Design of Open Loop Single Axis Solar Tracker System

Rizal Rinaldi 1, Bandiyah Sri Aprillia1,2, Cahyantari Ekaputri 1, Muhamad Reza1
1School of Electrical Engineering, Telkom University, Bandung, Indonesia
2bandiyah@telkomuniversity.ac.id

Abstract. The amount of power output in a solar power system depends on the intensity of solar radiation. The earth's movements however cause changes in the intensity of solar radiation received by solar panels on the daily. Therefore, the implementation of a controller that can track the position of the sun (solar tracker) is believed to increase the power output of solar panels. This research focuses on the design of a photovoltaic panel drive system using an Android-based application as a monitoring media. The application is used to monitor the current temperature and provide a desired angle input. Based on the test results, the average power output of a fixed PV reached only 17.15 Watt, while on a single axis PV, average output reached 21.50 Watt. It can be concluded that in the single axis PV, average power output increased by more than 25% compared to the fixed PV.

1. Introduction
Indonesia is a tropical country that has solar radiation intensity exposure reaching 4 kWh / m² / day in each area [1]. Thus, to take advantage of this fact, technology to convert solar energy into electrical energy has been widely implemented in Indonesia. One of the means of converting solar radiation into electrical energy commonly used are solar panels. Solar panel is a device consisting of several semiconductor-based solar cells that are able to convert sunlight radiation into electrical energy based on the principle of the photovoltaic effect. In general, solar power integration can be connected on-grid or standalone [2-4]. In standalone solar power systems, solar panels are connected to batteries or other energy storage media to be connected to a converter to meet load requirements [5]. On-grid solar power systems on the other hand involve solar panels being connected to the State Power Plant (PLN) network. The implementation of electric energy source control methods in an on-grid solar power system can also improve the efficiency of energy use, because energy flow can be adjusted according to load requirements [2, 6].

The amount of power output in a solar power system depends on the intensity of solar radiation [7, 8]. The earth's movements however cause changes in the intensity of solar radiation received by solar panels on the daily. Therefore, the implementation of a controller that can track the position of the sun (solar tracker) is believed to increase the output power of solar panels. In theoretical analysis and experimental evidence, the solar tracker is able to increase the output power of solar panels by up to 60% [9, 10].

To produce optimal power from photovoltaics we can use a control system that functions as a driving and monitoring. This research focuses on the design of a photovoltaic panel drive system using an Android-based application as a monitoring media. The android application is used to monitor the current temperature and provide the desired angle input.
2. Method

A single axis solar tracker is controlled by an open loop control system. Mechanical parts are used by servo motors that are connected to bike wheels to make solar panels move to follow the sun’s movements. Bike gear is used to reduce torque load on servo motors.

It is important to use gear because they are engine elements used to transmit motion and power from one shaft to another without slippage. The use of gear transmission is the appropriate choice because the distance between the drive and the driven components are not far apart, making it compact. For this study, straight gears are used. Using 15 gear drivers, for 18 gear driven drives, the gear ratio is 15/18 = 0.83. The gear driver rotates 1.2 times for every 1 gear driven rotation.

Connections between gears are maintained by using a belt (chain). The chain reduces slip between gears. The gear chain uses iron to reduce maintenance costs. To determine the length of the belt:

\[
L = \pi (r_1 + r_2) + 2x + \left(\frac{(r_1 - r_2)^2}{x}\right)
\]

where:

- \(x\) = shaft axis distance (mm)
- \(r_1\) = small shaft radius (mm)
- \(r_2\) = large shaft radius (mm)
- \(L\) = belt length (mm)

Therefore, the length of the belt (chain) is 133.97 cm

![Figure 1. Block diagram of a single axis PV drive system.](image)

The application used in this Android-based system can be controlled via mobile phones. In the app, there are features which can control the angle and monitor the temperature readings on the panel. Controls from the smartphone are very important because temperature and PV angle can greatly affect the output voltage generated by the panel.

The use of node MCU on the system is intended as communication media with the microcontroller. This communication uses the application media on mobile phones. Smartphones would send data through the application and then forward it to the controller. The data sent would be processed by node MCU and produce an angular output.

