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REGULAR ARTICLE

Design and Development of an Electric Current Sensor to Monitor and Automate the Cleaning of Photovoltaic Power Plants

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A number of harsh environmental conditions can affect the effectiveness and performance of photovoltaic (PV) panels. Understanding and managing these factors is essential to guaranteeing the durability and dependability of solar PV systems. Today, wide ranges of solar module manufacturing technologies are accessible globally, enabling the use of these PV modules in a variety of settings and applications. By simulating and testing the behavior of a solar module, one can investigate the different elements that affect a photovoltaic system's efficiency. Dust accumulation on PV modules in PV power plants is a major constraint in the maintenance and operation costs of solar power plants. Currently, various techniques are used to treat this dirt, ranging from mechanical interventions (brushing) to active and passive electrical interventions. This paper presents a theoretical and experimental study that characterizes photovoltaic modules by devel-oping an electronic card that allows the electrical and thermal performances to be obtained. The design of the card was followed with various comparative tests and validations with various internal and external test benches. The results obtained demonstrated the efficiency and effectiveness of the electronic card in collect-ing results according to the evolution of the working conditions of the solar panel.

Keywords: Solar panel, Current sensor, Arduino, Dust, Temperature, Photovoltaic.

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1. INTRODUCTION

Energy plays a crucial role in promoting sustainable socioeconomic development and raising living standards [1]. Owing to the global demographic growth and the escalation of economic activity, the demand for energy is still rising. The majority of projections indicate that the commercial use of primary energy may increase significantly by 2030 and triple by 2050 [2]. Today, photovoltaic solar energy occupies a central place in the contemporary energy landscape, as an ecological and renewable energy source. The technology is based on the transformation of sunlight into electricity through the use of solar panels [3]. The average length of sunshine in Algeria is around 3000 hours, making it an extremely sunny country [4]. Due to this characteristic, the use of solar energy is very important. On the other hand, Algeria is categorized as being in region 4, which is said to be one of the world's most exposed regions to dust [5]. The study of the effect of the dust on the energy performance of photovoltaic modules has become a key topic in the field of renewable energy due to the advancement of photovoltaic module manufacturing technology and the need for solar energy in various applications [6]. This has led to an increase in the surface area of photovoltaic fields, which in turn has increased cleaning costs. Therefore, it's important to gauge how much the dust affects PV module energy output and offer solutions that will enable future cleaning costs to be reduced [7].

This work focuses on the design and development of an electrical current sensor to monitor and automate the operation of photovoltaic power plants' cleaning systems.

2. DESCRIPTION OF THE DEVELOOPED SYSTEM

The automation of photovoltaic plant cleaning is based on the comparison of the electric current produced by two photovoltaic modules, the first being dusty and the second clean. The two current sensors are connected to an Arduino board and a computer for data acquisition. Once the safety threshold is reached, an order is sent to the pump to start cleaning the photovoltaic system. The Fig. 1 shows an overall diagram of the system being devolved.

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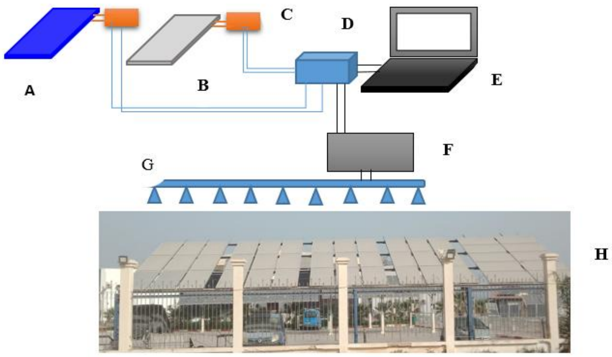

Fig. 1 – Block diagram of the cleaning system of photovoltaic power plants under development UDES-TIPAZA. A: Clean solar panel, B: Dusty solar panel, C: electric current sensor, D: Arduino card, E: computer for data acquisition, F: water pump, G: spray cleaning system, H: photovoltaic power plants.

3. SIMULATION PROTEUS OF THE SENSOR

This section aims to simulate the operation of the photovoltaic module. It aims to obtain the different parameters such as electricity (current-voltage) and the operating temperature of the photovoltaic module. As illustrated in the figure below, the plan of the board to be developed is made up of the following elements Fig. 2:

Block 1: concerns the PV module which is subject to characterization.

Block 2: includes the current measuring device (Current Sensor).

Block 3: the device used to measure the voltage (Voltage Divider).

Block 4: the device for measuring the operating temperature of the photovoltaic module.

Block 5: the processing unit.

The Arduino board is connected to all these modules and a 16x2 LCD screen to measure and display the voltage. A MOSFET is used to stabilize the current measurement. The results were displayed every 2 seconds.

