DESIGN AND DEVELOPMENT OF SOLAR PANEL TRACKING SYSTEM

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ABSTRACT

As non-renewable energy sources become scarcer, renewable energy sources are increasingly used to generate electricity. Non-renewable resources are limited and constantly depleted. The use of renewable resources such as solar energy is gaining momentum. The sunlight falling on the solar panel gets converted into electricity. A static solar panel cannot get even exposure to sunlight all the time and all the seasons. The goal of this work is to develop a dual-axis sun-tracking solar panel. The concept behind the work is to keep the photovoltaic modules to constantly orient themselves towards sunlight, maximizing solar radiation on solar panels. The idea behind the paper is to orient the photovoltaic modules constantly towards sunlight, maximizing the solar radiation on the solar panels with the objective of maximizing the power output. This work included the design and implementation of hardware, as well as the development of software for the microcontroller unit of the solar tracker. An ATmega328P microcontroller was used to control the movements of two servo motors that rotated the solar panels 360 degrees. The microprocessor calculated the amount of rotation based on data collected from four photo sensors near the solar panel.

Keywords: Solar Panel, Programmable Logical Controller, Tracker.

INTRODUCTION

A solar panel consists of solar cells or photovoltaic cells which are used to convert light energy into electrical energy. The power generation ability of a photovoltaic (PV) panel is roughly proportional to the intensity of sunlight falling on it. In this work, we designed and implemented a dual-axis solar programmable logical controller (PLC) based automatic tracking system, as well as its supervisory and control system. Since the Earth is in constant rotation, the intensity of sunlight on the solar panel is not fixed. The solar panel should absorb as much solar radiation as possible in order to efficiently convert solar energy into electrical energy. To achieve this, the panels must always be directed towards the sun. The tracking system regulates the elevation and orientation angles of solar panels, ensuring that the surface of the panel remains perpendicular to the sun at any given point of time. The outcome of this work would automatically track the sun and maintain the solar panels aligned with the sun for maximum efficiency.

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This paper has objectives related to SDG

The solar tracking system is broadly classified into single and dual axes tracking systems. Single-axis trackers only orient in east-west or north-south directions, while dual-axis trackers orient in both east-west and north-south directions. The proposed automatic tracking system regulates the elevation and orientation angles of solar panels to keep them perpendicular to the sun at all the time sunlight is available. The measured parameters of our automatic solar tracking system were compared with those of a fixed angle photovoltaic system. The automatic solar tracking system was found to be low-cost, dependable, and efficient. Two degrees of freedom operate as rotational axes in dual-axis trackers. These axes are usually perpendicular to one another. A primary axis is an axis that is fixed about the ground. A secondary axis can be defined as an axis that is referenced to the primary axis. Dual-axis trackers come in a variety of configurations. The direction of their principal axes about the ground is used to classify them. When modeling performance, the orientation of the module relative to the axis of the tracker is crucial. Modules on dual-axis trackers are usually aligned parallel to the secondary axis of rotation. Due to its capacity to track the Sun vertically and horizontally, dual-axis trackers provide optimal solar energy levels.

1. Literature Review

Kuttybay et al. (2019) proposed an intelligent automated solar tracking control system to increase solar energy production efficiency. The proposed cloud detection method, by adjusting the tilt angle of the solar panel in real time, allows the system to adapt to different weather situations. The algorithm for estimating the position of the solar panel is based on storing the known trajectory of the Sun for the entire year on a memory card and monitoring the output currents of small solar panels integrated into the system. The variation in current values of small solar batteries has been used to create and apply an algorithm for detecting the presence of clouds for a solar tracker. The Lo Ra AS32 TTL was used to build the architecture of the remote monitoring system and dispatching application. In cloudy weather, the energy gathered by the adaptive solar tracker outperformed the energy collected by the bi-axial solar tracker by 18%. This technique can be utilized to improve the efficiency of solar tracking systems in industrial settings.

