

A Remote Solar Photovoltaic Laboratory

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ABSTRACT

There has been a tremendous increase in the use and development of remote labs over the past decade. At Government polytechnic Ahmednagar, remote experimentation has been made possible through the use of a scalable and generic platform-the Instrumentation Engineering department iLabs Shared Architecture (ISA). With this middleware infrastructure, students in the College of Engineering, Design, Art and Technology have been able to remotely access and share scarce laboratory resources. Presented in this paper, is the design and implementation of a remote Solar Photovoltaic laboratory based on the ISA. In the laboratory design, a solar simulator which provides irradiation matching, is used to provide constant irradiation to a solar panel. A National Instruments Educational Laboratory Virtual Instrumentation Suite (NI ELVIS II+) prototyping board is used for data acquisition to obtain current and voltage values from the solar panel. The user interface to the Solar PV lab is a LabVIEW Virtual Instrument (VI), on which interactive controls for the Solar Simulator are exposed. A live video feed is also incorporated into the client user interface to enhance user interactivity and remote access to the VI is implemented within the interactive ISA. Graphs are plotted to illustrate the variation of irradiance and angle of incidence with solar panel characteristics. The data obtained can then be compared to theoretical predictions.

Keywords : Interactive iLabs Shared Architecture, LabVIEW, NI ELVIS, Solar Simulator, iLabs@Mak

I. INTRODUCTION

The photovoltaic effect is the physical phenomenon responsible for converting light to electricity. Solar PV (photovoltaic) energy is a tried and tested technology that was being used on satellites over fifty years ago. Since the 1990, improvements in technology and lower prices have led to massive growth in its popularity. With a proven track record, solar PV systems are very reliable and require very little maintenance as they have limited moving parts. Solar energy as a mode of power generation is said to be a cost effective source of off-grid energy as opposed to the conventional way, where huge capital investments have to be made in putting up transmission and distribution networks [1].

As of 2010, India had a total energy consumption of approximately 11 million TOE (tonnes of oil equivalent). The consumption is partially met by a number of energy sources including fossil fuels, biomass, geothermal, wind power, hydropower and solar power. With an installed capacity of 595MW, mostly consisting of hydro power, the national grid covers less than 10% of the urban population and less than 3% of the rural counterpart [3].

With the increasing electricity demand of 10% per annum, there will be an unprecedented electricity deficit in the country by 2030. In order to address such energy deficits, solar energy resources would need to be explored.

However, the extent of solar energy utilization in India is still very low despite its immense benefits. Only about 450,000 Indians are connected to the grid, thus there is still great potential for growth of solar energy; given that India is endowed with good isolation levels all year round ranging from 4000 to 6000 W/m²/day [3].

Failure of a country like India to launch into this arena of clean energy could be attributed to lack of practical experience and training in its academic sector. However, the iLabs@MAK project, under the Department of Electrical and Computer Engineering at Government polytechnic Ahmednagar has specialized in the deployment of remote, generic and scalable labs. These Labs could offer students studying concepts in renewable energy, this practical opportunity. The Labs are deployed online via the interactive iLabs Shared Architecture (ISA) - a Massachusetts Institute of Technology distributed software toolkit and middleware service infrastructure [4]. The ISA is coupled with the National Instruments Educational Laboratory Virtual Instrumentation Suite (NI ELVIS) with a host of add-on boards, supported by the Laboratory Virtual Instrumentation Engineering Work-bench (LabVIEW) graphical programming language. The prototyping add-on board hosted on the NI-ELVIS platform supports analog circuitry. The ease-of-use of conventional analog components facilitates the demonstration of solar PV concepts. The user interface of the solar PV lab is a LabVIEW Virtual Instrument (VI), on which interactive controls for the experiment equipment and data acquisition are exposed. Remote access to the VI is implemented within the interactive ISA.

The remote Labs have mitigated challenges arising from scarcity of laboratory equipment vis-à-vis the skyrocketing student numbers [4]. iLabs have been used to support several courses in the curricula of the Bachelors of Science in Electrical, Telecommunications and Computer Engineering programs at the College over the past decade.

The continuous research and development is intended to gradually fully integrate iLabs into the entire curricula.

