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Implementing National Instrument Environment for A Remotely Accessed Photovoltaic Module Characterizer

Mahmoud, I. M. [1,2*] Sweif, R. [2] and Abdel-Salam, T. S. [1,2]
1 Faculty of Energy and Environmental Engineering The British University in Egypt (BUE), Cairo,Egypt
2 Electrical Power and Machine Department, FOE, Ain Shams University, Cairo,Egypt
*Corresponding author e-mail: ibrahem.mohmaed@bue.edu.eg

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Abstract

This paper surveys how the characterization process for a Photovoltaic module (PV) is implemented to serve in introductory undergraduate courses and research purposes. The characterizer has the capability of measuring the I-V and P-V characteristic curve of the PV module attached to the system with indicating the solar irradiance that is sensed during the measurement. Also a control circuit design is implemented for dual tracking the PV module. In addition, the developed program introduces the facility of compering the measured data with a numerical based simulation data results from a PV simulator using MATLAB platform. The use of the National Instrument (NI) Environment facilitates the Internet publication opportunity where users can access the setup remotely. The remote accessibility is considered as a significant credit in integrating the setup as a demonstration tool in teaching modules as well as student accessibility. The results of the NI software are presented and discussed and analysed.

Introduction

SOLAR power generates electricity with no global warming pollution, no fuel costs, and no risks of fuel price spikes, and has the potential to help move the country toward cleaner, reliable, and affordable sources of electricity.

In developing countries, especially in Egypt, the replacement of the ordinary fuel-based electricity sources by renewable sources became an obligatory step toward better environment. Toward that, new programs targeting renewable energy in both undergraduate and postgraduate levels have been lunched. These programs should be accomplished by the desired Lab facilities for gaining more practical experience as well as better understanding of fundamental topics. Toward this aim, many techniques have been investigated in literature for implementing a robust remotely accessed experiment dealing with different renewable energy systems. These techniques were implemented and improved during the previous decades. The following paragraphs are dedicated for criticizing theses work types. However, the provided model was limited to be offline use where no friendly user interface was provided and glowing the attributed contribution of our proposed experiment.

In 1998, Stuart Bowden and Christiana Honsberg, work at the Solar Power Labs at Ain Shams University (ASU) [1], lunched the first online resources for photovoltaic education [2]. The website provides the users with basics theoretical examples demonstrating the main theory of operation for PV cells and its performance at different conditions. However, this contribution was limited to theoretical examples with no experimental assets.

After that, new technologies such as virtual reality Labs were enrolled in developing PV experiment as in [3]. A remote triggered photovoltaic solar cell experiment is presented to study the fundamental characteristics of photovoltaic solar cells where lake of hardware experimental work is also observed [3]. More toward theoretical modelling experiments, a mathematical model based on Matlab platform was implemented in [4]. The model allows the student to plot the I-V and the P-V curves at different environmental conditions for various PV module

Besides understanding the PV operation, information about solar irradiance should be provided especially for non-horizontal surfaces. Therefore, a remote accessed virtual laboratory based on Matlab is presented in [5]. The work demonstrates the solar irradiance at different tilting angle while no study for a full PV system was provided within the experiment. Another trial was made in [6] to simulate the sun paths and irradiance. This work enables students to study the performance of the sun and its effect on the PV module behaviour.

Hardware based remote experiments start to appear in Mexico, where there is a high need for replacing the ordinary sources of energy by renewable one, targeting well educated student in this field. A mobile PV system for educational purposes is implemented [7]. The prototype is consisted of four PV module associated with Data acquisition system. The systems showed a good performance; however its sustainability was not granted.

Approaching better hardware environment, a remotely accessible solar energy laboratory has been developed, aiming at representing a small photovoltaic (PV) system, including two PV cells, batteries, a charge controller and a dummy load [8]. In this work, A Raspberry PI microcontroller enables to control the different inputs, measures the voltages and the currents in the circuit and provides a remote access through the web. The system is built very well but it missed the student evaluation and the student's feedback.

