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Dual axis solar tracking system

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ABSTRACT

Now a days, many people use solar photovoltaic systems since they generate efficient and clean energy. Polycrystalline and monocrystalline silicon modules are currently the most widely used products in the solar industry. Aside from possessing a flawless lattice structure, a high level of material purity, a low grain boundary energy, a weak internal resistance, and a high level of efficiency, monocrystalline silicon cells also have a uniform color and a lack of spots, which contribute to its good aesthetic appeal. By placing the solar panels at the precise angle and direction specified by the motion of the sun, the system's efficiency can be increased. The solar tracking system for this research project uses light-dependent resistors (LDR) sensors that are connected to a microcontroller to track the sun's horizontal and vertical axes, while DHT11 and rain sensors are used to track the weather. This study offers a method for repositioning a solar array so that it faces the sun at all times. Since solar modules effectively convert sunlight into electricity, they are helpful solutions to the problem of power generation in remote areas. A microprocessor is used in the construction of such a system to operate a motor and sensor.

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1. INTRODUCTION

The development of solar tracking technology over time has been supported by a number of people and organisations, which is how the dual-axis solar tracking system was created. John Perlin created one of the first solar tracking devices in the 1970s that used a single-axis tracking mechanism to track the sun as it moved across the sky [1]. However, this design had limitations as it only tracked the sun's movement in one direction and was not optimized for capturing maximum solar energy.

In the 1980s, researchers at Sandia National Laboratories in the United States developed a more advanced solar tracking system that utilized a dual-axis mechanism. This device could track the sun's movement both horizontally and vertically, making it possible to position solar panels in the best possible way to gather the most solar energy possible throughout the day [2]–[4]. Since then, there have been numerous advancementsand innovations indual-axis solar tracking technology, with various designs and implementations being utilized in solar energy systems around the world. Dual-axis solar tracking systems are widely recognised as one of the most efficient and effective techniques to boost solar energy capture and raise the overall efficiency of solar power systems today [5]–[7].

A particular style of solar panel installation called a single-axis solar tracking system enables the solar panels to rotate around a single axis, usually one that runs north-south. The rotating axis can be level or inclined at an angle to correspond to the latitude of the installation location [8]–[10]. Single-axis tracking systems can only boost the overall energy production of a solar energy system by up to 25%, depending on the location, the weather, and other factors. However, single-axis systems have limits and might not be the best for capturing solar energy in times of diffuse sunlight or overcast weather because they can only track the sun's movement in one direction [11]–[13]. Dual-axis solar tracking systems are designed to circumvent these limitations by enabling more precise alignment with the sun's movement in both the horizontal and vertical axes [14]–[17].

The monocrystalline dual-axis solar tracking system with a weather sensor is the main focus of this research. Temperature, rain, and humidity are monitored by sensors; the results of these sensors can be displayed on an liquid crystal display (LCD) [18]–[20]. It uses an Arduino to control the spinning of DC motors by detecting the strongest light using light-detecting resistors (LDRs) to detect it. The solar panel is turned by DC motors. To assess the state of the weather, sensors are utilised. Energy has been needed and utilised by man for his existence and well-being at an increasing rate during the last million years [21], [22]. Solar energy has the potential to be an environmentally friendly energy source that is dependable. This makes this tactic more favourable and efficient for obtaining the maximum energy [23]–[25].

2. THE SUGGESTED METHOD

The block diagram of a dual-axis solar tracking system that uses weather monitoring is shown in Figure 1. The arrangement is made up of three parts: a light-detection device, a monitoring unit, and a movement-controlling unit. By allowing PV panels to rotate along two separate axes, the suggested tracking system follows sunlight more efficiently. Four light-dependent resistor (LDR) sensors, two stepper motors, and a PIC microcontroller make up the tracker. The tracker is tilted in the sun's east-west direction by a pair of sensors and one motor, and in the sun's north-south direction by a second pair of sensors and a motor linked to the tracker's bottom.

