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Active Solar Tracker Based on The Horizon Coordinate System

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Abstract. One of the disadvantage of solar panel as a renewable energy is lack of power output when the solar panel is not directly leading to the sun. To increase the output power of solar panel, an active solar tracker based on the horizon coordinate system of solar has been developed. The solar horizon coordinate system used to determine the position of the sun at every single time, thus the solar panel's position to the sun is more precise. This device consists of arduinouno as control system, two servo motors as a panel drive, a PLX-DAQ program as a data monitoring, ACS – 712 as the current sensor, and a DC voltage sensor as the output voltage sensor. Sensor characterization shows that ACS-712 measures current in mA orde and has a maximum relative error of 4.25%, meanwhile the voltage sensor detects the output voltage up to 15 Volt and has the maximum relative error of 4.34%. The output power of this device increases 83,89% to the other active solar panels. To determine the effect of altitude and azimuth data, measurements were carried out in two different cities, there are Bekasi city and Tangerang city. The results show that the output power in both cities differed by 77.7%.

1. Introduction

Electricity consumption in Indonesia is rapidly increasing, along with the growth of population and economy. Unfortunately, this is not accompanied by an adequate supply of energy, on the contrary there are getting less. Various type of alternative and renewable energy is developed, to reduce a dependence on fossil energy, as well as overcome the energy crisis problem. Indonesia is an equatorial country receives solar energy of 4.8 - 6.0 kWh/m² [1], thus solar energy is a proper solution to the energy crisis problem in Indonesia.

Solar cells or photovoltaic cells are used to convert solar energy into electrical energy [2]. To maximize the output power of solar panel requires a solar tracker system. Solar tracker is an active device system that allows solar panel to move towards the direction of sun. Active solar trackers use sensors as well as the electrical motors for their operation. The sensors are used to determine the position of the sun and use motors to adjust their equipment to the proper orientation [3].

The sun's position in the sky is mainly depend on the longitude and latitude, length of daytime and the seasonal changes of specific locations [4]. Thus, the solar panel must be equipped a system to determine the position of the sun at all times. Horizon coordinate system is one of the proper systems



used in determining the position of celestial bodies, especially related to the observer's position. The horizon coordinate system works based on solar altitude and azimuth data, though the location of the solar panel is more precise to the sun, and the maximum output power will be achieved. Regarding movement capability, sun tracking systems are designed to track the sun on a single axis (according to the azimuth angle) or to track the sun on both axis (according to the azimuth and solar altitude angles) [5]. In this paper, we focus on development of two axis solar tracking system based on the horizon coordinate system.

2. Experimental

The developed prototype was composed of current sensor type ACS-712 5A, voltage sensor, LM35 temperature sensor, LDR sensor, servo motor, and 11cmx11cm sized solar panel. The data of solar horizon coordinate system will be connected to the Arduino Uno software; therefore, the microcontroller works as the servo motor's controlling to drive the solar panel. Two pieces of servo motor allows the solar panel rotates horizontally and vertically in the direction of the sun. Physical parameters, i.e. voltage, electric current, light intensity, and temperature, are measured using sensor modules, then stored in a personal computer (PC) using the PLX program – DAQ. System schemes and developed tools are shown in Figure 1.

In this study, another active solar tracker was built as a comparison, that is solar tracker based on LDR sensor (tracker-1). LDR sensor serves as a determinant of the sun's position based on the intensity of received solar radiation. According to these results, the servo will control the solar panel's movement towards the position of the sun.

