The development of a remote laboratory for distance learning at Loughborough University

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Additional Information:

- This conference paper was presented at the 5th International Conference on Education and New Learning Technologies (EDULEARN), Barcelona, Spain, 1st-3rd July 2013.

Metadata Record: https://dspace.lboro.ac.uk/2134/17848

Version: Accepted for publication

Publisher: International Academy of Technology, Education and Development (IATED)

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Please cite the published version.
THE DEVELOPMENT OF A REMOTE LABORATORY FOR DISTANCE LEARNING AT LOUGHBOROUGH UNIVERSITY
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Abstract
The increasing deployment of photovoltaic systems requires large numbers of skilled engineers with a greater understanding of all aspects of PV technology both theoretical and practical. Developing experimental rigs at universities is expensive and limited to students physically attending the university. One recent approach to increase access to laboratories is the development of remote experiments. Here students can control real experimental equipment using a visual interface via the Internet. In this paper we explore the development of a photovoltaic laboratory to enable users to access and remotely control experimental equipment based at Loughborough University from anywhere in the world.

Keywords: remote laboratory, distance learning, LabView, photovoltaic panels

1 INTRODUCTION
Currently, there are several research and development projects being undertaken by various institutions to incorporate remote laboratories within their distance learning programmes. This increase drive for the development of remote laboratories to replace virtual laboratories have been fuelled by the rapid advances in Internet communication services over the last few years, allowing for the opportunity to remotely control physical apparatus at distance. This paper reviews some of the different approaches to date and presents the remote laboratory development project undertaken by the distance learning program at the Centre for Renewable Energy Systems Technologies (CREST) at Loughborough University.

1.1 Background Literature
There has been debate about the role of laboratories in engineering education [1]. The normal form of conducting experiments involving physical presence is generally termed as the hands-on laboratory. Recent developments in information and communication technologies during the last few decades resulted in new technologies like Internet based labs and simulated labs. These online labs allow remote access to a physical experimental system through Intranet/Internet. The first idea of implementing laboratories through the Internet for educational purposes was started in early 1990’s [2-6]. Since then, the number of Internet based laboratories have been increasing, for example an outdoor solar laboratory for schools [7] and the remote control of a Lego mobile robot for distance learning course [8].

There is also on-going debate and research on the effectiveness of hands-on laboratories compared to remote laboratories in engineering education and whether there are advantages and disadvantages with remote labs regarding student learning [9-11]. The possibility of sharing resources with other institutes, hence gaining economic benefits, is considered an advantage for remote laboratories. Another important thing to note is that, using real hardware engages students and helps them to comprehend their engineering studies. Some potential advantages of using remote laboratories are: (a) Reduce the number of student hours spending in the laboratory by increasing our self-paced learning offering, (b) Achieving practical experiences with real equipment through Internet connection from home, (c) Giving access to more learning materials, procedures and practical video presentations through e-learning, (d) Monitoring on real-time measuring systems by using a web camera and storage of the acquired data.
Students welcome remote laboratories because they increase access flexibility, so there are a growing in number of these across the world [1]. They are particularly beneficial to distance learning students as it avoids time and costs required to attend a physical laboratory at a given location.

The main disadvantages are that it can prove costly to replicate physical experiments as they will need some aspect of remote control equipment which is expensive. Others are that the system will need to access the Internet and therefore stringent network safety protocols must be followed and there is also the need to have a robust student timetabling and access system. These issues will be discussed in more detail in the paper where the overall aims of the project are presented. Subsequently, the methodological problem solving approaches taken to develop the remote laboratory are explained. Finally, a review of issues faced in developing the remote laboratory is presented in a form to help other developers undertaking this type of work.

1.2 Aim of the Project

The aim of the project was to develop a replica of a physical laboratory used in the full-time Master of Science in Renewable Energy Systems Technology for distance learners. The laboratory exercise is part of the overall assessment for the particular module. The physical laboratory is used to investigate the energy conversion properties of photovoltaic (PV) panels. The purpose of the experiment is to investigate the effects of temperature and irradiance on PV panels using the characteristic measurement called the IV curve. Fig.1 shows the schematic and physical apparatus.

