THE DEVELOPMENT OF A REMOTE LABORATORY FOR DISTANCE LEARNING AND ITS IMAPCT ON STUDENT LEARNING

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Abstract

Currently, there is an increase drive in the development of remote laboratories to compliment and sometimes replace physical and virtual laboratories. This drive is fuelled by the impact on the pedagogy of distance learning caused by the rapid advancements in information and communication technologies, especially the internet. In this paper we outline the systematic approach used in the development of the Photovoltaic Remote Laboratory at Loughborough University, highlighting challenges and successes. We also evaluate the impact the remote lab has on student learning to contribute to the growing debate.

Key words: *Remote Laboratory, Distance Learning, Pedagogy, Student's learning experience*

1 INTRODUCTION

Currently, there is a great deal of debate about the role of laboratories in engineering education and as a consequence the effectiveness of remote laboratories compared to hands-on laboratories and whether there are advantages and disadvantages with remote labs regarding student learning.

Research and development projects being undertaken by various institutions are evaluating the use of remote laboratories primarily within their full-time programmes but also for distance learning programmes. Some of the arguments in support are:

- Remote labs will increase access to laboratories, which is a key requirement for engineering students to gain understanding of both the theoretical and practical aspects of their chosen discipline.
- Developing experimental rigs at universities is expensive and limited to students physically attending the university and timetabling of space and
- Remote experiments provide an alternative where students can control real experimental equipment using a visual interface via the Internet. (ASEE 2010, Abdulwahed 2010, Almarshoud 2011).

Counter arguments include:

- It is costly to replicate physical experiments as they will need some aspect of remote control equipment which is expensive and
- Can the student learning experience be equivalent to hands-on experience? (Nagy et.al. 2008, Corter et.al.2004)

We have developed a remote lab with a graphical user interface, the Virtual Instrument, which allows students to manipulate parameters by controlling physical hardware located at Loughborough from anywhere in the world. Furthermore, a booking and login system was developed to facilitate student access to the laboratory. Students log onto the experiment through the Virtual Instrument which incorporates a web-cam so that students see the experimental rig in real time. In this specific experiment students can set and measure irradiance levels from a LED light source, control the temperature of the PV panels, change the PV panels on a turntable, and take IV curve readings for the open and closed circuit parameters under investigation. They can then download their results to critically analyse and discuss them in a laboratory report according to the coursework instructions.

Our hypothesis is that the student's experience can be matched and in some cases even bettered by using remote labs as they are potentially better for developing independent learning. Crucially we also believe that the use of remote labs can be extended beyond distance learning students to on-campus students.

In this paper we outline the systematic approach used in the development of the Photovoltaic Remote Laboratory at Loughborough University, highlighting challenges and successes. We also evaluate the impact the remote lab has on student learning to contribute to the growing debate

2 LABOTORY DEVELOPMENT

Photovoltaic (PV) devices convert light energy to electrical energy for use in various applications. Therefore, it is important that the energy conversion characteristics of a specific PV device is fully understood for a range of operational conditions. One method for assessing PV performance is by measuring the "characteristic" (or IV) curve. An experiment that produces IV curves of different PV technologies under varying light conditions including the effect of temperature on cell performance has been used by MSc Renewable Energy Systems Technology students at Loughborough University since the course began in 1994. The experiment has been updated as required. However, students only have a limited time to use the equipment and there a limited number of test rigs available. Figure 1(top) shows a schematic of the experimental set-up of the optical bench and Figure 1 (bottom) the physical equipment for on-campus students.

