Developing a Prototype of Solar Tracking for Solar Cell Energy Optimization with Internet of Things (IoT) Technology

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Abstract— **Indonesia is a country with various natural potentials energy, one of them is solar energy that can be used as an alternative source of electricity through Solar Power Generator (PLTS). The energy produced by PLTS is very dependent on sunlight conditions. To get the maximum energy, a prototype of solar tracking was developed. This research used Internet of Things (IoT) technology and combined in PLTS which utilizes internet connectivity for system control, and data sharing in real-time. This solar tracking system prototype using STM32 microcontroller, servo DS3218MG. Based on compilation testbed results of solar tracker, shown that there was increased value of current with 25%, 15% for voltage, 20% for light intensity, and 35% for power production. The testbed results of the solar tracker using the STM32 microcontroller get the maximum value of light intensity and current with the position of the sun's direction that is monitored and stored through the thinger.io webserver database in real-time.**

Keywords— ***Solar Power Generator, Solar Tracking, Internet of Things, STM32.***

I. INTRODUCTION

Sunlight is one of the natural potentials energy that can be used as an alternative source of electrical energy. Solar Power Generator (PLTS) is a type of generator that uses the sun's rays. Therefore, the energy produced by PLTS is also very dependent on natural sunlight conditions [1]. In PLTS, the most problem is the solar cell couldn't produce maximum power. Large light intensity will produce more current, and the power generated will be more maximal. So that the current value is always optimal, the solar panel must always face the sun. This research aim was to developed a prototype of solar tracking to get the maximum light intensity value. It is very important to find out the performance of PLTS by monitoring the current, voltage, and light intensity at the generator. PLTS monitoring should be routine and automatically [2].

Now a day's information and communication technology growth rapidly, the most popular technology is the Internet of Things (IoT). IoT is a technology that utilizes internet connectivity that is connected continuously and has capabilities such as data sharing and system control. PLTS can be monitored by looking at the information system website, so current, voltage, and light intensity can be easily monitored [3]. Also, the resulting view is easy to analyse because the display shown as a graphic chart. For this reason, a prototype of solar tracking and monitoring system of solar power plant based on the Internet of Things was developed.

II. LITERATURE REVIEW

A. Previous research

Asmarashid Ponniran made solar panels using a 16F667A microcontroller with a light intensity sensor, namely *Light Dependent Resistor (LDR)*. The microcontroller will send data to the motor to direct the motor to sunlight. Relays control from the rotation of the motor to rotating clockwise or counterclockwise. Solar panels that move on the motor will move according to the motor's direction [4]. Saravanan.D, Lingeshwaran.T makes solar panels with light sensors, namely *Ligh Dependent Resistor (LDR),* and using a PIC16F877A microcontroller as a controller. Then to drive the direction of the solar panels, a dc motor is used, and the display unit consists of 8051 micro-control boards, sensors, and an LCD. The transmitter unit consists of a router and sensors [5].

P. Gopi Krishna made solar panels using light sensors, namely *Ligh DependentResistor (LDR)* then the data will enter NodeMCU so that the light intensity data obtained can be displayed based on the value entered from the sensor [6]. Yudy Wiranatha Jaya Kusuma made solar panels using a photodiode sensor and an Arduino Mega 16 microcontroller. The results of the light intensity read by the photodiode sensor will be input for the microcontroller. Then the microcontroller drives the servo motor according to the ADC value obtained by the photodiode sensor. Furthermore, the solar panels' position will be moved according to the setting values that have been programmed [7].

Amalia makes a monitoring tool to measure the value of sunlight and wind using wind sensors, namely anemometer, ACS1750 30A current sensor, voltage sensor, BH1750 light sensor, and Arduino Uno microcontroller. The design of this monitoring system is done by connecting light sensors, wind speed sensors, voltage sensors, current sensors, data loggers and other peripherals with the Arduino Uno microcontroller according to the design that has been made [8].Yuval Away makes solar panels using current sensors INA219 voltage, DS18B20 temperature sensor, photodiode light sensor and microcontroller using the Arduino Mega. By obtaining the value of each sensor, the characteristic curves of the current and voltage in the solar module can be displayed [9].

