

# Remote and Proximal Delivery of The Laboratory Component of Electrical and Energy Systems Course

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**Abstract:** This paper describes the practical activities of Electrical Energy Systems (EES) course at University of South Australia (UniSA). The practical subject is Laboratory Component (LC). It is a compulsory subject for first-year students of bachelor of the engineering program. Students may do practically in conventional laboratories or by using Internet-based remote laboratory (RL). An experiment was conducted to explore the students' preference for practical approaches. Most students prefer the RL schedule flexibility while the others like to do real component wiring in an electrical laboratory. The combination between proximal and remote laboratories may become the best approach to delivering the LC practical.

**Key Words:** real laboratory, remote laboratory, laboratory component

**Abstrak:** Tulisan ini menjelaskan kegiatan praktis pada matakuliah Electrical Energy Systems (EES) di University of South Australia (UniSA). Subjek praktis dalam penelitian ini adalah Laboratory Component (LC). Sebagai matakuliah wajib untuk mahasiswa tahun pertama dari sarjana program rekayasa. Siswa diharapkan dapat melakukan praktek di laboratorium konvensional atau dengan menggunakan remote laboratorium berbasis internet (RL). Penelitian dilakukan untuk mengeksplorasi preferensi siswa pada pendekatan praktis. Kebanyakan siswa lebih suka fleksibilitas jadwal RL sementara yang lain ingin melakukan real component wiring di laboratorium listrik. Kombinasi antara laboratorium proksimal dan terpencil mungkin menjadi pendekatan terbaik untuk memberikan LC praktis.

**Kata kunci:** laboratorium nyata, laboratorium terpencil, komponen laboratorium

University of South Australia (UniSA) offers the Electrical and Energy Systems (EES) as a compulsory course for bachelor programs such as engineering and information technology. EES aims to introduce students to concepts, applications, basic analysis and measurements in electrical and energy systems. Basically, it consists of 39 hours of lecture, 10 hours tutorial and 16 hours practical.

The EES practical has been conducted in two ways: in campus or online. Australian and full time international students may do practical in real laboratories. However, accessing the real laboratory may be impossible for students who work after learning hours and ones who learn from overseas. For doing the practical, they should use a remote laboratory (RL), a computer-based learning environment that allows global students access and performs distance experi-

ments on real laboratory equipment via the Internet (Nafalski, et al, 2009).

This paper will describe the delivery of practical in both real and remote laboratories.

## METHOD

The engineers' community expects engineering graduates to develop practical skills during their undergraduate educational experience. In a real engineering laboratory, get opportunities to test their conceptual knowledge, to work collaboratively, to interact with equipment, to learn by trial and error and to perform experimental data analysis.

Work in a real laboratory requires time and physical boundaries both for students and lecturer. It obliges considerable scheduling effort and financial invest-

ments. Lately, universities are strongly adopting for the introduction of modern technology and the option of online delivery of courses both for internal and external students. Universities not following this trend are considered old-fashioned and are less likely to attract students and obviously cannot challenge for distance education students. Universities are therefore investing in computing infrastructure and consequently leaving less financial support for modernizing general-purpose engineering laboratories. Thus incorporating new technology, even though it has many benefits, leaves students with fewer practical skills (Steinemann & Braun, 2002).

A virtual laboratory provides a simulated environment. These easy-to-use software packages have been developed to simulation of real experiments. The simulator is also considered as a low-cost alternative for traditional practical since it has no time and physical restrictions. It may provide effective explanations of theoretical concepts and step by step experimental guidance. Although expertly formed virtual laboratories can be very applicable and simulations are essential in reinforcing students' conceptual understanding they are generally considered as miserable substitute for the practical work in the actual laboratory.

Remote Laboratories (RL) are a relatively new development concept, but their numbers are exponentially increasing due to recent technological progress and availability of tools for their design. RL facilitates collaborative learning, small-group learning, where the group members actively support the learning processes of one another (Ö. Göl & Nafalski, 2007). Students may do a tele-presence in the laboratory to perform experiments on real equipment as well as analyze factual data (Nedic, et al, 2003).

