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CPU-Based Data Acquisition in Assessing the Impact of Inclination on Solar Panels

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Abstract – *A data logging system has been deployed to monitor two solar panels positioned at distinct inclination angles. This system records crucial parameters such as current, voltage, solar radiation incident on the panels, and panel temperatures. Comprising an Arduino microcontroller, a current sensor, a current and voltage sensor, and a Memory Card, the data logger captures and stores data in .txt files at 20-minute intervals. Employing a real-time acquisition system, the obtained results indicate that the data logger effectively archives and presents a wealth of information about solar panel characteristics. Notably, the data reveals superior performance of the solar panels at a 35-degree tilt angle compared to 32 degrees during April in the Ouargla region of Algeria.*

***Keywords**: ARDUINO MEGA, Solar panel, Voltage sensor, Current sensor, Pyranometer, SD carte.*

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I. Introduction

The surge in electricity demand, driven by conventional and polluting sources like coal, oil, and natural gas, necessitates a strategic response to meet energy needs while mitigating environmental impact[1]. Addressing this challenge is crucial for both satisfying energy demands and minimizing the ecological footprint. On the flip side, the sun stands out as an abundant and inexhaustible energy source, capable of providing an amount of electricity equivalent to 27 years of global consumption in the form of light [2]. Embracing solar energy represents a sustainable alternative that not only caters to escalating energy demands but also offers a cleaner and more environmentally friendly solution.

Various approaches are undertaken to harness solar energy, encompassing both thermal and photovoltaic methods. Solar photovoltaic conversion, a key technique, involves transforming light energy into direct electricity through the photovoltaic effect [3]. This process is achieved through a device known as a solar cell. The applications of solar energy are diverse, ranging from architectural designs employing solar energy for heating and cooling, to addressing critical needs such as distillation and disinfection for drinking water. Solar energy is also utilized for daylight harvesting, water heating, solar cooking, and generating high temperatures for industrial processes, remote residences, and water pumping [4]. This versatility underscores the significance of solar energy as a viable and sustainable resource across various sectors and applications.

The intermittent nature of photovoltaic (PV) systems, coupled with environmental influences on solar energy, renders direct utilization impractical [5]. To integrate solar energy effectively into daily life, the deployment of storage devices becomes imperative. These storage systems should be equipped with a control mechanism capable of efficiently absorbing and supplying energy. Additionally, a power control stage, encompassing both DC-DC and DC-AC converters, is essential to maintain optimal voltage load levels [6-8]. Furthermore, the inclusion of controllers is necessary to safeguard the entire system against potential issues such as overload and reverse leakage [9]. This comprehensive approach ensures the reliable and sustainable integration of solar energy into practical, everyday applications.

The basis for data acquisition during the Micro SD card process lies in the measurement of electrical or physical events, encompassing parameters such as voltage, current, temperature, pressure, or humidity [10]. This process involves a computer equipped with programmable CC+ software and sensors dedicated to SD card measurements, collectively forming a micro SD card system [11]. In comparison to conventional measurement systems, PC-based SD card systems capitalize on the processing power, productivity, display, and connectivity capabilities inherent in standard computers. The utilization of industry-standard computer displays and connectivity not only enhances the overall power and flexibility of the measurement solution but also proves to be a more cost-effective approach [12]. This advanced system provides a robust, adaptable, and economical solution for efficient data measurement and acquisition.

Challenges arise during the acquisition process when measuring the fluctuation of current generated by a solar panel and storing these values in an SD card data sheet through the use of an Arduino Uno and a current sensor. These issues may encompass precision and calibration concerns in accurately gauging current variations, potential data loss during the transfer or storage process, and the need for an effective interface between the Arduino Uno, current sensor, and SD card system. Addressing these challenges is essential to ensure reliable and accurate data acquisition in the context of monitoring solar panel-generated currents and recording the data onto an SD card for subsequent analysis.

The main objective of the present work is the realization of the PV solar device with an onboard data acquisition system for analyzing and diagnosing data collected during its use.

II. Material and Methods

2.1. Panel solar

Solar panels are photovoltaic devices by which solar radiation is converted into electrical energy [13-15]. The cells are assembled in a grid-like pattern on the surface of the solar panels It mainly consists of a photo current source Iph, a diode current element Id, a shunt Rsh and series Rs resistors, respectively Rsh, Rs. The forme diode module model is given as:

$$Ipv = Iph + Id + Ish \quad (01)$$

The photoelectric model is shown in the Figure.1

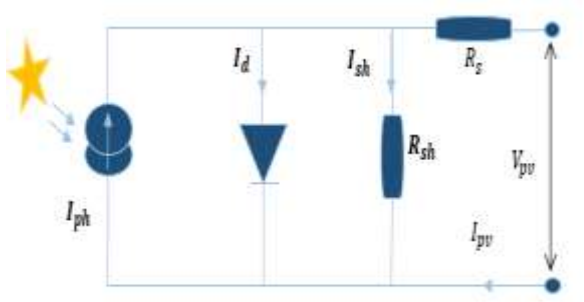

Figure.1.circuit equivalent panel solar [13]

2.2. Solar Irradiance Sensors (Pyranormeter)

Irradiance sensor a radiometric measure that measures how much solar energy returns per unit area. In this experiment, we used two solar cells of 6 watts, and we measured the energy released over their surface area as shown in Figure 2.

