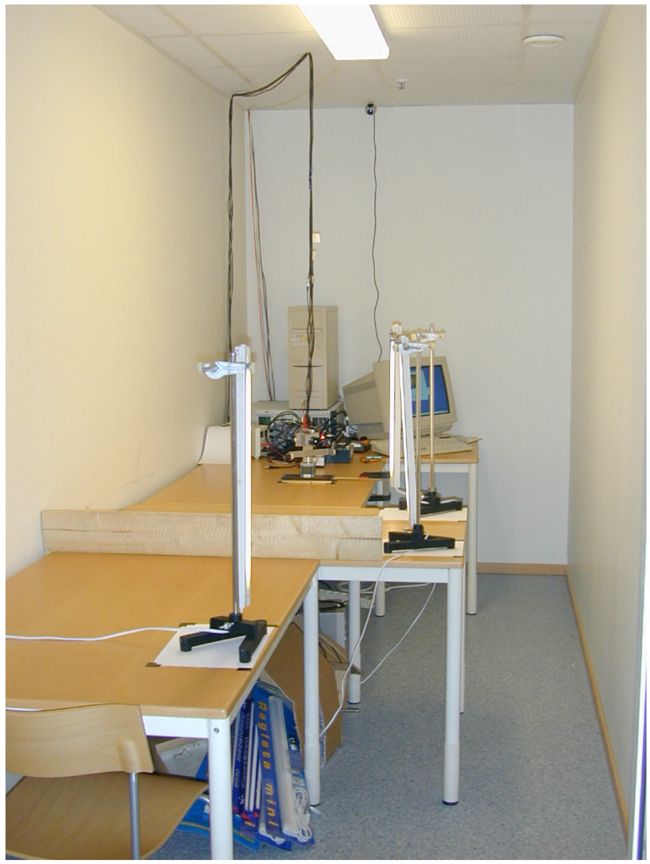

Figure 5:Room with experimental setup.

The lower part of the client window contains the virtual front panels of the instruments and the lab options panel controlling the switch matrix. The lab options panel and the oscilloscope screen are displayed at start-up (see figure 6). The student selects lab options and makes the settings. Then there is two choices. If the student presses the 'Single' button in the upper-right corner of the lower part of the client window, the settings made are sent to the instrument server. A second or two later the measurement data obtained will be returned from the server. On the other hand, if the student presses the 'Start' button, the request will automatically be repeated. The oscilloscope display will then be updated once or twice per second. The impression given is that this is an ordinary oscilloscope display. The fact is that this is a real oscilloscope with a TCP/IP link inside it. If the continuous mode of operation is selected, the response time for other clients will increase. Currently there is a time limit set for this mode.