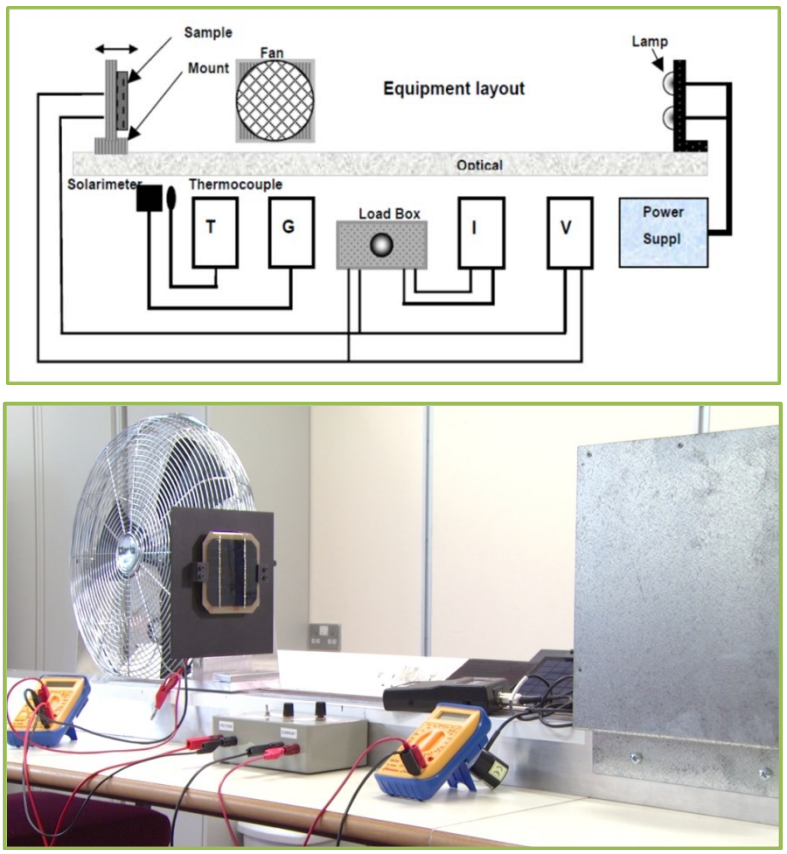

Figure 1: (Top) schematic of the experimental set-up and (Bottom) the physical equipment for on-campus students.

In the on-campus version of the PV lab shown in Figure1 (bottom) 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 Figure 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.

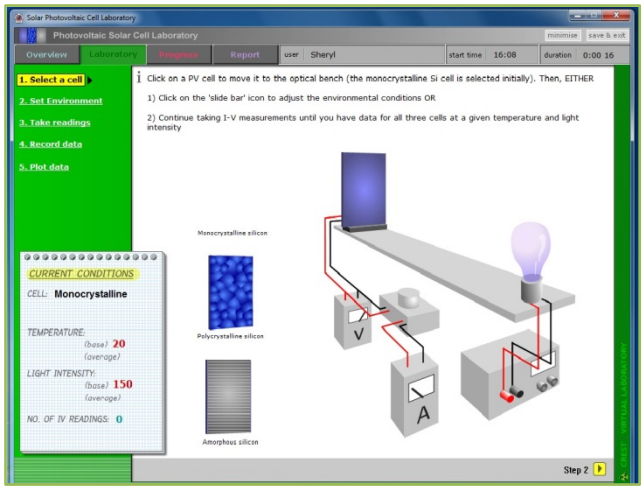

Figure 2: Computer simulation of physical experiment.

The development of a remote controlled laboratory presented a number of challenges. To replicate the physical apparatus shown in Figure 1 (bottom), 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.

2.1 Hardware Design

The hardware requirements to meet the experimental parameters led to two main design solutions, a controllable variable light source and a controllable temperature device to maintain PV panel temperature at the desired level. These solutions are described in the following sections.

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 Figure 3(top).

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.

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 Figure 3 (bottom). 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.

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. 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.