Figure.2 .cell solar

2.3. Arduino MEGA

Arduino is an electric board with open-source hardware and software that can be programmed using the Arduino 2560 software, which is based on the C++ programming language. The software is used to create and upload computer code to the actual board [16-18].

3.3. Voltage Sensor B25

The Arduino analog input is limited to a 5saV DC input, the sensor B25 is based on electric resistances to divider de voltage. It has the capacity to reduce voltage five times that of the input terminal connection. If you use 3.3V, the input voltage must not be higher than 16.5V, and you can use a maximum of 5V on the DC side to allow a maximum of 25V on the input side. However, it is only utilized with direct current [3].

3.4. Current Sensor ACS712

The Hall Effect, which occurs when electrons from an electric current travel through a magnetic field plate, is used by the ACS712 sensor to read the input current and convert it to voltage output. There is a voltage difference between the two sides of the plate as a result of the electrons being "pushed" to one side by the field. The sensor's output, the ACS712, which enables use of either DC or AC sources, is the difference in voltage from the plate's side [19].

3.5. Temperature Sensor (Thermocouple)

Every type of metal has a coefficient of heat transfer or electrons movement speed because when the electrons gain energy (heat), they diverge from one another, creating a voltage at the beginning of the wire, which is construed as a temperature degree. The thermocouple is a type of temperature sensor. It is composed of two wires made from a different metal. The wires are welded together at one end [20].

Thermocouples come in a variety of varieties, including J, K, T, and E. We picked the K type since it is the most common, least expensive, accurate, and reliable, and has a broad temperature range of -200 to 1260ºC.

The Amplifier MAX6675 performs cold-junction compensation and digitizes the voltage signal from a K-type thermocouple, SPI-compatible, read-only format. digitizes the voltage signal from a K-type thermocouple, compatible with SPI, read-only format, and performs cold-junction compensation.

3.6. G.SD card and Methods test:

The Arduino Uno can read and write files to the SD card. This module will be useful in projects where you need to save information periodically [21]. Methods test uses an Arduino board to monitor changes in the solar panel's current, voltage, and temperature in real-time. Then it transfers the data it collects to an Excel spreadsheet via card SD in real-time.

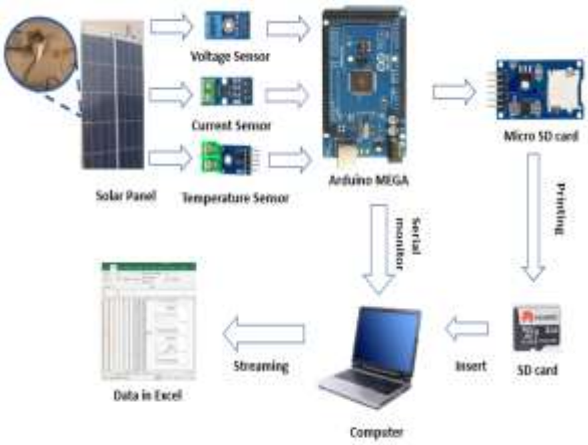

Figure.3. Real-Time Data Acquisition of Solar Panel System

III. BENCH TEST

The effect of both temperature and irradiance on the supplied power from the PV panel is studied are considered in the first experiment. To get reliable results, favorable climatic conditions must be acquired for different climatic conditions (wind, temperature, and shading). Different experiences are done for:

- Data acquisition in the panel at inclined 32°.
- Data acquisition in the panel at inclined 35°.

