200 WP Solar Panel Power Plant Optimization Using Dual Axis Solar Tracker System

by Erwan Eko Prasetiyo

200 WP Solar Panel Power Plant Optimization Using Dual Axis Solar Tracker System

Erwan Eko Prasetiyo[1], Gaguk Marausna[2], Dimas Wahyu Nugroho[3]

***Abstract*—Electrical energy is the main commodity used by almost all sectors of the economy. Therefore, the Indonesian people's demand for electrical energy is getting higher nowadays. The growing electricity demand is inversely proportional to the dwindling availability of fossil energy in the world. Energy sources from the sun can be utilized as alternative energy, both its radiation and thermal, to meet daily electrical energy demand. This study aims to optimize the electrical energy production from solar panels with a capacity of 200 WP by designing and implementing a dual axis solar tracker system on solar panels (photovoltaic). This research employed a mixed method approach, i.e., designing a solar tracker system experimentally by measuring the voltage and current values on solar panels, then calculating the electrical power generated by solar panels using solar tracker system control. After that, the calculation of electrical power generated by solar panels and electrical power used (load) by the solar tracker system to control the solar panel movement following the sunlight emission was conducted. Solar tracker controlled with a single axis produced an average voltage of 19.72 V, current of 1.34 A, and electrical power of 26.82 W, while solar tracker controlled with a dual axis generated an average voltage of 18.93 V, current of 1.9 A, and electrical power of 35.76 W. The test results showed that the total electrical power generated by solar panels with a single axis solar tracker system control system was 455.93 W and dual axis solar tracker system was 607.94 W. Data of testing results showed that the dual axis solar tracker system was able to optimize electrical energy production yielded by solar panels with a capacity of 200 WP.**

***Keywords*— Electrical Energy, Solar Panels, Solar Tracker, Single Axis, Dual Axis.**

I. Introduction

Electrical energy is the main commodity used by almost all economic sectors. The National Electricity Company (Perusahaan Listrik Negara, PLN) is intensively promoting electricity-saving initiatives for all levels of society, businesses, and government institutions due to the increasing demand for electrical energy by most of the Indonesian population [1]. Throughout the 21st century, the growing electricity demand is inversely proportional to the dwindling availability of fossil energy worldwide. In proportion to the electricity demand between 2000 to 2030, which reaches 70%, especially in industrialized countries, there is a need for new, more efficient, and environmentally friendly electricity sources as the main generation of electrical energy to support and maintain electricity demand at present and in the future [2]. Energy sources from the sun, both radiation and thermal, can be used as alternative energy to meet daily electricity demand because the new and renewable energy (NRE) that will never be used up is sourced from nature like the sun [3]. Located in the tropics and the equatorial area, Indonesia has a long tropical season; as a result, the sunlight emission in Indonesia lasts quite a long time throughout the year. Therefore, solar energy in Indonesia is ideally suited as alternative energy to meet daily electrical energy needs [4].

Geographically, all regions in Indonesia have immense potential to use solar panels (photovoltaic) to generate environmentally friendly electrical energy. In 2016, the Ministry of Energy and Mineral Resources (MEMR) allocated 1.4 trillion IDR to develop the NRE program by installing solar panels in offices, airports, and Correctional Institutions (LP) [5]. However, the current problem is that the utilized solar panels are still stationary or static. As a result, the sunlight energy absorption is still less than optimal [6]. Therefore, it is necessary to have a system that can control solar panels to move in the sunlight emission direction. Solar panels with a solar tracker control system are equipped with sensors as a light detector to read the highest sunlight intensity. In addition, they are also equipped with a microcontroller device to follow and absorb sunlight much more optimally and generate maximum electrical energy [7].

The solar tracker system is designed to increase the production of electrical energy generated by solar panels by following the direction of the sunlight emission from sunrise to sunset by positioning the solar panels perpendicular to the sun. From previous research, various types of solar tracker systems can be implemented, viz. using types of motors such as servo motors or linear actuators equipped with a light sensor and controlled automatically using Arduino microcontrollers [8], [9]. In addition, Arduino can also be connected to a WiFi module connected to the internet network for data communication based on the internet of things in sending data from the voltage and current value measurement results obtained by solar panels in real-time [10].

This study aims to optimize the production of electrical energy from solar panels with a capacity of 200 WP by designing and implementing a dual axis solar tracker system on solar panels. The analysis in this study was carried out by measuring the voltage and current values using a multimeter to determine the electrical power generated by solar panels with a dual axis solar tracker system. Then, the remaining electrical power that the solar tracker had used in controlling the solar panel movement was calculated to be utilized in daily electrical energy needs or implemented in other electrical energy uses.

