

Development of Low Cost Data Acquisition System for Photo Voltaic Systems

S.Parthasarathy ¹, Dr. N.V. Anandkumar ²

Research Scholar, Faculty of Engineering & Technology, North East Frontier Technical University, AP, India¹

Principal, Sri Venkateswara Institute of Science and Technology, Kolundhalur, India ²

ABSTRACT: Study of Photovoltaic (PV) module performance is one of the important procedures to ensure its quality, which needs a data acquisition system for measurement of parameters. This paper presents the design and implementation of a low cost data acquisition system for photovoltaic systems. A low cost pyranometer and temperature sensor is designed to monitor environmental parameters like irradiance and temperature respectively and PIC microcontroller for data logging process are implemented to evaluate the performance of PV module. The results were used for further analysis. From the analysis we infer that due to variation in the environmental conditions the performance of the PV module drops due to rise in temperature above the ambient temperature (25°C) and due to the variation in the irradiance the power quality of PV module gets affected.

KEYWORDS: Photovoltaic system, Data Acquisition System, Pyranometer, Temperature, Irradiance.

I. INTRODUCTION

Serious economic concerns along with the growing worries about the disastrous effects that technological progress accumulatively causes to world environment impose a shift towards renewable energy resources, which constitute an environmental friendly approach for power generation with satisfactory efficiency [1]. In the last years, renewable energy sources became extremely important, especially due to environmental benefits and energy security. Among them, photovoltaic systems become one of the most important [2]. These systems consist of PV cells for energy extraction from the sun and power converters for load or grid interface. The power converter connected to the PV cells is also used to generate maximum power from the PV module [3]. PV modules are also characterized by their nonlinear voltage–current characteristics as the solar irradiance and ambient temperature are unpredictable [4]. Due to the fast growth of photovoltaic (PV) installations, concerns are rising about the harmonic distortion generated from PV due to variation in the input solar irradiance. Hence the solar radiation is considered to be an important data for evaluating the performance of solar energy conversion [5]. This makes the necessity for measurement and storing of solar irradiance values and other environmental parameters of the place where the PV modules are installed. In order to obtain data about a PV panel such as temperature and irradiance, a data logging system along with various types of sensors are used that measures all the important values using a microprocessor based system [6]. Various research works regarding PV system monitoring are available in literature [7-20]. However they suffer their own drawbacks like cost of components and installation difficulty, which provides hurdle for its implementation. The present work is to explore the possibility of continuously monitoring and storing the temperature and irradiance in the PV system through PC and to analyze the PV output characteristics. A custom cost effective hardware is designed, and the corresponding application software and firmware are also developed for acquiring better and reliable data.

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II. SYSTEM MODEL

The system model of the outdoor measurement set up is shown in Fig. 1.

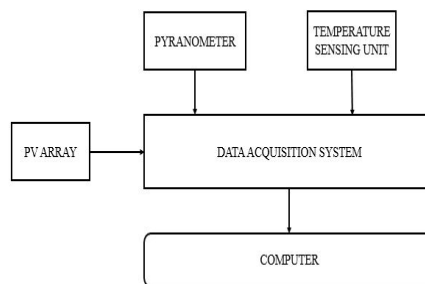


Fig. 1. System Model

II.1 PV ARRAY

The PV module used in this work consists of 36 silicon solar cells connected in series and each of them are capable of producing 0.55V. The maximum short circuit current of the PV module is $I_{SC} = 500$ mA, the maximum open circuit voltage produced by the PV module is $V_{oc} = 20$ V, the panel output power $P_{DC} = 10$ Watts. This rating of the panel is rated under 25° C with a solar irradiance of 1000 W/m^2 .

II.2 PYRANOMETER

Pyranometer is a device used to measure the solar irradiance in horizontal surface [21]. Measurement of solar radiation per unit of surface (W/m^2) is called irradiance. The pyranometer is a highly costly device due to the thermopile and semi-spherical glass domes. A low cost pyranometer for solar irradiation measurement was designed using BPW34 photo diode and signal conditioning and amplifying was done using IC LM308N. The constructed pyranometer possesses similar characteristics to those of standard pyranometers based on thermopiles at a significant lower price. The circuit diagram of the same is shown in Fig. 2 [22].

