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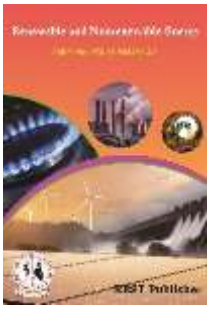

Testing and Monitoring the Performance of Photovoltaic Module –A Low Cost System

***K Kalyani Radha, B Omprakash**

JNTUACEA, Ananthapuramu, Andhra Pradesh, India.

*Corresponding Author Email: radha.mech@jntua.ac.

Abstract: *Growing importance in Renewable Energy Resources has caused the solar power market to expand rapidly. And the photovoltaic energy is becoming an increasingly important part of the Renewable Energy Resources. Investment in PV energy is rapidly increasing worldwide, and this has intensified the need to analyze the performance of PV systems and energetic productivity of PV arrays for estimating the profitability of their implementation in various locations. To evaluate PV performance outdoors it is very important to guarantee high quality of collected data which depends on the accuracy of the associated measuring instruments. Error sources must be minimized as much as possible. This paper presents a semi-automated system for testing and monitoring the performance of PV modules in outdoor conditions. The purpose of this paper is to develop a low cost system for testing and monitoring the performance of PV modules in outdoor conditions. In order to do this, we improved and adapted another measuring system. This system was developed by us and enables us to ensure the performance of the PV module through testing and monitoring, as well as saving collected data to a database. This database can be accessed through a graphical interface on a laptop connected to the system using serial interface. The error sources of this system are reduced to minimum because of human operators interfering with the system only through the graphical user interface. The performances of PV module were obtained in outdoor conditions and were saved to the database. They will be compared with the performances of the different PV modules to prove the efficiency of the module.*

Keywords: *photovoltaic energy, PV performance, testing, monitoring, database, graphical user interface*

1. INTRODUCTION

The word photo voltaic is derived from photo, the Greek word for light and volt, relating to electricity, photo voltaic cells are made-up of a material known as semiconductors, the most commonly used semi-conductor material in solar panel is silicon. When the light fall on the solar panel, it strikes directly to the solar cell, this cell absorbs the solar radiation. These solar cells converts radiation into direct electric current, each photo voltaic cell in the solar panel can generate 0.5 volts of maximum current. The maximum power can be achieved by placing these cells In-series and in-parallel can increase the total current. When manufacturing a solar panel it is necessary to place an anti-reflective coating such as glass plate is susceptible to dust from the surrounding environment. When this plate becomes dirty, thus power efficiency of PV panels will reduces.

Solar energy: The present population is growing day to day and demand for energy is also increasing accordingly. The scientists and researchers were investigating on the renewable energy sources. One such alternative energy is solar energy. Renewable energy sources came into existence in present days because of increasing oil prices. Solar energy is one of the most popular renewable energy produced (or) generated directly by the sun. Solar energy is the most readily available renewable energy. It does not belong to anybody and is therefore free. Owing to nonpolluting nature, it became most widely used non-conventional energy source.