## RESULTS AND DISCUSSION

The first remote laboratories were control engineering and robotics laboratories (Bohus, et al, 1995; Taylor & Trevelyan, 1995). Lately, remote laboratories have become more common in other engineering fields. Most of these new laboratories (<http://vlab.ee.nus.edu.sg/>; <http://www.ic.chalmers.se/ilab>). Utilize Lab VIEW Web server developed by National Instruments. There are also large-scale systems like Cyberlab (<http://www.cyberlab.org/>) and PEARL (<http://kmi.open.ac.uk/projects/pearl/summary/index.htm>), which network several remote laboratories into unified facilities. However, many of the existing remote laboratories do not give the user a feeling of actual presence

in the laboratory. NetLab (Nafalski, et al, 2009; Nedic, et al, 2003) may give students, as main users, the impression of working in an existent laboratory. A special graphical user interface (GUI) will be described later in the following section.

### NetLab

In September 2001, a team of four academics from the School of Electrical and Information Engineering at the University of South Australia won one of three Teaching and Learning Grants offered by the University (Nedic, et al, 2003). The aim of the proposed project was to develop an online remote laboratory (NetLab), which would be used by both lecturers for teaching and demonstrations during lectures and by students for conducting their practical assignments. Here, NetLab is a remote laboratory for experimentation with actual electronic instruments and electrical circuits. Furthermore, from 2008-2010, Australian Learning and Teaching Council awarded UniSA's School of Electrical and Information Engineering (EIE) with a project grant (Nafalski, 2009). The project aimed to develop, implement, evaluate and disseminate the best practice in international on-line collaboration of UniSA NetLab with other universities' RLs.

The NetLab basic architecture is shown in Figure 1. The system allows several users to conduct experiments remotely at the same time. In addition, a camera image with the real equipment is provided, which extends the user's feeling for a real experiment.

A graphical user interface (GUI) represents the actual instruments in the form of virtual instruments. Students can control remotely an oscilloscope, a multimeter and a signal generator and get their readings in real time. When student clicks a button on an instrument in NetLab, the corresponding real instrument in the laboratory responds in real time in exactly the same way as if he/she had physically pressed the button on the front panel. The waveforms displayed on the Net Lab oscilloscope are actual measured signals from the real circuit, displayed exactly as it appears on the real oscilloscope. Figure 2 depicts the images of the virtual instruments, used in the remote laboratory: Digital Multimeter, Function Generator, and Oscilloscope.

In electrical engineering programs, practical experiments often focus on circuit analysis. This involves constructing circuits from basic components such as resistors, capacitors and inductors and applying an input voltage waveform using a function generator. One of the difficulties with remote laboratories is the problem