Another technique based on NI equipment [9] was attached for data acquiring and controlling as in [10]. The PV system, with attached charging batteries unit, were controlled with the instrumentation software LabVIEW. A double axial tracking system, includes two motors to track the sun radiation, was also controlled using LabVIEW. This study focused on the battery charging voltage and current at different temperature and angle of incidence with less interest on the PV performance and characterization.

Still using LabVIEW, the work in [11] focused on the maximum power point tracking algorithms through implementing a remote distance learning LabVIEW platform and enables the student to access, monitor and control the experiment remotely. However, lake of accurate measurement was observed from the results leading to some uncertainties. Another LabVIEW trails were published in [12] and [13]. A virtual environment was emulated to show the main principles of PVs and its characteristics. The experiment implemented for both industrial as well as academic use, but no experimental work was demonstrated.

In this work, a low cost, high tracing PV characterization experiment is introduced. The setup is consisting of a double axial tracking system, with one axial controlled automatically and the other is manually controlled, supporting a 150-Watt PV module which is considered as the module under test. A NI-DAQ is embedded for data acquisition and a live stream video is provided through an attached web-cam. A LabVIEW front panel is designed showing the solar irradiance, module temperature and the I-V/P-V characteristic curves. The use of NI environment enables the publishing of the experiment front panel through the internet which provide the remote access to students to perform the experiment 24/7. An extremely high accurate Matlab based numerical simulator is developed for comparing simulation results with experimental one, giving the opportunity to estimate some small signal parameters such as PV series and shunt resistance. The innovation in this paper is not only attributed to the constructed setup but also in the robustness of the experiment setup and the accuracy of results. In addition, the low cost and repeatability of the experiment makes it easy for any other developing university to implement such an educational platform.

Learning Approaches and outcomes

Renewable energy became a critical strategic country's objective as an alternative, inevitable, source for electricity required for the economic and social development of the country. Among the different renewable energy sources, the solar energy occupies an advanced position as promising candidates in both local as well as international markets. The possible achievement of such strategic objective requires, besides other components, professional engineers and technicians specialized in the field of renewable energy and capable to understand and handle current as well as future related advanced technologies in such domain. Consequently, different Egyptian universities and higher education institutions have established "Renewable Energy Engineering" programmes at both the undergraduate engineering level as well as at the postgraduate engineering level aiming at graduating professional engineers and technicians with appropriate skills and capabilities.

Most of Egyptian universities face the problem of overcrowded classes and laboratories which affects the quality of delivered materials, either in classroom or in laboratories leading to a negative effect on the level of graduate. On the other hand, existing newly developed renewable energy programs, either for the undergraduate or for the postgraduate levels, also suffer from the lack of up-to-date specialized interactive experiments in such field due to; unaffordable cost required to build a typical renewable energy unit, lack of required space for installation and operation and lack of localized multi-disciplines expertise, within each institution, capable to design, implement and operate such new type of multi-disciplines experiments.

This paper addresses the implementation of a remotely accessed Photovoltaic characterization experiment. The experiment aims at providing an improved education quality in the field of renewable energy engineering through the development and implementation of new form of internet based practical activities, e-experiments, to support teaching and learning of corresponding courses delivered in renewable energy programs. The wider scope of the experiment outcomes focuses along the

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country's national priorities for the improvement of higher education and learning quality through the development of new learning and teaching tools. This will be achieved through the efficient utilization and deployment of available advanced biological tools and corresponding facilities for the development of a multi-platform e-experiments, which will be fully accessible and operational through the internet using any browser, providing a flexible learning tool and environment for both students and teachers. These new facilities will provide students with an unprecedented opportunity to use the available online e-experiment environment for enhancing their understanding of key concepts related to their study which will significantly improve their learning outcomes.

In addition, the developed e-experiments will provide students with a new non-conventional interactive technique for learning and understanding fundamental as well as advanced topics in the field of renewable energy through remote experimentation, which will be available and accessible 24/7. Besides that, these e-experiment will provide an optimum low cost solution based on the fact that different students from different universities and institutions can share the same platform, in other words not every university and every institution will be required to purchase separate specialized laboratories and test equipment.

part of a master thesis research, where results was validated and published in [14].

