PV Generator Performance Using Cassy System

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***Abstract* — This paper presents an experimental investigation for the performance of a PV generator using Cassy System environment. Two PV panels were exposed to severe environmental conditions such as high temperature, high humidity, relatively high irradiation and frequently high levels of dust deposition. Each PV panel of 150 W rating was feeding a variable resistive load. The measurement was taken through a conditioning amplifier and Profi-Cassy analog to a digital converter. Cassy System displayed the voltage, the current, the delivered power and the irradiation on-line with the desired frequency of measurement and storage rate. I-V and P-V characteristics were accurately displayed and stored. Cassy environment allows appending the characteristics for the sake of comparison, investigation and research purposes. The obtained results were validated against simulation to show a very good degree of accuracy. Cassy System environment has shown high degree of simplicity and flexibility in programming, to record and display a large number of variables manually and automatically. The measurement system has shown clearly the impact of dust, of high temperature and of the irradiation changes on the PV panel efficiency certifying his candidacy for research and educational purposes.**

Keywords- PV generator; Stand alone performance; Online monitoring; Weather effects, efficiency.

I. INTRODUCTION

The growing usage of renewable energies has resulted in the installation of a considerable amount of renewal power plant development, e.g. wind, photovoltaic, wave powers during last few decades all over the world. Conventional resources, such as fossil fuels, are depleted promptly due to the increasing demand of power which can results inferior standards of living around the world. Therefore, renewable energies are greatly needed as alternative energy to avoid any future turmoil and economic consequences. Photovoltaic systems have gained a lot of potential in the recent years due to the depletion of traditional energy resources. A free and virtually unlimited source of renewable energy can be tapped from the nature saving and limited use of energies such as oil and natural gas. One of energy sources is solar energy, which is readily available and can be tapped easily. In retrospect, the development of a standalone PV system is critical in analysis and mass production of solar array systems. Different ways have been used to analyze the output characteristics of solar panels and silicon solar cells by researchers, using different software such as MATLAB[1]. The integrated PV based solar insolation measurement and performance monitoring system has been studied [2]. The authors used hardware microcontroller and visual basic software for the monitoring system. Performance results and analysis of large scale photovoltaic system of 80 kW were presented [3]. They evaluated and analyzed performance of the PV system showing the effect of environment conditions on the operation characteristics. Electrical performance estimation of PV module using designed measurement system was studied [4]. The data measurement were obtained from visual studio – Basic.Net(2005) and measurement studio, National Instrument, equipped with interface and it was operated by a general IBM-PC. The monitoring of PV solar plants using a novel procedure based on virtual instrumentation was developed [5]. The measurements and processing of the data are made using high precision I/O modular field point (FP) devices as hardware, a data acquisition card as software and the package of graphic programming, LabVIEW. The system is able to store and display both the collected data of the environmental variables and the PV plant electrical output parameters, including the plant I–V curve. Data acquisition eas used to develop a new design method for various residential PV systems. Measurement data for 1-min interval were automatically memorized in a site computer and those data were delivered for host computer in Hamamatsu once a day through ISDN telephones line [6]. In this study, we are using the Cassy System for analyzing and on-line monitoring the solar panel characteristics.

This paper first proposes a monitoring system for solar panel parameters, then measures and analyzes the performance of solar panels under different conditions. Effectively this whole system integrates into a single system by the involvement of a solar panel, sensor device, personal computer (PC), Cassy modules and Cassy Lab software are used to measure and create a photovoltaic system and to analyze it. The block diagram of the experimental setup of Cassy is shown in the Figure 1. Different parameters are analyzed such as influence of solar irradiations and temperature on the performance of solar panels.