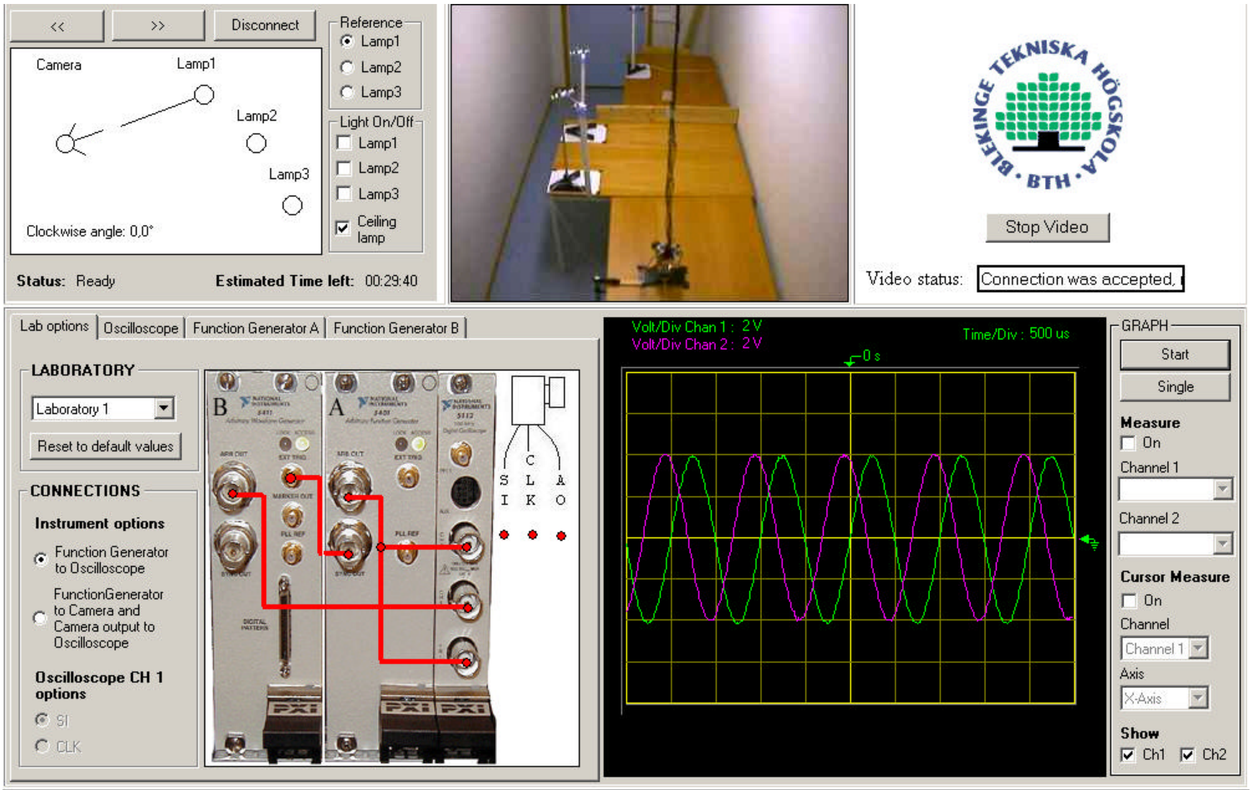

Figure 6: Block diagram of the experimental setup.

The upper-left part of the client window is used to manage the experiment server. One client can connect and log on to this server at any one time and have exclusive control over the fixture and lamps. For the time being the logon time is limited to 30 minutes. Another client can be waiting and receive control when the log in time for the first client has elapsed. When logging in, a text box will tell the second client the maximum time period to wait and the IP address of the client in control. Other clients can select a lab option, use the instruments and the transducers. They can also in the web camera picture see how the client in control rotates the fixture. If you are the waiting client you can use MS Netmeeting or some other means of communication to contact the client in control.

In the experiments with the camera (laboratory 1) the students are expected to test the camera performance, e.g. the view angle, bearing resolution and light sensitivity. With the aid of the ultra sound transducers students are expected to find out how they should design a meter with which to measure the distance to the obstacles (laboratory 2); is, for example, the strength of the echo correlated to the angle of incidence of the sound pulses sent towards the obstacle?

Conclusions

BTH has demonstrated that remote experimentation in electrical engineering is practically possible. Many experiments in electrical engineering education have no physical sensations and can be conducted remotely over the Internet, around the clock and without video transmission or other methods requiring high transfer bandwidth. In experiments with short time constants, several students can share the same remote hardware.

It is also possible to manage experiments with long time constants and physical sensations; only one client can then control the experiments, and video and/or sound transmission is required. At BTH, we have combined the two types of experiments in two laboratories and used them in an ordinary course in December 2001. Only one student can control the experiment from any one location, but other students from other locations can observe the physical sensations and perform parts of the experiments. This approach has not yet been evaluated though some students say they prefer to work in the local lab in the conventional way. Others appreciate the opportunity to do the experiments when they choose and using the time they need.

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References

1. Foss, B. A., Malvig, K. E., Eikaas, T. I., “Remote Experimentation – New Content in Distance Learning”, *Proceedings of the ICEE 2001 Conference in Oslo, Norway*, August 6 – 10, 2001.
2. Latchman, H. A., Saltzmann, Ch., Gillet, D. and Bouzekri, H., "Information Technology Enhanced Learning in Distance and Conventional Education", IEEE TRANSACTIONS ON EDUCATION, Vol. 42, No. 4., November ’99, pp. 247-254.
3. Berntzen, R., Strandman, J. O., Fjeldly, T. A., Shur, M. S., “Advanced Solutions for Performing Real Experiments over the Internet”, *Proceedings of the ICEE 2001 Conference in Oslo, Norway*, August 6 – 10, 2001.
4. Tuttas, J.,Wagner, B., “Distributed Online Laboratories” , *Proceedings of the ICEE 2001 Conference in Oslo, Norway*, August 6 – 10, 2001.
5. Gustavsson, I., “Laboratory Experiments in Distance Learning” *Proceedings of the ICEE 2001 Conference in Oslo, Norway*, August 6 – 10, 2001.
6. Gustavsson, I., “Remote Laboratory Experiments in Electrical Engineering Education”, to be published in *Proceedings of the ICCDCS 2002, Aruba,* April 17 – 19, 2002.
7. Nelsson, A., “A Project Course in Embedded Design”, submitted to *2002 ASEE Annual Conference.*

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