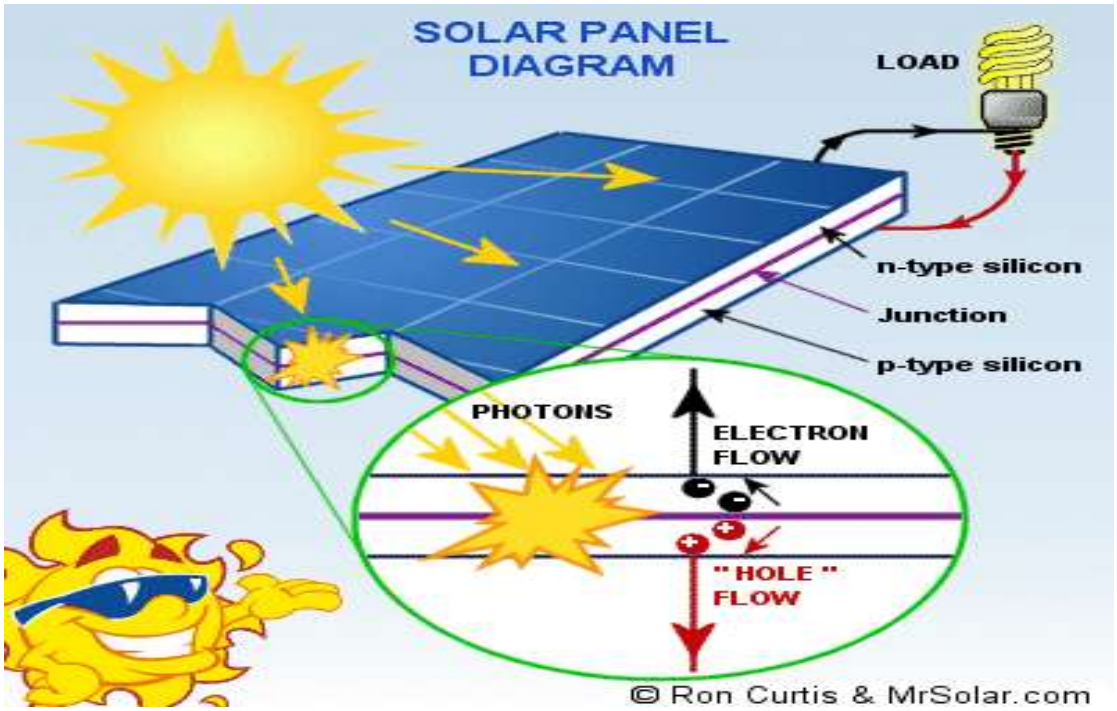

FIGURE 1. Photovoltaic cell receiving the light from sun and converting it into electricity

The sun creates its energy through a thermo nuclear process that converts about tons of hydrogen to helium every second. This process can generate the thermal heat and electromagnetic radiation spread out into all the space in all directions. Only a little fraction of the total radiation will reaches the earth. The solar energy can be received by the collectors (solar cells); the collector simply collects the energy and converts into electricity. The converted electricity is stores into the storage unit because non-constant nature of solar energy. Mainly electricity generation around the earth happens through the non-renewable energy sources, especially fossil fuels. This makes us to look for a renewable energy source such as solar energy.

PV panel performance monitoring: The PV panel performance testing is the important in the decision making of establishing a solar plant and purchase solar material. Test laboratory Albarubens chooses the best testing conditions by setting up their tests in natural sun light instead of test under artificial light conditions. The kipp and zonen CMP 11 pyrometer helps to measure the solar radiation very accurately for precise indication of the solar panel performance. Albarubens S.R.l. is a test laboratory generally located near Milan in Italy, this company specialist in solar energy system. The Albarubens performs testing and certification of PV panels for power plant projects, which helps us to makes the decisions for setting up solar plant. The main performance tests carried out by Albarubens is the measurement of maximum electrical power generated by a solar panel per square meter. The research and development in this domain results in improving the performance of the solar panel. The difference in performance of solar panels from various PV panel manufacturers is quite small, so the power measurement has to be made with very high precision. The electrical power generated from the PV panels depends on a number of factors: total incoming radiation, its spectrum, and angle of incidence and PV module temperature. The irradiance measurement for outdoor PV performance monitoring is usually carried out with pyrometers. Some of the standards suggest using PV reference cells. Generally reference cells are unsuitable for proof in bankability and in proof of PV system efficiency. Pyrometers will be great suitable for outdoor solar energy monitoring. The importance of outdoor photovoltaic testing is to compare the available resource to system output and thus to calculate the efficiency. The efficiency estimates the performance and stability of photovoltaic panels. It also serves as a reference for remote diagnostics and need for servicing.

FIGURE 2.PV module performance monitoring using graphical user interface

2. PROPOSED SYSTEM

A computer based data acquisition system to monitor and control photovoltaic power generation. Generally this concept based on graphical user interface and data acquisition system has been designed and implemented. A small size photovoltaic power generating solar panel and controller and serial communication protocol used in renewable energy source (RES) applications in order to collect data regarding the photovoltaic panel performance. The proposed system consists of a set of sensors measuring electrical parameters (photovoltaic voltage and current etc.)

Communication protocol: The communication channel is a TTL/RS -232 transceiver that permits the serial interfacing between a data logger and a computer (RS -232 voltage levels), executing the electronic load variation, the a digital-digital conversion from the solar irradiance, the communication with the 1-Wire sensor and the data transmission to and from the computer via RS- 232 interface. By using different buttons on a computer graphical interface, it is possible to visualize the results of the module characterization. The sensor data is collected by a microcontroller and stored in a serial flash EEPROM until uploaded to a portable computer. At the end of each data collection period, the acquired data is transmitted to the computer through a RS- 232 serial interface. The voltage and current data are acquired, processed and then transmitted. For voltage acquisition, a voltage divider was used, which means 10 mV for every one volt of solar panel output.