II. IMPLEMENTATION

A. Lab Equipment

The principal hardware for the remote Solar PV lab is the Solar Simulator . It provides constant irradiation to an 8cm by 8cm solar panel placed underneath. The NI-ELVIS II+ board was used as the main data acquisition device because it could be easily programmed using LabVIEW and seamlessly integrated with the ISA. The Board also had many analog and digital channels essential to the data acquisition as well as driving other devices in the circuit like the relays and Arduino board. A Logitech Webcam c170 was also incorporated to generate a live video feed of the experiment process and equipment during execution. The hardware for the Solar PV iLab is shown in Fig. 1.

To implement the Solar PV iLab on the NI-ELVIS II+ board, the various resistances and sources were connected as shown in the circuit diagrams Fig. 3 and 4. 6 volts DC relays were used as switches that were turned ON or OFF using digital signals with a swing of 0V-5V. Fig. 5 shows the system context diagram.



Figure 1: Left: Solar Simulator Top Left: c170 Logitech webcam, solar panel, Arduino Leonard board Bottom Left: NI ELVIS 11+, Servo Motor

B. Software Architecture and Implementation

The implemented using LabVIEW. The software development was carried out in different phases. Solar Simulator remote control: To achieve remote control, a java application for remote desktop control [5] was installed on the solar simulator, which was in turn connected to the Local Area Network. Using the Solar Protocol (IP) address, it could be remotely accessed and controlled from the Lab Server. Fig. 2 shows remote access of the Solar Simulator. Data acquisition: Experimental values were acquired through instruments integrated into the NI-ELVIS II+ board via analog input channels capable of reading both current and voltage. As per the circuit design, only one analog input channel was required to model the voltmeter and one other similar analog input channel to model the ammeter. Data acquisition from these channels was controlled using buttons and the values then displayed using numeric indicators on the user interface. Actual voltage and current values were acquired through Data Acquisition (DAQ) express VIs.



Figure 2: Remote control of the solar simulator using LabVIEW

Switching: In order to plot different data points required to obtain a suitable Current-Voltage (I-V) characteristic curve, experimental voltage and current values had to be measured across different resistances. Switching between resistances was achieved using relays which could be switched ON or OFF using digital signals supplied by the NI-ELVIS II+ board. Without this switching mechanism, changing these parameters would require the intervention of the lab administrator which is not practical. Various resistances were corresponding relay was switched ON while all other relays were switched OFF.

Motor control: Part of the experiment procedure was intended to investigate the variation of current and voltage with varying angles of incidence. The angle of incidence was changed by attaching the solar panel to a module consisting of a servo motor, Arduino Leonardo board and a metallic frame as shown in Fig. 6. Angles were programmatically controlled by digital signals from the NI-ELVIS board to the Arduino board. The Arduino board in turn, controlled a servo motor that varied the angle of inclination of the solar panel.

Live video feed: The Logitech camera was configured using the LabVIEW Vision Acquisition toolkit that specifically used NI-IMAQ drivers to read from and configure the USB camera. A Vision Acquisition express VI, as shown in Fig. 7, was used to achieve this functionality. It was configured to acquire continuous images, which when sampled at a high rate, were displayed in the form of a video feed.