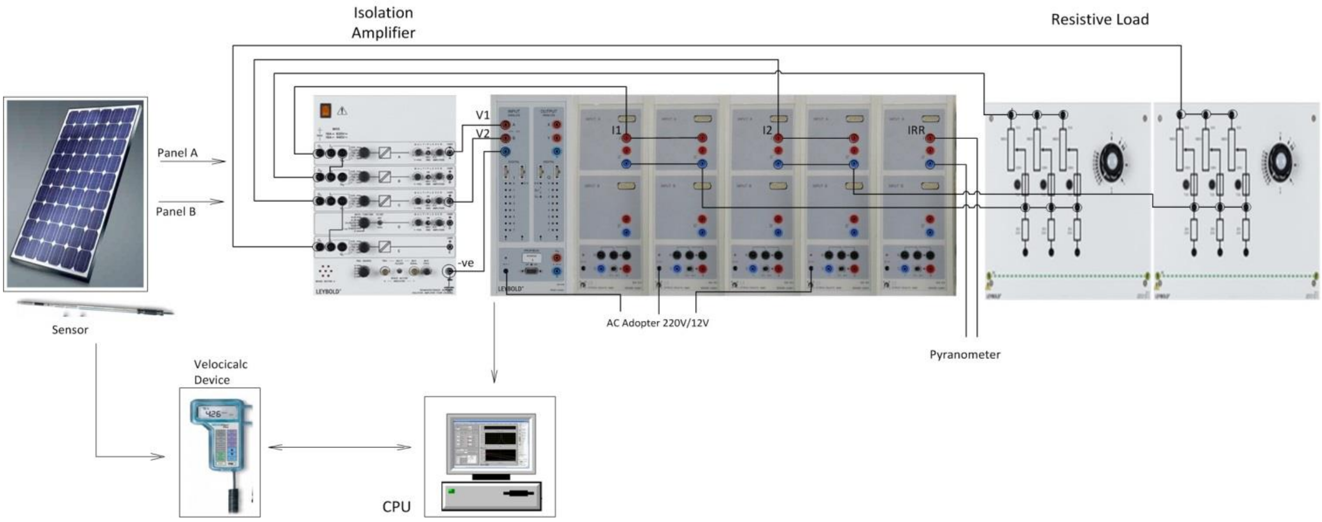

Figure 1. Block diagram of Cassy system

II. Components And System Development

1. Cassy Isolation Amplifier
2. Cassy Lab Software
3. Profi-Cassy
4. Sensor-Cassy
5. Resistive Load
6. Irradiance Sensor
7. Power Supply
8. Connecting leads and cables
9. Two PV panels (150 W as P_{max})

Three types of quantities are measured:
(1) Environmental conditions such as global and local solar radiation, local ambient temperature etc.
(2) Parameters of the panel such as temperature.
(3) Electrical characteristics like voltage and current.

All these parameters have to be measured periodically in real time to analyze and monitor the different parameters by the user. Also, the I-V and P-V characteristics of the panel are observed specifically when the solar radiation reaches certain values. Solar radiation directly influences solar panels output; the stronger the intensity of solar radiations the more energy solar panel will generate.

This project describes the development and features of a monitoring system of photovoltaic setup. The experimental setup in this study involved the integration of Cassy modules with personal computers, along with the peripheral components such as Profi-Cassy and Sensor-Cassy, Isolation amplifier, and Resistive load. Cassy Lab software is used for the PV monitoring system and to determine the characteristics of the PV system. The information obtained such as voltages and currents and irradiations is fed to the personal computer via Cassy modules for analysis. This custom-made interface has been developed by the use of Cassy Lab software.

The RESOL device CS10 Sensor type E is used to measure solar irradiation. The device measured short circuit current at any moment and is directly proportional to the generated photocurrent. The available solar irradiating power at the panel surface (W/m2) is linearly dependent on the measured short circuit current. The device short circuit current of 2030 µA corresponds to panel surface irradiating power of 1000 W/m2 (Sun=1). The device position is placed at the same inclination angle of the PV panel to reflect the panel surface available power. To monitor the accuracy of the irradiation measurement, the device is often calibrated.