Racharla and Rajan (2017) placed reflective sheets next to the solar panel to reduce the exorbitant cost of a solar tracker. When compared to other types of solar trackers, this concept is cost-effective and produces more efficiency at a lower cost. The results demonstrated that the efficiency of the 40 W solar panel is increased to 17.467 percent, while keeping the cost of the tracking system costs a minimum. The efficiency of the current value could be improved by combining the reflective sheet tracking system with the solar panel cooling system.

A revolutionary low-cost mirror reflecting linear focusing solar concentrator was proposed by Venkatesh and Karthik (2017). The increasing temperature of the panel is a result of the enhanced mirror augmented radiation intensity over the panel. However, if the panel temperature rises over 25 degrees Celsius, the open-circuit voltage and efficiency drop. As a result, appropriate cooling is required to boost panel performance. The performance of a mirror reflected solar panel (MRSP) with automatic cooling and tracking is compared in this article. The booster will block incident radiation because the mirrors are attached to the panel. As a result, a tracking device is created to focus the sunlight in a roughly perpendicular direction. The current and voltage values were measured under various tracking settings. For various combinations, the output power was determined and the figures were compared. According to the data, tracking with only reflection and only cooling gives more power than tracking without reflection and cooling, while tracking with reflection and cooling improves the result significantly.

Alam and Rahman (2016) employed Miura origami folding patterns and mechanical rotation of the panels, to design a portable solar panel system prototype that can be handled with minimal effort. To increase the efficiency of solar energy conversion, an active dual-axis solar tracking system based on a tilt-and-swing mechanism is added to the system. An Arduino microcontroller, photo-resistors, and stepper motors make up this low-cost solar-tracking device. The purpose of this project was to develop a simple and low-cost portable solar panel system.

Jasim and Taheri (2018) employed Light Dependent Resistors as sun tracker sensors with a precise control mechanism for the solar PV system. The power consumption can be lowered by enhancing the system design (Jasim & Taheri, 2018). Maharaja et al. (2015) proposed the design and implementation of an automatic single-axis active solar tracking system using Node MCU. Using ESP8266 module as the controller, the prototype was used for power generation source with high-power-rated solar panels.

Ghosh et al. (2019) achieved a solar tracking system using electrical characteristic of the panel. This opens circuit voltage that can detect the amount of sunlight that reaches the solar panel. This system was not only capable of maintaining optimal tilt angle for the PV cells but also capable of giving actuator signals to prevent unnecessary moves and logging data with real-time performance monitoring.

The innovative designs in sun- tracking systems have enabled the development of many solar thermal and photovoltaic systems for a diverse variety of applications in recent years compared to the traditional fixed panels. Solar systems that track the changes in the sun's trajectory over the day collect a far greater amount of solar energy, and therefore generate a significantly higher output power. Adabara et al. (2018) reviewed sun tracking systems developed over the past two decades. This paper classified sun tracking systems broadly as single axis and dual axis, depending on their mode of rotation. And further, the sun tracking system is classified as an active and passive tracker depending on the actuator. Overall, the results presented in this review confirm that the dual-axis tracking system in azimuth and altitude is more efficient than other tracking systems. However, from a cost and flexibility point of view, the single-axis tracking system is more feasible than a dual-axis. This paper presented details on in selecting an accurate and particular tracker concerning the region, available space, and estimated cost.

In this paper, a dual- axis solar tracker is designed and implemented to track the sun in both azimuth and altitude axes by using an AVR microcontroller. The implemented system consists mainly of the ATmega328 controller, DC motors, light sensors, and relays. The results show that the designed low-cost sun tracker increases the output power generation efficiency by 25-30 % as compared with the fixed panel systems. The effect of temperature and panel covering by colored cellophane, on the performance of the designed system is also studied. The temperature and the colored cello planes decrease the output power of the solar panel. In this paper, we have a dual-axis solar tracker that is more efficient in terms of the electrical energy output when compared to the single-axis tracker and fixed solar panel. The gain of the dual-axis tracking system is about 25-30% compared with the fixed system. For the temperature and covers, they decrease the output power of the solar panel. Therefore, any covering such as dust protection covers will harm the amount of power generated by the solar panel (Akbar et al., 2017).

