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Implementation of flexible axis photovoltaic system based on internet of things

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ABSTRACT

Electricity is a crucial aspect in human life. With population growth, ongoing regional development, and continuous construction activities, the demand for electricity and fuel in Indonesia is increasing. The substantial power consumption leads to larger financial expenditures for the community. Additionally, the use of electricity, as it has been traditionally employed, has negative environmental impacts. Solutions are needed to address these issues, and one effort involves the use of renewable energy, such as the development of solar power plants (PLTS). PLTS, also known as solar cells, is preferred as it can be used for various relevant purposes in different locations, particularly in offices, factories, residential areas, and others. However, the use of static, single-axis, and dual-axis solar panels still has drawbacks, such as suboptimal sunlight intensity and high motor power consumption. Therefore, a flexible-axis solar panel tracking system has been developed to follow the direction of sunlight, ensuring optimal power efficiency, and significant electricity generation. The flexible-axis tracker system results in a 34.13% increase in power efficiency.

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1. INTRODUCTION

Currently, there is an increase in demand for electrical energy worldwide, however, conventional methods of generating electricity such as the use of fossil fuels are no longer sustainable due to their increasing scarcity and cost [1]–[3]. Therefore, in recent years, the use of solar energy has become one of the primary clean and renewable energy sources globally. Particularly in Indonesia, solar energy has a potential of 4.8 kWh/m^2 or equivalent to 112,000 GW [4]. The main application of solar energy is in power generation using solar photovoltaic (PV) systems. This system converts direct sunlight into direct current (DC) through the PV effect [5]–[7]. To maximize the output power of PV panels, the panel position should be perpendicular to sunlight (radiation) [8]–[11].

The geographical location and changing sunlight conditions have an impact on the output power produced by solar PV panels. Additionally, the number and angle of solar radiation, types and quantities of cells, cell load temperature, and voltage are other factors that determine the amount of PV panel output power [12]–[14]. To address this issue, solar trackers can be utilized to maximize PV output power. Solar trackers receive the maximum amount of solar radiation during the day by positioning PV panels perpendicular to sunlight [15], [16].

However, the issue with uniaxial tracking systems is that they do not provide acceptable tracking capability due to module rotation limitations, resulting in the loss of a significant amount of solar energy produced by PV modules [17]–[20]. Several techniques have been employed to achieve optimal power in PV systems by adding sun-tracking control systems [20]–[23]. This aims to obtain the maximum power point from the PV and direct the PV towards the sun [24]–[26]. Solar panels also require control to track the sun's position to always follow the correct sun position, thus maximizing sunlight absorption [27]–[30]. This tracking system is used to track the horizontal rotation axis and vertical rotation axis. The horizontal axis is used to track the sun's elevation angle, while the vertical axis is used to follow the sun's azimuth. Therefore, this research aims to create a system that can track sunlight in all directions, thus generating maximum electrical power with a flexible axis system that can move in all directions without being limited by axes. The flexible axis is designed so that the PV surface always faces the sun, thereby improving the efficiency of the generated power.

2. METHOD

The rapid growth in the PV system market has sparked increasing interest in the development of solar tracking systems. The mounting structure that has been the focus of research is the pseudo-azimuthal system, where the rotation speed varies significantly for the primary and secondary axes, creating structural stability [14]. However, this system still faces challenges related to the limitations of PV module rotation movements. Limited rotation movements along specific axes can hinder the optimal absorption of solar energy. Therefore, there is a need to develop a more flexible tracking system capable of rotating in all directions (east, west, north, and south), ensuring that the PV panels remain perpendicular to sunlight throughout the day.

The proposed tracking system design embraces the concept of unrestricted flexibility along specific axes. This aims to create freedom of movement for PV module rotation, thereby enabling more optimal tracking of sunlight. The freedom to rotate in all directions is a primary advantage, allowing for efficient adjustment to changes in the sun's position. Several important aspects of the design involve the selection of materials capable of supporting the weight of PV panels, sturdy frame structures, efficient actuators, shafts as the main driving elements, wheel mechanisms for smooth movement, and accurate solar power measurement systems. Sustainability and system reliability are primary concerns during the development process. In implementing the design, ball-joint technology is used as the central shaft to enable free rotation. The height of the structure is limited by considering factors such as wind speed and the weight of the PV panels, ensuring overall system stability without sacrificing performance in different environmental conditions.

