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Embedded System-Based Characterization of Solar Photovoltaic Panel Performance Across Varied Atmospheric Conditions

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Abstract- This research paper presents an investigation into the application of smart embedded technology for the parametric analysis of solar photovoltaic (PV) panels. The proposed Arduino-enabled approach utilizes sensors to collect real-time data on various parameters such as temperature, irradiance, and voltage, allowing for comprehensive analysis of panel performance. Solar PV panels are widely used for harnessing renewable energy, but their performance can be affected by various factors such as shading, dust accumulation, and aging. Therefore, continuous monitoring and evaluation of PV panel parameters are crucial to ensure optimal energy generation.

Keywords: Solar PV, Arduino, Voltage and Current Sensor, Light Sensor, Temperature sensor.

I. INTRODUCTION

Photovoltaic cell is a solid state device which converts light into electric energy. A photovoltaic term comes from Greek, photo means light and voltaic means electric. Because the source light is usually the sun, they are called solar cell [1]–[3]. Sun light is made up of packet of energy, called photons whose energy depends only upon the frequency or color of the light [4], [5]. When light photons reach a PV cell, they knock electrons free in the P-N junction forcing them through an external electrical circuit and then returning them to other side of the PV cell to start process all over again.

The flow of electrons in the electrical circuit delivers power to the loads [6]–[8]. Reflected, direct and diffuse sunlight have sufficient energy to create the photovoltaic effect. The extra energy of the excited electrons generates a potential difference, or electromotive force (e.m.f.). This force drives the electrons through a load in the external circuit to do work [9].

A. Solar PV

A solar photovoltaic panel converts sunlight (photons) into electrical energy through the influence of the photovoltaic effect [10], [11]. The photovoltaic modules constitute the photovoltaic array of a photovoltaic system that generates and supplies electric energy from solar energy in commercial quantities for community uses. The common types of pho-tovoltaic modules are mono-crystalline, poly-crystalline, and thin film photovoltaic modules [13], [14]. In this study, a 12V, 20W solar panel composed of mono-crystal solar cell with an efficiency of 17 percent was selected. The manufacturer's technical specifications of the 12V solar panel is presented in Table 1 (Bluesolar Datasheet).

TABLE I
MANUFACTURER'S DESCRIPTION OF MONO-CRYSTALLINE SOLAR PANEL
MODULE TYPE: BLUESOLAR SERIES 4A SOLAR PANEL

Dimensions(mm)	440 × 350 x 25
Net Weight (kg):	1.9
Nominal power (PMPP-W):	20
Max-Power Voltage (PMPP-V):	18.5
Max-Power Current (IMPP-A):	1.09
Open-Circuit Voltage (VOC-V):	22.6
Short-Circuit Current (IOC-A):	1.19

B. Arduino UNO

The Arduino Uno, an open-source microcontroller board, is built around the Microchip ATmega328P microcontroller and was developed by Arduino.cc. Featuring a range of digital and analog input/output (I/O) pins, it allows seamless interfacing with various expansion boards (shields) and circuits. With 14 digital I/O pins (six supporting PWM output) and 6 analog I/O pins, the board is programmable using

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the Arduino IDE (Integrated Development Environment) via a type B USB cable. It can be powered either through the USB cable or an external 9-volt battery, accommodating voltages within the range of 7 to 20 volts [12].

C. Sensors

In this research work a comprehensive sensor array is essen-tial for gathering critical data about the panel's performance and environmental conditions [15], [16]. Light sensor, Voltage-Current sensor and Temperature sensor were used in this work. In combination, these sensors form a crucial part of a Solar PV panel monitoring system, offering insights into both environmental factors and electrical performance parameters essential for optimizing energy generation and ensuring the longevity of the solar installation.

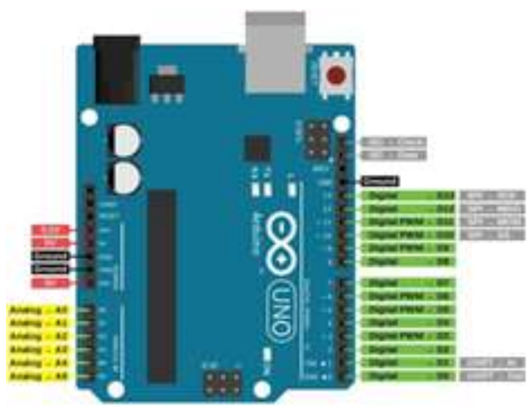


Fig. 1. Arduino UNO pin diagram.

