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Experimental monitoring system using Arduino microcontroller in studying the effect of temperature and light intensity of solar cell output power in Ma'an development area

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Abstract

Photovoltaic or solar energy systems have become one of the most promising fields in the engineering industry, and one of the most available green energy sources able to substitute the traditional and fossil fuel sources in power production. In order to maintain this system working properly, the solar cell monitoring system is needed, however, it is costly and not efficient sometimes. In this paper we designed and built a simple monitoring system using Arduino microcontroller and multiple sensors for data acquisition. The overall system is able to monitor the solar cell parameters such as produced current, voltage, cell temperature, light intensity which are display on an LCD screen. The system was mounted on top of the Engineering Faculty building at Al-Hussein Bin Talal University in the southern part of Jordan, and 180 data points were collected over a period of one month. The obtained results of this study show the effectiveness of the proposed monitoring system in measuring the different aforementioned parameters. Furthermore, based on experimental data a direct relationship between the light intensity and produced power was noticed. Conversely, a reverse relationship between cell temperature and the produced power is observed. The maximum power measured is 30W.

Keywords: experimental study, Arduino microcontroller, light intensity, temperature, power, solar cell, desert area

1. Introduction

Recently, the world is moving toward using the green energy resources instead of fossil fuel to reduce the amount of output pollutant coming from the fossil fuel resources, due to extreme resources diminishing, energy demand increase and human health concerns [1]. Solar energy is getting more attention over other green energy resources in Jordan, where it is considered better than wind energy or biofuel in terms of installation, operation and maintenance [2]. Furthermore it is totally silent, environmentally-friendly and inexhaustible [3]. Conversely, the starting cost of implementing photovoltaic (PV) cells and their dependence on the weather conditions is a major drawback [4]. The weather conditions especially in desert areas such as Ma'an Development Area (south of Jordan) has the major drawback when it comes to installation and operation of PV systems due to high variations of temperature, high wind speed and ambient dust density which, altogether, lower the efficiency of using such kind of green energy sources. Sun radiations and temperature have the major effect on the PV output power [2, 5]. Power losses in PV systems lower the system efficiency due to module mismatch [6]. PV cell temperature, sunlight intensity and produced power monitoring is very important in keeping this system working in good and healthy conditions. The researchers developed many techniques in order to monitor the PV system such as Zigbee-based data acquisition system [7], an internet of things (IoT)

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based smart solar photovoltaic remote monitoring [8], PV monitoring system using Agilent 34970A data acquisition (DAQ) [9] and artificial neural networks (ANN) [10].

In this paper, a simple monitoring system using multiple-sensor data acquisition facility was designed and used in order to monitor the PV cell parameters including voltage, current, power, light intensity and temperature in the Engineering Faculty premises at Al-Hussein Bin Talal University in Ma'an Development Area -Jordan. The experimental data was used to study the relationships among these parameters in this area in order to decide on the feasibility of using PV systems in an attempt to substitute the traditional electric power supply systems.

2. Methodology

In this paper, the PV monitoring system using Arduino microcontroller to reduce its cost, where the PV system site was as follows: latitude: 30.2N, longitude: 35.75E, altitude: 1130m and time zone: +2.0.

The best tilt and azimuth angles recorded were 30 ^{o} and 0 ^{o} respectively [2]. Four sensors were used including a light dependent resistor (LDR) sensor for measuring light intensity, a voltage divider to measure voltage, a current sensor to measure the current and a temperature sensor to measure the cell temperature. These sensors were connected directly to the PV cell whose output was linked to the Arduino microcontroller and the results were displayed on an LCD screen. Table 1 below lists the characteristics of the solar panel used in this work.

The sensors used herein are: (1) an Allegro™ ACS712 sensor for current measurement where the applied current flowing through the copper conduction path generates a magnetic field which is sensed by the integrated Hall IC and converted into a proportional voltage, (2) simple voltage divider circuit as a voltage sensor. The voltage divider is used to scale down the high voltage (Arduino voltage) to make it compatible with the Arduino 5 V standard, (3) light-dependent resistor (LDR) and resistance temperature detectors (RTDs) as light and temperature sensors respectively.