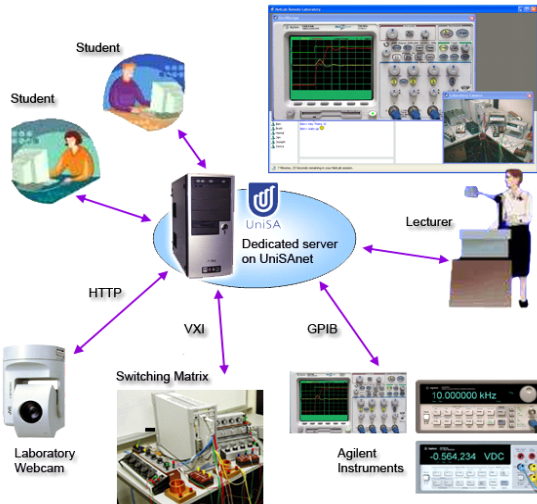


Figure 1. Structure of NetLab

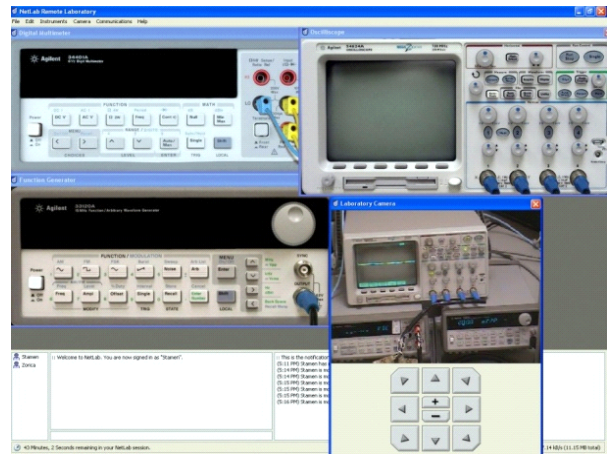


Figure 2. NetLab Interface-Instrumentation

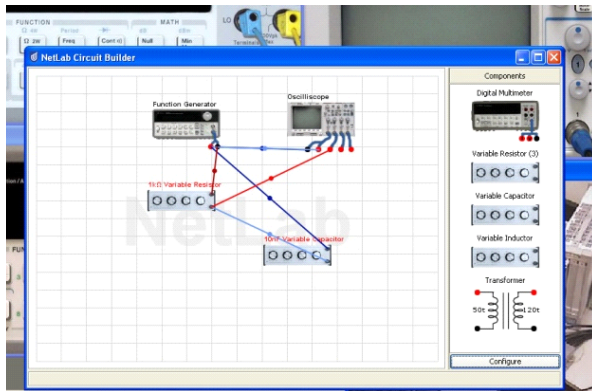


Figure 3. Basic Electrical Circuit built with the Circuit Builder

**Booking**

Please select the time you wish to book for: **Wednesday, 22 February 2012.**

All times are shown in your local timezone, according to your system clock.

You can book up to 1 more hour this week.

Hour	User 1	User 2	User 3	Hour	User 1	User 2	User 3
12:00am	Green	Green	Green	12:00pm	Green	Green	Green
1:00am	Green	Green	Green	1:00pm	Green	Green	Green
2:00am	Green	Green	Green	2:00pm	Green	Green	Green
3:00am	Green	Green	Green	3:00pm	Green	Green	Green
4:00am	Green	Green	Green	4:00pm	Green	Green	Green
5:00am	Green	Green	Green	5:00pm	Blue	Green	Green
6:00am	Green	Green	Green	6:00pm	Green	Green	Green
7:00am	Green	Green	Green	7:00pm	Green	Green	Green
8:00am	Green	Green	Green	8:00pm	Green	Green	Green
9:00am	Green	Green	Green	9:00pm	Green	Green	Green
10:00am	Green	Green	Green	10:00pm	Green	Green	Green
11:00am	Green	Green	Green	11:00pm	Green	Green	Green



**Legend**

- Green circle: Available slot
- Red circle: Unavailable slot
- Blue circle: Booked slot

Figure 4. The NetLab Booking System

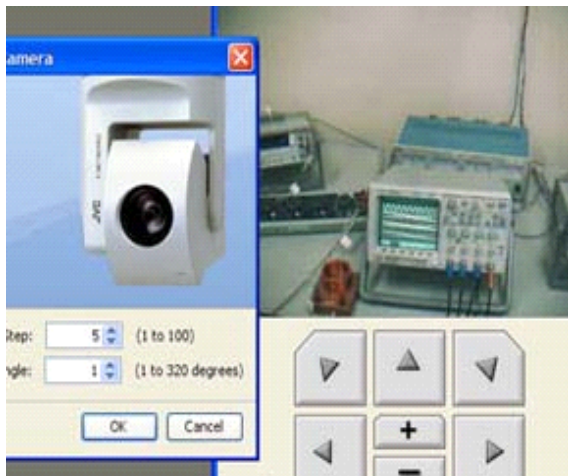


Figure 5. A Camera Image

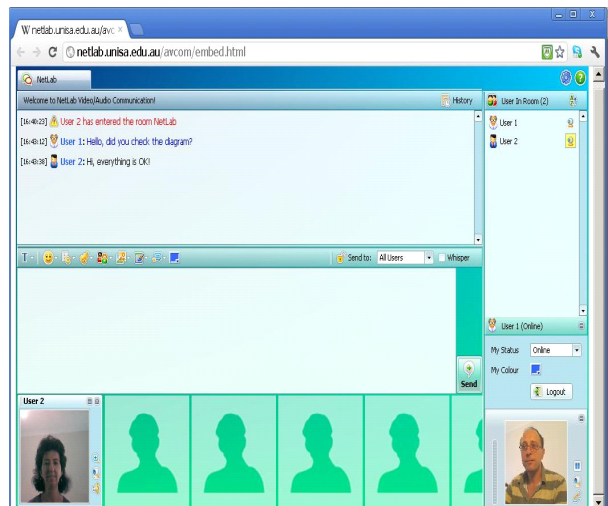


Figure 6. NetLab Multimedia Communication Environment

of connecting the circuit when user is not actually in the laboratory. NetLab solves this problem with an innovative feature called Circuit Builder. Students can pick components and instruments from a list shown on the right panel (Figure 3), drag and drop to arrange them and then wire them up using their mouse. With a click of a button, the circuit is configured in the laboratory exactly as specified by the user, by the use of a switching matrix.

