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.

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. This system is designed based on the sun position throughout the year, at any given location.

2 THEORETICAL BASIS

2.1 Photovoltaic (Solar Cell)

Photon energy could be converted into electrical energy through Photovoltaic. The amount of DC voltage generated from the solar cells is 0.5-2 V, the solar cells must then be connected in series to get a larger DC voltage output if desired. [1]

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. [2] In the following figure is the solar trajectory illustration.

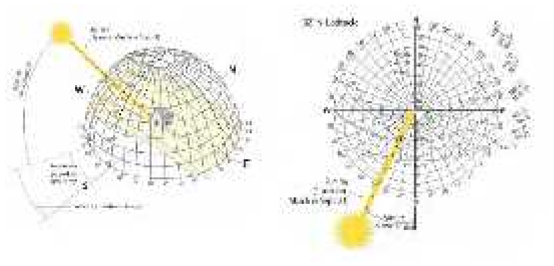

Figure 1: Solar trajectory illustration

The Sun circulates throughout each day and could be seen from geographical locations. To find the optimum solar light density in a certain location, we could utilize the tracker mechanism to get a perpendicular angle to the sun for the solar panels [2] Solar declination is defined by the angle formed between the line connecting the center of the Sun and Earth and it's projection on the equatorial plane. The optimum solar declination occurs at an angle of 23.45° by December and the lowest being -23.45° occurred by June 21st. [3,4]

2.3 Automatic Photovoltaic Tracking System

Dual Axis tracker is specifically designed for the automatic photovoltaic tracking system. The tracker itself consists of 2 axis, one that handles rotation, the other that handles normal. TTDAT (tip-tilt dual axis trackers) and AADAT (azimuth-altitude dual-axis trackers), both of which are the two most known implementations of the dual-axis solar tracker [4].

This tracker could also function as an alternative to measure direct solar radiation coupled using a pyrheliometer. The way it works, the tracker uses a linear solar tracker sensor signal to control the cursor [5]. While two stepper motors are operated to move the instrument platform, maintaining the sunlight to project right into the center of the sensor [6]. Figure 2 below shows Dual axis tracker.

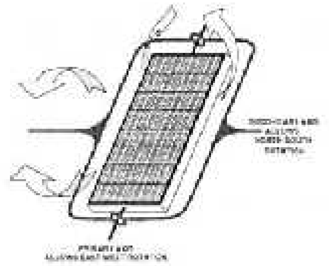

Figure 2: Dual axis tracker

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° in either direction for a total of 180° 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. [7]

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 [8] . 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. [9]

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, known to have the ability to establish interconnectivity amongst people, objects, at any indefinite time, at any location of the globe, using any kind of service that provides Internet connectivity as the name itself describes. This term is widely-known and referred in The IoT 6A Connectivity Concept [10.11].

As defined by The IEEE IoT Community: "… 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'' [12]. Fig. 3 below shows the diagram of the IoT's connectivity concept and some of its application areas.

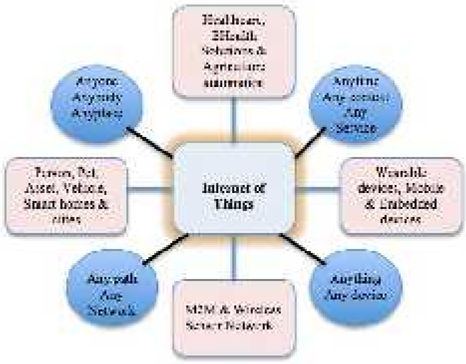

Figure 3: IoT's connectivity concept and application areas

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.

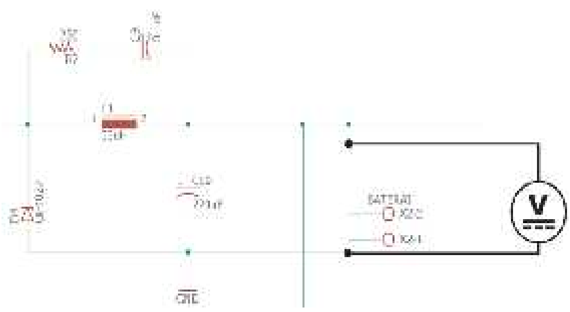

Figure 4: MPPT Control *Output* pin measurement

To determine the comparison or difference between the resulting voltage and current values where the solar panel acted as the main source, 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.