[1,2,3] *Program Studi S1 Teknik Dirgantara, Sekolah Tinggi Teknologi Kedirgantaraan, Jl. Parangtritis Km 4,5 Sewon, Bantul, D.I. Yogyakarta 55187 Indonesia (tel.: 0274-418 248; fax: 0274-4396163; email: [1]erwan.eko@sttkd.ac.id, [2]gaguk.marausna@sttkd.ac.id, [3]180102041@students.sttkd.ac.id)*

[Received: 28 February 2022, Revised: 6 July 2022]

The discussion in this paper is limited to the wiring of the dual axis solar tracker system control system. The design of the dual axis solar tracker system was carried out using Arduino Uno as a microcontroller device, a light-dependent resistor (LDR) as a light detection sensor, a DC motor from the power window as a drive, and two solar panels with a capacity of 100 WP connected parallel to each other. In this design, LDR was chosen as a light sensor because it can read the direction of the sunlight movement from sunrise to sunset. The LDR is characterized by its not-too-fast light reception response, corresponding to the direction of the sunlight movement.

II. METHODOLOGY

This research employed a mixed methods approach, specifically by designing an experimental solar tracker system by measuring the voltage and current values on the solar panels and taking into account the electrical power that could be generated by solar panels. In converting solar energy into electrical energy using a solar tracker system. The circuit on this dual axis solar tracker system was made and simulated beforehand to determine its quality and ensure that the entire system and components could function properly and work optimally.

The solar tracker system was designed with manual control that could be used as a solution to adjust the solar panel position if, in its operation, the automatic solar tracker control experienced damage in the light sensor (LDR) or failure in the solar tracker automatic control system. This solar tracker control was divided into two movement systems in an automatic mode that can be controlled or changed using a switch, i.e., the DC motor single axis movement that drove the solar panel horizontally; and dual axis movement using two DC motors that drove the solar panels horizontally and vertically. In addition, a manual mode was used in the event of interference or failure in the solar tracker control system. In this mode, the solar tracker was controlled using four push-buttons programmed on the Arduino Uno microcontroller to alter the motor rotation direction. The purpose was to control the solar panel movements, horizontally to move upward and downward, and vertically to move westward and eastward according to the pressed keys.

A. *The Design of Dual Axis Solar Tracker System*

The control system on the solar tracker plays a role in the control process and serves as a sensor circuit. All necessary components were combined into a single control circuit. This dual axis solar tracker system circuit employed four LDRs. A 1 kΩ resistor was given to each LDR before being connected to the ground (-) and given a 5 V (+) voltage. Arduino programming on this design was used to configure a program that would later be inserted into the Arduino Uno microcontroller. The Arduino program served to initialize the pins used for the "HIGH" or "LOW" logic commands which would enable or disable the output of the used pins. In broad outline, the input and output parts of the solar tracker system are shown in Fig. 1. The pin input used on the Arduino Uno is pin A0 for reading LDR east, pin A1 for reading LDR west, pin

Fig. 1 Block diagram of input and output pin on Arduino Uno.

A2 for reading LDR top, and pin A3 for reading LDR bottom. The pin outputs on the Arduino Uno are connected in series to connect the circuit on the L298 push-button, switch, and motor driver [11]. Each Arduino pin output is connected to a push-button and the switch is given resistance in the form of a 10 kΩ resistor. Output pins on the Arduino Uno connected to the push-button and switch were pin 12 to push-button 1 (bottom), pin 8 to push-button 2 (top), pin 4 to push-button 3 (west), pin 2 to push-button 4 (east), pin 7 to switch 1 (manual/automatic mode), and pin 5 to switch 2 (single/dual axis mode). In addition to being connected to push-buttons and switches, the pin output on the Arduino Uno was also connected to the pin input of the L298 motor driver as a DC motor controller 1 and 2. The utilized Arduino Uno pin outputs were pin 13 to IN 1 (L298), pin 11 to IN 2 (L298), pin 10 to IN 3 (L298), and pin 9 to IN 4 (L298). In the L298 motor drive, there were two inputs as a voltage source (+) 12 V for the DC motor and 5 V for the L298 motor driver as well as the ground (-). In addition, a 5 V input was also connected to the ENA and ENB power inputs on the L298 motor driver input as power for the control system. The outputs on the L298 motor driver DC motor 1 were connected with Out 1 and Out 2, while DC motor 2 was connected with Out 3 and Out 4. All components used in this solar tracker system circuit were loaded into a printed circuit board (PCB) and placed in a panel box of control system wiring measuring 25 × 25 cm.

The design of this solar tracker system employed two types of polycrystalline solar panels as the main components of generating electrical energy, with a capacity of 100 WP each. The two solar panels were connected in parallel so that they had the same voltage, while the electric current of the two solar panels was the amount of current in ampere units of each employed solar panel.