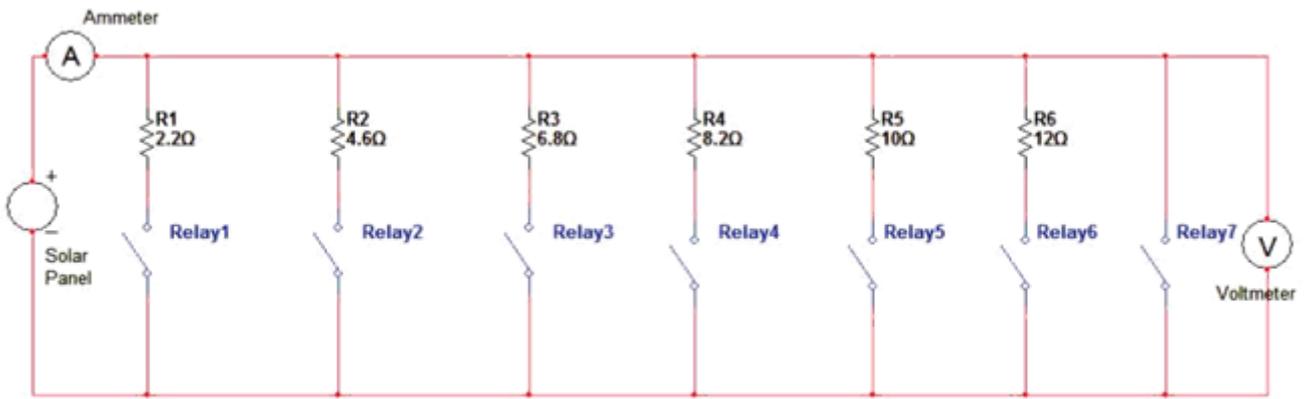


Figure 3: Circuit wiring diagram

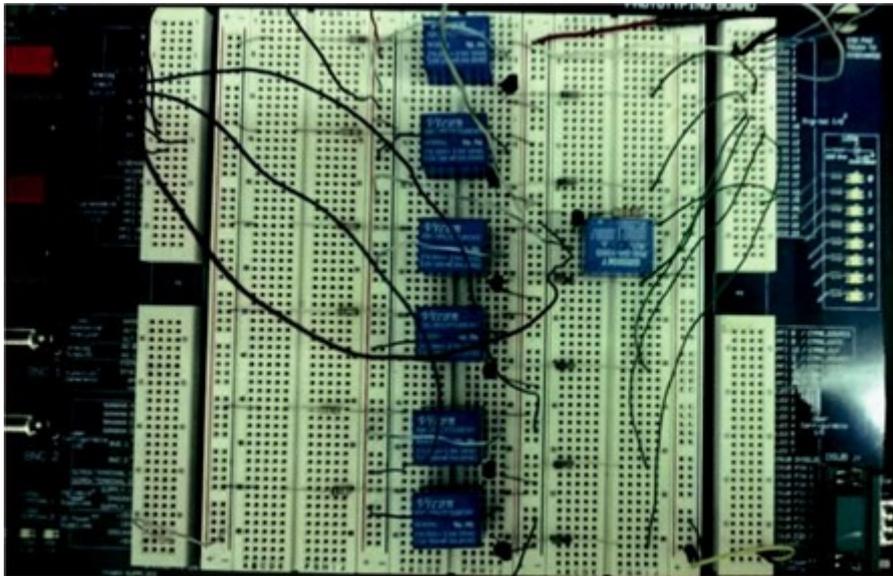


Figure 4: Circuit wiring on the NI-ELVIS II+ board

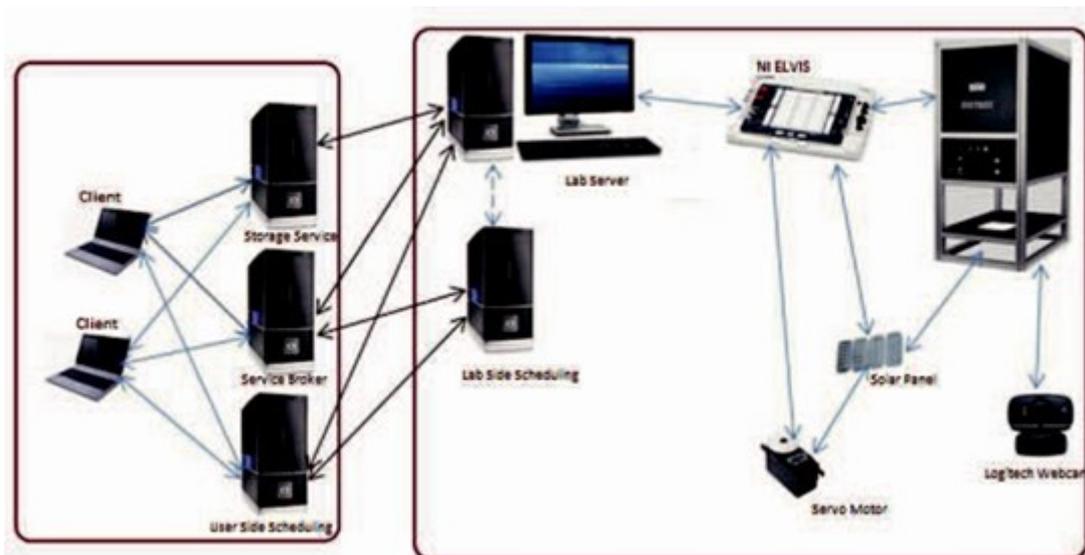


Figure 5: System context diagram

The video feed code had to run in a parallel loop so as to limit the effects of buffering caused by delays in the rest of the code.