The mechanical flexible axis solar panel system consists of solar panels, a DC motor with a gearbox, hollow iron, galvalume, nylon ropes, ball joints, and bearing rods. A DC motor with a gearbox is connected to four nylon ropes, and the ends of the panel pass through the installed bearing rods. The movement system of the nylon ropes differs on each diagonal, creating tension that drives the ball joints to move the solar panel without axis limitations. Data collection was undertaken for 12 hours from 07:00 to 17:00 WIB at the Vocational Faculty, Universitas Airlangga during the rainy season. The power formula, indicated in (1), is used to analyze the data generated by the solar panels to determine the comparison of power efficiency levels produced by the flexible axis system with the static system:

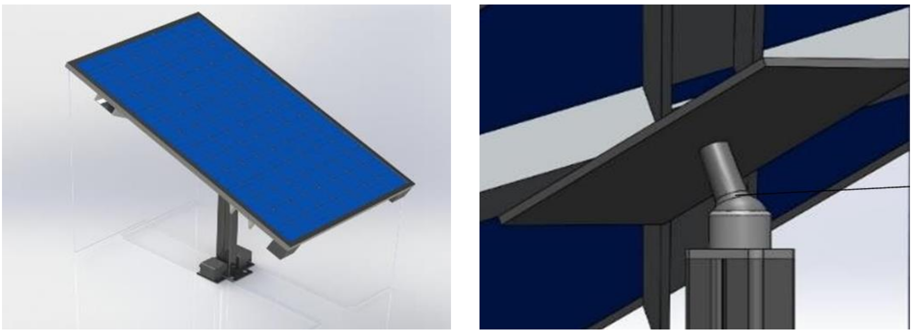
$$P = V \times I \tag{1}$$

with: P is Watt; V is Volt; and I is Ampere.

The percentage difference in power relative (ΔP) can be calculated using the (2):

$$\Delta P = \frac{P_{tracking} - P_{fixed}}{P_{fixed}} \times 100\,\% \tag{2}$$

where (2) explains that ΔP represents the percentage difference in power relative (%). $P_{tracking}$ is the power produced by the flexible axis system, and P_{fixed} is the power produced by the static system. Through these calculations, the percentage increase in solar panel power between those equipped with flexible axis trackers and those without trackers (static) is determined. Figure 1 is a model of a mechanical component from a flexible axis used to move the PV panel so that the PV surface faces the sun. Figure 1(a) depicts the design of the flexible-axis solar panel mechanism, while Figure 1(b) illustrates the rear-view design of the flexible-axis solar panel from the rear.



(a) (b)

Figure 1. The design of the flexible-axis solar panel mechanism shown from (a) an isometric view and (b) a rear view

In the design of this research, there are several designs for assembling the electrical circuit of the flexible axis and static systems. The microcontroller used in this research is the Arduino Atmega2560 as the proportional integral derivative (PID) controller, where the microcontroller will receive data from the encoder sensor in the form of position and motor speed values, and real-time clock (RTC) in the form of time values (hours, minutes, and seconds), thus providing signals to the motor driver to drive the DC motor with gearbox. Meanwhile, the NodeMCU ESP8266 serves as the controller for the PZEM-017 sensor and acts as a connection to Blynk. Other devices for the flexible axis system include the BTS-7960 motor driver, Modbus RS485 converter, RTC DS3231 sensor, encoder sensor, PZEM-017 sensor, digital pins, push buttons, LM2596 step down, power supply, and solar charger controller (SCC).