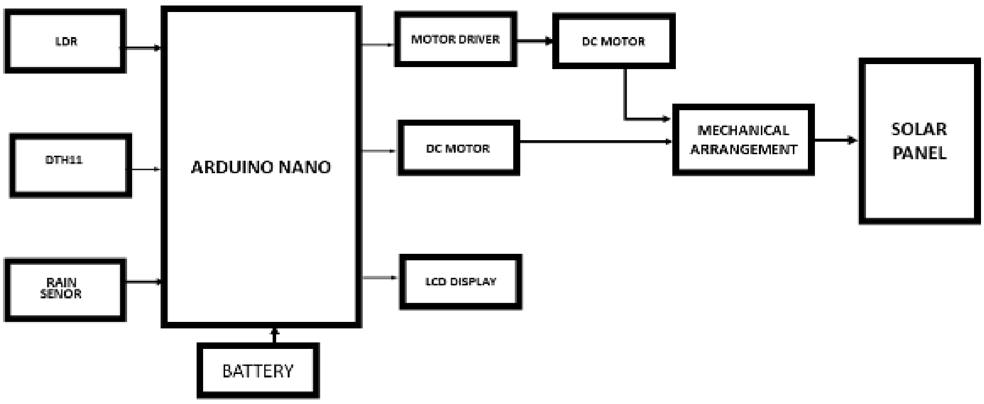

Figure 1. Dual-axis solar tracking system block diagram

2.1. Detecting light unit

A light-dependent resistor (LDR), often known as a photoresistor, is a passive electrical component that reacts to light by altering its resistance (see Figure 2). It is constructed of a semiconductor material with a high resistance in darkness and a low resistance in light, such as cadmium sulphide or cadmium selenide [4]. When light is detected, LDR sensors provide a signal to the microcontroller. The values of LDR resistance range from many megaohms in total darkness to only a few hundred ohms in bright light. Because of this variance in resistance, these resistors are frequently employed in a wide range of applications. The LDR sensitivity is also impacted by the incident light's wavelength. This resistor works according to the photo conductivity hypothesis.

2.2. Monitoring unit

According to Figure 3, the Arduino board serves as the apparatus primary monitoring device. LDR is attached to Arduino's first four pins, A0-A4. Arduino receives data from the LDR and, using that data, instructs servomotors to rotate either horizontally or vertically [4].

2.3. Movement controlling unit

Two DC motors make up the movement control unit. The DC motor may be powered by an input of roughly 4.5 volts and receives a 5-volt output from the Arduino. The vertical rotation is controlled by one motor, while the horizontal rotation is controlled by the other. To save power usage, just one motor is active at once [2], [3].

Figure 2. Sunlight is detected by a light dependent resistor (LDR)