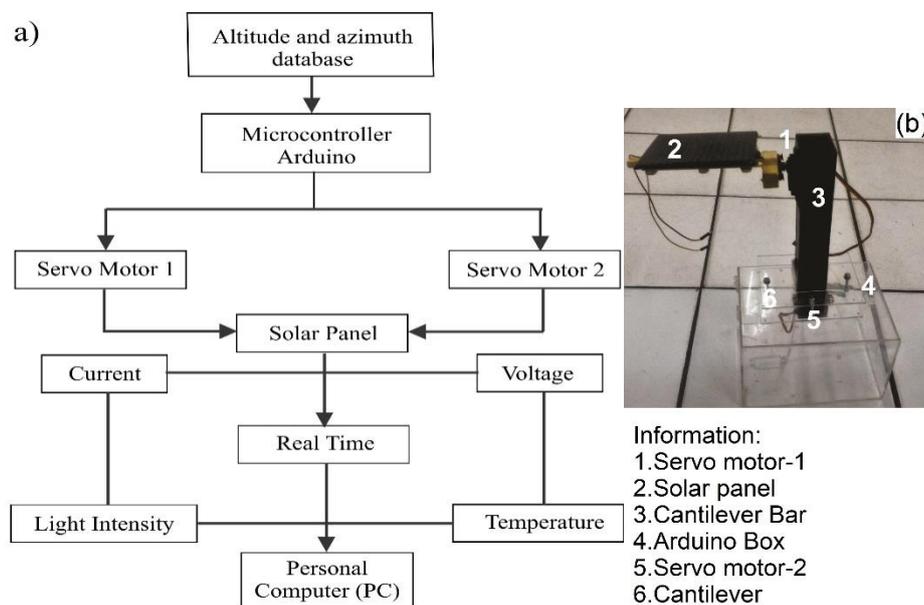


Figure 1. (a) System design scheme (b) Design of active solar tracker device

3. Result and Discussion

3.1. Sensors Characterization

Sensor characterization aims to determine accuracy and measurement range of the sensor. The ACS-712 current sensor characterization is carried out using a fixed input voltage of 5 Volts and five different resistors, there are 1000 Ω , 550 Ω , 510 Ω , 300 Ω , and 220 Ω . The results of the ACS-712

current sensor characterization shown in Figure 2a. The average electric current measured by both sensors and ampere meters for each resistor is following the equation:

$$I = 0,9667I_0 - 0,0544$$

Wherein I_0 is the actual current value measured by ammeter (Ampere) and I is the current measured by the sensor (Ampere).

Whereas, the voltage sensor characterization is executed by comparing the measured voltage by the sensor and by the voltmeter. The input voltage of 3.6, 9 and 12 volts respectively is given to the sensor input and voltmeter. Measurements were repeated ten times for each input voltage. Figure 2b illustrates the graph of voltage sensor characterization, showing the linear equation as follows:

$$V = 1,0248V_0 - 0,1288$$

Wherein V_0 is the actual voltage (Volt) and V is voltage sensor output (Volt). The maximum of measurement relative error is 5.79%. This result represents the voltage sensor is proper to measure the solar panel output voltage up to 12.0 Volt.

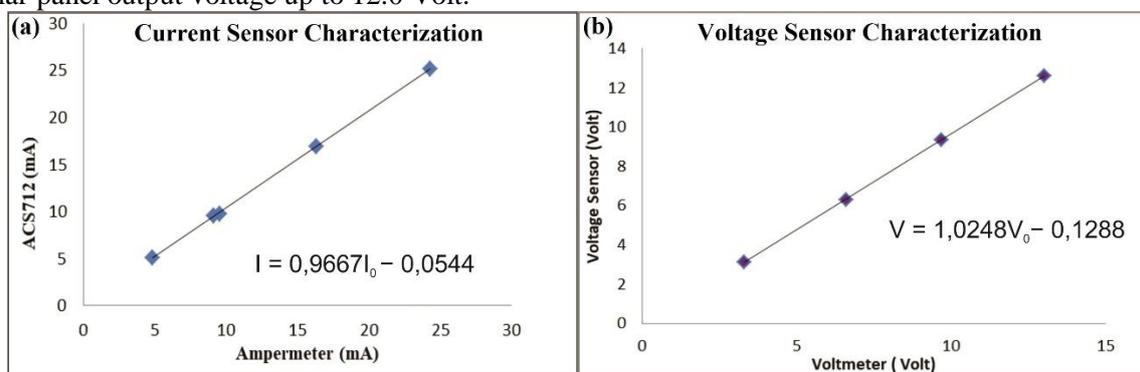


Figure 2. (a) The ACS-712 current sensor characterization. (b) voltage sensor characterization

3.2. The Power Output of Device

The physical parameters measured in this research are the electric current measured by ACS-712 sensor and the output voltage measured by the voltage sensor. Current sensors are arranged in series to solar panels and a resistance of 510 Ω . Solar panel output power is calculated using the current and voltage data measured by the sensor, both on tracker-1 and tracker-2. Tracker-1 works based on horizon coordinates, whereas tracker-2 works based on measurement of light intensity by the LDR sensor. Measurements were carried out at 9:00 a.m. to 3:00 p.m. in four days in two different cities.