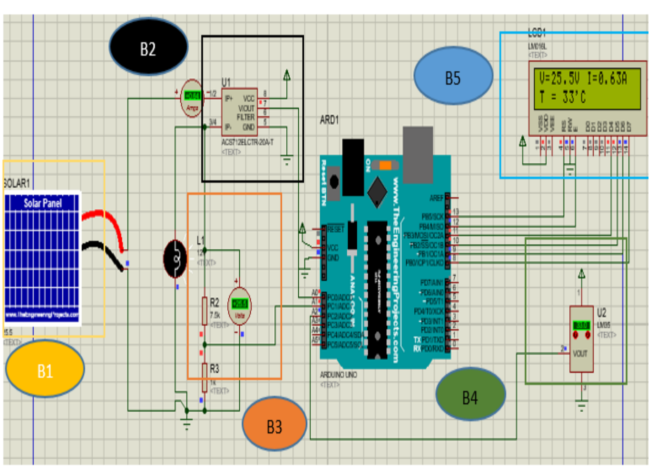

Fig. 2 – Current sensor circuit under proteus simulation environment

The simulation results are displayed on the LCD screen, in our case we obtained: a voltage of 25.5 Volt, a current of 0.63 A with an operating temperature of 33°C.

4. TEST OF MEASUREMENTS VERIFICATION CARRIED OUT BY THE CURRENT SENSOR (OUTDOOR TEST BENCH):

The following tests must be carried out on an external test banch in order to validate the developed electronic card's metrics. These experiments were carried out at UDES on July 30, 2024, under 30°C ambient temperature and 895 W/m^2 of lighting. The steps to take are as follows Fig. 3:

- Attaching the current sensor to the photovoltaic module and lampe (11-watt DC light, 12-volt CL1211C-2.2).

- Receiving various electrical and thermal measurements with the help of our electronic card.

- The collection of the I-V curve using a solar analyzer of the PROVA-200A type.

-We have determined the intersection point between the lamp's point (0, 0) (12v, 11/12) and the I-V curve obtained by the Prova-200A on the I-V curve.

-The intersection of the I-V curve and the charge right allow us to verify the current measured by the flow meter. We will use a multimeter to check the strain.

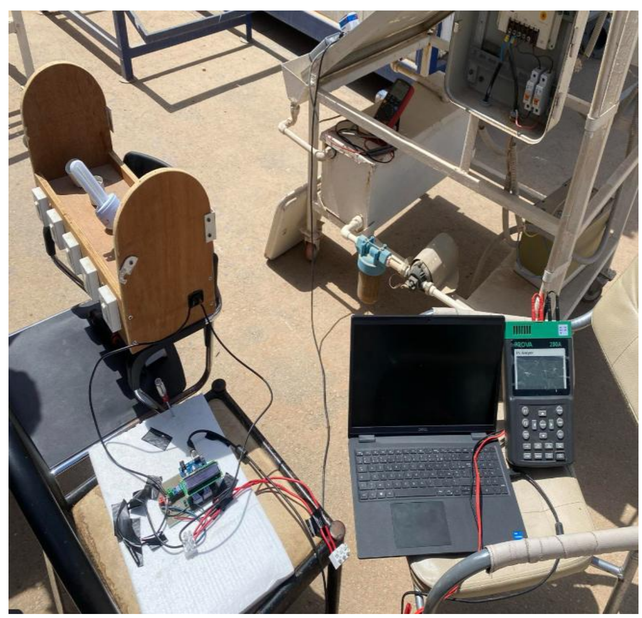

Fig. 3 – View of the entire external test bench used to confirm the proper operation of the current sensor.

4.1 Result and discussions

As shown in Fig. 4, the test values for current, tension, and temperature of the PV module measured by the developed card are displayed on the LCD screen of the electronic card. In our case, we obtained a current of 1.01 A, a voltage of 16.7 V, and a temperature of 43°C.

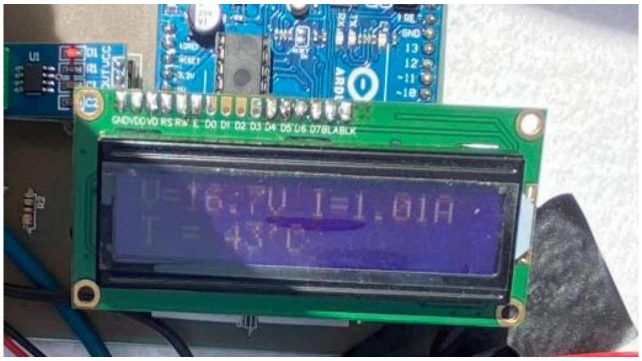

Fig. 4 – Value of the current, tension, and temperature as measured by the sensor

The curve I-V, measured by the solar analyzer Prova-200 A, is shown in Fig. 5.