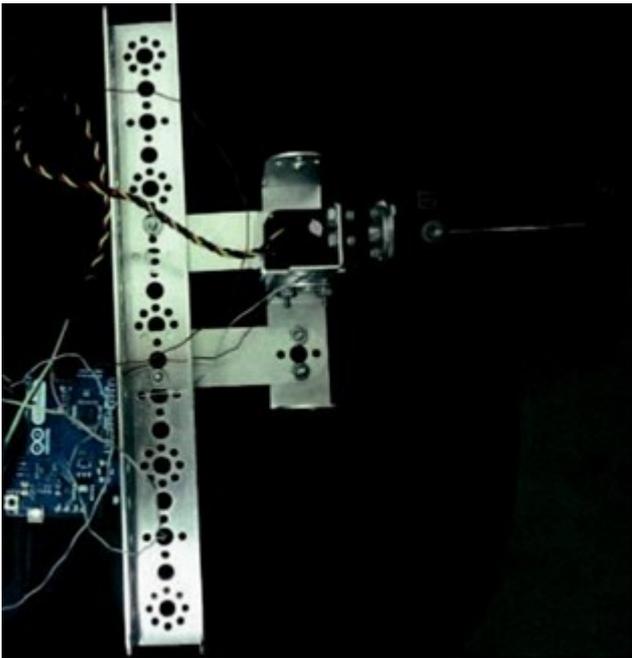


Figure 6: The solar panel hardware setup

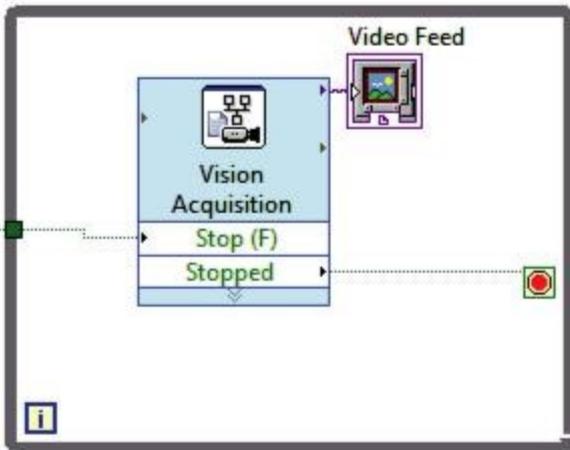


Figure 7: LabVIEW block diagram for acquiring video feed

Plotting results: Results were displayed in the form of graphs. By the end of the experiment, 5 graphs are plotted namely; I-V characteristics graph, Power vs. Voltage, Current and Voltage vs. Angle of Incidence, I-V characteristic variation with Irradiation intensity and Power-Voltage characteristic variation with Irradiation intensity. Tabs were used to toggle between the different graphs for easy viewing and readability as shown in Fig.8.

With an appropriate VI created, the next step was integrating it into the interactive ISA version 4.3.1 -

the deployment environment for the laboratory. The ISA was setup on a desktop computer running Windows Server 2008.