Hossain and Huq (2019) compared the solar panel performances of fixed tilt system, single axis tracking system and dual axis tracking system connected to DC submersible centrifugal fuel pump commonly used for fuel refilling purpose. From the results fixed tilt PV system has a huge loss in power compared to the sun tracker systems. This loss is not small enough to be compensated by the cutback in expense. However, single axis tracking system and dual axis tracking system has almost similar output, former one lagging behind a minuscule amount. This negligible extra power achieved from the dual axis system is not worth the resource and effort behind the construction of it. To conclude, a handheld fuel refilling pump operated by a single axis tracking solar system is feasible for fuel stations.

2. Design and Implementation Objectives

The proposed solution in this paper has the following objectives:

- To control the position of a solar panel by the motion of the sun.
- To study the existing solar panel already available.
- To design a block diagram for the solar panel.
- To design and construct a simple solar tracking system with specific hardware components.
- To ensure and validate the solar panel responses.

2.1 Methodology

The key to maximizing the benefits of freely available solar energy is to ensure that a photovoltaic solar panel, or a whole PV array, is precisely oriented and positioned about direct sunlight at all times of the day.

2.1.1 Methodology for Objective 1

The photovoltaic solar panel is a stationary device that is fastened to either a roof or mounted directly onto a frame, and it may be exactly oriented to receive the solar energy. The sun, on the other hand, is not in a fixed location in the azimuth of the sky and is continually shifting its position about the earth from dawn to night, making proper solar panel alignment challenging.

2.1.2 Methodology for Objective 2

A survey had been made by studying the recently published papers and the different technologies used in them. Advantages and limitations are also studied which will help us build the project in a better way.

2.1.3 Methodology for Objective 3

A block diagram will be designed according to the implementation of the project with the components used. It provides a clear view of the entire work.

2.1.4 Methodology for Objective 4

The specifications and data regarding the types of sensors and other components used will be examined and taken from the available literature and hardware manuals. The software will be created and installed for further automatic use of the project. A simple solar tracking system will be constructed with maximum efficiency using the specific hardware components.

2.1.5 Methodology for Objective 5

The sensor measures the voltage and current values received from the solar panel. These values are processed inside the software and are displayed on the screen and the values are stored on an SD card. To check the responses of expect and the actual outcome of the project, gives a clear review of how the solar panel tracker is working.

3. Working of the System

As we see in the block diagram in Figure 1, there are four Light Dependent Resistors (LDRs) which are placed at different locations on a common plate with solar panel. Light from a source strikes on them by different amounts.