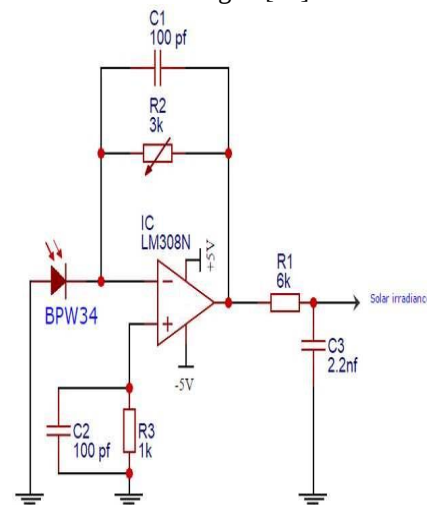


Fig. 2. Circuit Diagram of Pyranometer

This type of pyranometer works with a $\pm 3\%$ accuracy and their output characteristics curve is highly linear. The response of BPW34 photodiode to solar irradiance is produced in voltage. When 1 Watt/m^2 irradiance falls on BPW34 an output voltage of $580 \mu\text{V}$ is produced.

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II.3 TEMPERATURE SENSING UNIT

For the measurement of atmospheric temperature LM35 DZ temperature sensor is used. Fig. 3 shows the temperature sensing unit. The LM 35 series are precision integrated- circuit temperature sensors, whose output voltage is linearly proportional to the Celsius temperature [23].

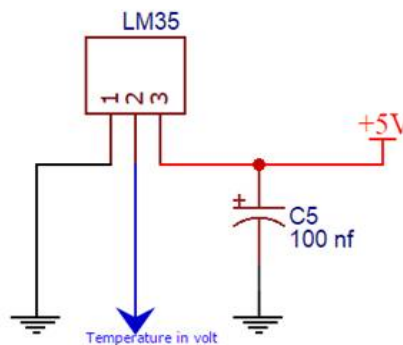


Fig. 3. Temperature sensor circuit

It is a linear device with $+10.0\text{mV}/^\circ\text{C}$ scale factor. The LM35 does not require any external calibration or trimming to provide typical accuracies of $\pm 1/4^\circ\text{C}$ at room temperature. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout easy. It can be used with single power supplies or with plus and minus supplies. As it draws only $60\text{ }\mu\text{A}$ from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 is rated to operate over a -55° to $+150^\circ\text{C}$ temperature range.

II.4 REGULATED POWER SUPPLY

A regulated $+5\text{V}$ DC power supply is designed to power up the PIC microcontroller. A 230V to $6-0-6\text{V}$, 500mA center tapped transformer is used to step down the AC Voltage. Bridge rectifier made of UF4007 is used for AC to pulsating DC conversion; capacitors are used to filter ripples. The voltage regulator IC 7805 is used to produce regulated $+5\text{V}$ and IC 7905 is used to produce regulated -5V dc supply. Fig. 4 shows the circuit of regulated power supply.

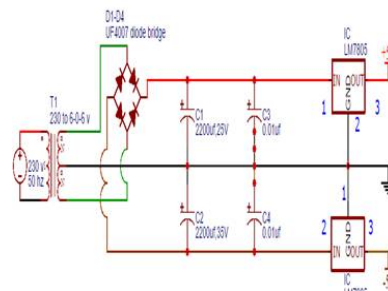


Fig. 4. Regulated DC Supply

II.5 DATA ACQUISITION SYSTEM

Data acquisition (DAQ) is the process of measuring an electrical or physical phenomenon such as voltage, current, irradiance, temperature, pressure, or sound with a computer. A DAQ system consists of DAQ measurement hardware, and a computer with programmable software. DAQ hardware acts as the interface between a computer and signals from the sensors such as pyranometer and temperature sensing unit. It primarily functions as a device that digitizes incoming analog signals so that a computer can interpret them. The three key components of a DAQ hardware used for measuring a signal are the signal conditioning circuitry, analog-to-digital converter (ADC), and computer bus. Signal conditioning