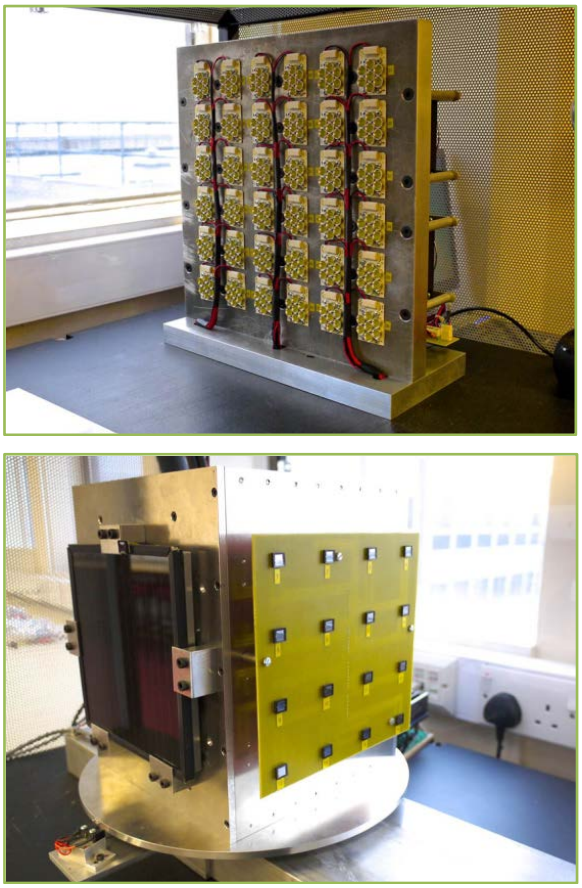

Figure 3: (Top) LED Array and (Bottom) PV panel / photodiode rotating platform.

As the hardware configuration was being constructed, the software to enable users to perform the experiments was developed. Bearing in mind the apparatus consists of the LED based lighting system for artificial irradiance, heating/cooling peltiers for the PV modules, stepper motor to change panel using turn table, temperature sensors for measuring temperature on the panel, programmable power supplies, a Keithley device for measuring current & voltage, a base for placing LED board & PV module, irradiance measurement sensors, GPIB cable and DAQ card with connection ports. There would be need to integrate this equipment to find a software solution to enable the experiment to work and allow for remote use.

2.2 Student Interface and control

There are different types of tools available in the market to implement these online laboratories (Corter2004). However, the LabVIEW software environment has been demonstrated to be suitable for remote control of equipment (Abdulwahed 2010, Uran 2007). 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.

The GUI VI front panel, shown in Figure 4 demonstrates what the remote user will see when they access the remote laboratory. There are two arrays of voltage and current values from the Keithley source meter. And using the same arrays a waveform graph is plotted. There are indicators for irradiance and temperature on front panel showing exact values. Two further indicators are used to show whether the required irradiance and temperature are reached or not. A window for the web-camera is placed at the corner of the front panel. A timer is visible to show elapsed time. The VI experiment is limited to 2 hours and therefore stops after this time. A booking system was developed to allow for users to pre-book their times on the laboratory (Uran 2007).When the user wants to measure an I-V curve they select the take measurement button to acquire data. Finally another switch allows the user to change the rotating platform between the photodiode and PV panels to allow the user to complete the experiment.

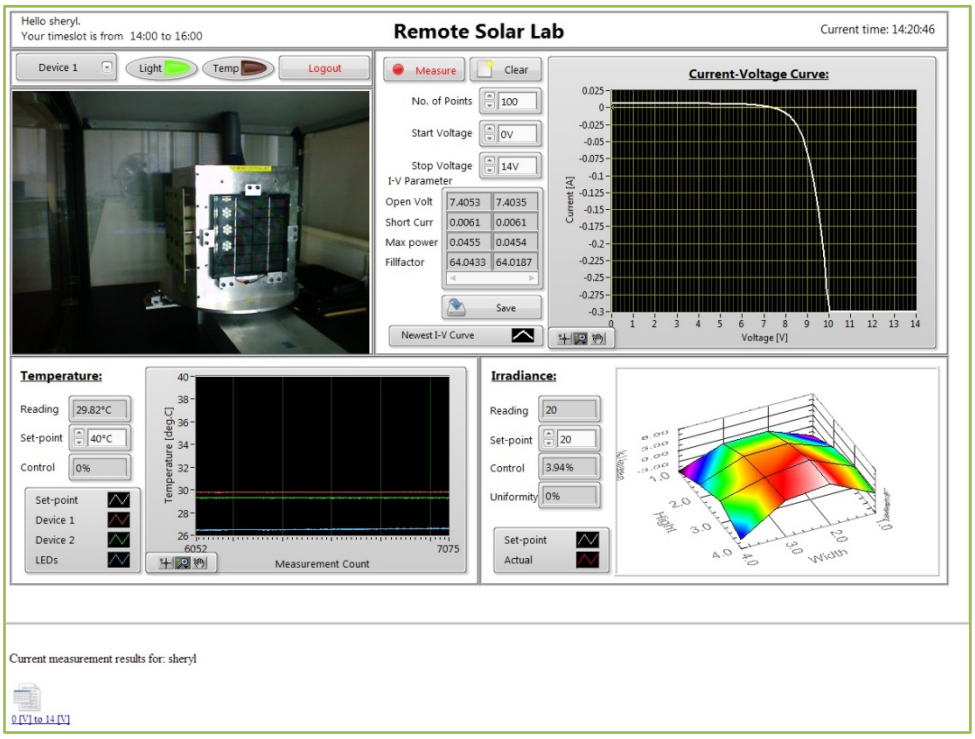

Figure 4: Remote laboratory graphical user interface

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 Figure 4. 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.