The PowMr charge controller served to control the electricity charging from the solar panel to the battery/accumulator so that there was no overcharging. In PowMr, there was also a display to monitor the solar panel's electrical power, the ambient temperature, and the overall program when setting the charging system on PowMr. Before the electrical energy generated by the solar panel was used or utilized, the battery/accumulator used in the solar tracker system was connected to an inverter to convert the DC electricity stored in the battery/accumulator into AC electricity. All components used to process electrical energy generated by solar panels were installed on the panel box of power system wiring measuring 60 × 70 cm.

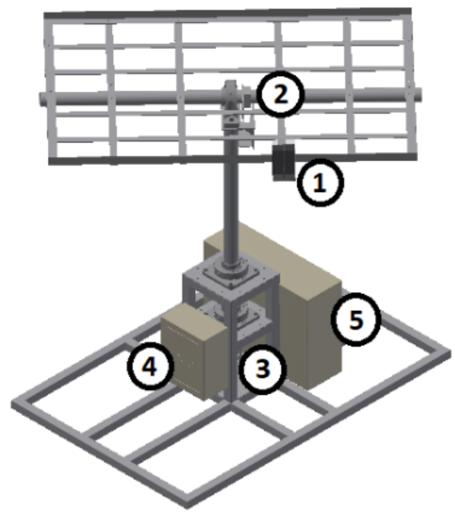
The materials used for the mechanical parts and frame structure were elbow iron, plate iron, strip plate iron, and pipe iron. In the solar tracker system, there were two working axes to move the solar panel following the sunlight emission direction from sunrise to sunset. The vertical axis working shaft employed pillow block bearings UCF 212 with a 68 mm custom gear that could rotate 360°. The horizontal axis working shaft employed pillow block bearings UCP212-36 with a 200 mm custom gear that could rotate 160°. All materials were joined together by welding all parts of the material components, and several parts were joined using bolts and clamps. The design of the dual axis solar tracker system and its parts are described according to the number shown in Fig. 2.

B. *Arduino Programming Algorithm*

The initial part of the Arduino Uno programming code (sketch) initialized the integer data used as input and output commands on the Arduino Uno mode pin with a serial data transmission and reception speed of 9,600 bps. Furthermore, if the program was run on an automatic control system to control the solar tracker system, there was an error value to align the solar panel angle to the sunlight emission direction. If the solar tracker were controlled using dual axis mode, the absolute value to determine the error in all four LDRs (top, bottom, west, and east) would be read by the Arduino program to determine the motor rotation direction and move the solar panel using two axes, i.e., vertical and horizontal axes. In addition, the solar tracker could be controlled automatically using single axis mode by reading the absolute values on the two LDRs (west and east) to move the solar panel using one axis, i.e., the horizontal axis. Some examples of dual axis solar tracker system program code are shown in Fig. 3.

If the value on the LDR west sensor is greater than that on the LDR east sensor, DC motor 1 will rotate on the vertical axis to move the solar panel westward. Conversely, if the value on the LDR west sensor is not much greater than the LDR east sensor value, the DC 1 motor will rotate on the vertical axis to move the solar panel eastward. In addition to being read by the dual axis mode, this command can also be read by the single axis mode on the solar tracker automatic control system. Next, if the value on the top LDR sensor is greater than the value of the bottom, the DC motor 2 will rotate on the horizontal axis to move the solar panel towards the top. Conversely, if the value on the top LDR sensor is not much greater than the value on the bottom LDR sensor, DC motor 2 will rotate on the horizontal axis to move the solar panel towards the bottom. If the absolute values of the four LDRs have the same value, DC motor 1 and DC motor 2 will stop rotating so that the solar panel is at a standstill.

The solar tracker can also be controlled using the manual control system. The program runs manual control by reading the conditions on all four push-buttons used to control the direction of rotation of DC motor 1 and DC motor 2 to drive the solar panel. If push-button 1 is active (on), the DC motor 2 will rotate on the horizontal axis to move the solar panel downward. Conversely, if push-button 1 is inactive (off) and push-button 2 is active, DC motor 2 will rotate on the horizontal axis to move the solar panel upward. Furthermore, if push-button 3 is in an active condition, the DC motor 1 will rotate on the vertical axis to move the solar panel to the west. Just like the conditions on push-button 1 and 2, if push-button 3 is inactive and push-button 4 is active, DC motor 2 will rotate on the horizontal axis to move the solar panel eastward. In manual control systems, if there is more than one push-button in active condition simultaneously to control the same DC motor, the DC motor cannot rotate to move the solar panel in a particular direction.



Notes:
1. LDR mount.
2. DC motor as a horizontal axis drive.
3. DC motor as a vertical axis drive.
4. Wiring panel solar tracker control system box.
5. Energy system wiring panel box.