B. Component Specifications

a. Photovoltaic

The word photovoltaic consists of two words namely photo and voltaic. Photo means light (from the language Greek namely phos, photos: light) and volta (derived from the name Alessandro Volta an Italian physicist who lived between 1745-1827) which means the unit of electric voltage. Word photovoltaic is usually abbreviated as PV. Photovoltaic is a technology that produces DC (direct current) electric power of the material semiconductor when exposed to photons. During light shining on the solar cell (named for individual photovoltaic elements), it will produce electric power. When there is no light, energy electricity also stops being generated [10].

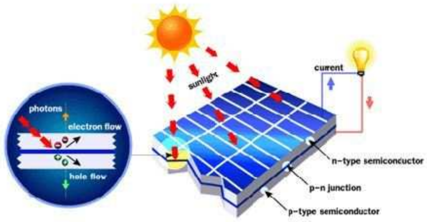

Figure 1. Solar Cell Work System

b. Microcontroller

The microcontroller used in this design is STM32. This STM32 which functions to receive programs that have been made in the form of programming at Arduino Ide then performs commands according to the desired program system such as detecting the function of each sensor and moving the servo motor used in this design. STM32 is STMicroelectronics with ARM 32 bit using ARM Cortex M3, 64 kb flash memory. STM32 with an operating voltage of 2.7V to 3.6V with the number of PWM pins 12, GPIO pins 37, analog input pins 10-12bit, and has 20kb of RAM [11].

c. Light Sensor

The light sensor is an electronic component that functions to convert an optical quantity (light) into an electric quantity. Light sensors based on the resulting electrical changes are divided into two types, namely photovoltaic and photoconductive. In this study, the Light Sensor BH1750 Module [12] was used.

d. Internet of Things (IoT)

Internet of Things (IoT) is a concept that aims to expand the benefits of continuous internet connectivity. Thinger.io was one of public cloud platform for IoT monitoring system[13]. Some of research on solar tracking system combine with IoT related can be found on paper [14-17], it is proven that IoT technology can made the solar tracking system will running optimal.

III. RESEARCH METHODS

A. Research stages

The research method used in the implementation and work of this thesis is a literature study method intended to study various theories related to the design of solar panel automatic drives:

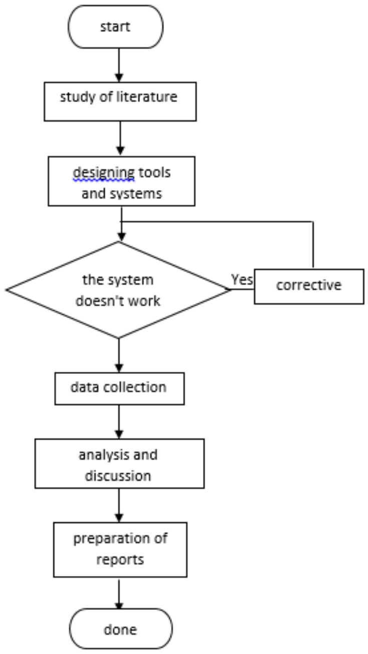

Figure 2. Research Flowchart

The research flow diagram to be carried out can be seen in Figure 2. It begins with designing tools, making tools and programs and continuing with testing the tools as a whole. This study aims to adjust the position of the solar panels so that they always point to sunlight so as to make the energy absorption in the solar panels maximum.

IV. RESULTS AND DISCUSSION

A. Component Testing

The tests carried out are divided into several stages, namely solar panel testing, DHT11 sensor testing, INA19 testing, and BH1750 light intensity sensor testing.

a. Solar Panel

Solar panel testing is carried out without any load. Solar panel testing is measured using a digital multi tester. This is done to determine the suitability of the Isc and Voc test values of solar panels according to the characteristics.

