PID Controller Design for Solar Tracking System

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Abstract: The aim of this research is to design solar tracking in order to orientate the solar panel to the maximum radiation at all times. In the present work, designing of an optimum proportional-integral-derivative (PID) controller is used to control a dual axis solar tracker system, namely: rotation and elevation. To obtain the optimum result, two kinds of testing were conducted, namely, testing of mechanical design and PID parameters. As a result, the mechanical testing indicated that this system can work properly based on the parameters input. Similar to the PID testing, the response of PID set point with set position rotation and elevation according to the parameters input. In addition, this research was conducted in an electrical power system Laboratory in the State Polytechnic of Ujung Pandang, Makassar, Indonesia.

1 INTRODUCTION

Renewable energy is a significant factor in solving the energy problems of the world. Renewable energy, such as solar energy, will be consistently cheaper than fossil fuels. Applying renewable energy to overcome the lack of electricity sources is cheaper than connected electricity from the utility. According to (Kåberger, 2018) renewable electricity is now starting to replace fossil fuels in other sectors as the principal low cost factor. Supporting the development of renewable energy technology can reduce their costs through economies of scale (Foster et al., 2017).

Renewable energy technology is a cleaner source than fossil energy technology. It has brought impact to the environmental side. The renewable energy technology has a lower environmental impact than fossil energy technology. According to (A.K.Akella, R.P.Saini, & M.P.Sharma, 2009) fossil energy sources are effective drivers to develop an economy for a society, however at the same time it can damage the environment and human health. In addition, renewable energy is an effective alternative for reducing air pollution and preventing resources depletion (C.Cosmi et al., 2003).

Some examples of renewable energy are: solar energy, wind energy and hydropower. Solar energy is an effective way keep the environment healthy as it does not produce water or air pollution. The authors in (A.H.Almasoud & M.Gandayh, 2015) argue that the cost of solar energy is cheaper than fossil fuels when the indirect cost created by fossil fuel generation includes health and environmental costs.

In China, the cost of solar power delivery to the large cities is around 20 $c/kWh (Labordena & Lilliestam, 2015). Similarly, in USA, the cost of solar energy ranges from 18 to 23 ¢/kWh, with the expectation that it will decrease to 5–10 ¢/kWh by 2015 (A.H.Almasoud & M.Gandayh, 2015). In addition, the cost of renewable energy including solar and wind energy is approximately $0.326 per kWh in South Korea (Park & Kwon, 2016). However, the energy cost for solar energy in Indonesia ranges from US$ 0.145 – 0.25/kWh (Hamdi, 2019).

Conversely,, applying solar energy in Indonesia has not been optimized. Some factors have been influenced by policy, location and technology. Improving technology to optimize solar energy has been required to get maximum power, particularly developing technology to get maximum power from the sun. Current technology only puts the photovoltaic cells on roofs. However, it is not effective in the afternoon or in the morning.

Controlling solar tracking is needed to get optimum result from the sun. Solar tracking assists to minimize the angle of incidence. Solar trackers create more electricity than stationary counterparts

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due to increased direct exposure to solar rays. On the other hand, solar trackers are slightly more expensive than stationary counterparts, due to the more complex technology and moving parts necessary for their operation.

Solar tracking systems are the best potential methods for solar power collection (Zheng, Zheng, Ji, & Niu, 2019). According to (Kim & Cho, 2019) in order to operate most efficiently, solar tracking systems must be installed to achieved an optimal tilt of solar panels. Solar tracking is a type of technical performance to achieve solar radiation by tracking the position of the sun accurately, considering various climate changes (Hyuna, Taehoon, & LeeMinhyun, 2019).

A PID controller is a smart control to manage the tracking system of the sun. This method was developed to get an accurate position of the tracking system. PID is a control loop mechanism employing feedback that is widely used in industrial control systems and a variety of other applications requiring continuously modulated control.