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circuitry manipulates a signal into a form that is suitable for input into an ADC. This circuitry can include amplification, attenuation, filtering, and isolation. Some DAQ devices include built-in signal conditioning designed for measuring specific types of sensors. An Analog-to-Digital Converter (ADC) is one that provides a digital representation of an analog signal received from sensors at an instant in time before they are manipulated by digital equipment such as a computer. In practice, analog signals continuously vary over time and an ADC takes periodic “samples” of the signal at a predefined rate. These samples are transferred to a computer over a computer bus where the original signal is reconstructed from the samples in software. In this work, a PIC microcontroller is used as the DAQ hardware which does the entire function of signal conditioning and ADC. PIC is a family of Harvard architecture microcontrollers made by Microchip Technology. The name PIC is referred to “Programmable Interface Controller”. PICs are popular with both industrial developers and hobbyists alike due to their low cost, wide availability, large user base, extensive collection of application notes, availability of low cost or free development tools and serial programming (and re-programming with flash memory) capability. We have selected PIC 16F877 for our application having following features [24]

- High-Performance RISC CPU
- Only 35 single-word instructions to learn
- All single-cycle instructions except for program branches, which are two-cycle
- Operating speed: DC – 20 MHz clock input
- DC – 200 ns instruction cycle
- Up to 8K x 14 words of Flash Program Memory
- Up to 368 x 8 bytes of Data Memory (RAM)
- Up to 256 x 8 bytes of EEPROM Data Memory Pinout compatible to other 28-pin or 40/44-pin PIC16CXXX.

The computer bus serves as the communication interface between the DAQ device and computer for passing instructions and measured data. A computer with programmable software controls the operation of the DAQ device and is used for processing, visualizing, and storing measurement data. In this work RS 232 was used as the computer bus. RS-232 stands for Recommended Standard 232. RS-232 is a standard used for serial binary data signals which connects DCE (Data Circuit-terminating Equipment) to DTE (Data Terminal Equipment), most commonly used in computer serial ports. [25]

III. RESULTS AND DISCUSSION

The outdoor measurement was taken at the location of latitude 12.9211° and longitude of 80.1652° . The designed pyranometer was made to measure the global irradiance data for every five minutes and the values are compared with the irradiance data of the same day and time procured from the local meteorological department. The values were coinciding with a tolerance error of plus or minus 3 in values validating the design. Hence we can say that instead of utilizing a high cost instrumental pyranometer, one can use our circuit based low cost pyranometer, for measurement of solar irradiance, making the data acquisition system to be low cost. The output of pyranometer is connected to the data acquisition system which scans the sensor for its data every five minutes and the data are stored in the computer for further analysis. In addition to the pyranometer data, values of ambient temperature measured using the temperature sensing unit was also stored in the computer through the DAQ. Also high accurate digital multimeter was used for measuring the output voltage of the photovoltaic (PV) array and the data was stored in computer through the DAQ. Out of various days of measurement, three different cases were selected for analysis. Case 1 is fully sun shine condition, case 2 is less cloudy condition, and case 3 is more cloudier condition. The irradiance, temperature and PV output voltage of those three cases has been plotted as graph with respect to time duration of the day and are shown in Fig. 5 to Fig. 7.

International Journal of Innovative Research in Science, Engineering and Technology

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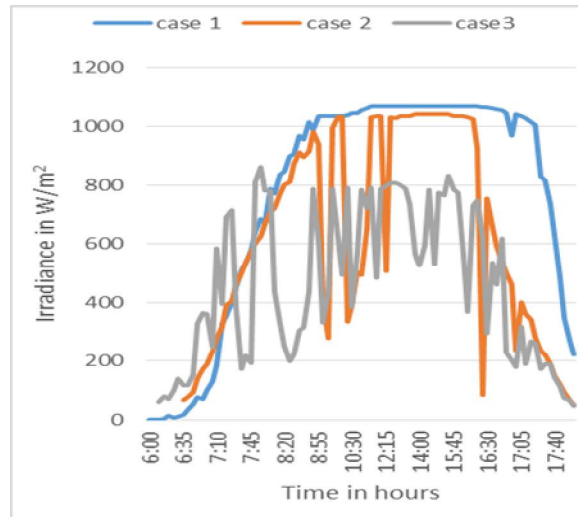


Fig. 5. Plot of solar irradiance with respect to time for 3 different cases

From Fig. 5 we can infer that the irradiance measured in case 1 condition is clear without any distortion and maximum irradiance level goes above 1000 W/m^2 , whereas for case 2 condition the irradiance plot is slightly distorted because of the passing clouds. And this distortion is very much higher for the case 3 condition in which cloud disturbance is more.