Fig. 2 Mechanical design of dual axis solar tracker system.

```
onoffswitch = digitalRead(switch1Pin);
singledualswitch = digitalRead(switch2Pin);}
    onoffswitch = digitalRead(switch1Pin);
    singledualswitch = digitalRead(switch2Pin);
    while  (onoffswitch == HIGH & singledualswitch == HIGH )
     topldr = analogRead(A2);
     botldr = analogRead(A3);
     eastldr = analogRead(A0);
     westldr = analogRead(A1);

     tberror = (((topldr+westldr)/2) - ((botldr+eastldr)/2));
     tbposerror = abs(tberror);
     error = (((eastldr+topldr)/2) - ((westldr+botldr)/2));
     poserror = abs(error);
        if (poserror > 10){
```

Fig. 3 Programming code (sketch) of dual axis solar tracker system.

C. *Block Diagram of Dual Axis Solar Tracker System*

The configuration of solar power plants (*pembangkit listrik tenaga surya*, PLTS) applied in this dual axis solar tracker

p-ISSN 2301 – 4156 | e-ISSN 2460 – 5719

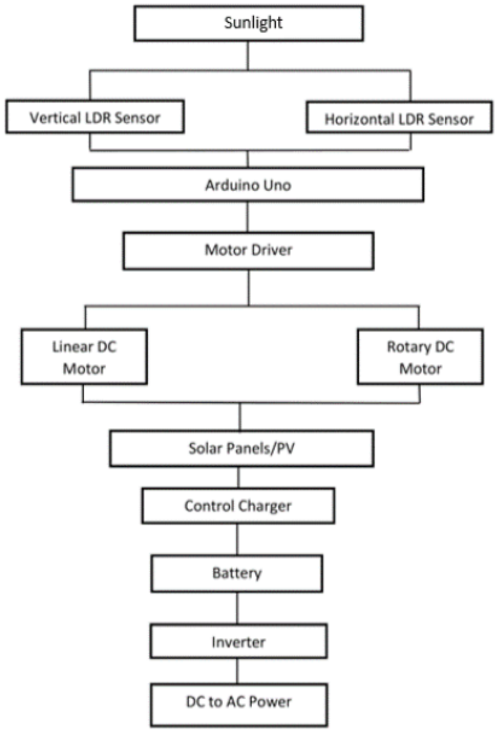


Fig. 4 Block diagram of a dual axis solar tracker system.

system was a centralized system (off-grid). The system utilized solar radiation to generate electricity using solar panels without being connected to the conventional electricity grid of the PLN. The system is also said to be the only main source of electricity generation using solar panels without any additional electricity input from other sources [12]. The design of the dual axis solar tracker system block diagram and its parts is shown in Fig. 4.

The working principle of the dual axis solar tracker system is described as follows. The LDR detects the highest sunlight intensity to direct the solar panel's movement following the direction in which it is positioned [13]. The Arduino Uno reads data from the LDR to operate the L298 motor driver and determines the direction of motor rotation. The DC motor coupled to the L298 motor driver will rotate on the vertical or horizontal axis according to the light intensity received by the LDR [14]. Energy from sunlight emitted by solar panels will be converted into electrical energy [15]. PowMr controls the voltage and current from the solar panel before being forwarded and stored on the battery/accumulator. The electrical energy stored in the battery/accumulator is converted from DC electricity to AC electricity using an inverter before being used or utilized in AC electrical devices [16].

III. Results and Discussion

The study's results were obtained from testing the solar tracker system on a sunny day when the sun shone optimally throughout the day. During testing, data collection and a

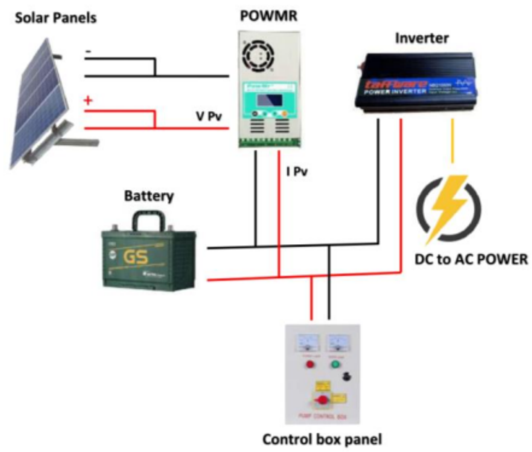


Fig. 5 PLTS wiring power system.

calculation of electrical power generated by solar panels using a single axis and dual axis solar tracker control system were conducted. Testing was carried out for 8 hours from 08:00 a.m. to 4:00 p.m. (western indonesia time) with seventeen time data collections. Testing was carried out on the 3rd floor of the Sekolah Tinggi Teknologi Kedirgantaraan Yogyakarta (STTKD) building.

The energy system wiring circuit of the solar tracker system design is shown in Fig. 5. V Pv is the value of the solar panel output voltage measured by PowMr, and I Pv is the value of the solar panel output current measured by PowMr. The voltage and current values of the solar panel were observed by looking at the values displayed on the PowMr display. PowMr automatically measured these output voltages and currents before being forwarded to the battery/accumulator.