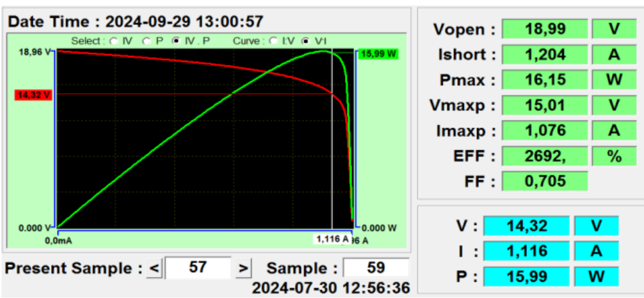

Fig. 5 – I-V Curve obtained with the assistance of the solar analyzer Prova-200 A.

With the help of the current sensor, the intersection of the I-V curve and the right of charge on the y-axis gives us the electrical current value that has to be shown on the LCD display. In our case, the result is 1.1 A Fig. 6, however the value we get on the LCD display is 1.01 A. This is a satisfactory result, and the difference between the two values is due to resistance losses in the two-meter-long PV module cable. We measured 16.5 Volts using a multimeter connected in parallel to the PV module while it was receiving an electrical charge. On the other hand, one experiences 43°C, which is the same temperature as shown on the LCD screen Fig. 7.

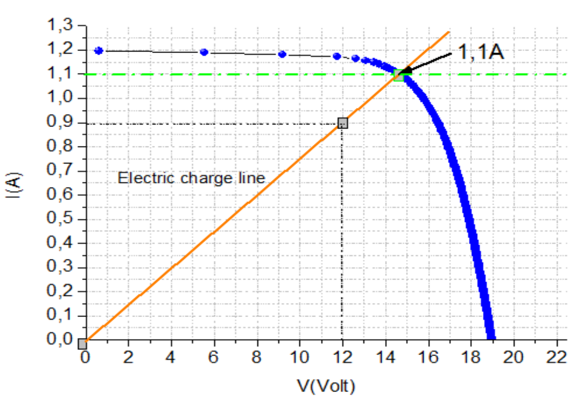

Fig. 6 – Curve with electric charge line

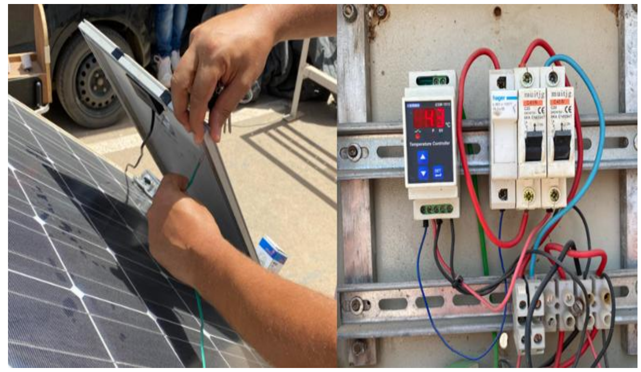

Fig. 7– Test bench for verifying the temperature value measured by a thermocouple

5. EXPERIMENTAL TEST ON THE OPERATION OF THE CURRENT SENSOR UNDER VARIOUS WORKING CONDITIONS

We demonstrate in this part the behavior of our created current sensor under various illumination conditions and tilt angles, as well as with two different PV module technologies (monocrystalline and polycrystalline), in order to validate its operation.

5.1 Indoor Test

The test bench was carried out in the UDES laboratory. We used a 1000 Watt halogen lamp as a light source, and a 20 Watt PV module (mono-Si) as an electric current generator. To measure the illumination on the front of the PV module, we used a Ref cell of the Si-v-1.5TC-batt-E type. A LINI-T UT71E Multimeter was connected to the Ref cell to measure the voltage at its terminal. The measured voltage value is multiplied by 1000 to obtain the illumination value. An 11-Watt DC lamp was used as an electric load source. All these devices are connected to the developed current sensor.

To evaluate the resistance of the current sensor to the variation of the illuminance, it is necessary to modify the position of the lamp in a variable manner in order to obtain different values of the illuminance. The results of the test according to the variation of the scale are presented in the table below. We note that our sensor evolves efficiently according to the variation of the illuminance; the more the illuminance increases, the more the value of the current increases, and the closer the lamp gets, the more temperature increases.

Table 1 – The results test of the current sensor under various illuminations (indoor test)

	illumination	T(°C)	V (Volt)	I (A)
Test1	88W /m²	33°	9.0 V	0.23 A
Test2	60W/m²	29°	8.3 V	0.17 A
Test3	53W/m²	28°	8.1 V	0.14 A
Test4	43W/m²	26°	7.7 V	0.11 A

5.2 Outdoor Test

In this procedure, we performed tests on the same solar panel (20 Watt mono-Si), this time outdoors. The data is presented on an LCD screen. In order to obtain a variation in illumination, it is necessary to modify the tilt angle of the PV module, as shown in the Fig. 8.