2 LITERATURE REVIEW

Some researchers have been investigated strategies to control sun tracking, for example, the solar central receiver developed by (Hu, Shen, & Yao, 2018) to define the tracking formula of the sun tracking strategy by using the coordinate rotation transformation method. The simulated result illustrated this method can improve the concentration efficiency of solar central receiver. Other researchers have developed a sun tracking design in Tunisia for a solar parabolic (Skouri, Ali, Bouadila, Salah, & Nasrallah, 2016). To design a new solar parabolic, the parameters of solar radiation and angle values were required to operate in more efficient and feasible ways. In addition, according to (Singh, Kumar, Gehlot, & Pachauri, 2018) the efficiency of the photovoltaic system can then be achieved by managing the tracking position of the sun. In this study, the solar tracking was developed by Programmable Logic Control (PLC), microcontroller and Field Programmable Gate Array (FPGA). The microcontroller applied according to the capacity and location has installed the solar tracking. The PLC is designed to assess the economic aspects.

A new concept of solar detection was developed by (Away & M.Ikhsan, 2017). This study described solar detection sensor by using a dual-axis sun tracking system. This design compares with other previous types, consequently, this sensor has a high quantity, accuracy and effectiveness, as shown in other research (Sinha & S.S.Chandel, 2016). It has developed two axes tracking compared with all tracking systems and fixed tilted photovoltaic system. The result of the research indicated that the horizontal axis generates 4.8 %-26.2 9% more energy per year than the existing fixed tilt photovoltaic system. This methodology has been improved and recommended to apply in any location in the world. However, none of these methods have been mentioned above applied solar tracking by using a PID controller.

A study of the PID controller has been illustrated in some references in (M.Mosaad, A.Attia, & Y.Abdelaziz, 2019; Pradhan, Majhi, KuPradhan, & Pati, 2018). Author in (B.Rabaoui, H.Hamdi, Braiek, & M.Rodrigues, 2019) considers the design of reconfigurable PID fault tolerant for a tracking controller. This method was developed to reduce the conservatism of previous methods with more parameters designed so as to minimize their disadvantages and to give better control loop performances, especially in terms of the accuracy and speed of trajectory tracking even when a fault occurs. However, the result of this research was not similar to this project. This project was designed to manage the solar tracking to be effective and smart and to accurately measure the position of the sun.

Figure 1 illustrates the general block diagram of PID controller:

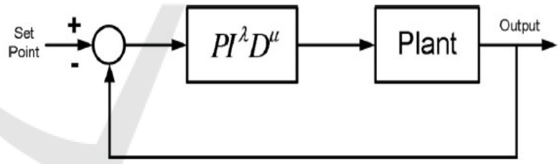

Figure 1: General Block Diagram of PID controller (Shah & Agashe, 2016).

$$C(s) = \frac{U(s)}{E(s)} = Kp + \frac{Ki}{S^{\gamma}} + K_D S^{\mu}, (\gamma, \mu \geq 0) \qquad (1)$$

where, C(s) is the controller output, U(s) is the control signal, E(s) is the error signal, *K P* is the proportional constant gain, *K I* is the integration constant gain, *K D* is the derivative constant gain, γ is the order of integration, and μ is the order of differentiator (Away & M.Ikhsan, 2017).

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3 RESEARCH METHODOLOGY

To describe the operational process and make it easier to understand the design, Figure 2 (below) illustrates the block diagram of solar tracking. Tracking control connected to the PID controller to manage the position of solar cells. The PID controller is used in this research as this control accurately receives the output. The PID controller connects to the driver motor to arrange the position required according to the command from the tracking control. Motor rotation and elevation were needed to manage the position of solar cell.

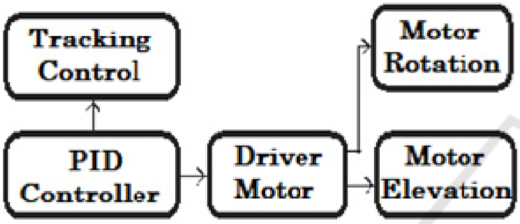

Figure 2: Block Diagram for solar Tracking

Figure 3 (below) indicated the mechanical design of solar tracking. To simplify, solar panels are only put above the framework. Consequently, it is easy for the solar panel to perform rotation and elevation style. In addition, the sun can directly face the solar tracking without any inside resistance.