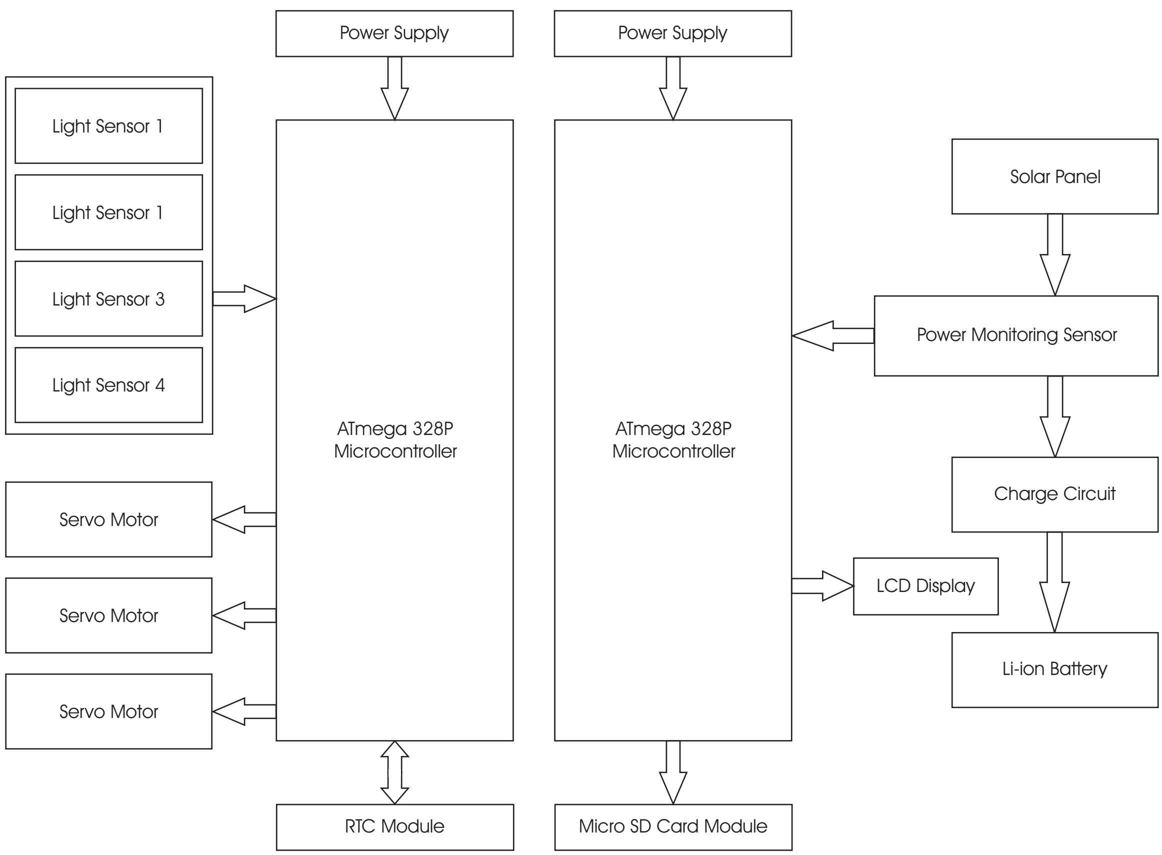

Figure 1. Block Diagram of the System

Due to their inherent property of decreasing resistance with increasing incident light intensity, i.e., photoconductivity, the value of resistances of all the LDRs is not always same.

Each LDR sends equivalent signal of their respective resistance value to the microcontroller which is configured by required programming logic. The values are compared with each other by considering a particular LDR value as reference.

One of the two DC servo motors is mechanically attached with the driving axle of the other one so that the former will move with rotation of the axle of latter one. The axle of the former servo motor is used to drive the solar panel. These three servo motors are arranged in such a way that the solar panel can move along X-axis, Y-axis and also Z- axis in order to have a 360 degree rotation.

The microcontroller sends appropriate signals to the servo motors based on the input signals received from the LDRs. Figure 2 shows the implementation of hardware connections and interfacing the components.

This work is divided into two parts, one is for tracking and the other is for measuring and therefore, two Arduino Nano boards are used. In the tracking part, as shown in Figure 2, when power is applied to the LDR on a device that is used to search for the brightest part of the sky where the light intensity is always high, the LDRs are rotated to that point using servo motors that move the LDR according to the reading. The real time clock on the Arduino Nano board, which is used to get the current time, and depending on the time consumption, the programmed controller unit will decide whether to have the tracking system on or off.

In the measurement part, as shown in Figure 3, the current and voltage measurement module (INA219) measures the values. The readings that are taken from the module are displayed on the OLED display. These values are used for various analyses for decision making of the tracking unit. Figure 4 shows the final testing setup of the solar tracking system of the PV unit.