The system operation overview is depicted in Figure 2, starting with the power supply providing power to the Atmega2560 through the LM2596 step-down to lower its voltage. Then, the entire system will be powered up, and the RTC and encoder sensors will provide data to the Atmega2560 microcontroller via Modbus RS485 to monitor and control device operations, as well as to send energy production data to the central control system. The Modbus RS485 is also connected to the ESP8266 microcontroller, and the voltage obtained by ESP8266 comes from Atmega2560. This causes the PSEM-017 sensor to activate and read data, which is then connected to the SCC. Similarly, the MPU6050 sensor is powered by ESP8266 to read data and transmit it to Blynk.

The flexible-axis system begins with the initialization of input/output, then the RTC sensor will read the time values (hours, minutes, and seconds), and the encoder sensor will read the values of motor position and speed before being forwarded to the Arduino Uno Atmega2560. During the process of solar panel movement following the direction of sunlight based on time, the PZEM-017 sensor will read the current, voltage, and power values obtained, which are then forwarded to the ESP8266 for processing and subsequently sent to Blynk for monitoring current, voltage, and power data via Wi-Fi.

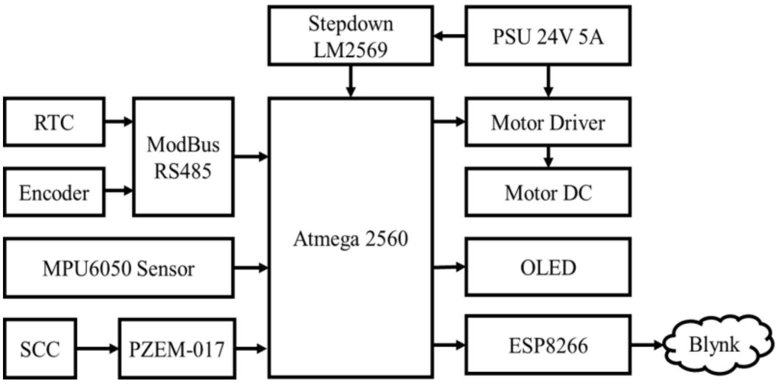


Figure 2. Electronic flexible axis operation system

3. RESULTS AND DISCUSSION

In this section, the data collection results obtained from solar panels using sun tracking systems with flexible axis and static approaches are presented in Table 1. The proposed system is designed to overcome the limitations of rotational movement of PV module rotation in the commonly used pseudo-azimuthal approach. Experiments and analyses were conducted to understand the performance of solar panels with two different tracking approaches. Solar panels were installed with a flexible axis tracking system utilizing a central shaft using a ball joint. This system allows the solar panels to rotate in all directions, namely east, west, north, and south, to keep the PV panels perpendicular to sunlight throughout the day. For comparison, solar panels were also installed with a static tracking system that limits movement along specific axes.

Table 1. Comparison of data results between flexible axis tracker and static solar panel conditions

Time	Flexible axis tracker			Static solar panel		
(Hour)	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)
8:30	20.4	0.20	4.08	17.9	0.27	4.83
9:00	20.8	0.30	6.24	18.8	0.27	5.07
9:30	21.2	0.20	4.24	19.4	0.28	5.43
10:00	21.3	0.30	6.39	19.4	0.30	5.82
10:30	21.7	0.40	8.68	20.1	0.37	7.43
11:00	21.7	0.50	10.85	20.3	0.45	9.14
11:30	22.8	0.84	19.15	21.9	0.53	11.60
12:00	22.3	1.00	22.30	21.7	0.60	13.02
12:30	22.6	1.10	24.86	21.2	0.70	14.84
13:00	21.7	1.00	21.70	20.6	0.98	20.18
13:30	21.4	1.30	27.82	19.5	1.10	21.45
14:00	21.3	1.00	21.30	19.3	0.82	15.82
14:30	21.3	0.92	19.59	19.3	0.76	14.66
15:00	21.2	0.85	18.02	17.9	0.27	4.83
15:30	21.1	0.76	16.03	18.8	0.27	5.07
16:00	21.1	0.60	12.66	19.4	0.28	5.43

From the collected data, the percentage difference in relative power (ΔP) can be calculated using (3)-(5).

$$\Delta P = \frac{P_{tracking} - P_{fixed}}{P_{fixed}} \times 100\% \quad (3)$$

$$P_{\text{total PS fa}} = 243.92\ W \quad (4)$$

$$P_{\text{total PS t}} = 181.84\ W \quad (5)$$

$$\Delta P_{\text{total}} = 62.08\ W$$

Then (6)-(9).