The Booking System (Figure 4) is an automated system which creates a user account automatically. Once the registration form is completed, the user can go to the booking page and book a timeslot. Users can book up to 3 hours a week, though if they need more time they can submit a request. The website also provides a way to edit students account details and to delete their account if they wish.

A high quality “pan, tilt, and zoom” web camera (Figure 5) is mounted in the laboratory that allows the NetLab users to observe the real instruments in real time as they operate them. Users can compare what they see on their NetLab displays with what the real instruments are displaying and see that they are identical and watch as they respond in real time while they interact with them with NetLab.

NetLab supports up to three users working together on the same experiment, thus encouraging collaboration among them. A chat window is embedded in the user interface which allows them to communicate (Figure 6). This greatly improves the cooperation and collaboration activities between students. Student groups must ensure they get time together by booking a session time on the website. Sessions are in one hour slots and currently up to three students are allowed to share a session in any given timeslot.

In addition to the chat window, users are provided with advanced communication video and audio environment. It can be found under the Communications tab—Launch Multimedia Communication Environment. Among the items, visualised on the screen are: a list of participating users, video camera screen, microphone sound level bar, history window and even a chat window (Figure 6).

### The Laboratory Component Practicals

The Laboratory Component (LC) practical introduce the EES students to the measuring equipment, how to conduct some fundamental measurements, and develop the required skills for the following computer-

**Table 1. Practical Experiments**

No	Experiment
1	Measuring Resistance
2	Reading Capacitance
3	Generation and measurement of 50 Hz sinusoidal wave frequency
4	Generation of 3.5 kHz square wave frequency
5	Turning ON/OFF, Selecting a channel, Channel menu
6	Setting the coupling – AC/ DC/ GND
7	Adjustment of Vertical and Horizontal Position/Sensitivity of the waveforms
8	Setting the trigger Level/ Mode
9	Saving a waveform data in a text file
10	Measurement of Peak-to-Peak voltage $V_{pp}$
11	Measurement of a Period
12	Advanced measurements with cursors
13	Voltage Divider Circuit - Resistors
14	Voltage Divider Circuit – Resistor and capacitor

ised measurement practical. First-year students should perform the LC practical in both the electrical laboratory and NetLab. They must write a practical report for assignment. Table 1 show the detail of experiments.

After finishing practicals, students were asked to write comments on each question in the survey rather than to just select yes/no answer. The survey found that some students spent their time just playing around with the camera and stated that this was an enjoyable “part” of the experiment. Students praised the chat window as a very useful tool in communication among members of a group working together.

Students were highly satisfied with the booking procedure and some very positive comments were made about the possibility to choose their own time for experiments. Majority of students preferred the evening and night time slots, especially for repeating experiments on their own. Most students booked again a time slot to be able to repeat the experiment alone. This is probably the most valuable advantage of a remote laboratory over the real laboratory since it is nearly impossible for students to come back to the laboratory and repeated the experiment after actual practical hours. It may increase their psychological mood in regards with the practical subject (Karadimas & Efstathiou, 2007). Furthermore, they believed that repeating the experiment contributed to their learning and better understanding of operation of instruments.

Not everybody agreed that mastering the NetLab interface was easy. Some of them is able to control via the Internet after several practicals. Majority of students also complain that using the NetLab was equivalent with conducting experiments in the real laboratory. Majority of them preferred to work in the

real laboratory and to be able to wire the circuit themselves.

NetLab is unable to change the laboratory work. The best delivery strategy is blending those two types together. Students may do an experiment in a real laboratory and repeat the practical using NetLab. It is very beneficial when students want to check their practical result and perform other missed experiments. Students may free to do practical without worrying about time and the availability of supervisors. Another alternative is used NetLab as practical preparation before performing experiments in the real laboratory.

### CONCLUSION

Remote laboratory has been applied in modern education due to its advantages. It may provide a persistence learner-centered learning process, learning outside the classroom, the possibility to do experiment frequently and rapid access to information.

NetLab, the previously described remote laboratory, may give students a very realistic impression of laboratory work. On the other hand, students' work in a real laboratory is a worthwhile and necessary experience. Students value the "actual thing" as well as the student-teacher interaction and that the virtual classroom cannot completely replace the real classroom (Machotka & Nedic, 2000). Balanced mixture of practical approaches are needed to maximize the efficiency of practical delivery.

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