Figure 1: Schematic (left) and photograph (right) of the physical experiment

In the on-campus version of the PV lab shown in Fig.1 right students are able to manipulate the equipment and influence the outcome of the experiment. However, this is not feasible for distance learning students who do the course without visiting the university. Currently, the distance learners use a computer simulation version of the laboratories which were developed 10 years ago when the distance learning version of the course began. This virtual computer simulation version of the PV lab as seen in Fig. 2 allows the distance learning students to achieve the same learning objectives as the on-campus students. However, the main disadvantages are that all the readings are pre-set and no unexpected situations occur and the students do not have the same sensory experience.

Figure 2: Computer simulation of physical experiment
The development of a remote controlled laboratory presented a number of challenges. To replicate the physical apparatus shown in Fig.1, a requirements capture exercise identified a number of sub-system requirements that would be critical to the functionality of the experiment.

- Create a Light source which can be remotely controlled to change the level of irradiance.
- Create a sub-system which will allow the changing of PV panels remotely.
- Create a sub-system to measure irradiance.
- Create a sub-system which will measure and control the temperature of the PV panels remotely.
- Connect and integrate the complete system to a computer which will allow the system to be accessed and controlled over the internet by users.
- A timetabling and accessing system to the allow users timed access.

The paper now details the systematic approach used in the development of the PV Remote Laboratory highlighting challenges and successes.

2 METHODOLOGY

A systematic approach was used in the development of the PV remote lab. The project was divided into three main sub-systems:

1. Hardware construction and configuration – Various Equipment
2. Student interface and control – LabVIEW Software
3. Booking time-slot and remote accessing – LabVIEW Software

2.1 Hardware construction and configuration

The remote PV laboratory is a unique apparatus and was designed and built in the electronics and mechanical workshops at Loughborough University. The hardware includes the light source, heating/cooling system for the PV panel and a movable base for switching between intensity measurement sensors and the PV panel.

2.1.1 Light Source

Light Emitting Diode (LED) modules were used for the light source as they were specifically designed to replicate the spectrum of sun light which was important in this application of testing PV devices. In addition, the LED produces differing levels of irradiance when a variable power source is available. This allows the users to vary the intensity of the light which is a requirement of the experiment. A total of 36 LEDs modules were arranged in a six-by-six array as shown in Fig. 3 left.

To record a measurement of the levels of irradiance, a visible light to IR photodiode rig was built and set up alongside the PV panels on the PV selector. This set up allows users to measure the actual irradiance the LEDs are producing to use in the experimental calculations. There are sixteen photodiodes which are arranged into a four by four array. The photodiodes were built onto a smaller circuit board which is shown in Fig.3 right.

2.1.2 Heating and Cooling System

Another variable in the experiment for the users to control is the temperature of the PV panels. This means that the temperature of the panel needs to be controlled and shown to the user. The control of this experimental variable was performed by a Peltier module (heating /cooling plate) arrangement on the back of the PV panels, as shown in Fig.4. The Peltier was linked into the LabVIEW programme which will be used to set and control the temperature. The measurement of the temperature of the panels was taken using a PT100 temperature sensor located on the back of the panel so that the heat from the LEDs does not affect the temperature reading.
2.1.3 PV selector

To ensure that the irradiance measured by the photodiode array was the same as that received by the test PV sample panels the PV panels and photodiode array was attached to a rotating platform on base platform for stability as shown in Fig. 5. A stepper motor control system was used to rotate the panel / photodiode arrangement. Two different PV panels were used to allow the student to compare their performance with varying irradiance and panel temperature levels.
2.2 Student Interface and control

There are different types of tools available in the market to implement these online laboratories [11]. However, the LabVIEW software environment has been demonstrated to be suitable for remote control of equipment [1] [12]. Indeed, it includes tools for designing automation control in engineering [13]. An additional factor in the selection of LabVIEW is the ability to publish to the web, which is crucial to the use of remote laboratories, through the Internet Toolkit facility. LabVIEW software was used for the student control interface, the control of the hardware and the required PV panel measurements.