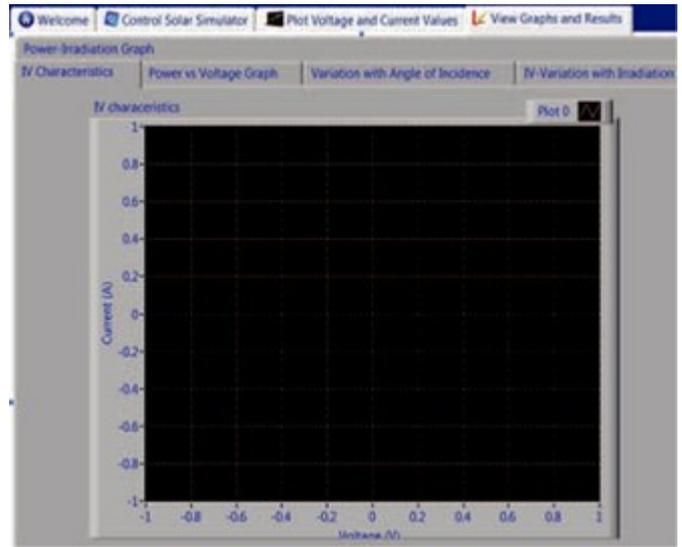


Figure 8: Different tabs for displaying results

III. USER EXPERIENCE

A. Lab Functionality

The remote Solar PV lab involves three stages: Controlling the Solar Simulator, Changing the Solar Panel Parameters and Display of the I-V Characteristics (Results). The Lab user interface allows interactive variation of virtual hardware controls of the solar simulator and switching between resistances to achieve each of these stages. The modular interaction with the lab is summarized in Fig. 10.

B. User Interface Design

The user interface features virtual control elements including knobs, switches, buttons, and run-time menus, in addition to indicators such as graphs. These were used to avail a rich and fully interactive front panel which doubled as a user interface within the interactive ISA. Tabs were used for navigation to allow easy access, control of the solar lab input parameters and display of results. All observed experiment data is relayed in graphical form to emphasize a holistic interpretation of the experiment at a glance.

IV. EXPERIMENT DYNAMICS

A typical experiment involves user login, selection of the experiment to be conducted and request for a reservation from the Service Broker. Exclusive access to the Lab is granted to the user during the reserved time. With the experiment, the experiment by remotely controlling the solar simulator, configuring the lab input parameters and finally viewing the graphed results.

A. Controlling the Solar Simulator

Within the active user interface, the experiment commences

the remote panel control of the Solar Simulator has been

accessed via its URL in the format <http://simulator IP:6060> as illustrated in Fig. 11. In this mode, the lamp is providing constant irradiation.

With the increasing student numbers, coupled with scarce laboratory resources, the remote lab will play a big role in improving the pedagogical experience of students and researchers at Government polytechnic Ahmednagar.

However, the Lab does not investigate all the factors that affect solar PV energy. Newer models of the Solar Simulator enable variation of additional parameters such as temperature and would thus be better suited to future research. Plotted graphs also did not have sufficient data points due to limited resistances that could be fitted on the board. Future labs will use better switching mechanisms such as the SCXI-1169 switch module; equipped with up to 100 Single-Pole-Single-Throw (SPST) mechanical relay switches and inserted into a chassis (NI SCXI-1000) containing the circuitry for powering, fanning and interfacing with the computer hosting the hardware. In addition, unreliable internet connection was a challenge to accessing the lab remotely.

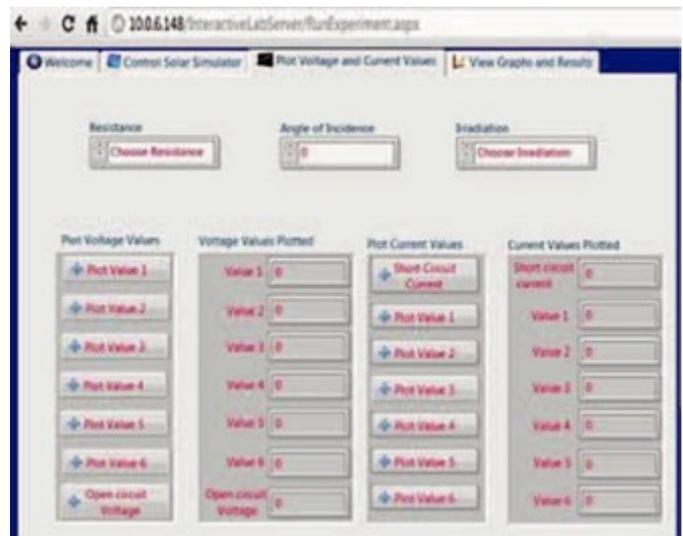


Figure 9: TKH 3lot Voltage and Current Values' tab

B. Configuring Solar Panel Parameters

The user selects the 'Plot Voltage and Current Values' tab. An appropriate angle of incidence and a constant irradiation intensity are selected. The user then measures the Open Circuit Voltage and Short Circuit Current. Subsequent voltage and current values are then taken across the other six resistances in the circuit. Resistances, Open Circuit and

Short Circuit conditions are selected from the 'Choose 5HVLVWDQFH' drop down menu. Different values of voltage and current are obtained by clicking on 'Plot Value;' buttons as illustrated in Fig. 9.