Table 1. Specifications of solar panels

Specification	Information
Max. *Power (Pmax)*	50 *Watt*
Max. *Power Voltage* (V)	18 *Volt*
Max. *Power Current* (I)	2,88 *Ampere*
Open Circuit Voltage (V_{oc})	22,5 *Volt*
Short Circuit Current (I_{sc})	3.04 *Ampere*

b. DHT sensor11

Testing of temperature and humidity sensors is carried out using an accumulator that has been installed with a liquid crystal display. This is done to determine the suitability of the power consumption test value on the electronic device used in the tool. The test results show that the input voltage is 5 volts and the current consumed by the sensor is 0.02 A.

c. INA219 Module Current and Voltage Sensor

Current sensor testing is done by providing voltage and current to the sensor and connecting all of its pins to the STM32, then the voltage and current will be measured.

Figure 2. INA219

d. BH1750 sensor

BH1750 sensor a lampshade is installed with the aim that in the data retrieval process received by the sensor it has a more and better lux range, so that when the sensor is faced directly facing the incoming sunlight it does not directly reach the maximum rating value of the sensor.

Figure 3. Sensor BH1750 using a lamp shade

e. Servo Motor Rotation Functional

This test initiates the activation of the device, where the solar panel moves according to a predetermined angle in accordance with the direction of movement of sunlight, with input parameters in the form of light intensity and time.

B. Program Testing

The sensors used are DHT11 sensors, INA21 sensors, and BH1750 sensors. Testing is done by connecting the sensor to the microcontroller, then entering the Arduino program script then viewing it on the serial monitor.

Figure 4. Sensor test results

Figure 5. Data Graph of PV Flow, Servo Current, Light Intensity, and Temperature and Humidity.

Graph of data retrieval results. The data displayed is data obtained when the client accesses the server address via a browser. If the browser is refreshed, the graphic will disappear and display the graph after the browser is refreshed. However, the data from previous measurements are not lost because the data is -stored in the database server. To retrieve data from the database, the author logs in on the thinger.io web server.

C. Result Data

Figure 6. Solar Tracking System

The movement of the solar cell during data collection with changes in angles of 30,60,90,120 and 150 degrees. The display of the measurement data will be visible on the Thinger.io website. Thinger.io will record data for 3 days from 18 August 2020 to 22-23 August 2020, measurements will be taken starting from 08:30 WIB to 16:00 WIB. During the process, real-time data recording will take once every 15 seconds, where when converted into a data line there are 1680 data every 1 day.

The intensity obtained on the passive and active panels during the data collection process, data retrieval of sunlight intensity is obtained using the BH1750 sensor which is installed and connected to a microcontroller.

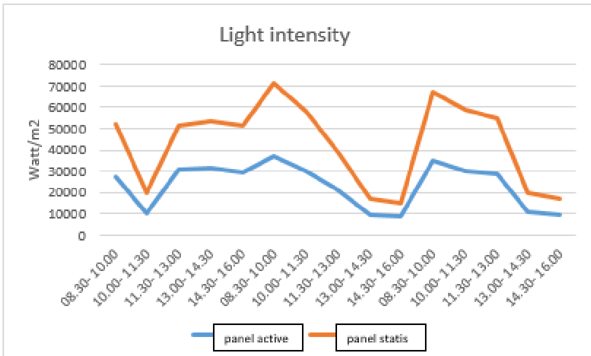

Figure 7. Light Intensity Graph

On August 18, the largest difference in the value of sunlight intensity is 10116 lux at 11: 30- 13:00 WIB, and the smallest difference in intensity is 1393 lux at 10: 00-11.30 WIB. there are cloudy conditions with light rain. It can be concluded that solar panels using a solar tracker and without a solar tracker increases the light intensity value by 20%.