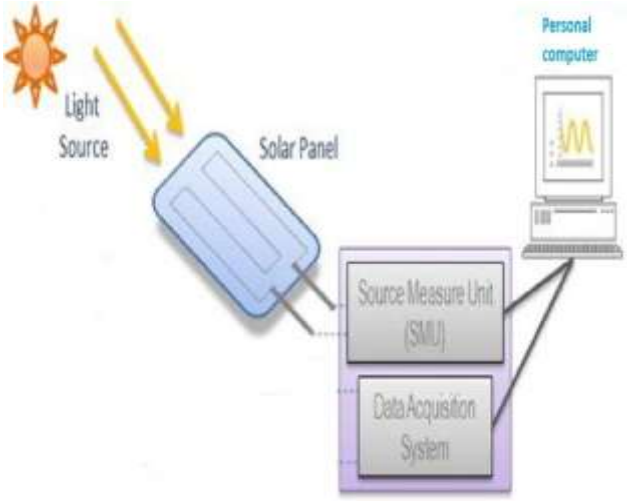

FIGURE 3. Architecture of proposed Testing and Monitoring the Performance of Photovoltaic Module

Sensor connectivity: A set of sensors are used to measure quantities regarding the electricity produced by a hybrid PV generator power system, such as PV array voltage and current. The collected data are further processed, displayed on the monitor and stored in hard disk. This section describes a low cost concept for data logger applied to decentralize RE plants for use in developing countries, based on free software anda serial interface. Considering this most of Data loggers found in literature use a serial TTL/RS-232 transceiver for the connection to a Personal computer. The motivation is that currently TTL/RS-232 represents the most diffused peripheral - to -PC connection standard thanks to its flexibility, expandability and ease of use. In this way, there are two possibilities for data collection: data can be locally collected with the USB channel or remotely by GPRS, aiming to be stored on a data base, making possible a posterior analysis . In most of the mentioned references, the data storage is done on a PC hard disk, whereby there is a requirement to provide constantly, a dedicated powered PC on - site only for this purpose, which makes the monitoring system more expensive. In the proposed data acquisition systems, the variables are stored directly in the data acquisition systems EEPROM, making the complete monitoring system cheaper.Equipment's designed and built for specific applications tend to be less costly, enhance performance and to provide user- friendly environment for control and communication. It is clear that a commercial data logger has a greater operation range, but for specific applications, it makes sense to use a cheaper developed version. Microcontroller data logger is a self -contained, rugged data loggerthat includes battery- backed, real - time clock and nonvolatile data storage. It has an on -board keyboard and 16*2 backlit LCD for accessing information on- site. The microcontroller features removable Input/output connections, and RS- 232 ports.

3. HARDWARE APPARATUS

A) ARM7TDMI-SPROCESSOR: The ARM7 TDMI-S processor is a member of ARM (Advanced RISC Machine) family of general purpose 32 bit microprocessor. The ARM family offers higher performances for very low power consumption. The ARM architecture based up on RISC (Reduced instruction set of computer) principles. The RISC instruction set and related decode mechanism are much simpler than those of CISC designs.

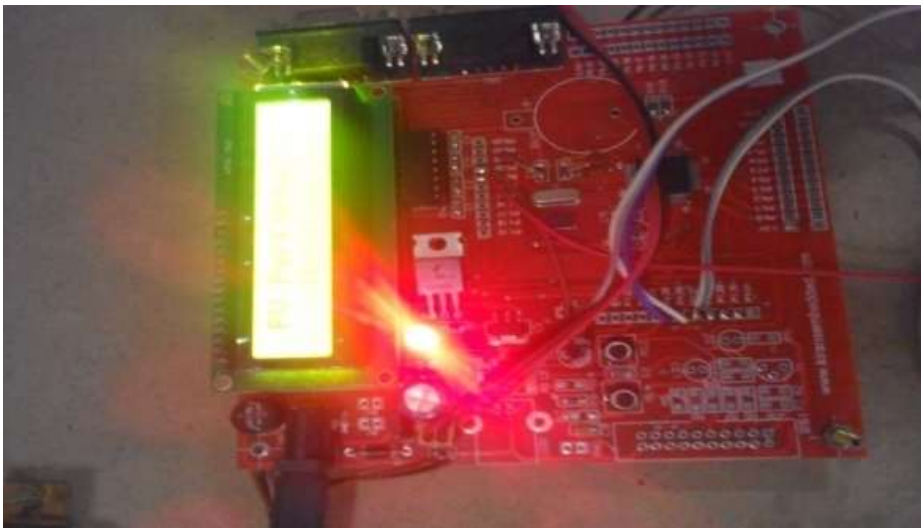

FIGURE 4 .ARM7 TDMI-S (LPC2148) processor

The features of ARM7TDMI-S processor are listed below.