Here after, the user varies the angle of incidence as reflected on the live video feed and then corresponding voltage and current values are plotted. The user can then vary the irradiation intensity by selecting the different irradiation values after which, corresponding I-V characteristic curves are plotted.

C. Displaying Results

The results are displayed in a graphical form with different tabs showing various I-V characteristics. Featured characteristics are a representation of how solar panel Current-Voltage (I-V) characteristics vary with varying angles of incidence and varying irradiance levels. Fig. 12 shows typical I-V characteristics of a solar panel.

V. CONCLUSION

The development of the Solar PV iLab has contributed to the increasing number of online laboratories available at Government polytechnic Ahmednagar. The Lab will render support to curricula in the courses of Renewable Energy Technologies where there is currently no available laboratory.

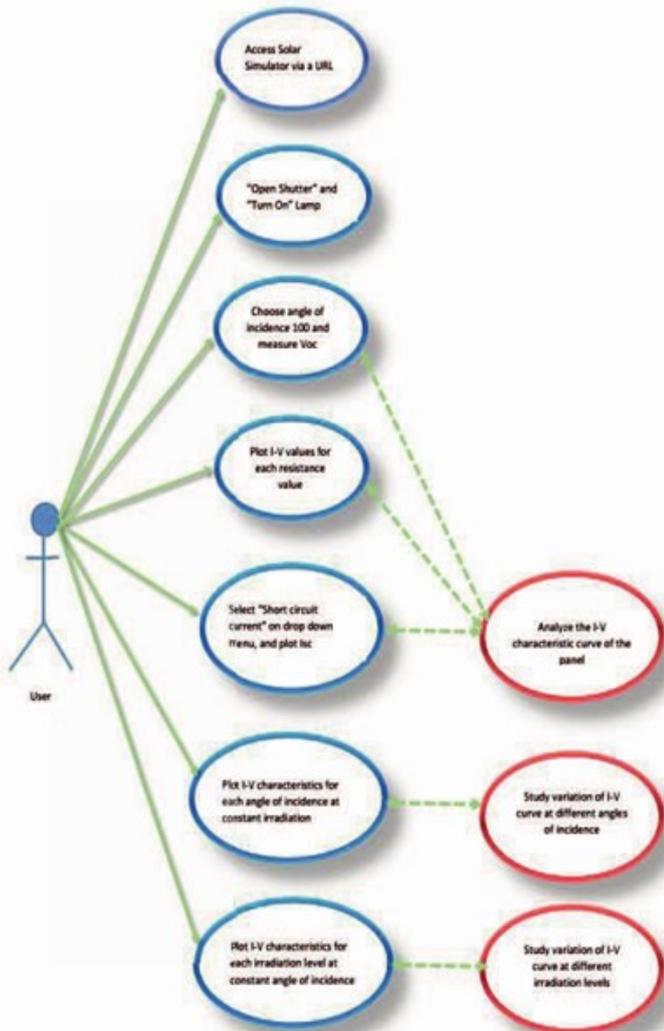


Figure 10: Modular interaction of the Solar PV lab



Figure 11: The Control Solar Simulator Tab

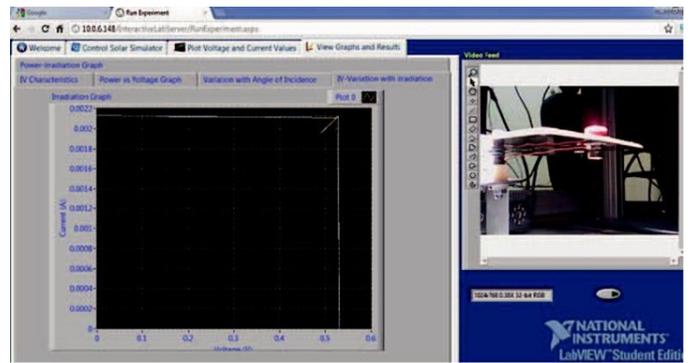


Figure 12: I-V Variation with irradiation

VI. ACKNOWLEDGMENT

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