3.2.1. Data acquisition in Bekasi. The data of current and voltage on days 1-2 was acquired in Tambun Baru, Bekasi city by 30 data sampling in every 15 minutes. The measurement results are shown in Figure 3. The graphic pattern of solar panel output power on the first and second days is similar. The output power obtained by tracker-1 is higher than tracker-2. The maximum power of tracker-1 is obtained at 1:15 p.m. and tracker-2 occurs at 1:00 p.m., on the first day (bright shine day with air temperatures of 32^o). Meanwhile on the second day, sunny day with air temperatures of 31^o, the maximum power on tracker-1 and tracker-2 occurs at the same time, at 12.45 p.m. The maximum output power difference of the tracker 1 to tracker 2 is 83.89% on the first day, and 47.7% on the second day. The output power difference is quite significant due to the influence of weather and temperature, thus affecting the amount of radiation received by the solar panel.

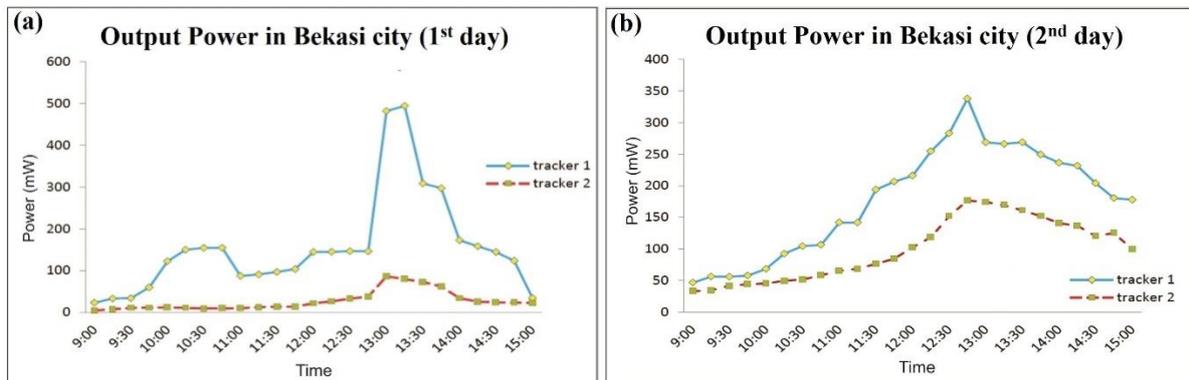


Figure 3.(a)The data measurement of solar panel's power output on first day in Bekasi city. (b) The data measurement of solar panel's power output on second day in Bekasi city.

3.2.2. *Data acquisition in Tangerang.* The data of current and voltage on days 3-4 was acquired in Tangerang Selatan, by 30 data sampling in every 15 minutes. The aim is to find out whether there is an affecting of the difference places to the output power of solar panel. The measurement results are shown in Figure 4. The Figure 4a and 4b has the same patterns as Figure 3a and 3b, output power of tracker-1 higher than tracker-2. The maximum power of tracker-1 is obtained at 12:45 p.m. in the bright shine day with air temperatures of 31° .