From the user perspective the virtual instrument (VI) front panel gives the students the ability to control the experiment. Once the main LabVIEW programs were written, interfaced with the hardware, validated and integrated, next step was the remote connection facility. The development of this functionality is described in the following section.

The front panel is the interactive graphical user interface (GUI) of a VI, named because it looks similar to the front panel of a physical instrument, as shown in Fig. 6. Controls resemble the physical buttons, knobs and switches that can be found on a conventional instrument. Controls need data or response from user to supply the block diagram for processing. The indicators display the generated data for user, received from the LabVIEW program outputs.

Figure 6: Student virtual instrument front panel for viewing and control of equipment.
2.3 Booking time-slot and remote accessing

Students will book a time-slot and access the remote lab through a special booking system built using LabVIEW software. This booking system uses similar protocols to those in the student interface and control system and has a front panel view similar to Fig. 6. To prevent any comprise to the university network, access to the system is conducted through firewall port. Students are authenticated through their university login and password and access the booking and remote lab VIs is restricted to the university virtual learning environment LEARN.

As the remote lab forms part of the summative assessment in the first semester, time-slots are only available within this period on a 24 hour 7 days basis. The booking system indicates the available time-slots and is synchronised with the main program to verify the student access when they login into the main program. Students are allowed two hours to work on the remote lab with a clock indicating the time remaining while conducting the experiment. An additional hour is added within the booking system to allow time for student access. However, once the student starts the experiment they have two hours on the equipment. If for some reason the student did not complete the lab in the allocated time, the system stores their work to date and they are allowed to booking another two hour slot to complete the work. A random measurement point is generated when a student completed all the required tasks; this is used to ensure integrity of the system.

3 THE PV REMOTE LAB

![Image of the working PV remote laboratory](image)

Figure 7: The working PV remote laboratory

The PV Remote Laboratory as shown in Fig. 7 allows distance learners to use the bespoke and purpose designed booking system to select a time to do the experiment. They will then log onto the experiment through the student interface as in Fig. 6. With the aid of a webcam the students can see the experimental rig in action. Students can then follow a series of instructions to set and measure irradiance levels from the LED light source, control the temperature of the PV panels, change the PV panels on a turntable, and take IV characteristics curves for the different conditions. They can then download their results to critically analyse and discuss them in a laboratory report according to the coursework instructions.

3.1 Lessons Learnt

There were many challenges faced in the development of the remote lab; however the reward of achieving the originals aim and objectives made the efforts worthwhile.

The list below highlights some of the essential considerations which should be included when undertaking a project of this nature:

- There must be a dedicated team in place to achieve the objectives
- Skills required – mechanical, technical, hardware and software design, management
• Consultation must be with the IT Services to ensure integrity of the university network system
• Lead time/learning curve must be include in the projected completion dates

The list below highlights some of the rewards and benefits when a project of this nature is accomplished:

• Pushing the boundaries
• Exciting experience
• Creating a real experience for students
• Good resource for the university
• Potential to be used by other institutes

4 CONCLUSIONS
A remote access experiment was designed and developed to enable users to access apparatus to permit remote learning about the characteristics of different PV materials. The project developed a rig with hardware components that could be programmed using LabVIEW to respond to user commands. Furthermore, the user could be remote from the experiment so that it is controlled via a VI GUI.

The remote laboratory developed in Electronic Electrical and Systems Engineering, Loughborough University is not only an attractive tool of teaching measurement technology for students but it also has industrial importance. At present globalised students often travel from one side of the globe to the other to study and to improve their knowledge on the use or operation of a system. In many of these cases distance learning students could study from their homes and control experiments in laboratories via the Internet without personal appearance. This technology would improve their practical knowledge and also allow for students to repeat the experiment at a time to suit their needs. This is not feasible in a physical laboratory [1].

Future developments are likely to include student evaluation of the experiment.

5 ACKNOWLEDGEMENTS
The project was part funded a Loughborough University distance learning enhancement fund. Adam Lee and Srikanth Reddy Eluri for the initial developmental work on the system.

REFERENCES