Figure 5 shows the tracking part or positioning of the solar panel. Initially, the date and time are set. The microcontroller is the main component used in this. It calculates if a time is present between sunrise and sunset, otherwise the microcontroller returns to step 1 where the

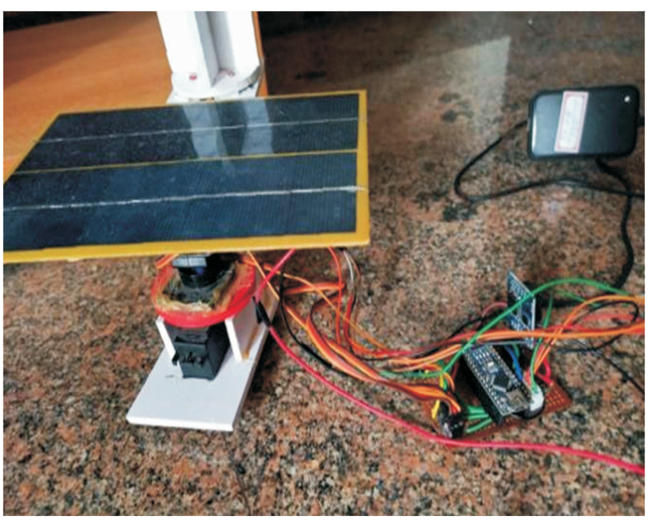

Figure 2. Hardware Connections of Tracking Part

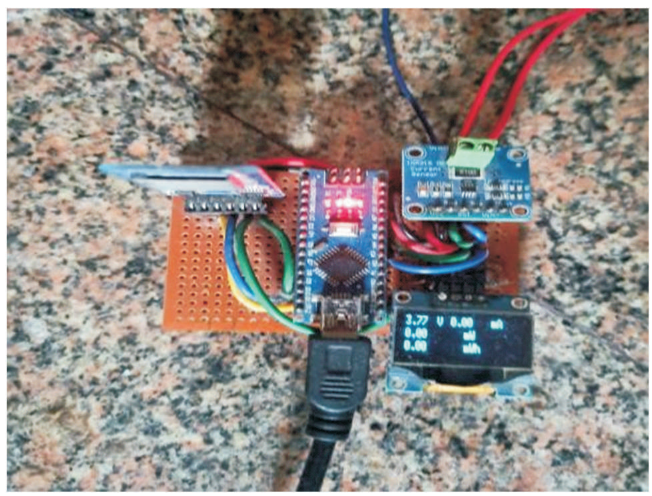

Figure 3. Hardware Connections for Measuring Part

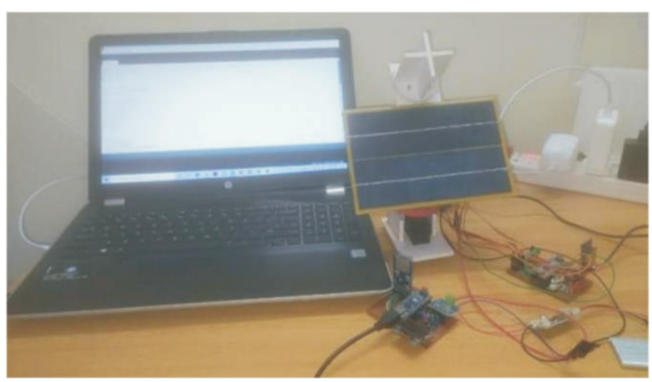

Figure 4. Final Setup after Connections

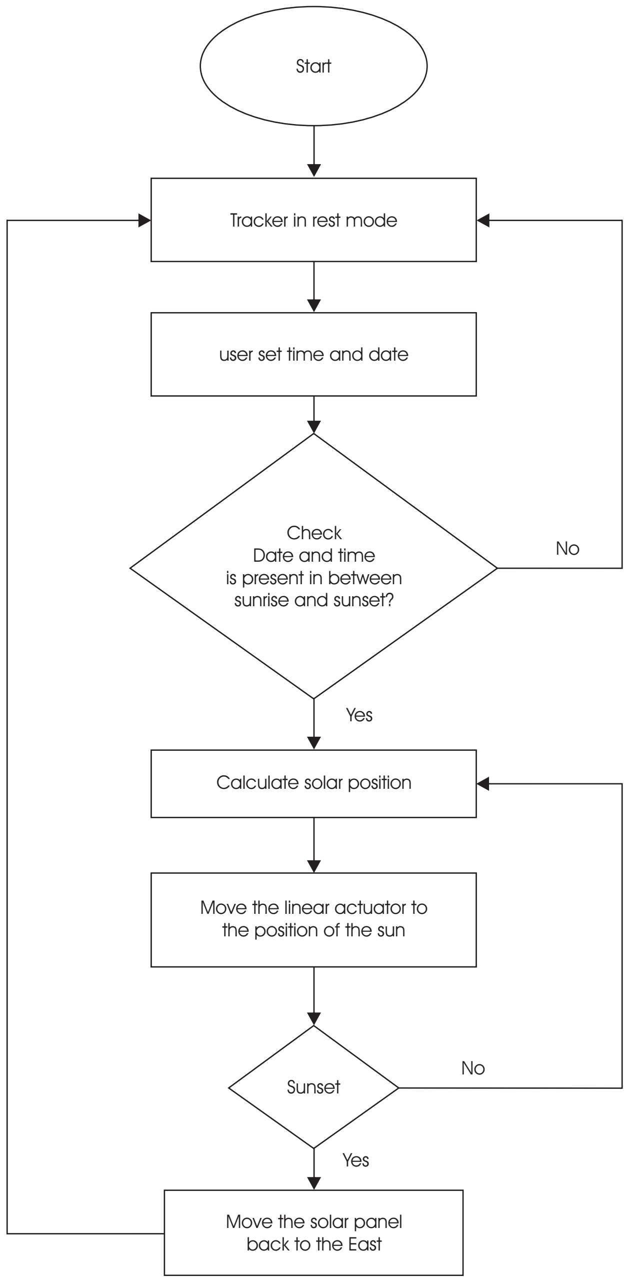

Figure 5. Flowchart of Programmable Logical Controller (PLC)

tracker is in rest mode, as the solar panel stops working at night. The microcontroller proceeds to the next step only in the daylight hours and calculates the position of the sun based on longitude and latitude, as well as time. When the microprocessor determines the position of the sun, it forces the actuator to align with a straight line parallel to the solar panel's vertical axis. The solar panel will be directly facing the sun due to actuator movement to the solar panel and continues to track the sun. The microcontroller proceeds back to the rest mode if the sun is not effectively set towards the panel or the time after the sunset.

4. Results and Discussion

