Solar Power Plant Tracker Upgrade and MPPT Control with Internet of Things

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Abstract: To maximize sunlight absorption by forming a perpendicular axis between the sun and the solar panel. A method which could be implemented on the solar panel system that could follow the sun's movement is needed. On this design, the system uses a light diode sensor (LDR) that functions as the light detector, an Atmega238P-PU microcontroller as the command logic storage, and a servo motor as a mover to dislocate the position of the solar panel with Internet of Things (IoT). In the solar panel test which runs for 11 hours using the dual-axis solar panel tracker has yield a power of 9.4 W and after passing the MPPT control battery, it gives an average of 10.6 W. Compared to using a static solar panel method, it only yields a power of 6.8 Watt, and after passing the MPPT control battery, it gives an average power of 9.25 W.w

1 INTRODUCTION

1.1 Background

To maximize the absorption of sunlight, a method which forms a perpendicular axis between solar panel and sunlight is needed. Hence the need to make a model that could be implemented into a solar panel system that could follow the sun's direction is crucial. There is also an excess power from the solar panel into the battery itself, so a MPPT (Maximum Power Point Tracker) control battery is also needed. While the use of dual-axis solar tracker is already discussed in past studies, the implementation of said dual-axis tracker using Internet of Things (IoT) to be remotely controlled through a website haven't been developed.

1.2 Model Simulation

The methodology used in this study is to design a prototype Solar Power Plant Tracker with the IoT-based MPPT battery using ATMEGA328P-PU microcontroller. The system are designed to calculate the sun position at anytime, at any location, and any day of the year.

2 THEORETICAL BASIS

2.1 Photovoltaic (Solar Cell)

Photovoltaics are able to convert photon energy into electrical energy. One solar cell usually could produce DC voltage around 0.5 – 2 V when illuminated. Several solar cells will need to be arranged in a series to get a larger desired voltage(Notosudjono and Adzikri, 2018).

2.2 Solar Panel Tracker System

Each square meters in the solar panel surface area that faces the sun could harvest around 1000 W solar power (assuming 100% efficiency). Thus, to increase the solar panel's energy efficiency, a simple but accurate solar detector mechanism is needed as seen in the Figure 1 below, known as tracker mechanism.

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(Prinsloo and Dobson, 2015) In the following figure is the solar trajectory illustration.

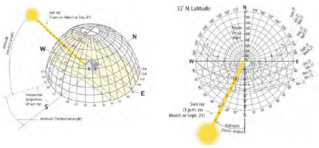


Figure 1: Solar trajectory illustration.

The Sun follows a certain path when seen from a geographical location. A sun tracker mechanism is used to find the sun's position in a certain location to keep the solar panel perpendicular against the sun. (Prinsloo and Dobson, 2015) Solar declination can also be defined as the angle between the line joining the centers of the Sun and the Earth and its projection on the equatorial plane. The solar declination changes mainly due to the rotation of Earth about an axis. It's maximum value is 23.4°Con December and the minimum is -23.4°C on June 21st (Mansour et al., 2015; Elsherbiny et al., 7 09).

2.3 Automatic Photovoltaic Tracking System

Automatic Photovoltaic system is designed using dual-axis tracker. Dual axis trackers have two degrees of freedom that act as axes of rotation. These axes are typically normal to one another. Two-axis tracker tracks the daily east to west movement of the sun and the daily declination movement of the sun. Two common implementations are TTDAT (tip-tilt dual axis trackers) and AADAT (azimuth-altitude dual-axis trackers) (Elsherbiny et al., 7 09).

This tracker gives the possibility for automatic measuring of direct solar radiation with a pyrheliometer. In the active operation mode, the tracker uses the signal of a sun detecting linear sensor to control the pointing (Roth et al., 2005). Two stepper motors move the instrument platform, keeping the sun's beam at the center of the sensor.Duarte, et al. (Duarte et al., 2011) designed a two axis sun tracking system. Figure 2 below shows Dual axis tracker.

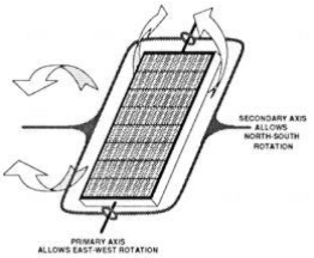


Figure 2: Dual axis tracker.