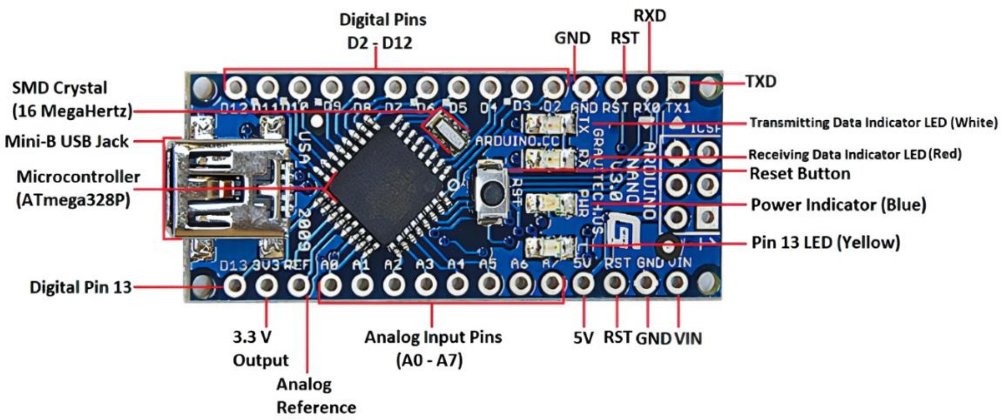

Figure 3. Pin description of Arduino Nano

3. METHOD

The fixed solar panel of the dual axis solar tracking system rotates in response to the sensor's determination of the sun's position. Figure 1 shows how the Arduino's four analogue pins, A1, A2, A3, and A4, are connected to four resistors and four LDRs, respectively. Internal connections between these parts form a voltage divider arrangement. The Arduino's digital pins 9 and 10 provide pulse width modulation (PWM) inputs to the DC motor, as seen in Figure 3. The primary light sensors are LDRs [5], [8]. Two solar panels that are mounted to the building support the servo motor. The microcontroller receives an upload from an Arduino programmer. As to how it operates: each LDR detects light coming from the top, bottom, left, and right directions in turn, counting the amount of light that enters the device as sunlight hits it. The analogue readings from the two top LDRs and the two bottom LDRs are compared to perform north-south tracking. The bottom set of LDRs' bottom light will then cause the vertical DC motor to rotate in that direction. The DC motor advances in that direction if the top LDRs detect lighter more light there. The analogue values from two left LDRs and two right LDRs are contrasted for angular deflection. If the right set of LDRs detects lighter than the right set, the horizontal DC motor will move in that direction [6], [11]. Researchers could therefore test the device's performance by mounting it on a rooftop (see Figure 4). When DC is vertical, the motor will drive in that direction if the appropriate set of LDRs detects lighter than the appropriate set.

- Bring the two solar panel wires for testing, then mark the locations of four LDRs on each of the panel's four corners.
- Trim one of the LDR's two leads so that one lead is shorter and the other longer to demonstrate polarity and facilitate soldering.

– Before the perforated metal strips (aluminum) are bent into the correct shapes as shown in Figure 5, the four LDRs should be put into the four designated positions on the printed circuit board (PCB). One of the bent metal strips should be glued to the back of the PCB [15].
– As shown in the circuit, solder the LDRs' two leads together. Solder 10k resistors to the LDR's leads opposite ends. Wires are used to connect the four leads on the four LDRs.
– Now, attach them to the LDRs using bus wires so that you may receive their output. Give each pin on the Arduino board its corresponding output. As depicted in Figure 5, insert it into the perforated metal strip.
– Now attach connecting wires to resistors and to the circuit as specified.
– To supply VCC and GND, run two additional wires through the perforated metal sheet. The resistors and the second wire should be connected to the LDR's opposite side, with one wire connecting to the other.
– With wires connected to the resistors, short the LDR's leads. Now use glue and screws to attach a DC motor to the metal strip. Connect them to the corresponding pins on the Arduino board.
– Take a second aluminum perforated metal strip that has been bent into the corresponding shape as illustrated in Figure 5. Now attach a second DC motor to this metal strip using glue and screws [14].
– Initially, an i2c module is linked to the 16*2 LCD display. As indicated in Figure 5, the VCC pin is then linked to the Arduino's 5-volt power supply, and the I2C module's ground is connected to the Arduino's ground. The ground, VCC, and signal pins of the DHT11 sensor are connected to the Arduino.