When source light falls on the panel of this Dual Axis Solar Tracker, the panel changes its location according to the highest intensity of light falling perpendicular to it, achieving the project goal. This was accomplished by employing light sensors to detect how much sunshine reaches the solar panel. If there is a large discrepancy in the values produced by the LDRs, the panel is actuated using a servo motor to the point where it is approximately perpendicular to the rays of the sun. A system with four stages or subsystems was used to accomplish this. Each level has a distinct function.

The stages are as follows:

- An input stage was in charge of transforming incident light into a voltage.
- The actuation and decision making were controlled by a control stage.
- A servo motor and a driver stage control the actual movement of the PV array.
- The current and voltage are measured in the measurement stage.

The voltage divider circuit in the input stage is designed to provide the necessary range of illumination in bright lighting conditions. As the resistance fluctuates with light, LDRs were proven to be the best choice for this project. LDRs are inexpensive and widely available. A microcontroller in the control stage receives voltage from the LDRs and decides the action to be taken. The microcontroller is configured to send a signal to the servo motor, which moves in response with the error tolerance.

The drive circuit, which mainly consisted of a servo motor, was the last stage. The torque of the servo motor was sufficient to drive the panel. Servo motors are quiet inexpensive, and can spin up to 180 degrees. The INA219 sensor measures current and voltage, which is displayed on the OLED.