Fig. 8 – Outdoor test bench for test the operation of the current sensor with mono-Si

Table 2 – The results test of the current sensor under various illuminations (outdoor test) for mono-si

Tilt angle (°)	illumination (W/m²)	T (°C)	V (Volt)	I (A)
0°	845	30°	17.3	0.85
25°	918	32°	18.1	0.93
36°	929	35°	18.4	1.01
60°	890	32°	18.1	0.91
90°	456	30°	4.1 V	0.67

5.3 Outdoor Test with Polycristalline Si PV module

The same experiments that were conducted previously outside were carried out again, however this time we used a silicon polycrystalline PV module. This module is larger than the first 20-watt module and generates a short-circuit current of (8 A). It is necessary to use a higher electrical charge in these test settings, which consists of three parallel-connected 11-watt lamps. This allows for the measurement of higher current values. To obtain different values of solar illumination, the tilt angle of the photovoltaic module is set between 0° and 90°. Note that all the different tests are carried out at noon.

Table 3 – The results test of the current sensor under various illuminations (outdoor test) for poly-si

Tilt angle(°)	illumination (W/m²)	T (°C)	V (Volt)	I (A)
0°	845	35°	9.3 V	2.85
25°	918	35°	9.2 V	2.98
36°	929	46°	9.3 V	3.10
60°	890	48°	9.3 V	2.85
90°	456	49°	8.0 V	1.99

We notice in this experiment of the result of Table 3, that we can measure larger current values provided that a larger electric load is used.

5.4 Comparative study of PV module tested with and without dust

This section involves testing an autonomous photovoltaic system that consists of a 150-watt photovoltaic module Fig. 9 a charge regulator, a storage battery, and a water pulverization device for cleaning solar panel. The module is tested both with and without a dust; the tests are conducted at room temperature (35°C) and midday solar radiation levels (900 W/m²).

Fig. 9– Test bench and characterization of the autonomous cleaning system with the current sensor

Table 3 – The result test obtained by the pv module current sensor with and without dust

Number of lamps used	I(A) with Dust	I(A) without Dust	V(Volt) with or without dust)
5	4.32 A	4.68 A	19 V

According to the results obtained, we notice that the PV module with dust presents with low current in comparison with the clean PV module with the same operating voltage, this remark helps us to know the value necessary to trigger the cleaning system which depends on the level of the dust.

6. CONCLUSION

In this study, an electric current sensor for controlling and automating the operation of the cleaning system of photovoltaic power plants was developed and tested. The simulation and design of the electronic board was done under a proteus environment. After this step, further tests were carried out to examine the efficiency of the developed board with the effect of changing solar radiation, tilt angle and presence of dust on the solar panels. Further tests were carried out to verify the capability of the developed board. to give the electrical properties of high-power solar panels. As a future perspective for this work, we aspire to connect the board and develop it to work with the solar panel cleaning system.

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Розробка датчика електричного струму для моніторингу та автоматизації очищення фотоелектричних електростанцій

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Ряд суворих умов навколишнього середовища може впливати на ефективність та продуктивність фотоелектричних (ФЕ) панелей. Розуміння та управління цими факторами є важливим для гарантування довговічності та надійності сонячних ФЕ систем. Сьогодні широкий спектр технологій виробництва сонячних модулів доступний у всьому світі, що дозволяє використовувати ці ФЕ модулі в різних умовах та застосуваннях. Моделюючи та тестуючи поведінку сонячного модуля, можна дослідити різні елементи, що впливають на ефективність фотоелектричної системи. Накопичення пилу на ФЕ модулях ФЕ електростанцій є основним обмеженням витрат на обслуговування та експлуатацію сонячних електростанцій. Наразі для обробки цього бруду використовуються різні методи, починаючи від механічного втручання (очищення щіткою) і закінчуючи активним та пасивним електричним втручанням. У цій статті представлено теоретичне та експериментальне дослідження, яке характеризує фотоелектричні модулі шляхом розробки електронної плати, що дозволяє отримати електричні та теплові характеристики. Конструкція плати була доповнена різними порівняльними випробуваннями та перевірками на різних внутрішніх та зовнішніх випробувальних стендах. Отримані результати продемонстрували ефективність та результативність електронної плати у зборі результатів відповідно до зміни робочих умов сонячної панелі.

Ключові слова: Сонячна панель, Датчик струму, Arduino, Пил, Температура, Фотоелектричні елементи.