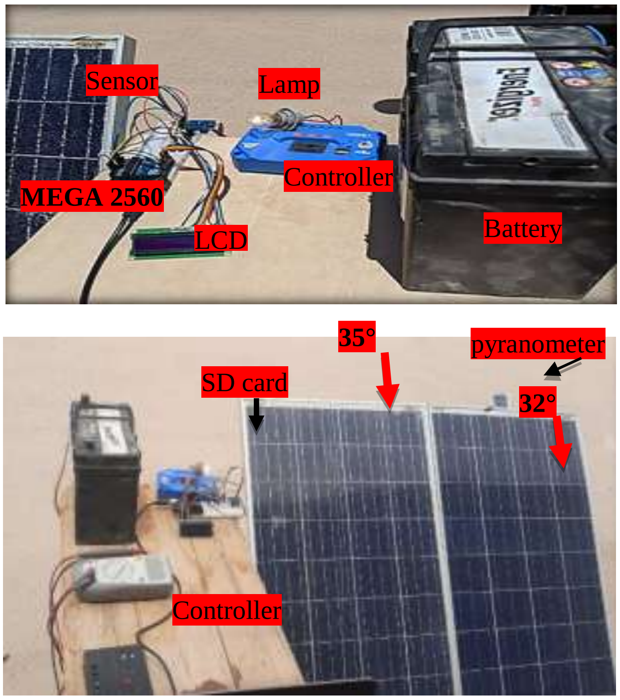

Figure 4. Experimental setup of the data logger to measure PV parameters

IV. Experimental results

The exploratory test is done on the test bench on April 15, 2022. The sensor readings from the SD card device are done in this section to analyze the performance of the PV system. All measurements were taken with the two angles of inclination of the panel.

The alternative data logger system for the solar panels proposed in this research is made of readily available parts and runs on open-source software. Since the Arduino MEGA (CPU) board's optimized analog input is used by this data logger via an Integrated Circuit (IC) Multiplexer, it can also take in a lot of data. According to earlier reports, the outcomes of tests carried out by a live solar panel data monitoring system the numerous results gathered are presented in the parts that follow, together with their scientific interpretation.

After launching the various necessary tests on the experimental device, the following figures show the important results. Figure 5 presents the solar temperature during the day. It can be noted that the temperature is equal 28.15°C at 8 AM. Then begins to gradually rise to reach its highest value of 57.7°C at 14 PM-15.30 PM. Then, gradually decreases until reaching a value of 28°C at 6 PM.

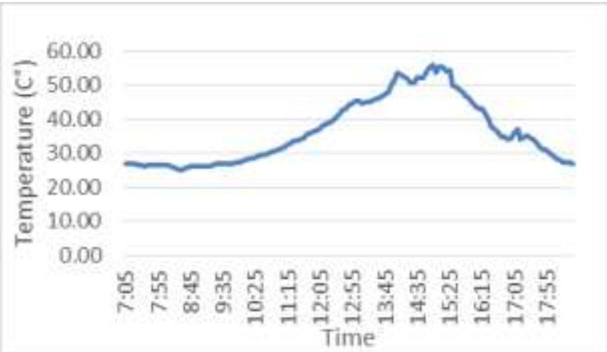

Figure.5.Température profile

One can see from Figure 6; the curves in red and blue represent curves that change the evolution of solar radiation as a function of time, it can be noted that the change in irradiance level changes during the daytime. At 8 AM we record a value of 110 W/m². The irradiance curve reaches its highest value (peak) at 2 PM which is equal 904.1W/m² for 32° inclination, and 954 W/m² for 35° of inclination. Then, the irradiance decreases gradually until reaching a value of 575.6 W/m². it can be also noted from the curve fluctuations and oscillations due to several factors such as wind and other fluctuating factors.

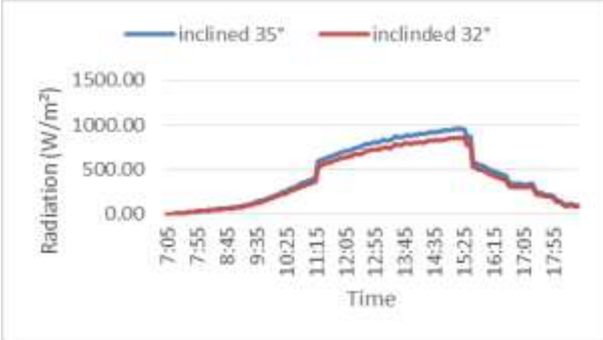

Figure 6. Radiation profile

The Figure 7 Presents the graphic curve of the PV panel current (A) which varies with time (min). It can be observed that the current value is small at the first minutes of measurement, then, this value increases from 9:10 AM to 5:02 PM; where it achieves its highest value which equals 2.66 A with inclination, then, it gradually decreases until it stabilizes.

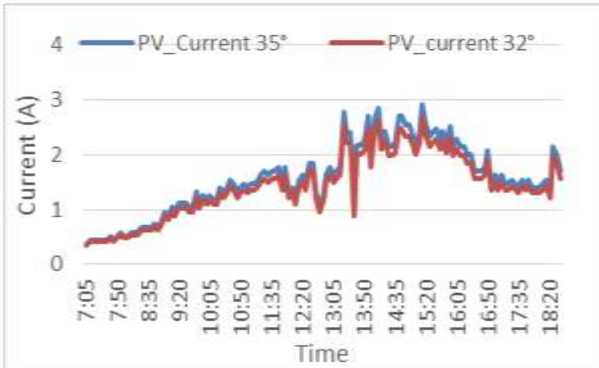

Figure.7.PV Current versus time

The Figures 8 and 9 present the variation of PV panel voltage (V) over time (Min). It is noted from the results that the voltage value increases during the experiment until reaching a maximum value of 14.21 V at 15:55 PM. Then, it decreases until it stabilizes, due to the effect of the surrounding conditions on the PV panel.