II. METHODOLOGY

In this work, an Arduino-based solar parameter-measuring system was designed and constructed using Arduino Uno and multiple sensors. The system was found to be capable of measuring different solar PV parameters including the voltage, current, real time temperature and light intensity. The mea-sured parameters were simultaneously logged into a personal computer (PC) for future analysis or references. The primary purpose is to ensure local, reliable and flexible power for urban and rural communities.

This technique is fitting for oversee applications, where a modest, simple and minimal topology fit for self-ruling activity is fascinating. Computing resources and software systems are also used in the process. The proposed work encompasses the use of DHT11 sensor, BH1750 sensor, and ACS 755/ACS 712 voltage-current sensor module with Arduino UNO board for monitoring the PV panel and hence optimizing the power efficiency of the same. The connections are made for the sensor with the microcontroller and the required code is uploaded onto the board using Arduino IDE.

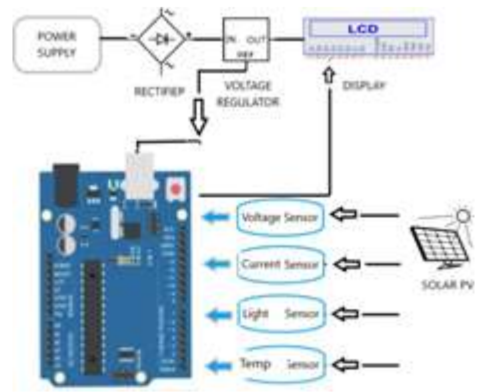


Fig. 2. Block diagram.

A. Relation between current and light intensity

If the light intensity falling on the solar PV is assumed to be ϕ then the equation for current of the solar PV in milliamperes

Fig. 3. Experimental setup.

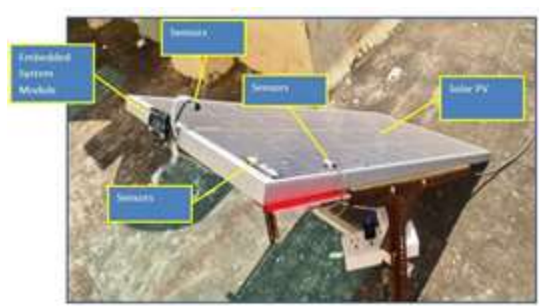


Fig. 4. Field experimental setup

is

$$i = 1301 - 1.802\phi + 0.002652\phi^2 - 0.000001\phi^3 \quad (1)$$

B. Relation between current and temperature

If the temperature of the solar PV is assumed to be t then the equation for current of solar PV in milliampers will be

$$i = -2347 + 304.8t - 9.283t^2 + 0.09279t^3 \quad (2)$$

III. RESULTS AND DISCUSSION

Fig 3,4,5,6,7 & 8 shows the result of current v/s light in-tensity, current v/s temperature,voltage v/s temperautre,voltage v/s light intensity, power v/s light intensity and power v/s temperature respectively of the under study PV panel.Also Fig 9,10,11 & 12 provides insight into the experimental setup and the comparative analysis of calculated data with the experimental data.

Thus on analysis of the calculated and experimental values for the Solar PV panel it is found that at 30 degree centi-grade the PV panel generates the maximum current of 948 milliamperes when the light intensity is around 941 lux.

IV. CONCLUSION

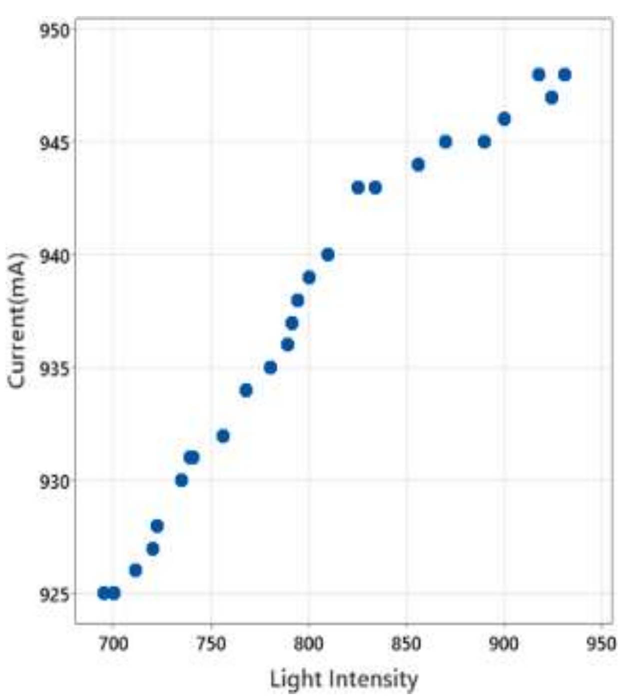


Fig. 5. Current v/s Light Intensity.