2.4 Servo Motor

Servo motors have been around for a long time and are used in many applications. They are small in size but powerful and are very energy efficient. Servos control by sending an electrical pulse of variable width (or pulse width modulation (PWM)) through control wire. Servo motor could only turn 90°C in either direction for a total of 180°C movement. The position where the servo has the same amount of potential rotation both in the clockwise or counterclockwise direction is defined as the servo motor's neutral position (Ramadhan et al., 2018).

2.5 Maximum Power Point Tracker (MPPT) Method

Tracking the maximum power point (MPP) of a photovoltaic array is an essential stage of a PV system (Femia et al., 2008) . As such, many MPPT methods have been introduced and numerous variants of each method have been proposed to overcome specific disadvantages. The methods all vary in complexity, number of sensors required, digital or analogue implementation, convergence speed, tracking ability, and cost effectiveness(Babaa et al., 2014).

2.6 ATMEGA328P-PU Microcontroller Pin Configuration

Atmega328P-PU has the ability to separate memory for program code and for memory so that it can maximize work in parallelism, or commonly called Harvard architecture which only requires 5Vdc.

2.7 Internet of Things (IoT) Concept

The Internet of Things is envisioned to allow for the interconnectivity of anyone and anything at anytime and in anyplace. This connectivity should ideally be possible using any service over any conduit, path or network. This is popularly referred to as The IoT 6A Connectivity Concept (Takpor et al., July; Perera et al., 2013).

The IEEE IoT Community defines the Internet of Things as: "… a self-configuring and adaptive system consisting of networks of sensors and smart objects whose purpose is to interconnect "all" things, including every day and industrial objects, in such a way as to make them intelligent, programmable and more capable of interacting with humans" (IEEE, 2015).

Figure 3. shows a structure of the connectivity concept of IoT and some of IoT's application areas.

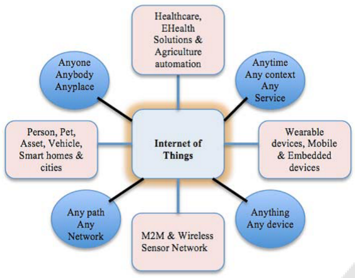


Figure 3: IoT's connectivity concept and application areas.

3 TESTING AND ANALYSIS

3.1 Solar Panel and Control MPPT Test

The Solar Panel Test and Control Battery Test with MPPT method are conducted to determine the amount of power output from the solar panel, before and after passing MPPT control. In the MPPT control test, we observe the current and the voltage detected by the current and voltage sensors on the LCD display. This is done by measuring directly on the output pin from this MPPT control electrical circuit. Fig. 4 below shows the output pin of the MPPT control.

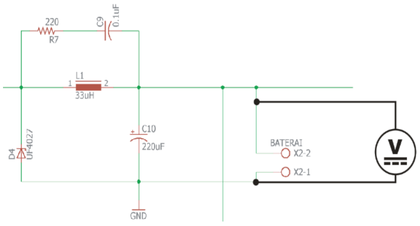


Figure 4: MPPT Control Output pin measurement.

To determine the comparison or difference between the resulting voltage and current values where the main source is the solar panel, the measurement on the input pin of the MPPT control is needed so it is not solely based on the current and voltage values displayed by the LCD. Fig. 5 below shows the input pin of the control before passing through MPPT control.

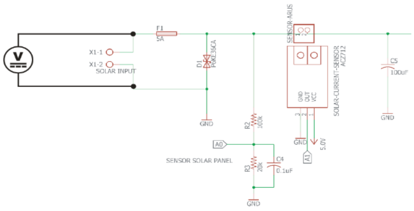


Figure 5: MPPT Control Input pin measurement.

After the current and voltage data from using tracker method and static method with and without the MPPT control is obtained, we can obtain the theoretical power value from the solar panel by using Voc and Isc as seen in the eq. 1 below :

$$SolarCellOutputPower = V_{oc} * I_{sc} \tag{1}$$

The following 10 Wp solar panel test result using the tracker method for 11 hours in the Figure 6 and Figure 7 :

Time	Static Solar Panel		
	Voltage (V)	Current (A)	Power (W)
07.00	15,34	0,4	6,13
08.00	15,88	0,46	7,30
09.00	16,5	0,49	8,08
10.00	18,21	0,45	8,19
11.00	19,33	0,46	8,89
12.00	19,43	0,51	9,90
13.00	18,36	0,49	8,99
14.00	17,29	0,38	6,57
15.00	16,13	0,30	4,83
16.00	15,6	0,21	3,2
17.00	14,2	0,19	2,69
Average	**16,93**	**0,39**	**6,80**

Figure 6: Solar Panel Tracker and MPPT Control Test for 11 hours.

