Sensorless Solar Tracker Based on Sun Position for Maximum Energy Conversion

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Abstract- **The performance of solar panels energy conversion is dependent on sunlight it receives. Therefore, it is necessary to design a tracker device that can set the direction of the solar panel always follow the sun position. The two-axis sensorless trackers have developed in this research to maximize energy conversion. Position of solar panel move based on sun position using sunrise and sunset database. By using linear interpolation the sun position in latitute and longitude direction for other time can be obtained during a day. Based on these value the solar panel set its position using two servo motor which drived by Arduino. This technique independent from weather conditions, although cloudy, panel position remains consistent with the maximum illumination when the weather is sunny back later. By this way, the solar panel absorbs maximum sunlight as well as generate maximum electricity**.

Keywords—Solar tracker; Photovoltaic; Sunrise and sunset; Linear interpolation.

I. Introduction

In recent years, due to the global energy crisis the interest in renewable energy sources has been steadily increasing. Solar energy is one of the new and renewable energy being actively developed in Indonesia as a tropical country. Indonesia solar energy potential is huge around an average of 4.8 kWh / m2 / day, equivalent to 112,000 GWp, but which has been used only about 10 MWp [1]. In conventional applications of solar panels has many shortcomings, especially on the relatively low output efficiency. There are several factors that affect the electric power generated by solar panels, such as material type solar cells, the level of light intensity and temperature of the working of solar panels.

The performance of solar panels is dependent upon sunlight it receives. In general, the sun will rise from the east toward the west in seconds, minutes and hours. As well as the sun will slight change in position from south to ward the north in monthly. Generally, solar panels installed permanently (fixed) on the stand. For subtropical countries generally exposes the panels towards the south or to the north [2]. Meanwhile, a tropical country installation is done tends to be flat. Installation techniques like this will cause the light of the morning sun and afternoon are not in the right position against the direction of the sun. As a result, the amount of electrical energy that can be raised to a little more than it should [3]. Therefore, it is necessary to design a device that can set the direction of the solar panel always follows the sun position or perpendicular to the sun using traker position of the sun to produce maximum energy conversion.

Tracking the sun during the day in order to maximize the amount of collected energy. It is possible to gain a significant amount of energy when mounting PV systems on trackers. This gain depends on location, but will generally be 20-35% for a two-axis tracking system [4].

II. Photovoltaic Solar Energi Conversion

Photovoltaic (PV) technologies convert energy from sunlight into electricity using semiconductor material such as silicon which are commonly known as solar panels. The photoelectric effect that causes them to absorb photons of light and release electrons. When light energy strikes the solar panels, electrons are knocked loose from the atoms in the semiconductor material. These free electrons are captured, an electric current results that can be used as electricity.

The solar radiation varies according to the orbital variations. The total solar radiation output from the sun in all frequencies at a distance R from the sun centre [5] is equal to:

$$S = 4\pi R^2 \, Q(R) \qquad (1)$$

If the radiation flux per unit area at a distance R represented by Q(R) and the earth approximately 150x106 km away from the sun. Hence, the total solar output is about 3.8 x 1026 W. Since, the surface area of the earth is 4πr2; the amount of solar radiation per unit area on a spherical planet becomes as 340 W/m2 [5]. Therefore the solar energy has a large potential for future renewable energy sources.

Photovoltaic equivalent circuit consists of a current source driven by sunlight in parallel with a real diode and resistance (Rp) series with resistance (Rs) as shown in Figure 1. The value of current and voltage are of a photovoltaic module are dependent on the solar irradiance and the ambient temperature. Then the output power can be calculated using multiplication of current and voltage which varies according to sun radiation.