The research work achieves all the objective which are : to measure solar panel parameter such as the temperature, volt-age, current, light intensity and power. Using the temperature sensor DHT11 that sense the changes in panel temperature, for the voltage parameter was by using the voltage sensor in order to reduce the maximum value of the solar panel to the voltage value suitable for the Arduino UNO of power supply and lastly the current parameter was by using the current sensor module. Next, to find the best position and time for the solar power effectively energize the electricity. The data from measurement part shows that the best position of the

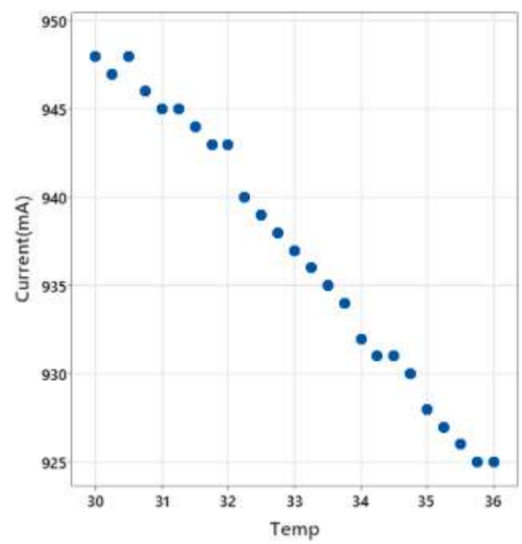
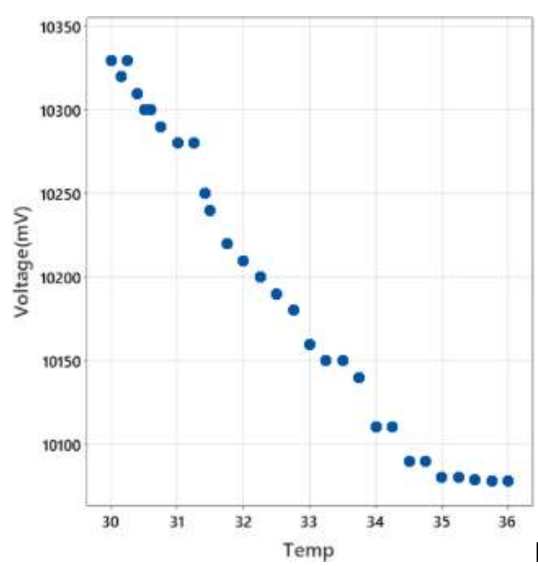


Fig. 6. Current v/s Temperature.



b

Fig. 7. Voltage v/s Temperature.