Time	Static Solar Panel		
	Voltage (V)	Current (A)	Power (W)
07.00	15,53	0,52	8,07
08.00	16,67	0,49	8,16
09.00	18,08	0,59	10,84
10.00	19,26	0,59	11,36
11.00	19,36	0,60	11,61
12.00	19,43,	0,64	12,43
13.00	19,17	0,50	9,85
14.00	18,15	0,50	9,07
15.00	16,23	0,50	8,11
16.00	15,78	0,40	6,31
17.00	15,6	0,40	6,24
Average	**17,56**	**0,52**	**9,25**

Figure 7: Solar Panel Tracker and MPPT Control Test for 11 hours (extension).

As seen in the Figure 6 and Figure 7 above, the average power from running the test for 11 hours can be measured from 07.00 – 17.00 (Indonesian Western Time) with a capacity of 10 W, 21.6 V open circuit voltage (Voc) , and 0.61 A short circuit current (Isc).

Using the static method without the MPPT control for 11 hours, it generates 6.8 W by having a loss of 3.2 W = 10 W – 6.8 W. However, after passing MPPT control battery, the power output becomes 9.25 W by only having a 0.75 W loss.

In comparison by using a tracker method which follows the same 11 hours test period from 07.00 – 17.00 (Indonesian Western Time), it can be seen that the output voltage varies and that it generates a higher power of 9.4 W with only a 0.6 W loss compared to 6.8 W using the static method. A 2.6 W difference can be observed between them.

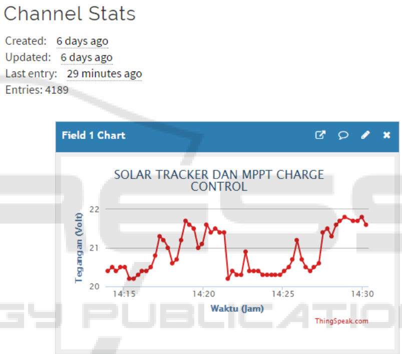
3.2 IoT with ESP8266 Module and Thingspeak Web Test

ESP8266 Module automatically uploads data to the web *(http://thingspeak.com)* periodically. In the following Fig. 8 is a program to connect the WiFi network to ESP8266 to be uploaded to thingspeak web.

```
// ------------------------- ESP8266 --------------------------------

String apiKey = "ERXMMSGLK352QQSN"; //apiKey dari Thingspeak
const char* ssid = "hudannn";       //Nama WIFI (Hotspot Android)

const char* password = "hudan2911"; //Pasword WIFI (Hotspot Android)

const char* server = "api.thingsspeak.com"; //Alamat WEB Thingspeak

// Koneksi Pin 2 Untuk TX Sebagai Serial USB
// Koneksi Pin 3 Untuk RX Sebagai Serial USB

SoftwareSerial ser(2,3); // RX, TX
```

Figure 8: Program code using ESP8266.

The uploaded data is the voltage value data from the solar panel according to time as seen in Fig. 9 below:



Channel Stats

Created: 6 days ago
Updated: 6 days ago
Last entry: 29 minutes ago
Entries: 4189

Figure 9: Voltage data uploaded using ESP8266.

4 CONCLUSION

After conducting observation and instrument test, it can summarized as below:

1. In the solar panel test for 11 hours (07.00 – 17.00 Indonesian Western Time) using the dual-axis solar panel tracker method has obtained the average power output of 9.4 W before passing through the MPPT control battery and 10.6 W after passing through the MPPT control battery which matches the maximum power on the solar panel of 10 W_p.
2. In the solar panel test for 11 hours (07.00 – 17.00 Indonesian Western Time) using the static solar panel method has obtained the average power output of 6.8 W before passing through the MPPT control battery and 9.25 W after passing through the MPPT control battery which is close to the maximum power on the solar panel of 10 W_p.

3. The Solar panel that uses the dual-axis tracker method generates a higher power output of 9.4 W compared to 6.8 W generated by static method which gives a difference of 2.6 W. This is due to the static solar panel method not always perpendicular to the sun, this problem could be solved using the dual-axis tracker solar panel to ensure the solar panel always perpendicular to the sun.

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