Figure 4. Prototype testing

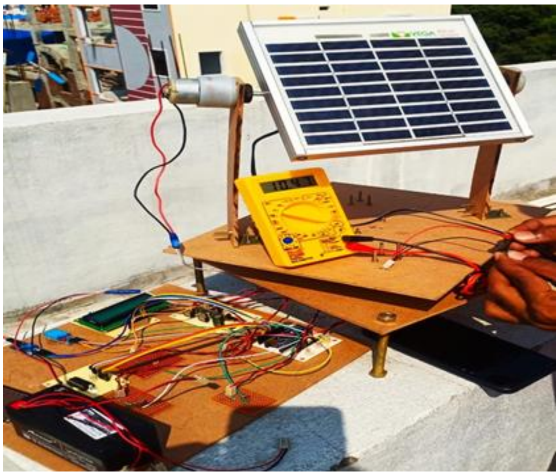

Figure 5. Hardware model of dual axis solar tracking

4. RESULTS AND DISCUSSION

The Tables 1 and 2 provides the output values at various time internals from 9:00 AM to 6:00 PM. Given that dual axis solar trackers are more effective than single axis solar trackers and that the output voltages of the two tracking systems are compared [12]. The effectiveness of single- and dual-axis solar tracking devices is shown in Tables 1 and 2, respectively. The graphic representation of single- and dual-axis solar tracking systems is shown in Figures 6 and 7.

Table 1. Performance of single-axis solar tracking systems

Time (hours)	Voltage (V)	Current (A)	Power (W)
9 AM	5.7	0.12	0.607
10 AM	10	0.16	1.71
11 AM	11	0.21	2.1
12 PM	13	0.29	3.5
13 PM	14	0.33	4.49
14 PM	13	0.31	4.05
15 PM	12	0.25	2.86
16 PM	9	0.15	1.28
17 PM	7	0.11	0.72
18 PM	2.5	0.05	0.12

Table 2. Performance of dual axis solar tracking system

Time (hours)	Voltage (V)	Current (A)	Power (W)
9 AM	12.4	0.24	2.9
10 AM	13.4	0.26	3.5
11 AM	13.9	0.29	3.93
12 PM	13.9	0.31	4.3
13 PM	14.9	0.31	4.6
14 PM	13.9	0.31	4.3
15 PM	12.9	0.27	3.9
16 PM	9.9	0.26	2.6
17 PM	6.9	0.21	1.46
18 PM	5	0.1	0.5

Figure 6. Graphical representation of single axis solar tracking system

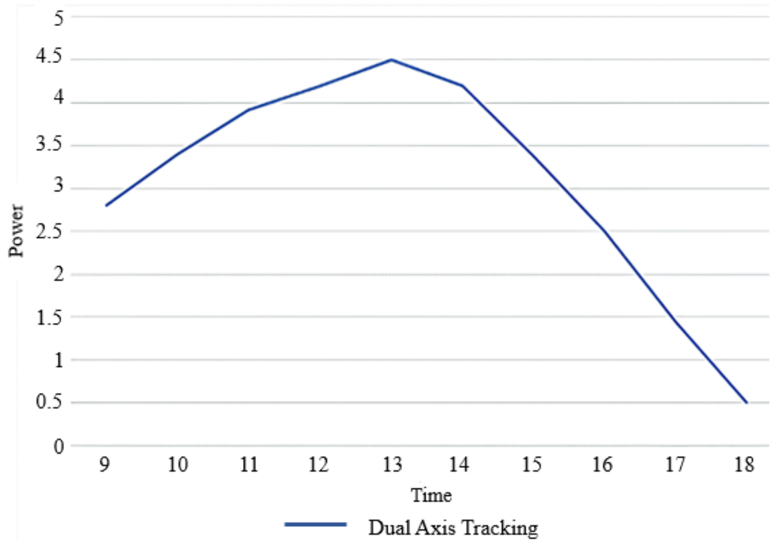

Figure 7. Graphical representation of dual axis solar tracking system

The single axis solar tracking and dual axis solar tracking systems comparative table is shown in Table 3. The Table 3 displays the output values at various time periods. The output voltages of the two tracking methods are compared because dual axis solar trackers are more effective than single axis solar trackers. It is common knowledge that a single axis solar tracker system is unable to collect the whole range of solar energy. The solar energy that was expected to be captured by the single axis solar tracker could not be. One of the two axes of motion of the sun is only followed by single-axis solar tracker technology. As a result, we recommended setting up a dual axis solar tracking system atop each structure [17]. Observation of weather sensor is shown in Table 4.