Conclusion

This paper presented the prototype development of the objective of achieving continuous and maximum solar energy absorption with the dual axis tracking system successfully. As a result, when compared to a single axis, better efficiency is better as mentioned in various literatures. The presented work demonstrated the use of microcontrollers to track the location of the sun. It shows, in particular, a working software method for maximizing electricity energy production by placing the solar panel in a location with maximum light intensity. The dual-axis tracker exactly aligns with the direction of the sun and records the movement of the sun more effectively, resulting in a significant performance boost. According to the findings, dual-axis tracking outperforms single- axis tracking and fixed module systems. During the whole observation period, the power captured by the dual-axis solar tracker is high, and it maximizes the conversion of solar irradiance into electrical energy production.

Future Work

The goal of this work is to design and build an Automated Solar Tracking System that uses a PLC to control a DC motor that moves the solar panel from east to west and north to south and returns to its original position. The second stage of this work is to achieve the goal to create an automatic tracking system that can detect the sun during the day.

This work has the potential to be scaled up significantly. More efficient sensors will be investigated in future projects, which should also be cost-effective and require little electricity. Shading, on the other hand, hurts the operation of solar panels. As the PV cells are connected in series, shading in a single cell will affect the entire panel. As a result of the shading, the tracking system will be unable to boost efficiency as required.

References

[1]. Adabara, I., Hassan, A. S., & Ian, L. (2018). Design and implementation of an automatic sun tracking solar panel without light sensors. *International Journal of Electrical and Electronic Science*, 5(3), 77-83.

[2]. Akbar, H. S., Siddiq, A. I., & Aziz, M. W. (2017). Microcontroller based dual axis sun tracking system for maximum solar energy generation. *American Journal of Energy Research*, 5(1), 23-27. https://doi.org/10.12691/ajer-5-1-3

[3]. Alam, S. M. S., & Rahman, A. M. (2016, January). Performance comparison of mirror reflected solar panel with tracking and cooling. In 2016, *4th International Conference on the Development in the in Renewable Energy Technology (ICDRET)* (pp. 1-4). IEEE. https://doi.org/10.1109/ICDRET.2016.7421513

[4]. Ghosh, J., Dey, N., & Das, P. (2019, September). Active solar tracking system using Node MCU. In 2019, *International Conference on Computing, Power and Communication Technologies (GUCON)* (pp. 924-928). IEEE.

[5]. Hossain, M. B., & Huq, S. (2019, March). Performance Evaluation of solar tracking systems for submersible centrifugal fuel pump. In 2019, *International Conference on Energy and Power Engineering (ICEPE)* (pp. 1-5). IEEE. https://doi.org/10.1109/CEPE.2019.8726775

[6]. Jasim, B., & Taheri, P. (2018, November). An origami-based portable solar panel system. In 2018, *IEEE 9th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON)* (pp. 199-203). IEEE. https://doi.org/10.1109/IEMCON.2018.8614997

[7]. Kuttybay, N., Mekhilef, S., Saymbetov, A., Nurgaliyev, M., Meiirkhanov, A., Dosymbetova, G., & Kopzhan, Z. (2019, June). An automated intelligent solar tracking control system with adaptive algorithm for different weather conditions. In 2019, *IEEE International Conference on Automatic Control and Intelligent Systems (I2CACIS)* (pp. 315-319). IEEE. https://doi.org/10.1109/I2CACIS.2019.8825098

[8]. Maharaja, K., Xavier, R. J., Amla, L. J., & Balaji, P. P. (2015). Intensity based dual axis solar tracking system. *International Journal of Applied Engineering Research*, 10(8), 19457-19465.

[9]. Racharla, S., & Rajan, K. (2017). Solar tracking system–a review. *International Journal of Sustainable Engineering*, 10(2), 72-81.

[10]. Venkatesh, A., & Karthik, R. (2017, August).

Investigation on enhanced performance of solar tracking through dual reflective system. In 2017, *International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS)* (pp. 417-419). IEEE. https://doi.org/10.1109/ICECDS.2017.8390200

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