III. Experimental Setup

The experimental set-up shown in figure 1 uses Cassy cascaded modules (Profi-Cassy and Sensor-Cassy) to communicate with the personal computer through USB port then joines the leads and cables to the manual variable resistive load to complete the system set up. Two Sensor-Cassy modules are cascaded to expand the analog inputs and digital outputs channels to accommodate more variables to measure and record. Channel A of the Isolation Amplifier is directly connected to panel 1. The panel high voltage (V1) is measured using '/10' scale position and delivered to the input A of Profi-Cassy channel where the digital conversion is achieved then processed and displayed by Cassy Lab interface. Channel B of the Isolation Amplifier is dedicated for panel 1 current (I1) measurement using (1V/A) scale position. Two Sensor-Cassy modules are used in parallel for current I1 measurement. It was necessary to divide the current into two equal values because the current reading may exceed the maximum limit of one Sensor-Cassy module. Similarly, channel C of the Isolation Amplifier is used to connect the leads of second solar panel for voltage (V2) and then its output is delivered to the input B of Profi-Cassy. Channel E of the Isolation Amplifier is used for Current (I_2) measurement and treated similarly to current I_1. Each panel power is delivered to its dedicated resistive load bank as shown in figure 1. The load resistance is manually varied from an infinite value to a zero value to obtain the required I-V curve and consequently the required P-V curve.

The solar irradiation measurement is conducted through the RESOL device CS10 Sensor type E. The device measured short circuit current at any moment is directly proportional to the generated photocurrent. The available solar irradiating power at the panel surface (W/m2) is linearly dependent on the measured short circuit current. The device short circuit current of 2030 µA corresponds to panel surface irradiating power of 1000 W/m2 (Sun=1). The device position is placed at the same inclination angle of the PV panel to reflect the panel surface available power. To monitor the accuracy of the irradiation measurement, the device is often calibrated.

IV. CASSY LAB INTEFACE

Cassy Lab software interface, once open, will prompt you for setting the configuration on setup dialog window as shown in figure 2. At first the display shows the current arrangement as detected by Cassy modules for activating and setting the voltage and current channels. The active channels are marked with colors. The default defined variables for current and voltage of first module is identified as I_{A1} and U_{B1} respectively. Each panel power is obtained by the corresponding product of current and voltage using the proper scale factor. Thus new quantities such as irradiation, power, voltage and current can be defined in the next tab named ‘Parameter/Formula/FFT’ by using corresponding mathematical formulas on formula option. Next tab named ‘Display’ is configured to display the required quantities on the table and diagram window. The required quantities for display are also defined for x and y-axis. Different colors are used to show different quantities and curves.

Cassy interface allows automatic and manual data control and recording. Automatic recording is selected for monitoring the performance of PV panels. The number of measuring points, time interval and measuring time are to be selected before starting the data recording each time automatically. Manual recording is selected for plotting and evaluating of I-V characteristics. The user will decide continuous or window frame data collection. Several variables could then be recorded at the same time. Data can be appended for sequential recording of multiple measurement series. Once measurements are taken, the data can be exported to excel file for further evaluation and analysis.

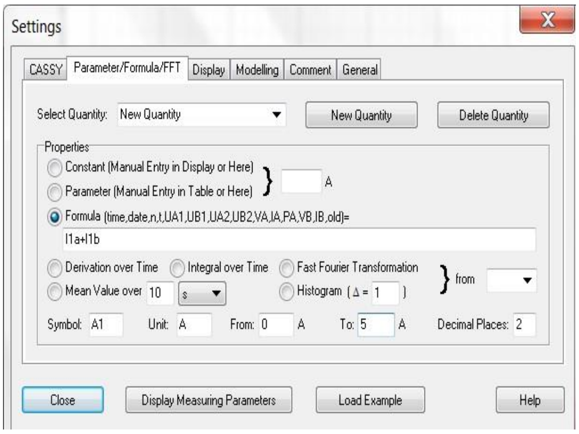

Figure 2. Cassy parameter settings window

V. RESULTS

The Cassy system shows in figure 3, the continuous measurement for two consecutive clear days at the rate of 2 minutes. The PV panel (150W) is cleaned and the performance follows the Gaussian distribution affected by the irradiation level and the panel temperature. The maximum power is recorded on the first day is 110W at 10:45AM at the panel temperature of 41.2°C and under irradiation level of 835W/m^2. For the second day the behavior is similar to the first day. Although the irradiation level is relatively high we are far away from 150W maximum power rating, the reason for which is much higher temperature than the standard.