The average power produced by the solar panels is 2.144 W for single axis solar trackers and 3.085 W for dual axis solar trackers. For dual axis trackers, efficiency is 98.083%, whereas for single axis trackers, it is 77.045%. Dual axis sun tracking systems have been shown to gather solar energy more efficiently and with a stronger output than single axis systems. Dual axis trackers have higher power outputs than single axis trackers. Both trackers attain their maximum power outputs at one o'clock. When the temperature and humidity data are presented in the LCD, power is increasing from 9.00 AM TO 1.00 PM; while it is decreasing from 1.00 PM to 6.00 PM, the temperature will decrease from 43 to 27 °C. With single axis trackers and dual axis trackers at 4.49 W and 4.5 W, respectively, the power peaks at noon. A dual axis tracker produces more electricity than a single axis tracker [16].

Table 3. Performance evaluation of dual and single axis tracking systems

Time	Single axis tracking			Dual axis tracking		
(hours)	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)
9 AM	5.7	0.12	0.607	12.4	0.24	2.9
10 AM	10	0.16	1.71	13.4	0.26	3.5
11 AM	11	0.21	2.1	13.9	0.29	3.93
12 PM	13	0.29	3.5	13.9	0.31	4.3
13 PM	14	0.33	4.49	14.9	0.31	4.6
14 PM	13	0.31	4.05	13.9	0.31	4.3
15 PM	12	0.25	2.86	12.9	0.27	3.9
16 PM	9	0.15	1.28	9.9	0.26	2.6
17 PM	7	0.11	0.72	6.9	0.21	1.46
18 PM	2.5	0.05	0.12	5	0.1	0.5

Table 4. Observation of weather sensor

Time (hours)	Temperature (℃)	Humidity (%)
9 AM	28	81
10 AM	32	75
11 AM	35	60
12 PM	41	52
13 PM	43	47
14 PM	45	42
15 PM	39	40
16 PM	35	50
17 PM	29	64
18 PM	27	79

Figure 8 depicts a visual comparison of single and dual axis solar tracking systems. The dual axis sun tracker device has the ability to capture high voltage. When compared to other ways, graphic depiction unquestionably demonstrates the better solar energy conversion. There are other, more efficient ways to detect solar radiation, but they are all quite expensive. Examples include central receiver concentrators, parabolic trough concentrators, parabolic dish concentrators, and power towers. Due to their lower cost and higher efficiency, dual axis solar systems are now being used more frequently [12].

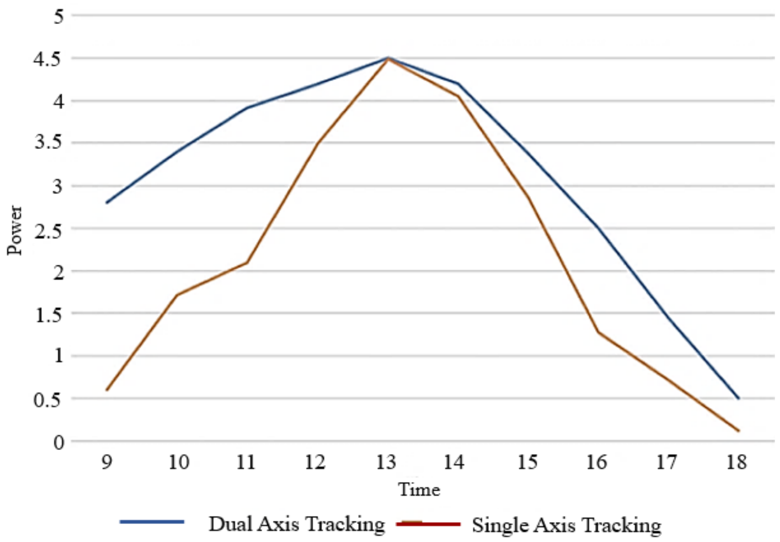

Figure 8. A visual comparison of single and two axis solar tracking devices is presented

5. CONCLUSION

In order to produce electricity, dual axis solar trackers constructed of monocrystalline are mounted to follow the sun's rays in all directions with the highest intensity. It is the cheapest method of energy conversion compared to other systems. Dual axis solar tracking systems are more efficient and produce more energy than fixed and single axis sun tracking systems, as shown by the comparison of the two types of solar tracking systems in this article.