The PV Remote Laboratory as shown in Figure 5 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 Figure 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.

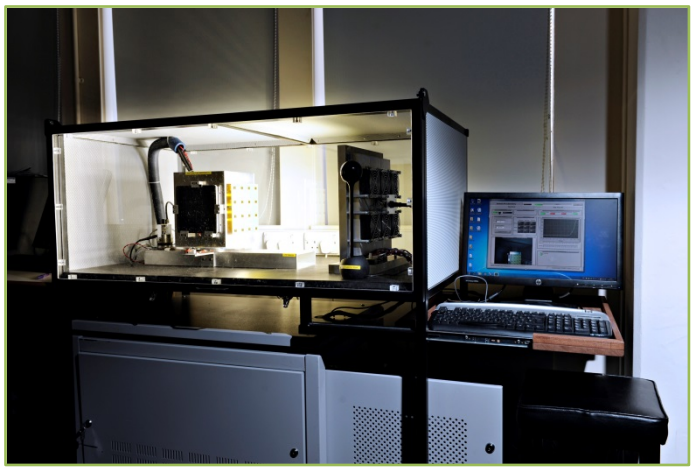

Figure 5: The working PV remote laboratory.

3 STUDENT LEARNING EXPERIENCE STUDY

To prove our hypothesis that the student's learning can be matched and in some cases even bettered by using remote labs, we need a systematic critical analysis of student experience while using the remote lab. This will entail a qualitative and quantitative study of the student's views to prove or disprove our hypothesis. The student's experience and views will be garnered, compared and assessed through three different models of laboratory work; model 1 – on campus group labs, model 2- computer simulations (individual lab) and model 3- remote laboratory (individual lab).

Previous research has highlighted the need to use an assessment model which incorporates various factors that affect student learning. As such we will include; learning styles, student experimental background, gender, disabilities, computer literacy, previous knowledge and experience, mental perception of hardware, collaborative needs and tutor support.(Nickerson et. al., 2007, Corter et.al., 2004, Corter et.al., 2011).

We will development questions for an online survey and recruit and select approximately 40 students for three groups. Students from the three groups will be randomly selected to participate with at least two of the models and the order in which they conduct the different modes will be changed to ascertain the effect of prior knowledge. Students will be expected to partake in a test before and after the study to test their knowledge of the underlying theory of the experiment.

The data from the questionnaire will be analysed to inform and reflect on the remote lab from the students' experience. By listening to students and incorporating their views, we will continue to enhance our practice and ensure we make the best use of the remote lab we have constructed.

The results of the student experience study will be published in our future work.

4 CONCLUSIONS

A remote access experiment was designed and developed to enable users to access apparatus to permit 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 via the Internet. The student's results from the experiment can be exported and downloaded for interpretation in a summative assessment. A booking system allows users to access the remote laboratory at a chosen time and avoids the possibility of more than one user accessing the rig.

There were challenges that were dealt with. This is a complicated experiment incorporating, hardware, software, electronics, control, automation and measurement. Not to mention remote Internet access.

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 with the deployment of photovoltaic technologies around the world. 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 contrast, distance learning students could study from their homes and control experiments in laboratories via the Internet without this need to travel. This remote experiment technology would improve their practical knowledge and also allow for students to repeat the experiment at a time to suit their needs. This is often not feasible in a face-to-face physical laboratory (Abdulwahed 2010). The laboratory has been piloted in its use by students. Feedback has been encouraging with students commenting on the logical design of the interface and their ability to successfully complete the experiment. Future work will involve evaluating the student experience.

One remote laboratory alone cannot meet the skills need of the renewables sector. Having created the experiment there is no reason why this cannot be replicated for other situations in training remotely.

Acknowledgments

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