Table 1. Solar cell characteristics

Solar Module Type :	**PVM-50**
Maximum Power (Pmax)	50 W
Voltage at Pmax	18 V
Current at Pmax	2.78 A
Open-Circuit Voltage	21.6 V
Short-Circuit Current	3.1 A
Power Tolerance	+/-3 %
Weight	3.4 Kg
Size	630mm x 540mm x 18mm
Cells	36pce, 125x62.5, mono-crystalline silicon

Arduino Uno microcontroller type was used in this study, which has 14 digital input/output pins, 6 analog inputs, a 16MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or a battery. Pulse width modulation (PWM) charge controllers are used to reduce the amount of power applied to the batteries as the batteries get closer to full charge. In PV systems the charge controller is important to regulate the power from the solar panels primarily to prevent overcharging the batteries; which has the impact of reducing the battery lifetime and, hence, may cause damage to the battery. The battery used to store the voltage is sealed lead–acid rechargeable battery of type RB1275BS 12V7. DC voltage stored in the battery is inverted to the standard 120Vac used in most common applications such as lighting, appliances, and motors using basic inverting circuits. The dc from the battery is electronically switched on and off and filtered using simple capacitor to produce a sinusoidal ac output. The ac output is then applied to a step-up transformer to get the required 120Vac.

PV system parameters including voltage, current, light intensity and cell temperature are measured and displayed by the Arduino Uno microcontroller on an LCD screen. Fig. 1 below shows the block diagram of the PV system with monitoring devices. The real image with LCD screen of the system is shown in Fig. 2 below.

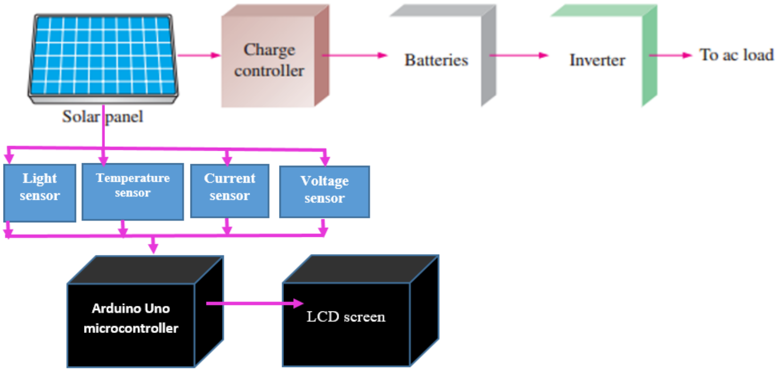

Fig. 1. Block diagram for PV monitoring system using

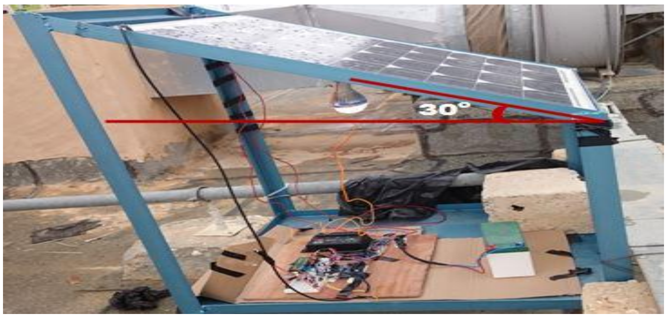

Fig. 2 (A): PV monitoring system using Arduino Uno microcontroller

Fig. 2 (B): PV system results on LCD

Fig. 2. PV monitoring system using Arduino Uno microcontroller and the results on LCD

In this study, a code was produced for the Arduino to record the readings of the monitored parameters and store them on an hourly basis. The system was operated for six hours every day from 9AM to 3PM over a period of one month. As a result, 180 readings were collected for this PV system in the Engineering Faculty building at Al-Hussein Bin Talal University in Ma'an Development Area-Jordan.

3. Results and Discussions

The maximum output power for our solar cell is 50W in the ideal condition. In this study the maximum output power recorded was 30W as shown in Figs. 3 and 4 below. This maximum output power was produced from 11:00AM to 12:00PM in only one day. This is due to the varying weather conditions including temperature fluctuations, rain, winds and clouds. Moreover, the accumulation of high dust and its density in this area during the period of study, and the efficiency of the solar cell in use had some effect on the results.