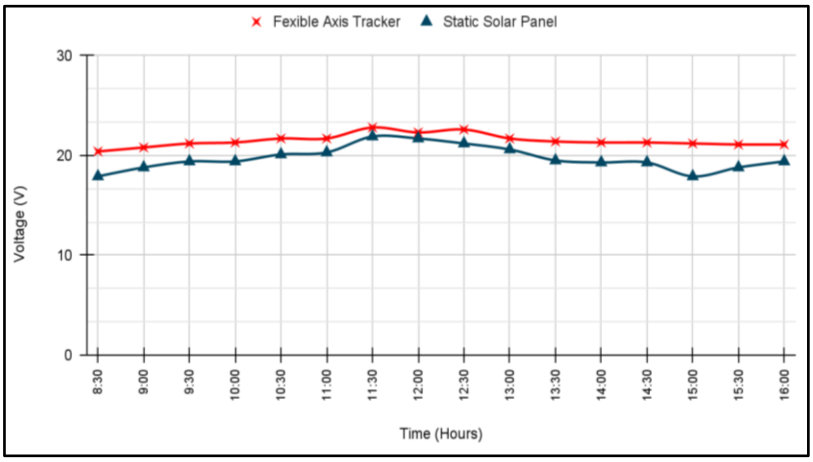
$$\Delta P = \frac{P_{tracking} - P_{fixed}}{P_{fixed}} \times 100\% \quad (6)$$

$$\Delta P = \frac{243.92 - 181.84\ W}{181.84\ W} \times 100\% \quad (7)$$

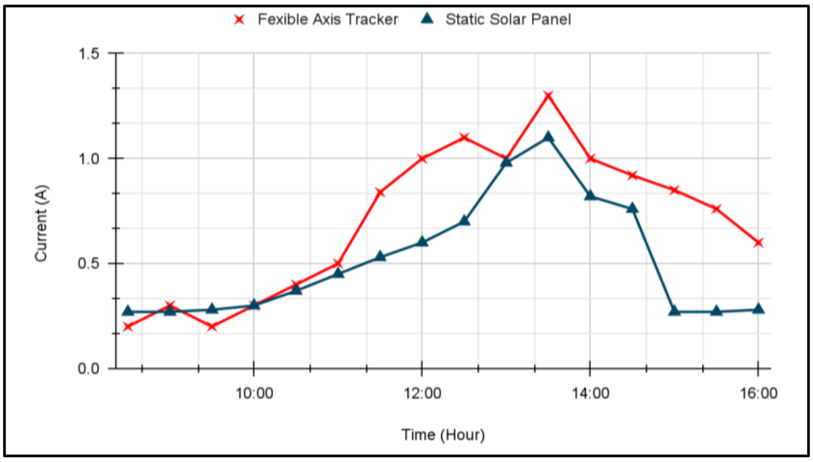
$$\Delta P = \frac{62.08\ W}{181.84\ W} \times 100\% \quad (8)$$