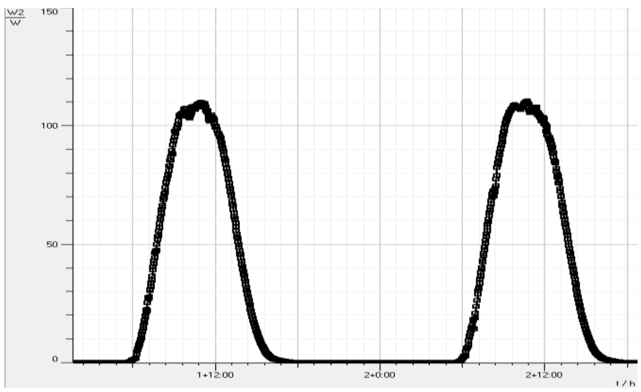

Figure 3. Online PV panel output power for two days

Figure 4 shows the continuous measurement for the whole day of two PV panels and compares the output performance of PV clean and dusty panels. The upper red curve of the clean panel expresses a superior performance over the lower black curve of dusty panel. The difference of 15W is observed between clean and dirty panel at maximum power.

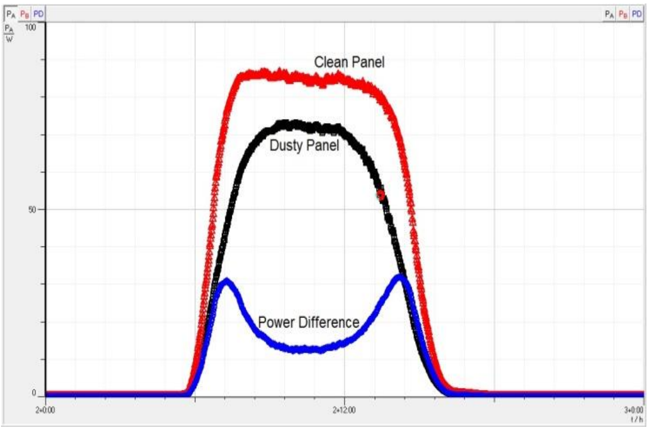

Figure 4. IV & PV curves of clean & dusty panels

In figure 5, this Cassy system shows its capability of simultaneously displaying many variables like, irradiation, voltage, current and power. The blue curve is for power with the scale 0-150W. The black curve is for voltage (scaled from 0-50V). The red curve is for current (scaled from 0-5A). The purple curve is for irradiation (scaled from 0-900W/m^2). Each curve has its own scale and the scale button is shown on the upper left corner of figure 3. The ON scaled button in this figure is for irradiation while the scale for power, voltage and current is hidden.

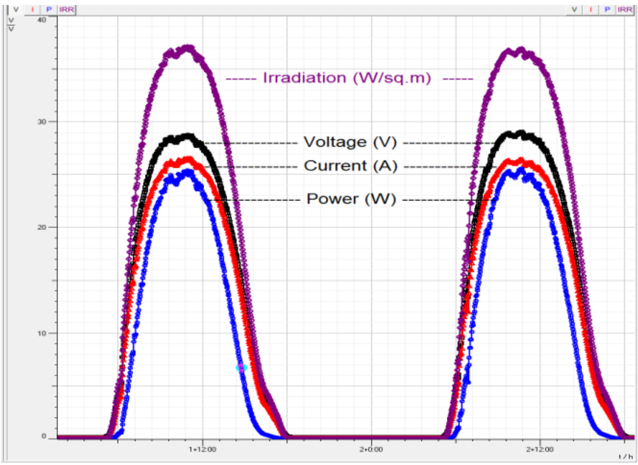

Figure 5. Cassy display for online PV measurement

Figure 6 compares the performance of PV clean and dusty panels. The black I-V curve, along with the corresponding red P-V curve of the clean panel, express better performances than the red I-V curve, along with the corresponding blue P-V curve, of the dusty PV panel. The black I-V curve is taken at 1095 W/m^2 and a panel temperature of 62 ^{o}C. The maximum obtained power was 109.54 W. The red I-V curve is taken at air irradiation of 1095 W/m^2 and a panel temperature of 54 ^{o}C. Due to the dust accumulation on the panel, the effective panel irradiation level is reduced to 855 W/m^2. The maximum obtained power is 73.96 W. The dust deposition on the panel reduced the power output, the load current as well as the panel temperature. Cassy system also reveals clearly the flat pattern of the black upper (clean panel) I-V curves while the red lower (dusty panel) I-V curve has much higher slope. This observation is believed to announce the changes of the electrical parameters of the dusty panel.