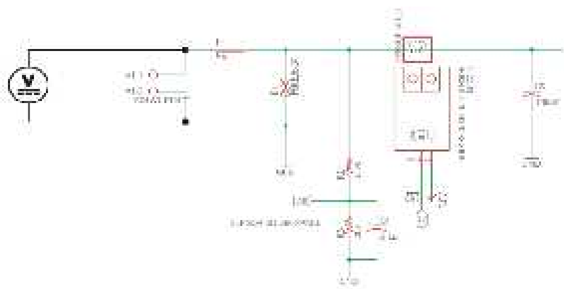

Figure 5: MPPT Control *Input* pin measurement

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 :

$$\textit{Solar Cell Output Power} = V_{oc} \times I_{sc} \quad (1)$$

The following 10 Wp solar panel test result using the tracker method for 11 hours in the Table 1:

Table 1: Solar Panel Tracker and MPPT Control Test for 11 hours

Time	Static Solar Panel			MPPT Control Battery		
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)
07.00	15,34	0,4	6.13	15,53	0,52	8,07
08.00	15,88	0,46	7.30	16,87	0,49	8,16
09.00	16,5	0,49	8.08	18,08	0,59	10,84
10.00	18,21	0,45	8.19	19,26	0,59	11,36
11.00	19,33	0,46	8.89	19,36	0,60	11,61
12.00	19,43	0,51	9.90	19,43	0,64	12,43
13.00	18,36	0,49	8.99	19,17	0,50	9,58
14.00	17,29	0,38	6.57	18,15	0,50	9,07
15.00	16,10	0,30	4.83	16,23	0,50	8,11
16.00	15,6	0,21	3.27	15,78	0,40	6,31
17.00	14,2	0,19	2.69	15,6	0,40	6,24
Average	**16,93**	**0,39**	**6,80**	**17,66**	**0,52**	**9,26**

As seen in the Table 1 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* (V_{oc}) , and 0.61 A *short circuit current* (I_{sc}).

Using the static method without 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. 6 is a program to connect the *WiFi* network to ESP8266 to be uploaded to *thingspeak* web.

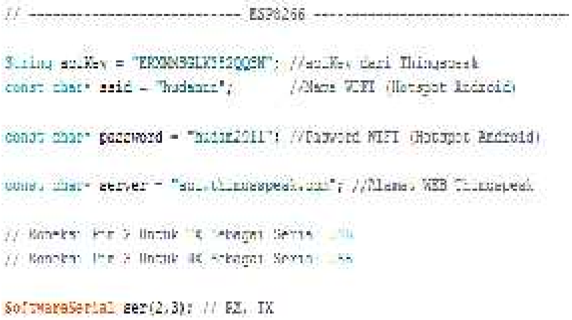

Figure 6: Program code using ESP8266

The uploaded data is the voltage value data from the solar panel according to time as seen in Fig. 7 below:

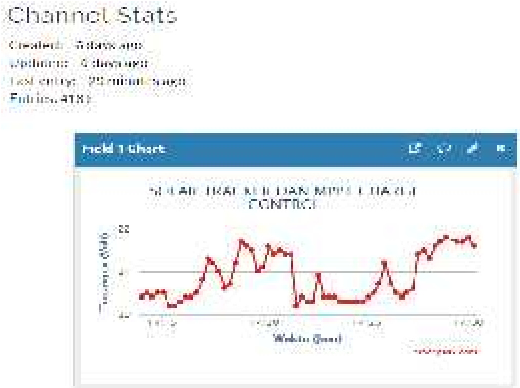

Figure 7: Voltage data uploaded using ESP8266

4 CONCLUSIONS

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 MPPT control battery. The value of 9.25 W is close to the maximum power of 10 W_p on the solar panel.
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 maintaining a 90^o degree against the sun.

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