$$\Delta P = 34.13\% \quad (9)$$

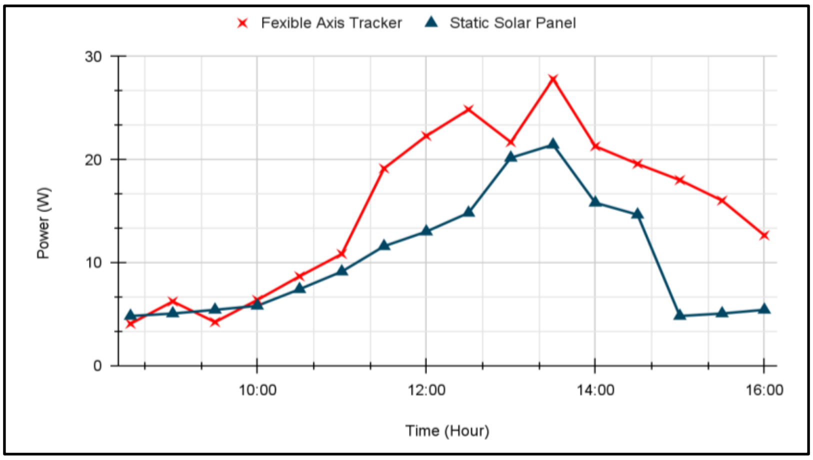
Based on the data obtained from (3)-(9) explaining the derivation of the solar panel tracking efficiency formula, a 34.13% reduction in power was observed in the flexible axis solar panel system compared to the static system. The comparison graph of power is presented in Figure 3, where the blue line represents the system using a flexible axis to track sunlight, and the orange line represents the system without a tracker (static), demonstrating a significant difference. As seen in the figure, the voltage in Figure 3(a), current in Figure 3(b), and power in Figure 3(c) of the flexible axis tracker are consistently higher than those of the static system throughout the day. This indicates that the flexible axis tracker is more efficient in capturing sunlight, thereby generating more electrical power. The dynamic adjustment of the flexible tracker allows it to maintain an optimal angle relative to the sun, maximizing energy absorption, whereas the static system fails to adapt to the changing position of the sun, resulting in lower performance. Overall, the data clearly illustrates the advantages of employing a flexible axis tracking system in solar power generation.



(a)



(b)



(c)

Figure 3. Comparison of (a) voltage, (b) current, and (c) power between flexible axis tracker compared to static solar tracker

4. CONCLUSION

The research concludes that the integration of a novel flexible axis in the design of mechanical, software, and electronic components significantly enhances solar energy collection efficiency. The implemented system successfully followed programmed instructions, resulting in a marked increase in electrical power output. Specifically, the flexible axis solar panel system generated 243.92 W, compared to 181.84 W from the stationary system, demonstrating a 34.13% improvement in power efficiency. The notable power difference of 62.08 W underscores the superior effectiveness of the novel flexible axis tracker. Additionally, the system's efficiency allows for a reduction in the number of DC motors required, further highlighting its advantages over stationary, single-axis, and dual-axis tracking systems. This study provides concrete evidence that novel flexible axis trackers substantially boost solar power generation, making them a highly efficient solution in solar energy technology.

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REFERENCES

[1] R. Abdallah, A. Juaidi, S. Abdel-Fattah, and F. Manzano-Agugliaro, "Estimating the optimum tilt angles for south-facing surfaces in Palestine," *Energies*, vol. 13, no. 3, p. 623, Feb. 2020, doi: 10.3390/en13030623.

[2] V. A. Kusuma, H. Aprillia, S. S. Suprapto, M. N. Ramadhani, A. A. Firdaus, and D. F. U. Putra, "Analysis of the effect of a microcontroller-based solar panel cooling system on temperature and power output," *International Journal of Applied Power Engineering (IJAPE)*, vol. 12, no. 2, pp. 119–125, Jun. 2023, doi: 10.11591/ijape.v12.i2.pp119-125.

[3] A. K. Yadav and H. Malik, "Optimization of tilt angle for installation of solar photovoltaic system for six sites in India," in *2015 International Conference on Energy Economics and Environment (ICEEE)*, Mar. 2015, pp. 1–4, doi: 10.1109/EnergyEconomics.2015.7235078.

[4] U. Agarwal *et al.*, "Adaptable pathway to net zero carbon: a case study for techno-economic & environmental assessment of rooftop solar PV system in university campus," *Energy Reports*, vol. 9, pp. 3482–3492, Dec. 2023, doi: 10.1016/j.egyr.2023.02.030.

[5] S. Bouguerra, M. R. Yaiche, O. Gassab, A. Sangwongwanich, and F. Blaabjerg, "Solar tracking system with photovoltaic cells: experimental analysis at high altitudes," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 9, no. 3, pp. 3114–3126, Jun. 2021, doi: 10.1109/JESTPE.2020.3006267.