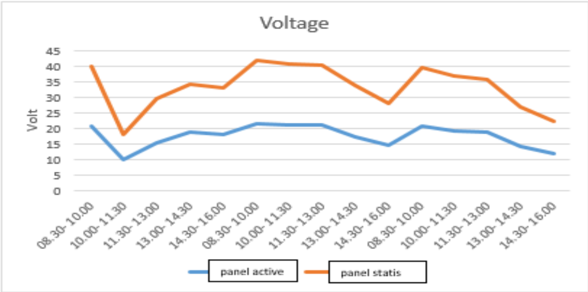

Figure 8. Voltage Graph

The graph of the data results from the measurement of the voltage value carried out at several different hours starting from 08:30 WIB to 16:00 WIB. The condition of the solar panels when the weather is sunny increases the temperature of the solar cells so that it decreases the voltage value even though it is not significant. Solar cell voltage conditions change according to the influence of weather conditions during measurement. It is found that solar panels use a tracker against static panels with an average increase of 15%.

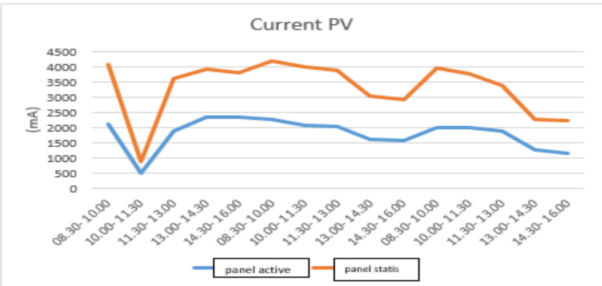

Figure 9. PV Flow Graph

The largest current value of solar panels using a tracker at 2335 mA at 13: 00-14: 30WIB on August 18 with sunny weather and the smallest current value for solar panels using a tracker of 490 mA at 10: 00-11: 30 WIB on August 18 with cloudy weather rain. When the weather is sunny, the condition of the solar panels will increase the intensity value and the irradiation of solar cells, thereby increasing the value of the solar cell currents significantly. Current conditions in solar panels change according to the influence of weather conditions during measurement. It is found that solar panels use a tracker against static panels with an average increase of 25%.

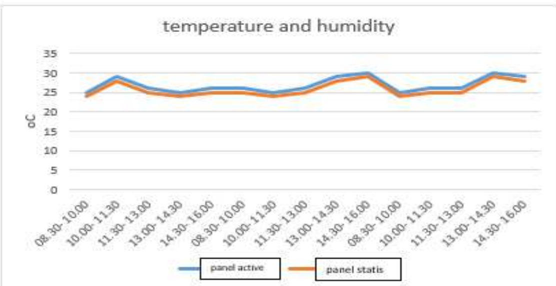

Figure 10. Temperature and Humidity Graph

Measurements start from 08:30 WIB to 16:00 WIB using the DHT11 sensor. It is known that the difference in temperature and humidity values is 1oC at the time of data collection. The temperature conditions on the solar panel using a tracker corresponds to its characteristic curve. The increase in temperature values on solar panels using a tracker against static panels will be significant if the weather conditions are clear. The temperature of the solar panels using raise the average increase of 10%.

D. Economic Analysis

Table 2. Current and Component Usage Time

Component	Current (mA)		Time (s)	
	Standby	Work	Standby	Work
DS3218MG	100	100	0	324000
BH1750	7	7	0	324000
DHT11	1	1	0	324000
ESP8266	80	80	0	324000
INA219	10	10	0	324000

The tool's energy value is strongly influenced by the value of the power generated by a static 50 Wp solar panel or by a tracker. This is because energy is the value of the power generated by the tool when the solar panels get sunlight.

The measurement results can be seen from the power value generated by the tool. The value of the resulting energy level will be compared to the tool's energy consumption of the work process. The energy produced by solar cells can be calculated using the following equation:

$$W = P\,xt$$

Becomes,

$$W = V\,x\,I\,xt$$

Where, W = Energy (Wh); I = Current (mA);
P = Power (Watt); t= Time (seconds)