The obtained results demonstrated that the irradiance and temperature are the mean factors that determine the level of power harvested by the PV panel terminals. Where the inclination of 35° of the PV panel was determined and gave good performance compared to the 32° of inclination.

The findings gained illustrate the benefits of the suggested method, which contained data that may be represented graphical over time. Because it is less expensive and saves a lot of time, it can thus take the role of human intervention to eliminate potential errors caused by data readings from many sensors. Because of this, the suggested method can make it easier to assimilate data, log it, create customized reports, and then evaluate them to boost the performance of PV systems. Each result has advantages and disadvantages, and the PV system characteristics at 32° and 35° are compared in Tables I and II.

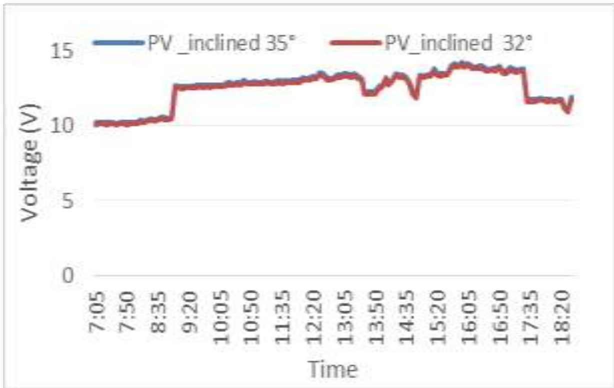

Figure.8. PV Voltage versus time

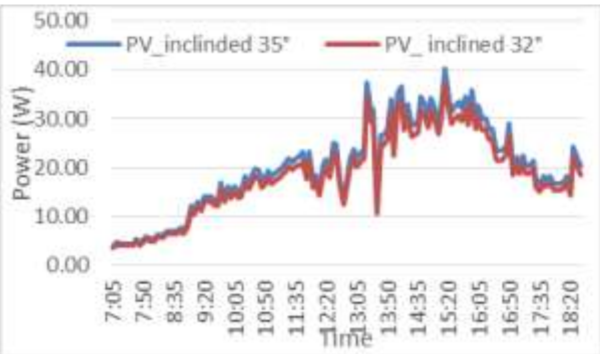

Figure.9.PV Power versus time

Tables I. PV System characteristics at 32°

/	Inclined 32°			
Time	**E(W/m²)**	**I (A)**	**V(V)**	**P(w)**
8 :00	108.2	0.48	10.23	4.9104
12:00	640	1.23	12.87	15.8301
14 :00	822	1.78	12.74	22.6772
17 :00	316	1.52	13.17	20.0184

Tables II. PV System characteristics at 35°

	Inclined 35°			
Time	**E(W/m²)**	**I (A)**	**V(V)**	**P(w)**
8 :00	110	0.52	10.23	5.3196
12 :00	697	1.3	12.90	16.77
14 :00	890	1.92	12.74	24.4608
17 :00	340	1.63	13.2	21.516

V. Conclusion

Two GPVs with in-house systems are built at a reasonable cost to collect data for analysis and diagnosis of the test platform at various inclination angles. The Arduino map-based real-time data acquisition system (ATmega2560) was designed with the two PV boards and the features of the Arduino AT MEGA 2560 board in mind, as well as the data collection system on the boards and the light side of the array. The latter is connected to the following components: K-type thermocouple, B25 voltage sensor, Acs712, current sensor, 12V voltage regulator, LCD (16 x 2). Therefore, the current work aims to measure five variables of two solar panels with the same properties: temperature, voltage, current, panel intensity, and PV radiation, and then transfer them from the Arduino board to the SD card to convert it to an Excel file and calculate the necessary appropriate parameters.

The results obtained, which are presented and discussed in this paper, show that the illumination received at the surface of the photovoltaic cell and the ambient temperature are among the main factors which determine the electrical power available at the terminals of the photovoltaic. The experimental results of inclination with 35 degrees of the solar panel were well determined and given good performance than the other.

Future works will focus on improving this kit while always keeping the side light and the data acquisition system on the board of this device.

Declaration

- The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.
- The authors declare that this article has not been published before and is not in the process of being published in any other journal.
- The authors confirmed that the paper was free of plagiarism.

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