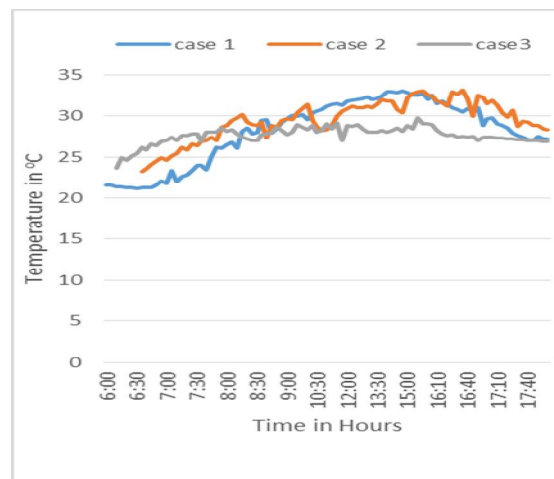


Fig. 6. Plot of temperature with respect to time for 3 different cases

On seeing the temperature plot (Fig. 6) we could find that in case 1 the temperature is very high which goes upto 34°C . In case 2, the temperature is almost same as that of case 1 except that there is a temporary dip wherever cloud disturbs. But in case of 3 which is more cloudy condition the temperature is almost reduced to 25°C .

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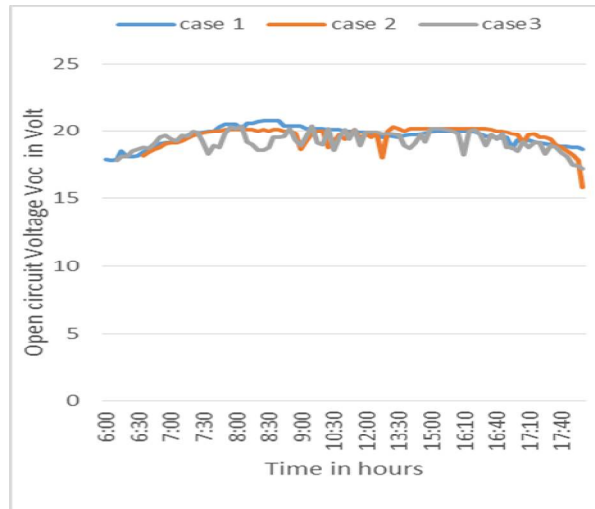


Fig. 7. Plot of PV output voltage with respect to time for 3 different cases

Fig. 7 shows the plot output voltage of PV module with respect to the time duration of the day. From the plot we could infer that the output voltage of PV module gets saturated during the middle of the day that is when the temperature is almost constant and whenever there is dip in temperature that gets reflected in the voltage plot showing the dependence of voltage with temperature.

IV. CONCLUSION

The development of low cost data acquisition system and its implementation was described in detail. The necessary graphs were plotted with the stored data and analysis was made. From the analysis we infer that due to variation in the environmental conditions the performance of the PV module also varies in terms of voltage variation with respect to temperature and power quality variation with respect to irradiance since output of PV module is dependent on the input solar irradiance. This makes the necessity for measurement and storing of solar irradiance values and other environmental parameters of the place where the PV modules are installed. Construction of the pyranometer is conceptually very simple and cheap. The newly developed Pyranometer can be used in any installation where reliable measurement of solar irradiance is necessary, especially if cost becomes a deciding factor when choosing a Pyranometer. We can say that this data acquisition system will be very much useful to the researchers in collecting the required data for the photovoltaic analysis. This data acquisition system can be installed any where easily and it will be very much useful to study the performance of PV system.

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