A. *Testing Procedure*

The program code was uploaded to the Arduino Uno contained in the box of the solar tracker control system wiring panel. Furthermore, all jumper cables on the battery/accumulator, socket, and all cables on the terminal were installed. The cable circuit existing on the panel box of power system wiring was installed in sequence. The jumper cable on the battery/accumulator was installed beforehand, and then it was continued by connecting the solar panel power cable on the terminal to PowMr. In the initial testing, the solar panel's position was automatically set using the solar tracker control system single axis system to move on the horizontal axis following the sunlight emission direction. In the second test, the solar panel's position was automatically set using the dual axis solar tracker system control system to move with two axes, vertical and horizontal. This step was done to detect the direction of the best sunlight emission in generating electrical energy. The next step was to observe all movements of the single axis and dual axis solar tracker system and record all result data listed on the PowMr and AVO meter displays. After the test was complete, all jumper wires and cables on the panel box were removed back in sequence, from the solar panel wires

TABLE I
SINGLE AXIS SOLAR TRACKER SYSTEM TESTING RESULTS

No	Time	Voltage Pv (V)	Current Pv (A)	Power Pv (W)
1.	8:00 a.m.	20.30	1.10	22.33
2.	8:30 a.m.	19.00	1.20	22.80
3.	9:00 a.m.	20.20	3.30	66.66
4.	9:30 a.m.	20.10	0.90	18.09
5.	10:00 a.m.	19.40	1.70	32.98
6.	10:30 a.m.	20.00	0.60	12.00
7.	11:00 a.m.	20.00	0.60	12.00
8.	11:30 a.m.	20.50	0.60	12.30
9.	12:00 a.m.	20.20	2.00	40.40
10.	12:30 p.m.	19.00	2.10	39.90
11.	13:00 p.m.	20.60	2.10	43.26
12.	13:30 p.m.	20.10	2.10	42.21
13.	14:00 p.m.	20.50	2.60	53.30
14.	14:30 p.m.	20.00	0.50	10.00
15.	15:00 p.m.	18.90	0.50	9.45
16.	15:30 p.m.	18.60	0.50	9.30
17.	16:00 p.m.	17.90	0.50	8.95
Average		19.72	1.34	26.82

TABLE II
DUAL AXIS SOLAR TRACKER SYSTEM TESTING RESULTS

No.	Time	Voltage Pv (V)	Current Pv (A)	Power Pv (W)
1.	8:00 a.m.	17.30	3.8	65.74
2.	8:30 a.m.	20.10	3.9	78.39
3.	9:00 a.m.	20.00	1.9	38.00
4.	9:30 a.m.	19.70	0.8	15.76
5.	10:00 a.m.	19.50	0.7	13.65
6.	10:30 a.m.	19.20	0.6	11.52
7.	11:00 a.m.	19.60	0.8	15.68
8.	11:30 a.m.	19.20	1.2	23.04
9.	12:00 a.m.	18.50	1.3	24.05
10.	12:30 p.m.	19.80	4.2	83.16
11.	13:00 p.m.	18.20	4.8	87.36
12.	13:30 p.m.	18.30	2.0	36.60
13.	14:00 p.m.	17.80	1.6	28.48
14.	14:30 p.m.	14.90	1.4	20.86
15.	15:00 p.m.	19.70	1.2	23.64
16.	15:30 p.m.	20.10	1.1	22.11
17.	16:00 p.m.	19.90	1.0	19.90
Average		18.93	1.9	35.76

to the PowMr wires. This step was performed to protect the PowMr from damage.

B. *Single Axis Solar Tracker System Testing*

This testing employed a single axis system solar tracker control system. The resulting data are presented in Table I. In this testing, the solar panel only moved on one axis, the horizontal axis. The solar panel movement followed the sunlight emission direction read by the LDR from sunrise to sunset. Table I shows that a single axis controlled solar tracker generated an average voltage of 19.72 V, a current of 1.34 A, and electrical power of 26.82 W.

C. *Dual Axis Solar Tracker System Testing*

This testing employed a dual axis solar tracker control system. The generated data are presented in Table II. In this testing, the working principle of the dual axis solar tracker system remained the same as that of the single axis solar tracker system. The solar panel moved following the sunlight emission direction read by the LDR. The difference is that solar panels were driven on two axes, vertical and horizontal, following the sunlight emission direction. The data in Table II shows that the dual axis controlled solar tracker generated an average voltage of 18.93 V, a current of 1.9 A, and electrical power of 35.76 W.