Figure 1 Tracking system for a 150 Watt PV module

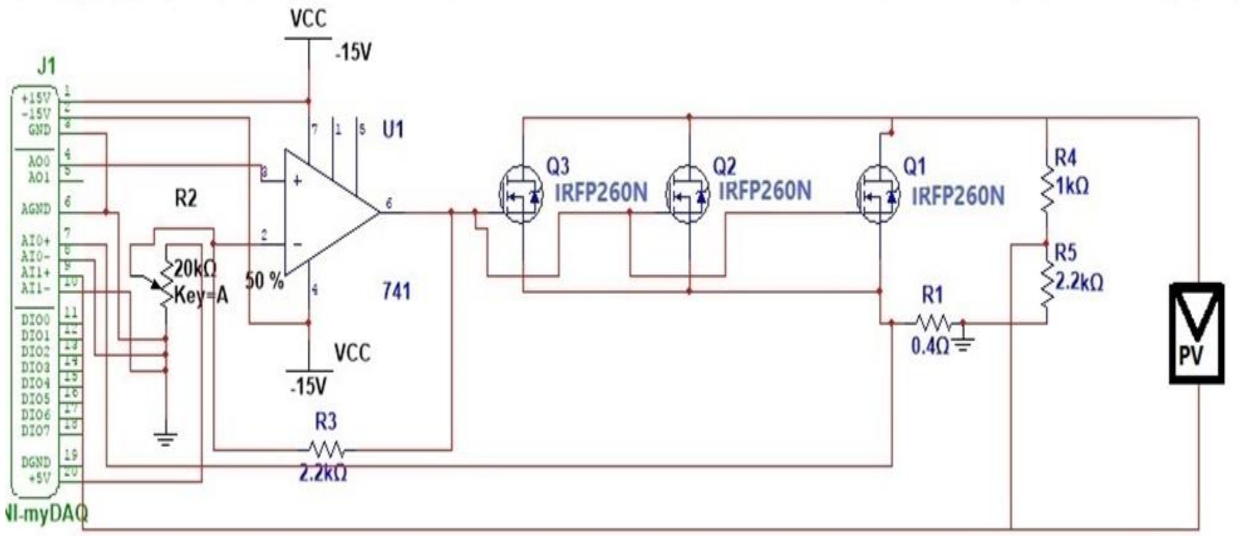

Figure 2 Cntroling Unit

In a specific manner, this experiment has been performed as a part of a postgraduate courses in both Ain shams university and the British University in Egypt. The students enrolled in these courses in both universities practiced the experiment and evaluate it according to a given evaluation form, more details are found in section V.

Experimental Setup

A double axial tracking System for a 150 watt PV module is attached to the characterization unit as shown in Figure 1. This system was established as a

The tracking system is controlled remotely using control unit. This unit is consisting of a parallel branch of low resistivity high power resistors connect directly to the PV to estimate the irradiance from the short circuit current. In addition, a motor driver is connected to the tracking system motor to provide an east to west angular motion. Finally, an ultra-high tracing frequency characterization circuit is printed to measure the I-V characteristic curve with more than one thousands point per curve. The I-V characteristics of a 150 Watt polycrystalline PV module [13] were traced using the circuit shown in Figure 2 with a power MOSFET (IRFP260N) as a varying electronic load. The characteristics of the MOSFET in both linear and saturation regions are described respectively by [13].