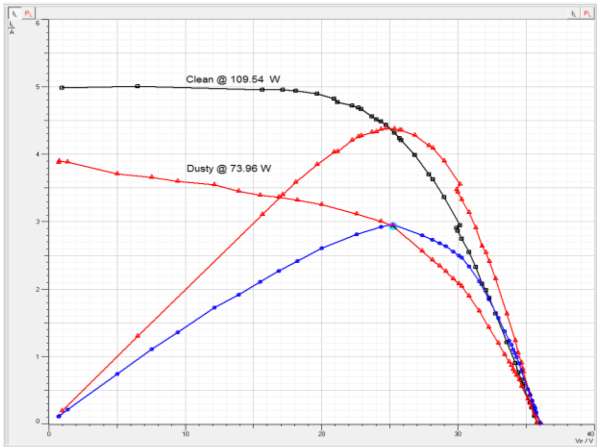

Figure 1. IV & PV curves of clean & dusty panels

Figure 7 displays both I-V & P-V curves for two similar panels (150W each) at three different levels of irradiation 1140 W/m^2 (high), 995 W/m^2 (medium) & 460 W/m^2 (low) at respective maximum power of 110.16 W, 100.37 W and 51.48 W on the same day. The black, purple, green I-V curves with their corresponding red, green and dark blue consecutively P-V curves are attributed to the clean PV panel. The red, blue, dark blue I-V curves with their corresponding blue, purple and pink color consecutively P-V curves are attributed to the dusty PV panel. The relevant effective irradiations are 860 W/m^2, 825 W/m^2 and 290 W/m^2 at maximum power of 74.94 W, 65.50 W and 28.84 W respectively. Though this Cassy system figure reveals similar behavior as in figure 6 it demonstrates clearly the impact of irradiation level on the performance on the PV panels clean or dusty.

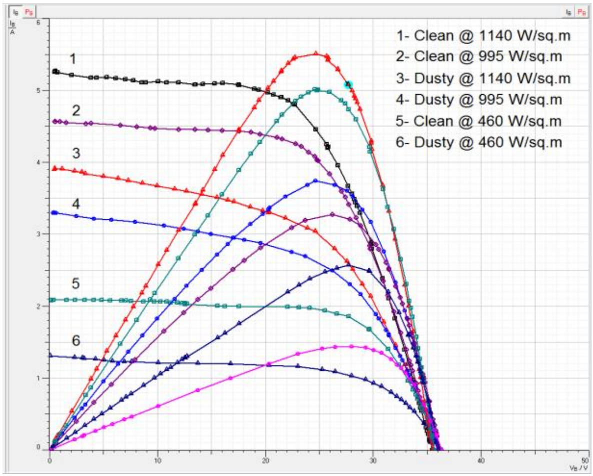

Figure 2. Performance behavior of clean & dusty PV panel with Irradiation

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VI. CONCLUSIONS

An experimental set-up was built for a standalone PV system to feed a resistive load. Cassy System with its computer interface was successfully implemented and tested to monitor the PV panel output for on-line and automatic measurement under several environmental conditions. The system was similarly tested for I-V and P-V curves for several different conditions

- For clear day time and clean panel conditions the output power was monitored. The performance follows the Gaussian distribution affected by the irradiation level and the panel temperature. Cassy system was capable to follow and record the data with high measurement rate.
- Cassy system has proven its capability of simultaneously displaying many variables like irradiation, voltage, current and power for several consecutive days. Each panel variable could be monitored within its operating range. It has the flexibility of switching scales.
- The performances of PV clean and dusty similar panels were investigated using Cassy system. I-V curve along with its corresponding P-V curve for each panel have demonstrated clearly better performance in favor of the clean panel. Cassy system also revealed a much higher slope for the dusty panel I-V curve to declare the change in the electrical parameters of the dusty panel.
- Cassy system has successfully tested and displayed the performance of clean and dusty panels under the impact of different levels of irradiations.
- Cassy System interface has proven simplicity, flexibility and very good capability to monitor the PV performance and to educate students about the impact of the environment on the PV output power and parameter changes.

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