D. *Power Calculation Analysis*

The testing results showed a dissimilarity in the performance of the single axis solar tracker system and the dual axis solar tracker system in generating electricity from solar panels. Based on the data in Table I and Table II, it can be seen that using a dual axis solar tracker system can optimize the electrical energy production on solar panels with a capacity of 200 WP. A solar tracker system operated in a dual axis can generate an average electrical power of 35.76 W (observed every half hour). In comparison, a solar tracker system which was operated on a single axis only generated an average electrical power of 26.82 W (observed every half hour). A comparison of the electrical power generated by these two systems is presented in Fig. 6.

Based on graph data in Fig. 6, the testing results show that the total electrical power generated by solar panels with single-axis and dual axis solar tracker control systems was 455.93 W and 607.94 W, respectively. The generated electrical power has not been reduced by the power used by the solar tracker system to control the DC motor. The power consumption used by the single axis solar tracker system to control the movement of solar panels on one axis can be calculated using (1).

$$P_{load} = V \times I_{load}$$
$$P_{load} = 13.56 \times 0.09 \quad (1)$$
$$= 1.2\,W.$$

The electrical power that can be utilized from solar panels with a single axis solar tracker system control system can be calculated using (2).

$$P_{out} = P_{tot} - P_{load}$$
$$P_{out} = 455.93 - 1.2 \quad (2)$$
$$= 454.73\,W.$$

Furthermore, the power consumption used by the dual axis solar tracker system to control the movement of solar panels with two axes can be calculated by (1).

$$P_{load} = V \times I_{load}$$
$$P_{load} = 13.30 \times 0.50$$
$$= 6.65\,W.$$

p-ISSN 2301 – 4156 | e-ISSN 2460 – 5719

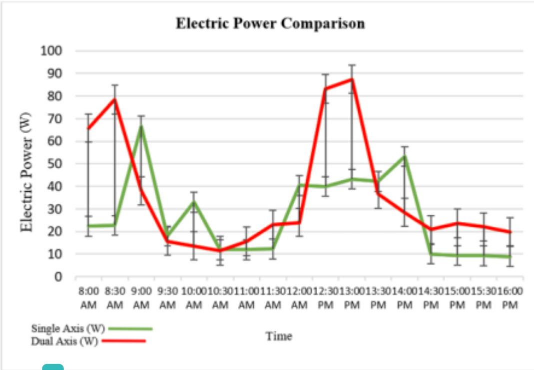


Fig. 6 Comparison of electrical power generated by solar panels using a solar tracker control system.

The electrical power that can be utilized from solar panels with a dual axis solar tracker system control system can be calculated using (2).

$$P_{out} = P_{tot} - P_{load}$$

$$P_{out} = 607.94 - 6.65$$

$$= 601.29 \text{ W}.$$

Based on the testing results data of the performance of the single axis solar tracker system and the dual axis solar tracker system, it can be seen that the dual axis solar tracker system can optimize the production of electrical energy produced by solar panels with a capacity of 200 WP, compared to previous studies that only designed simulated solar tracker using LDR and linear actuators to move solar panels with one axis following the sunlight emission direction [14]. Solar panels with a capacity of 50 WP were used in [14], while in this study, two solar panels with a capacity of 100 WP were connected in parallel. The total capacity of solar panels in this study reached 200 WP. LDR was employed to detect the sunlight emission direction, and DC motors were used as vertical and horizontal axis shaft drivers.

IV. Conclusion and Suggestion

After carrying out the design and testing, as well as implementing the solar tracker system, several conclusions can be drawn about this research. The single-axis solar tracker system can generate an average voltage of 19.72 V, a current of 1.34 A, and electrical power of 26.82 W, while the dual axis solar tracker system can generate an average voltage of 18.93 V, a current of 1.9 A, and electrical power of 35.76 W. From the 8-hour testing with seventeen times data collection, the total electrical power was obtained using the single axis and dual axis solar tracker system control systems, namely 455.93 W and 607.94 W. The electrical power that can be utilized for daily electrical energy needs after deducting the power of the solar tracker control system is 454.73 W on the single axis solar tracker system and 601.29 W on the dual axis solar tracker system.

Based on the data from the measurement results and calculations of the performance of the solar tracker system, it can be concluded that the dual axis solar tracker system can optimize the production of electrical energy generated by solar panels with a capacity of 200 WP, compared to a single axis solar tracker system. For further development of the results of this study, it is recommended that the LDR be given the addition of a light reflector so that the light sensor is more optimal when absorbing sunlight. Other types of light sensors, such as photodiodes, can also be used.

Conflict of Interest

The authors had no conflict of interest with any parties while researching and writing the paper titled "200 WP Solar Panel Power Plant Optimization Using Dual Axis Solar Tracker System."

Author Contribution

Here is how each author contributed to this research. Conceptualization, Erwan Eko Prasetiyo and Gaguk Marausna; Methodology, design of solar tracker device and control systems, Dimas Wahyu Nugroho; writing, drafting the original draft, Erwan Eko Prasetiyo and Dimas Wahyu Nugroho; data collection, Gaguk Marausna.