[6] E. R. A. Larico and A. C. Gutierrez, "Solar tracking system with photovoltaic cells: experimental analysis at high altitudes," *International Journal of Renewable Energy Development*, vol. 11, no. 3, pp. 630–639, Aug. 2022, doi: 10.14710/ijred.2022.43572.

[7] D. Das, S. Madichetty, B. Singh, and S. Mishra, "Luenberger observer based current estimated boost converter for PV maximum power extraction-a current sensorless approach," *IEEE Journal of Photovoltaics*, vol. 9, no. 1, pp. 278–286, Jan. 2019, doi: 10.1109/JPHOTOV.2018.2877418.

[8] F. R. A. Bukit, S. Rambe, and R. Dinzi, "Comparison of single axis solar tracking system without sensor with LDR sensor and real time clock (RTC)," in *2023 7th International Conference on Electrical, Telecommunication and Computer Engineering (ELTICOM)*, Dec. 2023, pp. 254–259, doi: 10.1109/ELTICOM61905.2023.10443161.

[9] A. Devarakonda, N. Karuppiah, T. Selvaraj, P. Balachandran, R. Shanmugasundaram, and T. Senjyu, "A comparative analysis of maximum power point techniques for solar photovoltaic systems," *Energies*, vol. 15, no. 22, p. 8776, Nov. 2022, doi: 10.3390/en15228776.

[10] M. M. Farag *et al.*, "An optimized fractional nonlinear synergic controller for maximum power point tracking of photovoltaic array under abrupt irradiance change," *IEEE Journal of Photovoltaics*, vol. 13, no. 2, pp. 305–314, Mar. 2023, doi: 10.1109/JPHOTOV.2023.3236808.

[11] A. Fathy, A. G. Alharbi, S. Alshammari, and H. M. Hasanien, "Archimedes optimization algorithm based maximum power point tracker for wind energy generation system," *Ain Shams Engineering Journal*, vol. 13, no. 2, p. 101548, Mar. 2022, doi: 10.1016/j.asej.2021.06.032.

[12] D. Gielen, F. Boshell, D. Saygin, M. D. Bazilian, N. Wagner, and R. Gorini, "The role of renewable energy in the global energy transformation," *Energy Strategy Reviews*, vol. 24, pp. 38–50, Apr. 2019, doi: 10.1016/j.esr.2019.01.006.

[13] K. Kaldellis, J. Kalognomos, and A. Kaldellis, "An integrated optimum PV-based solution for urban households' energy autonomy, including clean electro-mobility," in *16th International Conference on Meteorology, Climatology and Atmospheric Physics—COMECAP 2023*, Oct. 2023, p. 209, doi: 10.3390/environsciproc2023026209.

[14] C. Jamroen, C. Fongkerd, W. Krongpha, P. Komkum, A. Pirayawaraporn, and N. Chindakham, "A novel UV sensor-based dual-axis solar tracking system: implementation and performance analysis," *Applied Energy*, vol. 299, p. 117295, Oct. 2021, doi: 10.1016/j.apenergy.2021.117295.

[15] C. Jamroen, P. Komkum, S. Kohsri, W. Himananto, S. Panupintu, and S. Unkat, "A low-cost dual-axis solar tracking system based on digital logic design: design and Implementation," *Sustainable Energy Technologies and Assessments*, vol. 37, p. 100618, Feb. 2020, doi: 10.1016/j.seta.2019.100618.

[16] R. B. Mansour, M. A. M. Khan, F. A. Alsulaiman, and R. B. Mansour, "Optimizing the solar PV tilt angle to maximize the power output: a case study for Saudi Arabia," *IEEE Access*, vol. 9, pp. 15914–15928, 2021, doi: 10.1109/ACCESS.2021.3052933.

[17] V. V. S. Murthy, "Estimation model on electricity generation from solar energy," *International Journal for Research in Applied Science and Engineering Technology*, vol. 9, no. 6, pp. 1353–1356, Jun. 2021, doi: 10.22214/ijraset.2021.35270.