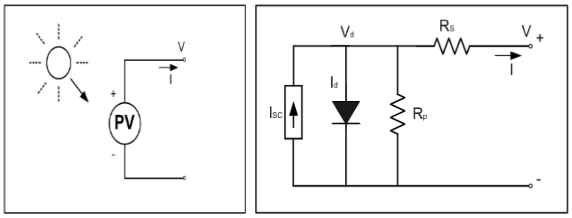


Figure 1. Equivalen circuit for photovoltaic cell [6]

The ideal equivalent circuit of PV cell consists of a current source in parallel with a diode. Ideally the voltage-current (VI) equation of PV cell [7] is given by:

$$I = I_{pv} - I_0 (e^{qV/akT} - 1) \qquad (2)$$

Where Ipv,cell is the current generated by the incident light (directly proportional to the sun irradiation), I_0, cell is the reverse saturation of the diode, q is the electron charge (1.60217646 x 1019 C), k is the Boltzmann constant (1.3806503 x 10-23 J/K), T is temperature of the p-n junction and a is the diode ideality constant.

Figure. 2 shows the V-I curve and Ppv-V curve based on equation (2).

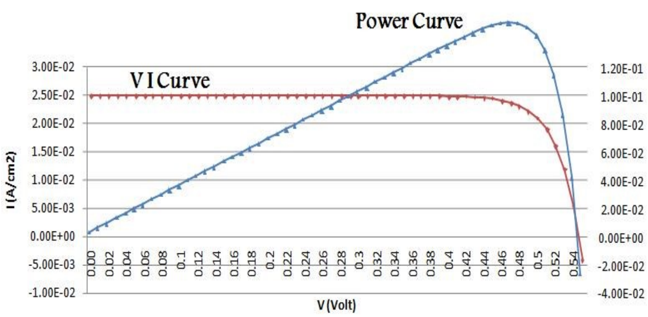


Figure 2 Characteristic I-V curve of Photovoltaic

General photovoltaic model using voltage and current of equivalent PV module to calculate the output power. Efficiency of the PV module is very important to determine the effectiveness of the PV system. The comparison of output power of PV per area (P_{PV}/A) and the input power as sun radiation per m^2 define as PV efficiency.

Efficiency = (output power/input power)*100% (3)

There is the factor that can affect the efficiency of the PV system [8]:

a) Natural climatic conditions of the place where the system is to be used.
b) Optimal matching of the system with the load.
c) Appropriate spatial placement of the modules (placing the modules at an optimal inclination angle to the horizontal plane).
d) Availability of solar tracking mechanism in the system.

The last factor have been directed in this research in order to maximum solar energy conversion

III. Methodology

Tracking of solar systems can be made in a number of different ways. The two-axis trackers have used in this research to ensure that the solar panel absorbs maximum sunlight to generate maximum electricity. Position of solar panel move based on sunrise and sunset databased created from sun position website of our previous work [9,10]. The latitude of the University Andalas -0.9129° and longitude 100.4558° are used as panel location to created sun posistion database Figure 3.

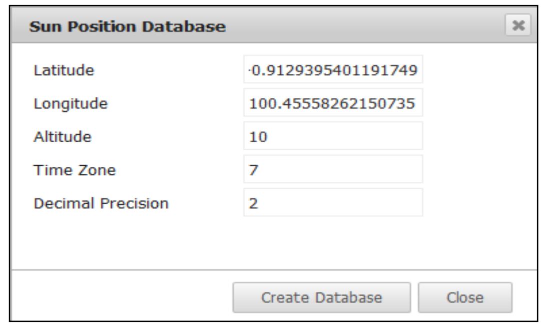


Figure 3. Create database for reserch location

The sunrise and sunset databased created as shown in figure 4 and firgure 5 repectively.