Acknowledgment

Gratitudes are expressed to the Sekolah Tinggi Teknologi Kedirgantaraan (STTKD) Yogyakarta for the assistance and financial support in the implementation of the Merdeka Belajar Kampus Merdeka (MBKM) research scheme.

References

[1] G.B. Ardina, "Rancang Bangun Dual Axis Solar Tracker Pembangkit Listrik Tenaga Surya Berbasis Mikrokontroler Arduino Uno," Result Seminar, Institut Teknologi Nasional Malang, Malang, Indonesia, 2019.

[2] W. Saputra, "Rancang Bangun Solar Tracking System untuk Mengoptimalkan Penyerapan Energi Matahari pada Solar Cell," Undergraduate thesis, Universitas Indonesia, Jakarta, Indonesia, 2008.

[3] S. Hutasuhut, "Perancangan Pembangkit Listrik Tenaga Surya (PLTS) sebagai Sumber Energi Lampu LED Superbright dan Pompa Air DC pada Kolam Ikan Mas," Final project, Universitas Muhammadiyah Sumatera Utara, Medan, Indonesia, 2021.

[4] A.S. Anwar, "Analisis Kelayakan Pembangkit Energi listrik Tenaga Surya Rooftop di Gedung Fakultas Teknik Universitas Siliwangi," Undergraduate thesis, Universitas Siliwangi, Tasikmalaya. Indonesia, 2021.

[5] Suwito, Suhanto, and Kustori, "Sistem Baterai Charging pada Solar Energy System dengan Buck Boost Converter untuk Berbagai Tingkat Pencahayaan di Bandar Udara," *J. Teknol. Penerbangan*, Vol. 1, No. 1, pp. 39–48, Apr. 2017.

[6] K.W. Fauzi, T. Arfianto, and N. Taryana, "Perancangan dan Realisasi Solar Tracking System untuk Peningkatan Efisiensi Panel Surya Menggunakan Arduino Uno," *TELKA: J. Telekomun. Elektron. Komput., Kontrol*, Vol. 4, No. 1, pp. 63–74, May 2018.

[7] H.E. Santoso, "Rancang Bangun Solar Tracking System Menggunakan Kontrol PID pada Sumbu Azimuth," Final project, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia, 2014.

[8] J. Rezkyanzah, L.P. Purba, and C.A. Putra, "Perancangan Solar Tracker Berbasis Arduino sebagai Penunjang Sistem Kerja Solar Cell dalam Penyerapan Energi Matahari," *Scan: J. Teknol. Inf., Komun.*, Vol. 11, No. 2, pp. 55–60, Jun. 2016.

[9] S.H. Budi, "Pengembangan Solar Tracker Single Axis Berbasis Arduino untuk Meningkatkan Perolehan Energi Matahari," *J. ESDM*, Vol. 7, No. 2, pp. 82–86, Nov. 2015.

[10] A.S. Syahab, H.C. Romadhon, and M.L. Hakim, “Rancang Bangun Solar Tracker Otomatis pada Pengisian Energi Panel Surya Bebasis Internet of Things,” *J. Meteorol. Klimatol., Geofis.*, Vol. 6, No. 2, pp. 21–29, Sep. 2019.

[11] Q. Hidayati, N. Yanti, and N. Jamal, “Sistem Pembangkit Panel Surya dengan Solar Tracker Dual Axis,” *Pros. Sem. Nas. Inov. Teknol. Terapan Politeknik Negeri Balikpapan*, 2020, pp. 68–73.

[12] A.W. Hasanah, T. Koerniawan, and Y. Yuliansyah, “Kajian Kualitas Daya Listrik PLTS Sistem Off-Grid di STT-PLN,” *J. Energi Kelistrikan*, Vol. 10, No. 2, pp. 93–101, Sep. 2019.

[13] M. Margana, “Solar Tracking Dual – Axis Berbasis Arduino Uno dengan Menggunakan Lensa Fresnel Guna Meningkatkan Efisiensi Pengfokusan Cahaya Matahari,” *EKSERGI: J. Tek. Energi*, Vol. 15, No. 2, pp. 77–80, May 2019.

[14] A.M. Putra and Aslimeri, “Sistem Kendali Solar Tracker Satu Sumbu Berbasis Arduino dengan Sensor LDR,” *JTEV (J. Tek. Elektr., Vokasional)*, Vol. 6, No. 1, pp. 322–327, Feb. 2020.

[15] J. Asmi and O. Candra, “Prototype Solar Tracker Dua Sumbu Berbasis Microcontroller Arduino Nano dengan Sensor LDR,” *JTEV (J. Tek. Elektr., Vokasional)*, Vol. 6, No. 2, pp. 54-63, May 2020.