[18] M. M. Farag, F. F. Ahmad, A. K. Hamid, C. Ghenai, and M. Bettayeb, "Real-time monitoring and performance harvesting for grid-connected PV system—A case in Sharjah," in *2021 14th International Conference on Developments in eSystems Engineering (DeSE)*, Dec. 2021, pp. 241–245, doi: 10.1109/DeSE54285.2021.9719385.

[19] N. Kumar, B. Singh, and B. K. Panigrahi, "LLMLF-based control approach and LPO MPPT technique for improving performance of a multifunctional three-phase two-stage grid integrated PV system," *IEEE Transactions on Sustainable Energy*, vol. 11, no. 1, pp. 371–380, Jan. 2020, doi: 10.1109/TSTE.2019.2891558.

[20] S. D. Riyanto, Supriyono, and F. Hazrina, "Optimizing of electric power solar cell by various angle using the activator panel based on the timer and light sensor," in *2018 International Conference on Applied Science and Technology (iCAST)*, Oct. 2018, pp. 109–114, doi: 10.1109/iCAST1.2018.8751564.

[21] P. Manoharan *et al.*, "Improved perturb and observation maximum power point tracking technique for solar photovoltaic power generation systems," *IEEE Systems Journal*, vol. 15, no. 2, pp. 3024–3035, Jun. 2021, doi: 10.1109/JSYST.2020.3003255.

[22] M. S. Farhan, M. H. Majhool, and H. Th. S. Alrikabi, "Using internet of things application for monitoring photo-voltaic panel based on ask sensors cloud," *Design Engineering*, pp. 3884–3896, Oct. 2021, doi: 10.17762/de.vi.5340.

[23] A. Ramschie, R. Katuuk, and S. Eksan, "IoT implementation for monitoring and controlling solar power plant systems," *International Journal of Computer Applications*, vol. 185, no. 37, pp. 23–31, Oct. 2023, doi: 10.5120/ijca2023923177.

[24] M. Elyaqouti, S. Hakim, S. Farhat, L. Bouhouch, and A. Ihlal, "Implementation in arduino of MPPT using variable step size P&O algorithm in PV installations," *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. 8, no. 1, pp. 434–443, Mar. 2017, doi: 10.11591/ijpeds.v8.i1.pp434-443.

[25] M. N. A. M. Said, S. A. Jumaat, and C. R. A. Jawa, "Dual axis solar tracker with IoT monitring system using arduino," *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. 11, no. 1, pp. 451–458, Mar. 2020, doi: 10.11591/ijpeds.v11.i1.pp451-458.

[26] S. Sumitaa, N. Goyal, M. Kumar, S. Bairwa, N. Soni, and S. Choudhary, "Effect of tilt angle of solar panel on power generation," *International Journal of Research Publication and Reviews*, vol. 5, no. 1, pp. 5975–5978, Jan. 2024, doi: 10.55248/gengpi.5.0124.0375.

[27] L. Sun, J. Bai, R. K. Pachauri, and S. Wang, "A horizontal single-axis tracking bracket with an adjustable tilt angle and its adaptive real-time tracking system for bifacial PV modules," *Renewable Energy*, vol. 221, p. 119762, Feb. 2024, doi: 10.1016/j.renene.2023.119762.

[28] A. Badhoutiya, "Evaluation of different methods used to clean solar panel surface," in *2023 Second International Conference on Electronics and Renewable Systems (ICEARS)*, Mar. 2023, pp. 46–48. doi: 10.1109/ICEARS56392.2023.10085478.

[29] S. A. Solarin, M. O. Bello, and F. V. Bekun, "Sustainable electricity generation: the possibility of substituting fossil fuels for hydropower and solar energy in Italy," *International Journal of Sustainable Development & World Ecology*, vol. 28, no. 5, pp. 429–439, Jul. 2021, doi: 10.1080/13504509.2020.1860152.

[30] Y. Zhu, J. Liu, and X. Yang, "Design and performance analysis of a solar tracking system with a novel single-axis tracking structure to maximize energy collection," *Applied Energy*, vol. 264, p. 114647, Apr. 2020, doi: 10.1016/j.apenergy.2020.114647.

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