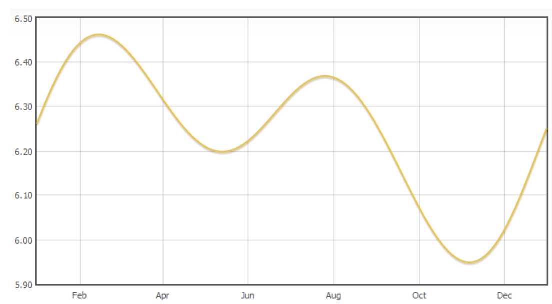


Figure 4 Sunrise database for one year

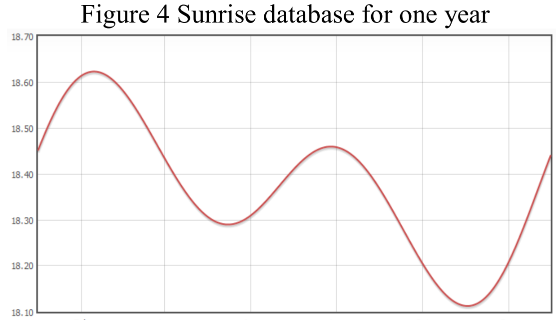


Figure 5 Sunset database for one year

Based on these pair values per day sunrise and sunset using interpolation the sun position in latitute angle (β) and longitude angle (φ) for other time can be obtained for one day. Then two servo motor set the solar panel position to coordinat spherical coordinat (φ,β) as shown in figure 6 and figure 7.

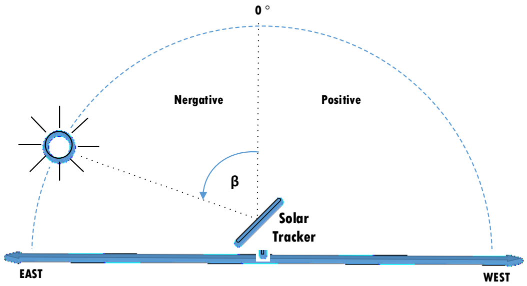


Figure 6 Latitude angel for servo #1

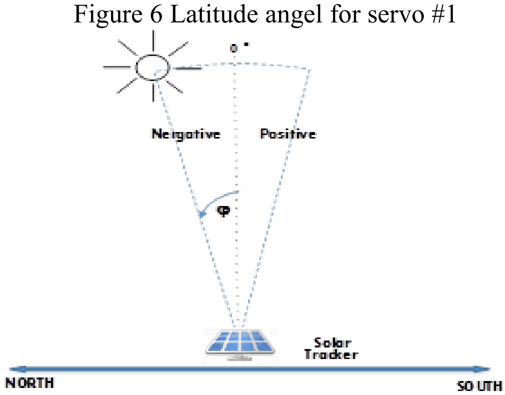


Figure 7 Longitude angel for servo #2

The other longitude angle and engle can be calculated using interpolation equation (4) and (50)

$$\beta_t = \beta_{sr} - \frac{T_t - T_{sr}}{T_0 - T_{sr}} \beta_{sr} \tag{4}$$

Where:
β_t = latitude angle for t.
T_t = time long t
β_{sr} = sunrise time latitude angle.
T_{sr} = sunrise time long
T_{sr} = transit long time (angle 0°)
And

$$\varphi_t = \varphi_{sr} + \frac{T_t - T_{sr}}{T_{ss} - T_{sr}} (\varphi_{ss} - \varphi_{sr}) \tag{5}$$

Where:
φ_t = longitude angle time t.
T_t = time long t
φ_{sr} = sunrise time longitude angle.
T_{sr} = sunrise time long
φ_{ss} = sunset time longitude angle.
T_{ss} = sunset time long

IV. RESULT AND DISCUSSION

The solar panel was used Sharp NU 185 A1H which maximum pawer in STC 185 Watt, 30,2 Volt. The system test on Thuesday 14 May 2015 with databased:

```
5,14,5,56,18,32,18.67,-94.42,18.80,94.42
```

The meaning of these values are: Sunrise time 5:56, with longitude angle 18.67° and latitude angle -94.42° (in east direction) and Sunset time 18:32, with longitude angle 18.80 and latitude angle 94.42. The other longitude angle and engle can be calculated using interpolation equation (4) and (5). The results summerized as table 1 below:

TABLE 1 LATITUDE AND LONGITUDE ANGLE FOR ONE DAY

Time	Hour*60+minute	Latitude Angle	Longitude Angle
5:56	356	-94.42	18.67
8:00	480	-62.25	18.69
9:00	540	-46.69	18.70
10:00	600	-31.13	18.71
11:00	660	-15.56	18.72
12:00	720	0	18.73
13:00	780	14.45	18.74
14:00	840	28.90	18.75
15:00	900	43.36	18.76
16:00	960	57.81	18.77
17:00	1020	72.26	18.78
18.32	1112	94.42	18.80

A. Electronic circuit

The electronic circuit of solar tracker consist of Real Time Clock (RTC), Micro SD and Arduino Mega 2560 as shown in figure 8. The circuit will read real time date and time using RTC and compared them to date and time of sun position database to determine latitude and longitude angle. Then these angles used as arduino input to set servo motor directed solar panel always follow the sun position or perpendicular to the sun in order to produce maximum energy conversion.

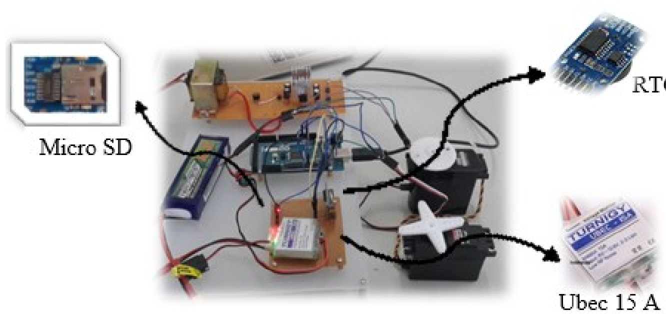


Figure 8 The electronic circuit of solar tracker

The solar tracker algorithm which download to arduino mega is state below:

```
1. Read current date and time from RTC
RTCval = RTChour*60+RTCminute;
2. SD.open to read database of sun position.
3. Compare RTC date dan time with database date
and time to get sunrise, sunset time and its
latitute and longitute.
4. Calculate current latitute and longitude
using Linear Interpolation eq.(4) and (5).
5. Set servo #1 based on current latitude.
6. Set servo #2 based on current longitude.
7. SD.close(file) to close database.
8. Set delay(15*60*1000) to activate solar
tracker for next 15 minute.
```

B. Mechanical construction

The mechanism of electro-mechanical displacement consists of two servo motors, one for altitude and the other for longitude displacements. The functionality of solar tracker mechanism have tested using small solar panel 4 Wp which mechanical costruction as shown in figure 9. The solar tracker have moved based on sun position derived from sunrise and sunset databased created from sun position website of our previous work [9,10].

Figure 9. Solar Tracker Prototype

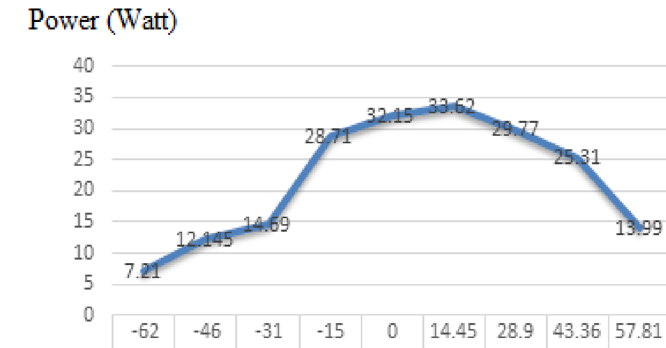
Then function of solar tracker mechanism tested using real 185 Wp solar panel. The mechanical construction of solar panel shows in figure 10. This construction can move solar panel in two direction which east and west direction 180° for daily movement and ± 25° for north and south direction for six monthly movement.