[16] M.H. Prayogo, “Implementasi Sistem Kontrol dan Proteksi Pembangkit Photovoltaic Skala Kecil,” Undergraduate thesis, Institut Teknologi Nasional Malang, Malang, Indonesia, 2019.

200 WP Solar Panel Power Plant Optimization Using Dual Axis Solar Tracker System

ORIGINALITY REPORT

16%	8%	13%	6%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Singgih Hawibowo, Imadudin Ala, Rachmana Berlindo Citra Lestari, Fahmy Rinanda Saputri. "Stepper Motor Driven Solar Tracker System for Solar Panel", 2018 4th International Conference on Science and Technology (ICST), 2018 Publication	2%
2	Submitted to Universitas Mercu Buana Student Paper	2%
3	A Setyawan, T Sutandi. "Off-grid solar power plant for refrigeration system: A case study in Bandung, Indonesia", IOP Conference Series: Materials Science and Engineering, 2020 Publication	1%
4	Submitted to Forum Perpustakaan Perguruan Tinggi Indonesia Jawa Timur III Student Paper	1%
5	Sandeep D. Hanwate, Yogesh V. Hote. "An Optimal Control Design for Solar Tracker System via Contrast Controller Approach",	1%

2022 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES), 2022
Publication

6	eudl.eu Internet Source	1 %
7	N. Othman, M.I.A. Manan, Z. Othman, S.A.M. Al Junid. "Performance analysis of dual-axis solar tracking system", 2013 IEEE International Conference on Control System, Computing and Engineering, 2013 Publication	1 %
8	jurnal.polines.ac.id Internet Source	1 %
9	Parija Gupta, Vinay Gupta, Madhu Sharma, Rupendra K Pachauri, Jamil Akhtar. "Design and Performance Analysis of Three axis Solar Tracking System", 2022 7th Asia Conference on Power and Electrical Engineering (ACPEE), 2022 Publication	1 %
10	Dian Wahyu Widyanto, Danar Susilo Wijayanto, Cucuk Wawan Budiyanto, Soenarto, Mochammad Bruri Triyono. "Comparison Study of Solar Panels with Horizontal Turbine as an Alternative Electric Energy Source", Journal of Physics: Conference Series, 2021	1 %

Publication

11	www.raysolar.com Internet Source	1 %
12	H M Deepika Jain, N Harshitha, K Padmavathi, R M Suprita, G Maya. "Simulation study of FLC based MPPT for unshaded and partially shaded PV system", 2021 International Conference on Computational Performance Evaluation (ComPE), 2021 Publication	<1 %
13	Submitted to Higher Education Commission Pakistan Student Paper	<1 %
14	www.journal.ugm.ac.id Internet Source	<1 %
15	N U C Suhartaya, R Rochmadi. "The effect of pH upon corrosion rate of aircraft component type MD 80 on fuselage part", IOP Conference Series: Materials Science and Engineering, 2020 Publication	<1 %
16	Muhammad Abdul Rafiq Septiyanto, Indreswari Suroso, Noviana Utami. "Analisis kekerasan dan keausan bearing pada pesawat Cessna Grand Carravan 208B", Turbo : Jurnal Program Studi Teknik Mesin, 2022 Publication	<1 %

17	Submitted to Asia Pacific University College of Technology and Innovation (UCTI) Student Paper	<1 %
18	Submitted to Universiti Tenaga Nasional Student Paper	<1 %
19	Submitted to Anglia Ruskin University Student Paper	<1 %
20	Submitted to Institute of Research & Postgraduate Studies, Universiti Kuala Lumpur Student Paper	<1 %
21	Submitted to The Hong Kong Polytechnic University Student Paper	<1 %
22	Submitted to University of Sunderland Student Paper	<1 %
23	Submitted to Institute of Technology, Sligo Student Paper	<1 %
24	pingpdf.com Internet Source	<1 %
25	"Advances in Smart Communication Technology and Information Processing", Springer Science and Business Media LLC, 2021 Publication	<1 %

26	I W Ratnata, S Sumarto, W S Saputra. "Prototype of Pico Hydro – Solar Photovoltaic Hybrid System", IOP Conference Series: Materials Science and Engineering, 2018 Publication	<1 %
27	iesr.or.id Internet Source	<1 %
28	Zahra Fakhroueian, Alireza Massiha, Pegah Esmaeilzadeh, Mehdi Assmar et al. "<i>In Vivo</i> Animal Model Evaluation of a Powerful Oral Nanomedicine for Treating Breast Cancer in BALB/c Mice Using 4T1 Cell Lines without Chemotherapy", Advances in Nanoparticles, 2022 Publication	<1 %
29	repository.umsu.ac.id Internet Source	<1 %
30	www.e3s-conferences.org Internet Source	<1 %

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		