- 16-bit/32-bit ARM7TDMI-S microcontroller in tiny LQFP64 packages.
- 40kB of on-chip static RAM and 512 Kb of on-chip flash memory.
- In-system programming/In-Application Programming (ISO/IAS) via on-chip boot loader software.
- USB 2.0 Full-speed compliant device controller with 2kB of endpoint RAM.
- Two 10-bit ADCs provide a total of 14 analog inputs
- Two 32-bit timers/external event counters (with four capture and four compare channels each). PWM unit (six outputs) and watchdog.
- Low power Real-Time Clock (RTC) with independent power and 32 kHz clock input.

- Multiple serial interfaces including two UARTs. Two Fast I^2C-bus (400 Kbit/s), SPI and SSP with buffering and variable data length capabilities.
- Up to 45 of 5V tolerant fast general purpose I/O pins in a tiny LQFP64 package.
- On chip integrated oscillator operates with an external crystal from 1 MHz to 25 MHz
- CPU operating voltage range of 3.0V to 3.6 V (3.3 V+- 10 pct) with 5 V tolerant I/O pads.

B) PV panel: Solar panel material used in this project is mono crystalline silicon. In the manufacturing of high performance solar cells, Mono crystalline silicon is used. Solar panel is an arrangement of solar cells in series or in parallel to achieve more power. Generally the antireflective surface of solar panel can be made up of either plastic or glass. These solar panels can be available in different power ratings (watts) according to the application.

FIGURE 5. Photovoltaic (PV) module

c) Hyper terminal: The communication theory says transmitting info from one person to another. In terms of computers it could be as simple as connecting two devices. Hyper terminal is an application we can use in order to connect our computer to other remote systems. It comes with Windows as preinstalled. Search your programs list if you could find it (hint: communications). It allows us to connect using modem, Ethernet, or serial port. It could possibly talk only about connecting a microcontroller to Hyper Terminal. When we connect microcontroller over a COM port say COM_1, Windows automatically detects the phone and ask for COM port to use. Then after setting the port settings like baud rate, data bits, parity and flow control etc., we are connected to the microcontroller. Use AT command to test if it is really connected. At Basic level type AT on the hyper terminal screen and hit the return key. OK means successful response.

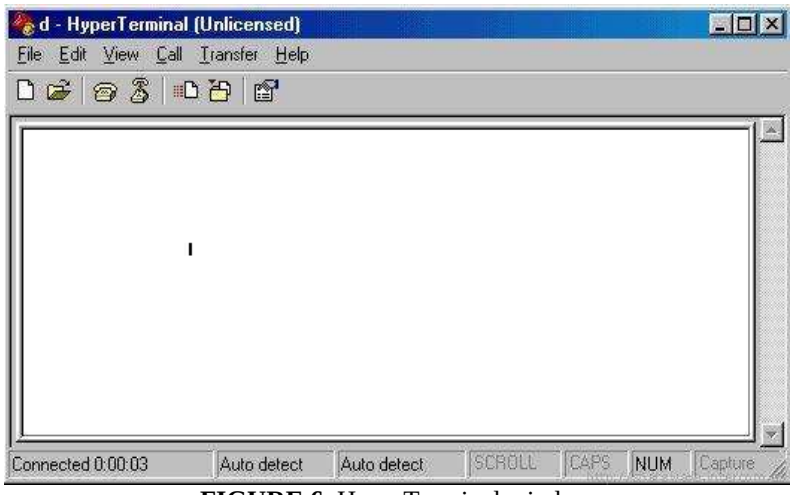

FIGURE 6. HyperTerminal window

4. RESULTS AND DISCUSSIONS

A) Voltage and current characteristics of solar panel under different irradiation levels: The below figure7 shows voltage and current characteristics of the PV panel under different irradiations levels: 200W/m^2, 600 W/m2, and 1000W/m^2. The solar PV panel produced a maximum voltage of 7v as recorded for the 1000 W/m^{2}condition and minimum of 2vas recorded for the 100W/m^2 conditions. It can summarize from the graphs that the highest power could be produced when the panel is under good irradiances conditions.