REFERENCES

[1] F. I. Mustafa, S. Shakir, F. F. Mustafa, and A. T. Naiyf, "Simple design and implementation of solar tracking system two axis with four sensors for Baghdad city," in *2018 9th International Renewable Energy Congress (IREC)*, Mar. 2018, pp. 1–5, doi: 10.1109/IREC.2018.8362577.

[2] T. M. T. Thentral, M. Kannan, V. Sai Mounika, and M. Nair, "Dual axis solar tracker with weather sensor," *International Journal of Recent Technology and Engineering*, vol. 8, no. 2, pp. 3308–3311, 2019, doi: 10.35940/ijrte.B1558.0982S1119.

[3] V. Patro, C. P. Kumar, P. Godthi, and S. Murugan, "Dual Axis Solar Tracker," *International Journal of Advanced Research in Basic Engineering Sciences and Technology (IJARBEST)*, vol. 4, no. 4, p. 2456, 2018.
[4] H. A. E. Salama and A. T. M. Taha, "Practical Implementation of Dual Axis Solar Power Tracking System," in *2018 Twentieth International Middle East Power Systems Conference (MEPCON)*, Dec. 2018, pp. 446–451, doi: 10.1109/MEPCON.2018.8635197.
[5] S. I. Palomino-Resendiz, F. A. Ortiz-Martínez, I. V. Paramo-Ortega, J. M. González-Lira, and D. A. Flores-Hernández, "Optimal Selection of the Control Strategy for Dual-Axis Solar Tracking Systems," *IEEE Access*, vol. 11, pp. 56561–56573, 2023, doi: 10.1109/ACCESS.2023.3283336.
[6] L. Jiang, S. Cui, P. Sun, Y. Wang, and C. Yang, "Comparison of Monocrystalline and Polycrystalline Solar Modules," in *2020 IEEE 5th Information Technology and Mechatronics Engineering Conference (ITOEC)*, Jun. 2020, pp. 341–344, doi: 10.1109/ITOEC49072.2020.9141722.
[7] V. Dhanalakshmi, L. Prasanna, V. Priyanka, and K. J. Rani, "Dual Axis Solar Tracker Using Arduino Uno," *International Journal on Recent and Innovation Trends in Computing and Communication*, vol. 4, no. 6, pp. 386-388, 2016.
[8] IRENA, "Renewable Energy Prospects: Indonesia, a REmap analysis, " *International Renewable Energy Agency (IRENA)*, 2017. http://www.irena.org/remap.
[9] R. Xu, K. Ni, Y. Hu, J. Si, H. Wen, and D. Yu, "Analysis of the optimum tilt angle for a soiled PV panel," *Energy Conversion and Management*, vol. 148, pp. 100–109, Sep. 2017, doi: 10.1016/j.enconman.2017.05.058.
[10] S. J. M. Shareef, "The Impact of Tilt Angle on Photovoltaic Panel Output," *International Journal of Applied Nanotechnology*, vol. 29, no. 5, pp. 112–118, 2017.
[11] N. Sharma and B. Sharma, "An Analysis of Automatic Dual Axis Sun Tracking Solar System," *International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering ISO*, no. 12, pp. 2321–5526, 2016, [Online]. Available: https://www.researchgate.net/publication/311669575.
[12] T. Blaschke, M. Biberacher, S. Gadocha, and I. Schardinger, "'Energy landscapes': Meeting energy demands and human aspirations," *Biomass and Bioenergy*, vol. 55, pp. 3–16, Aug. 2013, doi: 10.1016/j.biombioe.2012.11.022.
[13] M. A. Ioniţă and C. Alexandru, "Dynamic optimization of the tracking system for a pseudo-azimuthal photovoltaic platform," *Journal of Renewable and Sustainable Energy*, vol. 4, no. 5, Sep. 2012, doi: 10.1063/1.4757630.