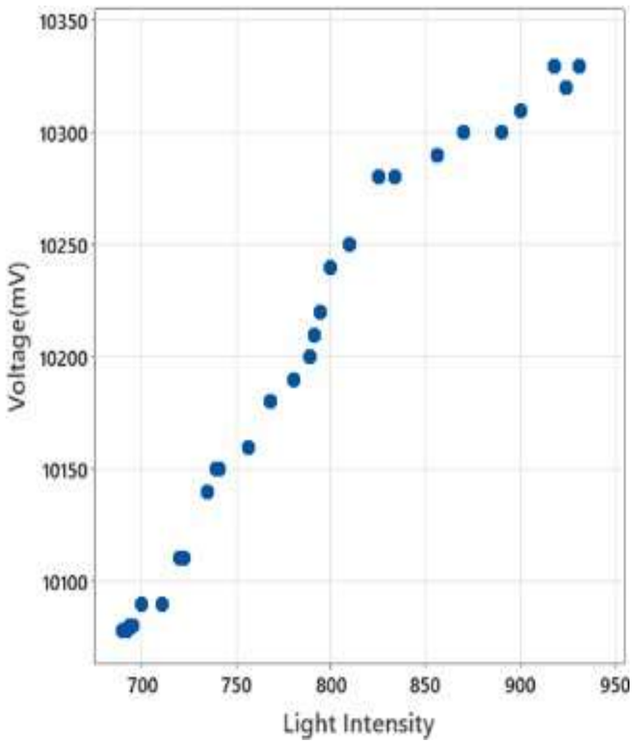


Fig. 8. Voltage v/s Light Intensity

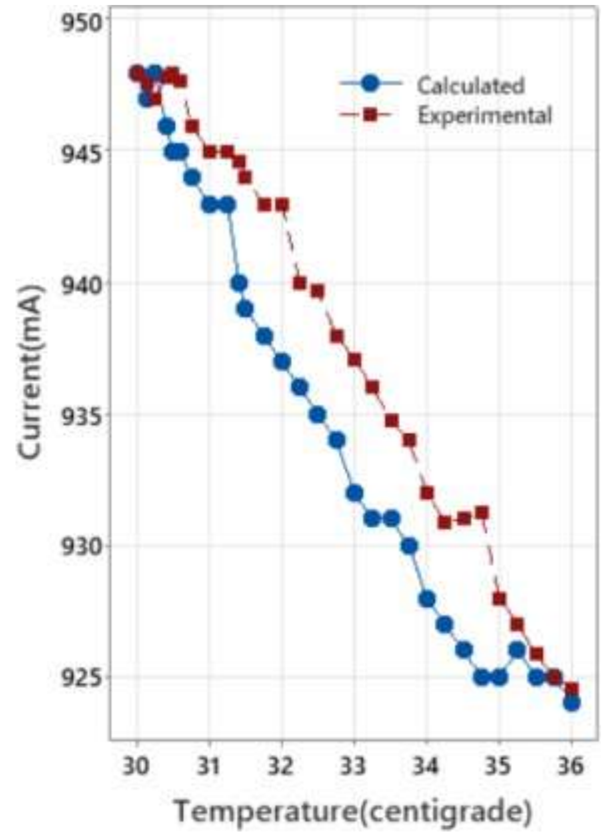


Fig. 11. Calculated v/s Experimental data for current and temperature

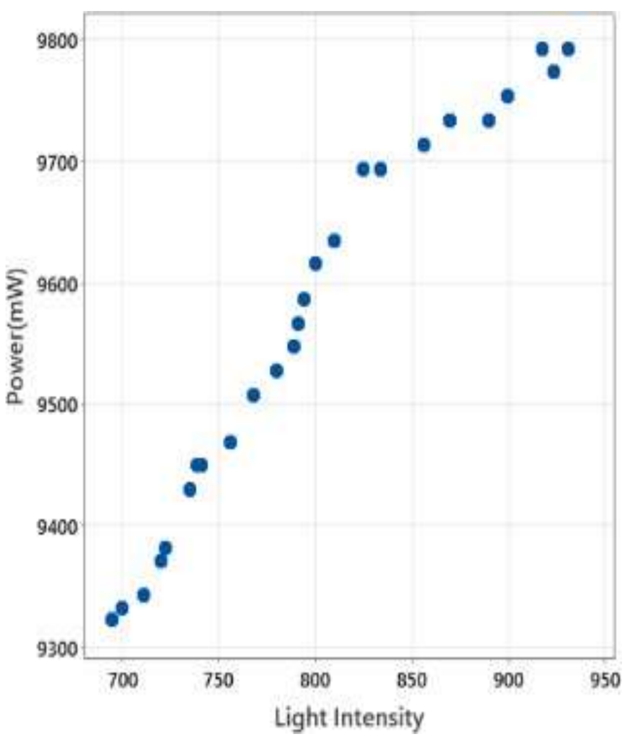


Fig. 9. Power v/s Light Intensity.

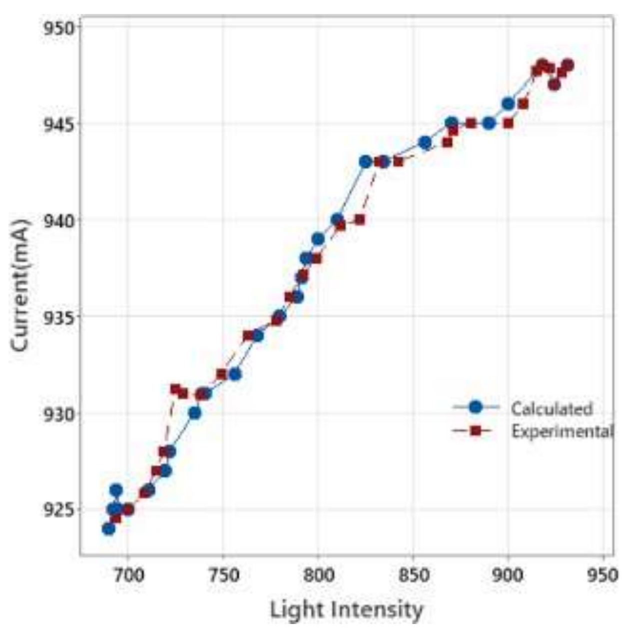


Fig. 12. Calculated v/s Experimental data for current and light intensity.

solar panel effectively energize was the sunrise position with the highest current value which is 948 milliamperes at time 11.00am have been recorded.

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