Fig. 3 below shows the relation between the powers produced from the solar cell and the light intensity, where a slight increase in power results from increase in light intensity. Once the light intensity increases, the electrons inside the solar cell acquire more kinetic energy to be free which results in increasing the current, while the voltage is not affected; thus the power increases slightly as the sun light intensity directed to the solar cell is increased. In August 2019 where the study was conducted, the light intensity varied between less than 100 to more than 800 W/m^2, this is due to the desert area nature and the high effect of dust density [11, 12]. The power produced on average was about 15W for a single solar cell.

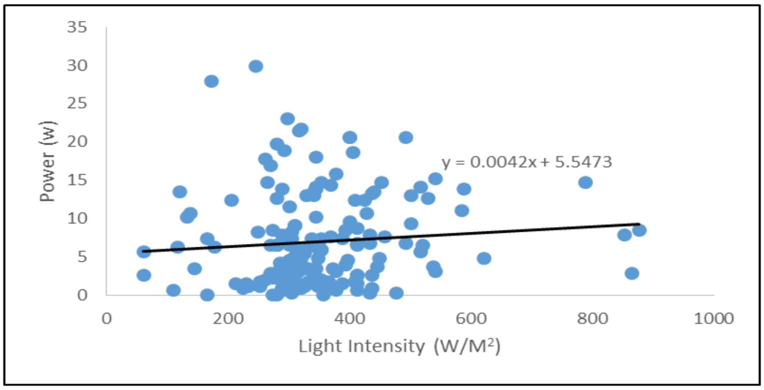

Fig. 3. Experimental power and light intensity relationship on proposed PV system in Ma'an Development Area.

Fig. 4 below shows the relationship between the solar cell temperature and the output power produced. It is observed that a reverse relationship between the temperature and power is produced as a result of reducing the voltage across the solar cell while the current is not affected.

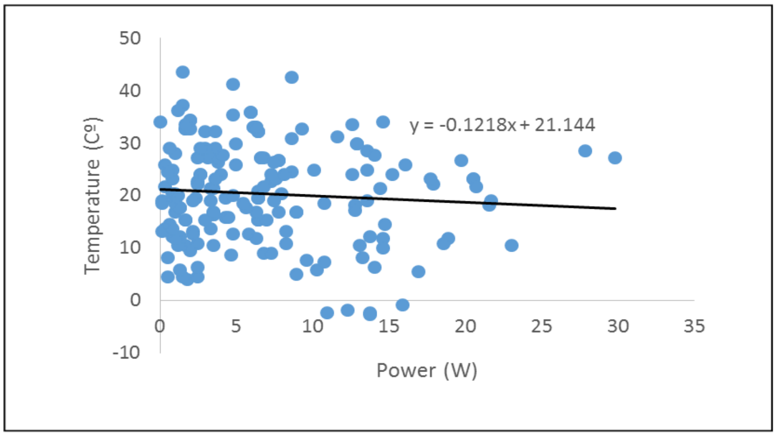

Fig.4. Experimental power and temperature relationship on proposed PV system in Ma'an Development Area

4. Conclusion

This study investigated the effect of temperature variation and light intensity on the power produced from a simple solar cell on the top of the Engineering Faculty building – Al-Hussein Bin Talal University in Ma'an Development Area - Jordan. The maximum power produced was equal to 30W, while the average power was about 15W for a single solar cell.

In this study, proportional linear relationship between the light intensity and power produced due to increasing the current. On the other hand, a revere linear relationship between the solar cell temperature and the power due to lowering the output voltage as the cell temperature increased. This experimental study opens the door wide in front of using simple Arduino microcontroller in monitoring the solar cell parameters such as solar cell voltage, current, temperature, and light intensity. It also opens the feasibility of encouraging the decision-makers at Al-Hussein Bin Talal University to install solar systems and replace the traditional electrical power supply with low cost.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

All authors have participated in (a) conception and design, or analysis and interpretation of the data; (b) drafting the article or revising it critically for important intellectual content; and (c) approval of the final version.

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