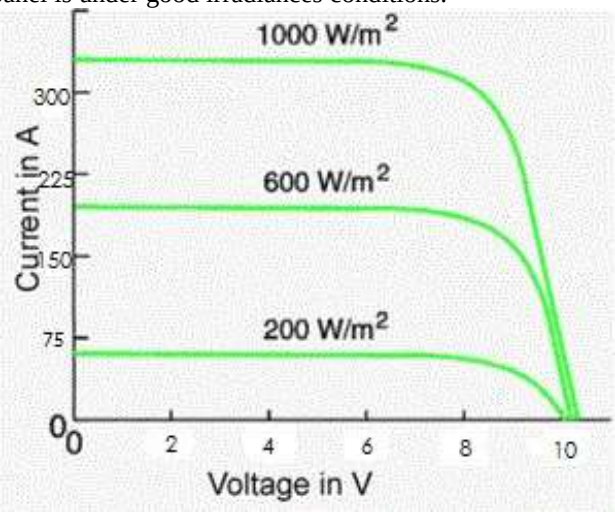

FIGURE 7.-characteristics of solar panel under different irradiations levels

TABLE1 Output Voltage and Current for Different Irradiation Conditions of Solar Panel

Output power for different irradiation conditions					
200 W/m^2		600 W/m^2		1000 W/m^2	
Voltage (V)	Current (A)	Voltage (V)	Current (A)	Voltage (V)	Current (A)
0.25	5	3	202	5	308
0.5	32	3.5	220	6	351
1	65	4	256	6.5	376
2	122	4.5	280	7	413

FIGURE 8. Minimum voltage produced at100W/m^2 condition

FIGURE 9. Maximum voltage produced at1000W/m^2 condition

b) Peak power for different irradiation conditions of solar panel: The effect of dust on the panel is quantified by tabulating the peak powers of PV panel under each and every experiment condition. Shown in table1 are the values of peak powers from different conditions of solar panel. The table shows that highest peak value obtained at panel not covered with any dust.

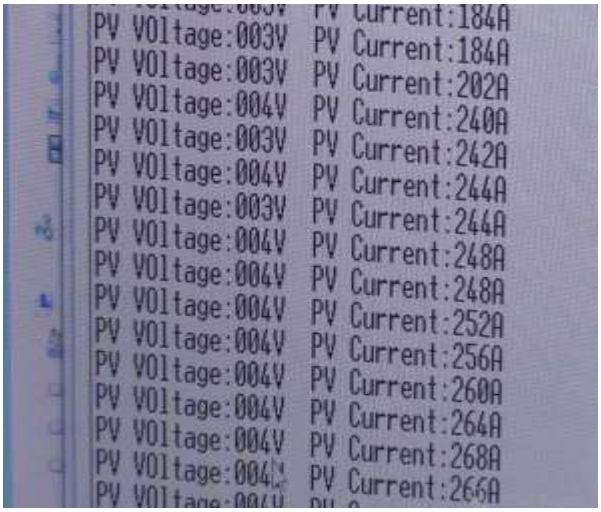

FIGURE output voltage and current for different irradiation conditions of solar panel

C) Calculating the efficiency of solar panel: A solar cell may operate at wide range of voltages and currents. By increasing resistive load on an irradiated cell continuously from zero (short circuit)to a very high value (open circuit), that can determines the maximum power point of a solar cell. The maximum power point of solar panel varies according with incident illumination. For example presence of dust on solar panel reduces the maximum output power of PV panel. A maximum power point tracker tracks the instantaneous power by continuously measuring the voltage and current and finally this database is used to dynamically adjust the load to transfer constant maximum output power to the load. Another parameter in the behavior of solar cell is the fill factor. Fill factor is defined as maximum power point (Pm) divided by the open circuit voltage (Voc) and short circuit current (Isc).

$$FF = \frac{P_m}{V_{OC} \times I_{SC}} = \frac{\eta \times A_c \times E}{V_{OC} \times I_{SC}}.$$

- Where η= efficiency of solar panel
- Pm= maximum power point
- Voc= open circuit voltage
- Isc= short circuit current

The fill factor affects the output power of the solar cellsseries and shunt resistance.

5. CONCLUSION

The rapid evolution of renewable energy sourcesduring the last two decades resulted in the installation of many renewable energy power systems all over the world. A disadvantage of these systems is that the installation cost is still high, so their design optimization is desirable. However, such an effort requires detailed knowledge of the data regarding to output power of the site where the solar system will be installed and operational results from similar systems, if available. Hence, in practice we used microcontroller and graphical user interface based data acquisition systems have been developed in order to collect and process such data, as well as monitor the performance of photovoltaic panels under different irradiation conditions, in order to evaluate their performance, displayand store the collected data in the PC disk & it can be easily extended for controlling the renewable energy system operation.

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