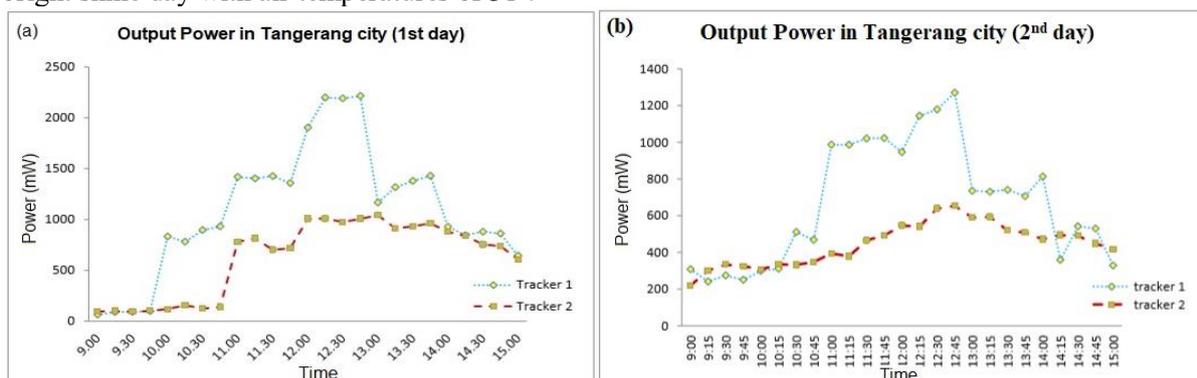


Figure 4.(a) The data measurement of solar panel's power output on first day in Tangerang city. (b) The data measurement of solar panel's power output on second day in Tangerang city.

3.2.3. *Azimuth and altitude effect.* The effect of altitude and azimuth on tracker-1 is observed in Figure 5. There is a difference achievement time of the maximum power of solar panels. The maximum power in Tangerang city is obtained at 12.00 p.m.-1:00 p.m. time intervals. Whereas in Bekasi city, the maximum power obtained at 1:00p.m. to 1:30 p.m. time intervals. The difference in the time interval is due to differences in altitude and azimuth. Tracker -1 that uses the horizon system is strongly influenced by the tilt angle of altitude and azimuth of two regions. Because of the shape of the earth, solar radiation will fall in different intensities on various regions. Azimuth and altitude data of both two cities during the data acquisition is shown in Table 1. It appears that the altitude and azimuth of Tangerang city are greater than Bekasi, thus influences the maximum power of solar panels in each city. The tilt angle of solar panel has been adjusted according to table 1, therefore it can lead precisely to sun's position, thus the results of power received by the solar panel are close to the optimum value. The significantly increasing of power maximum in Tangerang to Bekasi by 77.7% is also influenced by weather and air temperature factors during data acquisition.

Table 1: Data of Azimuth and Altitude

Time	Bekasi City		Tangerang City	
	Altitude	Azimuth	Altitude	Azimuth
8a.m	26,93	67,76	27,17	69,25
9a.m	40,45	61,9	40,86	63,56
10a.m	52,99	51,55	53,63	53,43
11a.m	63,08	31,95	64,08	33,74
12 p.m	67,21	358,71	68,49	358,87
1 p.m	62,54	326,22	63,62	324,7
2 p.m	52,2	307,44	52,97	305,73

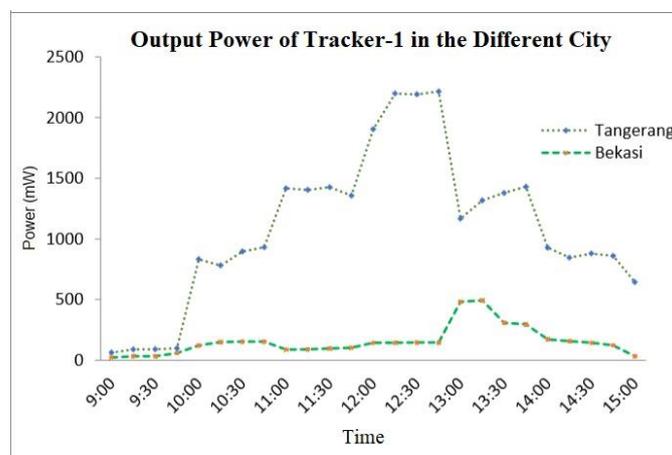


Figure 5. The output power of Tracker-1 in Tangerang city and Bekasi city

Conclusion

Development of an active solar tracking system equipped a solar horizon coordinate system has been carried out successfully. Altitude and azimuth data usage in order to regulate the movement of solar panel towards the sun's position, is capable of running the device functionally at 9:00 a.m. to 3:00 p.m. As well as being able to detect output power's dissimilarity of two different cities

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