Figure 3: Mechanical Design for solar Tracking

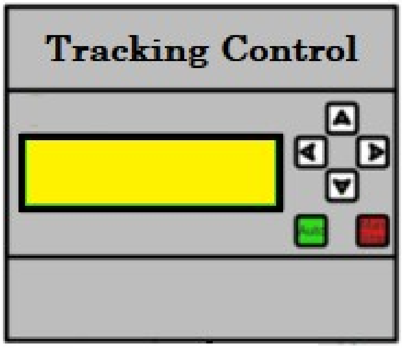

Figure 4: Tracking Control Box

Figure 4 illustrates the tracking control of this design. The function of tracking control is to manage the position of the tracking system. This design allows the consumer to arrange the position of the solar panel. In this research, auto and manual settings were developed to assist consumers to achieve optimum results. Some options were provided in this design, namely: upper and bottom, left and right. The green and red buttons are for ‘run’ and ‘stop’.

Figure 5 (below) illustrates the mechanical design of solar tracking for elevation motor. The function of elevation motor is to assist this system to elevate the position. Elevation motor was required when the command from tracking control asked to elevate the position of the solar panels.

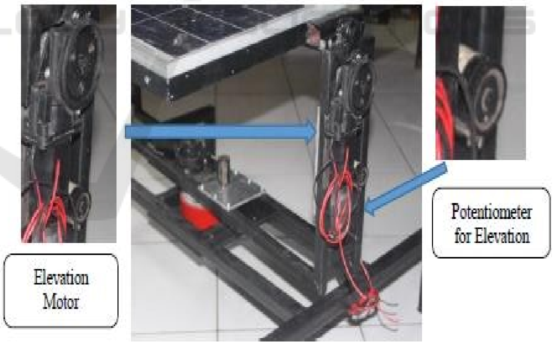

Figure 5: Mechanical Design of Solar tracking-elevation motor.

Figure 6 (below) illustrated the mechanical design of solar tracking for the rotation motor. As previously shown, the rotation motor was needed when the command from the tracking control asked to rotate the position of solar panels.

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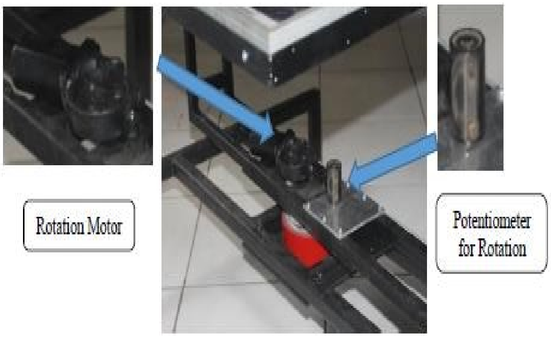

Figure 6: Mechanical Design of Solar tracking-rotation motor.

4 RESULT AND ANALYSIS

4.1 Testing of Mechanical Design

Figure 7 (below) illustrates the result of mechanical testing for the standard elevation. This position was selected as the solar panel directly faces towards the sun.

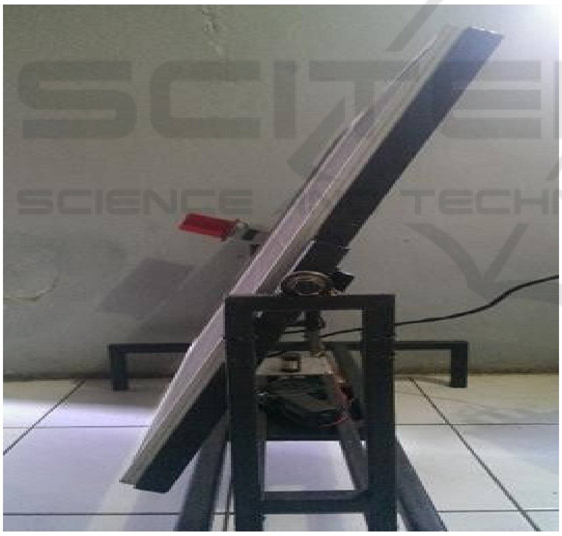

Figure 7: Standard Position of elevation

Figure 8 (below) illustrates the position of solar panel -30°C from standard elevation. Based on this Figure, the elevation position is 30°C clockwise from standard elevation. To get this position, the consumer only sets up by tracking control.

Figure 8: Position of solar panel with -30°C from standard elevation

Figure 9 (below) illustrates the result of mechanical testing for standard rotation. The position of standard rotation was 90°C. To simplify, this position was selected as the standard rotation. There are some examples of the position that was conducted in this research. However, only 30°C was illustrated as an example to represent that the rotation function was worked properly, as illustrated in Figure 10.