$$I_D = K_N(2(V_{GS} - V_T)V_{DS} - V_{DS}^2) \quad (1)$$

$$I_D = K_N(V_{GS} - V_T)^2 \quad (2)$$

Three power MOSFETs are used to tolerate the maximum power of 150 Watt as shown in Figure 2. The MOSFETs are operated in its ohmic region where the resistive value is controlled through the gate voltage which is generated V_T the threshold voltage and I_D the drain current of the MOSFET. As V_{GS} is less than the threshold voltage V_T, the MOSFET will be OFF. When V_{GS} is increased above V_T the MOSFET will operate in the saturation region and the drain current rises quadratically with V_{GS}. At lower solar module voltage the operating point of the MOSFET shifts to the linear region where the drain current changes linearly with V_{GS}. Thus, by sweeping the gate voltage the operating point of the MOSFET sweeps the I-V characteristic of the module between V_{OS} and I_{SC}. Pulse width modulation (PWM) process is used to control the gate voltage. The PWM frequency is set to 1 KHz and a saw-tooth signal is used to vary the pulse duration. The modulation process is developed by connecting the saw-tooth generator with the duty cycle adjuster of the square wave generator. The saw-tooth frequency is adjusted to be 1 Hz so that a complete characterization process occurs in 1 sec with 1000 samples. In order to isolate the DAQ to avoid any loading problem, a buffer is implemented using LM741 with an adjustable gain to calibrate the operating point according to the required gate voltage

The implemented unit is also capable of measuring the module temperature through attaching a thermocouple on the top corners of the module to avoid any shading effects. NI 6009 DAQ is used in this setup for data generation and acquisition. In addition, a LabVIEW front panel, shown in figure 3, is designed for user interfacing to show the output of the PV characteristics.

As mentioned in the introduction section, one of the novelty points of this work is related to the cost. The implemented 150 Watt PV system with the mechanical tracker was locally funded from the British University in Egypt with total cost around 6000 LE. Other driving and controlling accessories including the tracing circuit coasts about 2000 LE. As a result, the implemented setup cost totally around 8000 LE with the capability to serve students 24/7 with a high speed remote access.

User Interface

The below snapshot, Figure 3, demonstrate a real case study picked up from the developed characterizer on Tuesday 14/05/2019 at mid-day. The figure shows a real time video streaming window showing the on-roof PV module where two bush bottoms are placed on the right hand side of the front panel for controlling the PV module motion across the east west polar coordinates. The figure also shows the solar irradiance, module temperature as well as the module electrical efficiency indicators. On the left hand side of the front panel, user can find out the measured verses the simulated I-V and P-V characteristic curves.

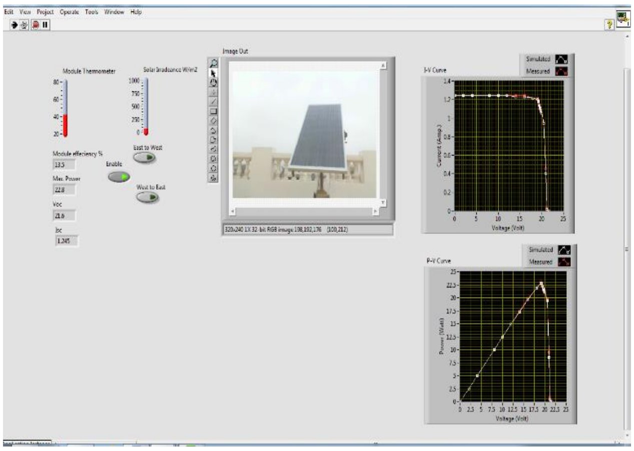

Figure 3 Snapshot from the LabVIEW front panel

Conclusions

Based on LabVIEWTM, NI-DAQ card and essential circuits, a Remote instrumental system that measures the characteristics of PV cells is designed and implemented in this study. In addition, a comparison between simulation and the experimental results are developed to be built in the interface window. The system can be used to measure irradiation, open-circuit voltage, short-circuit current, I-V curve, and output voltage/current/power under different conditions for educational purposes. The project aims to make a facility for a remote accessibility for the PV systems. The developed technique can be used to monitor and collect data for PV generation system with an advantage of being low cost.

A possible future application of this work is upgrading the PV system to study the charging and discharging of the batteries as backup system of the PV. The objective of this experiment is the applicability to execute on different renewable energy source as wind energy and bio-mass. Building like these systems on different renewable energy application will lead to improvement in the education process in both undergraduate and post graduate studies related to renewable energy fields.

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