[14] S. A. S. Eldin, M. S. Abd-Elhady, and H. A. Kandil, "Feasibility of solar tracking systems for PV panels in hot and cold regions," *Renewable Energy*, vol. 85, pp. 228–233, Jan. 2016, doi: 10.1016/j.renene.2015.06.051.
[15] W. Nsengiyumva, S. G. Chen, L. Hu, and X. Chen, "Recent advancements and challenges in Solar Tracking Systems (STS): A review," *Renewable and Sustainable Energy Reviews*, vol. 81, pp. 250–279, Jan. 2018, doi: 10.1016/j.rser.2017.06.085.
[16] A. Z. Hafez, A. M. Yousef, and N. M. Harag, "Solar tracking systems: Technologies and trackers drive types – A review," *Renewable and Sustainable Energy Reviews*, vol. 91, pp. 754–782, Aug. 2018, doi: 10.1016/j.rser.2018.03.094.
[17] H. Fathabadi, "Novel high efficient offline sensorless dual-axis solar tracker for using in photovoltaic systems and solar concentrators," *Renewable Energy*, vol. 95, pp. 485–494, Sep. 2016, doi: 10.1016/j.renene.2016.04.063.
[18] F. A. Salem, "Mechatronics Design of Solar Tracking System," *International Journal of Current Engineering and Technology*, vol. 3, no. 3, pp. 750-762, 2013.
[19] C. D. Rodriguez-Gallegos, O. Gandhi, S. K. Panda, and T. Reindl, "On the PV Tracker Performance: Tracking the Sun Versus Tracking the Best Orientation," *IEEE Journal of Photovoltaics*, vol. 10, no. 5, pp. 1474–1480, Sep. 2020, doi: 10.1109/JPHOTOV.2020.3006994.
[20] M. Saeedi and R. Effatnejad, "A New Design of Dual-Axis Solar Tracking System With LDR Sensors by Using the Wheatstone Bridge Circuit," *IEEE Sensors Journal*, vol. 21, no. 13, pp. 14915–14922, Jul. 2021, doi: 10.1109/JSEN.2021.3072876.
[21] H. Fathabadi, "Novel Online Sensorless Dual-Axis Sun Tracker," *IEEE/ASME Transactions on Mechatronics*, vol. 22, no. 1, pp. 321–328, Feb. 2017, doi: 10.1109/TMECH.2016.2611564.
[22] K. Achuthan *et al.*, "Remote Triggered Dual-Axis Solar Irradiance Measurement System," *IEEE Transactions on Industry Applications*, vol. 56, no. 2, pp. 1742–1751, Mar. 2020, doi: 10.1109/TIA.2020.2966156.
[23] Y. R. Al-Saadi, M. S. Tapou, A. A. Badi, S. Abdulla, and M. Diykh, "Developing Smart Self Orienting Solar Tracker for Mobile PV Power Generation Systems," *IEEE Access*, vol. 10, pp. 79090–79099, 2022, doi: 10.1109/ACCESS.2022.3194026.
[24] R. Xu, X. Ji, C. Liu, J. Hou, Z. Cao, and H. Qian, "Design and Control of a Wave-Driven Solar Tracker," *IEEE Transactions on Automation Science and Engineering*, vol. 20, no. 2, pp. 1007–1019, Apr. 2023, doi: 10.1109/TASE.2022.3177353.
[25] C. F. Abe, J. B. Dias, G. Notton, G.-A. Faggianelli, G. Pigelet, and D. Ouvrard, "Estimation of the Effective Irradiance and Bifacial Gain for PV Arrays Using the Maximum Power Current," *IEEE Journal of Photovoltaics*, vol. 13, no. 3, pp. 432–441, May 2023, doi: 10.1109/JPHOTOV.2023.3242117.

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