Figure 9: Standard Position of rotation

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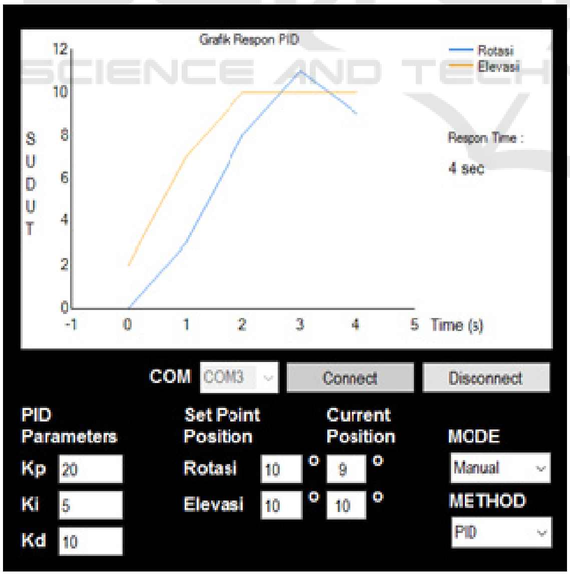
Figure 10: Position of solar panel with -30°C from standard rotation

4.2 Testing of PID Parameters

To operate this system, there are two kinds of settings provided: manual and auto. To investigate whether this system was working properly, the manual setting was chosen for the case study. To control under the PID method, the values of Kp, Ki and Kd were required to analyze this system. In this research, the parameters of Kp, Ki and Kd were 20, 5 and 10, respectively.



Respon Time :
4 sec

COM: COM3

PID Parameters
Kp: 20
Ki: 5
Kd: 10

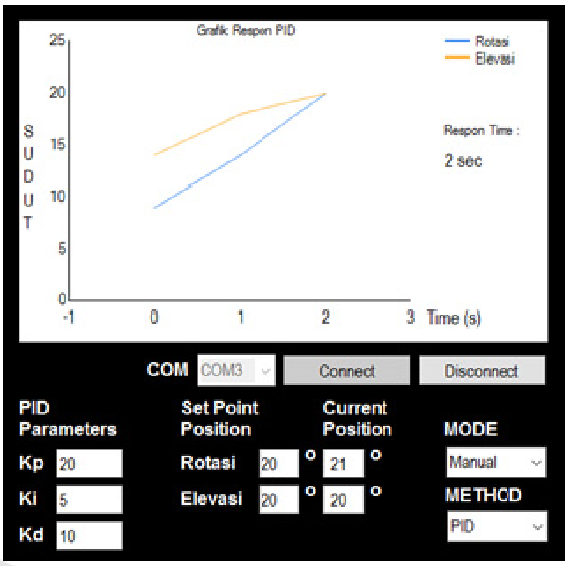
Set Point Position
Rotasi: 10°
Elevasi: 10°

Current Position
Rotasi: 9°
Elevasi: 10°

MODE: Manual
METHOD: PID

Figure 11: Response of PID set point

Testing of PID parameters aims to recognize that the PID control gives a response according to a given angle. The graphic response of PID is when the set point of rotation and elevation were 10°. As a result, response time was 4 seconds, as illustrated in Figure 11 above.



Respon Time :
2 sec

COM: COM3

PID Parameters
Kp: 20
Ki: 5
Kd: 10

Set Point Position
Rotasi: 20°
Elevasi: 20°

Current Position
Rotasi: 21°
Elevasi: 20°

MODE: Manual
METHCD: PID

Figure 12: Response of PID set point

Figure 12 illustrates the response of PID set point with set position rotation were 20° for rotation and elevation. Similar to the previously method, the response time to get this position is 2 second. Based on the Figure above indicated that the PID parameters give a response accurately (see Figure 12). However, only graphic respond PID for rotation was unprecise, as illustrated in Figure 11.

5 CONCLUSIONS

This research illustrates the design of a sun tracking system by a PID controller. In order to orientate the solar panel to the maximum radiation at all times, this system is designed with dual axis control, such as: rotation and elevation. According to the mechanical test, the function of rotation and elevation can work properly based on the parameters input. In addition, the PID parameters give a response precisely based on the parameters input. Consequently, the solar tracking can recognize the position of the sun more accurately.

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