This system uses a motor as a drive which can later move the plan to a system in the form of a 100 Wp solar panel with a mass of 7 kg. Servo motor specifications on the system have a torque that can rotate that weighs 23 kg and can rotate up to 180 degrees of angle. The PV position would be adjusted to correspond to the input command given by the application and driven by a servo motor.
Based on Figure 2, the system will identify the angle value. Furthermore, this angle value is in the form of data sent through the mobile application and then processed by the controller. If the data has reached the controller, the data in the form of an angle value will be a reference to the system. The servo will move if there is a deviation from the reference angle value and will adjust back. This angle will affect the position of the panel so that the resulting output voltage is always at maximum values.

Figure 2. System Flowchart
Figure 3. Overall Drive System Mechanism Design

Figure 3 represents a mechanical merging of the whole system that has been connected with solar panels, modules and a 23 kg servo motor. In this mechanism, both sides of the triangle can be folded and then inserted into the iron beam at the bottom.

3. RESULT AND DISCUSSION

Figure 4. Testing of Angle Validation and Potentiometers.
Based on Figure 4, it can be seen that the error in an open loop drive system compared to the results entered from the application with an angle value has an average error value of 1.94% and compared with a potentiometer reaching an average error value of 1.4%. This error value is obtained from the average value of the whole test.

![Figure 5. Solar Panel Power Output untracking and tracking systems.](image)

To measure the power output between a fixed and single axis PV as in Figure 5, current and voltage measurements are taken. Figure 5 shows a slight increase in power output for the single axis PV.

![Figure 6. Statistical study of Solar Panel Power Output for untracking and tracking systems.](image)

To investigate variations in solar panel output during the day, statistical studies have been provided in Figure 6. In general, the distance between the various parts of the box shows the degree of spread
and slope in the data, and shows the outlier. In addition, from the bottom up, each line represents the minimum value, the bottom quartile, the median upper quartile, and the maximum values respectively [11]. An average power output of 17.15 Watt is obtained from the fixed system, while the single axis system shows an average power output of 21.50 Watt. An increase of more than 25% for the single axis systems

4. CONCLUSION

Based on the results of testing a single axis PV drive system, the error in the open loop drive system compared to the results entered from the application with angle values has an average error value of 1.94% and compared with a potentiometer reaching an average error value of 1.4%. This error value is obtained from the average value of the whole test. The average power output in the fixed system reached 17.15 Watt, while in the single axis system the average power output reached 21.50 Watt. It can be concluded that in the single axis system the average power output has increased by more than 25% compared to the fixed system.

References

[1] N. Handayani, and D. Ariyanti 2012 Potency of solar energy applications in Indonesia. *International Journal of Renewable Energy Development* 1(2) 33-38.
[2] Rahmawati, D., et al. 2020 Design of Automatic Switch System of Solar Panel and Power Plant for Residential Load using Artificial Neural Network *MS&E* 771(1): p. 012008.
[3] Aprillia, B.S. and M.A.F. Rigoursyah 2020 Design On-Grid Solar Power System for 450 VA Conventional Housing using HOMER Software *MS&E*.
[4] Al Nabulsi, A. and R. Dhaouadi, 2012 Efficiency optimization of a DSP-based standalone PV system using fuzzy logic and dual-MPPT control *IEEE Transactions on Industrial informatics* 8(3) 573-584.
[5] Afif, A., B. Aprillia, and W. Priharti, 2020 Design and Implementation of Battery Management System for Portable Solar Panel with Coulomb Counting Method *MS&E*.
[6] Silalahi, D., et al. 2020 Design of Automatic Switch System of Residential Load From Solar Cell and Power Plant Resources using Neural Network *MS&E* 771(1) p. 012006.
[7] Aprillia, B.S., M.R. Zulfihami, and A. Rizal, 2019 Investigasi Efek Partial Shading Terhadap Daya Keluaran Sel Surya *Jurnal Elektro dan Mesin Terapan* 5(2) 9-17.
[8] Tan, D.W.W.W 2006. A simplified type-2 fuzzy logic controller for real-time control *ISA transactions* 45(4) 503-516.
[9] Fuentes, M., et al. 2014 Design of an accurate, low-cost autonomous data logger for PV system monitoring using Arduino™ that complies with IEC standards *Solar Energy Materials and Solar Cells* 130 529-543.
[10] Purwadi, A., et al. 2011 Prototype development of a Low Cost data logger for PV based LED Street Lighting System *Proceedings of the 2011 International Conference on Electrical Engineering and Informatics*.
[11] Pangaribuan, P., B. Aprillia, and A. Wibowo 2020 Automatic Gate System Based on Water Flow Within the Intake of a Micro-Hydro Power Plant. *MS&E* 771(1) p. 012004,