Figure 10. Solar Tracker construction of 180 Wp solar panel

The prototype solar tracker which consists of digital electronics circuit and mechanical tracker construction has been functioning as expected, especially for small-sized of solar panel. As for the solar panel with large size need motor with high power from DC motor types.

C. Power measurment

The electrical power generated by solar panel have measured for two condition of solar panels positions mounted flat and by moving perpendicular of solar lighting. The measurement of the electrical power output of solar power between a flat position compared to the upright position of sunlight has resulted in a greater power. Thus the method of solar tracker without sensor has increased efficiency and output power of Solar Power Generation (PLTS). The power generated solar panels to variations in the sun's position is shown in figure 11.



	-62	-46	-31	-15	0	14.45	28.9	43.36	57.81
Power	7.21	12.145	14.69	28.71	32.15	33.62	29.77	25.31	13.99

Figure 11 Electrical power result by solar panel under sun position variation

For the cloudy wheather the effect of solar tracker not so significant, cause of sun light near the same for any other direction. However by using sensorless solar tracker based on sun position have maximized the amount of collected solar energy.

V. Conclusion

An accurate solar tracker based on sun position have been developed. Position of solar panel move based on sunrise and sunset databased created from sun position website of our previous work. The solar energy capture have been improve by using a devise that set solar panel always follow the sun position. The prototype solar tracker which consists of digital electronics circuit and mechanical construction has been functioning as expected, especially for small-sized of solar panel. As for the solar panel with large size need motor with great power from DC motor types. For the cloudy wheather the effect of solar tracker not to significant, cause of sun light near the same for any other direction. However by using sensorless solar tracker based on sun position have increased the amount of solar energy collected.

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REFERENCES

[1] Pusat Data dan Informasi Energi dan Sumber Daya Mineral KESDM, 2010, “ Indonesia Outlook 2010, Kementrian ESDM, 2010

[2] Takle, E. S., and Shaw, R. H., Complimentary Nature of Wind and Solar Energy at a Continental Mid-Latitude Station. New York. International Journal of Energy Research, Volume 3, Issues 2, 2007, pp. 103-112.

[3] Cheng, C. L., Chan, C.Y., and Chen, C.L., An empirical approach to estimating monthly radiation on south-facing tilted planes for building application, Amsterdam, Journal of Energi, Volume 31, Issue 14, 2007, pp. 2940-2957.

[4] Khadidjaa B, Drisa. K, Boubekerb.A, Noureddine S., Optimisation of a Solar Tracker System for Photovoltaic Power Plants in Saharian region, Example of Ouargla,The International Conference on Technologies and Materials for Renewable Energy, Environment and Sustainability, TMREES14, 2014.

[5] Zekai Sen, Solar energy in progress and future research trends, Progress in Energy and Combustion Science, Volume 30, Issue 4, 2004, Pages 367-416

[6] Syafii, K. M Nor, M Abdel-Akher, Grid-connected Photovoltaic Models for Three-Phase Load Flow Analysis,3rd IEEE International Power and Energy Conference PeCon 2010, Kuala Lumpur November 29-30, 2010.

[7] D. Das, R Esmaili, L. Xu, and D Nichols,” An Optimal Design of a Grid Connected Hybrid Wind/Photovoltaic/Fuel Cell System for Distributed Energy Production”, 2005.

[8] M.A. Ghias, Kh.S. Karimov, S.I.A. Termizi, M.J. Mughal, M.A. Saqib and I.H. Kazmi, A Photo-Voltaic System with Load Control, Proceedings of the International Conference on Electrical Engineering (ICEE 2007), Lahore (Pakistan), 2007.

[9] Kamshory, Syafii,"Simulator Posisi Matahari dan Bulan Berbasis Web Dengan WebGL", Jurnal nasional Teknik Elektro Vol: 3 No. 2 September 2014.

[10] Simulator Posisi Matahari dan Bulan Website: http://planetbiru.com/apps/trisula3d/