Table 3. Energy data from solar panels

Time	Power (Watt)		Energy (Wh)	
	Solar Tracker	Statis	Solar Tracker	Statis
08.30- 10.00	44,38	37,36	14379120	12104640
10.00- 11.30	4,80	3,07	1555200	994680
11.30- 13.00	29,07	24,49	711,9243	7934760
13.00- 14.30	44,13	24,98	14298120	8093520
14.30- 16.00	42,17	22,81	13663080	7390440
08.30- 10.00	48,51	40,21	15717240	13028040
10.00- 11.30	43,96	37,88	14243040	12273120
11.30- 13.00	42,65	35,86	13818600	11618640
13.00- 14.30	28,16	23,29	9123840	7545960
14.30- 16.00	22,92	18,79	7426080	6087960
08.30- 10.00	41,96	36,76	13595040	11910240
10.00- 11.30	38,68	31,25	12532320	10125000
11.30- 13.00	35,26	25,77	11424240	8349480
13.00- 14.30	17,93	12,70	5809320	4114800
14.30- 16.00	13,47	11,47	4364280	3716280
Total (Wh)			**151950231,9**	**125287560**

The energy produced by a solar tracker with static or stationary solar panels from the graph is known that the solar tracker produces energy of 151950231.9 Wh. In contrast, solar panels are static or silent 125287560Wh. The results show that solar panels with solar tracker increase the energy against static or stationary solar panels by26662671.9 Wh with a large percentage of 20%.

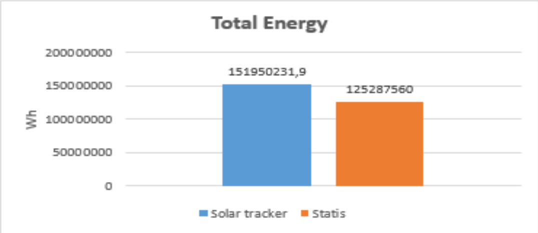

Figure 11. Total energy from a solar tracker with silent panels

In this research, the solar panel using a tracking system requires components, as in table 3, to see the solar panels' energy when making measurements. Some of the sensors and servo motors used will consume energy. At the same time, data collection lasts for approximately 7 hours starting from 08:30 WIB to 16:00 WIB, which has been converted in seconds, namely to 342000 seconds, which is multiplied by the power consumption at each sensor and servo motor.

Table 4. Consumption of solar tracker

Component	Total	Current (mA)		Time (detik)		Energy (Wh)
		Standby	Work	Standby	Work	
DS3218MG	1	100	100		30	75000
BH1750	1	7	7		324000	1134000
DHT11	1	1	1		324000	1620000
ESP8266	1	12	12		324000	19440000
Total						22269000

The energy produced is equal to 151950231.9Wh: 3 = 50650077.3 Wh while the energy required is 22269000 Wh so that more energy is 28381077.3 Wh or 315345.30 Wh per hour.

E. Effect of temperature on solar cell energy produced

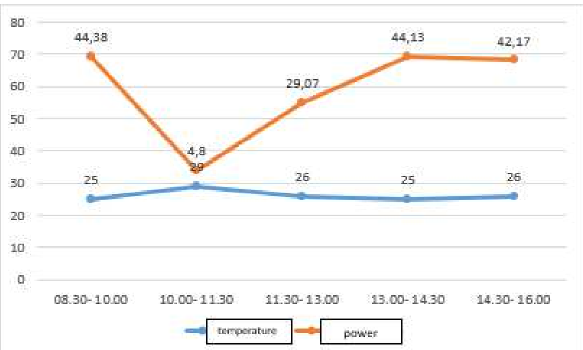

Figure 12. Graph of the temperature value against the power generated by the solar panel

The greatest power was obtained at 08.30 - 10.00 WIB, sunny weather with a temperature of 25 oC, the power was 44.38 Watt, and the smallest power was obtained at 10.00 - 11.30 WIB, rainy weather with a temperature of 29 oC, the power produced was 4.8 Watt. The greater the temperature, the value of the power generated by the solar panel module will be smaller than the maximum power value of the solar panel module. So it can be seen that an increase in temperature causes the output power to decrease so that the effect of temperature on the power produced is very significant.

F. Effect of tilt angle on the power produced

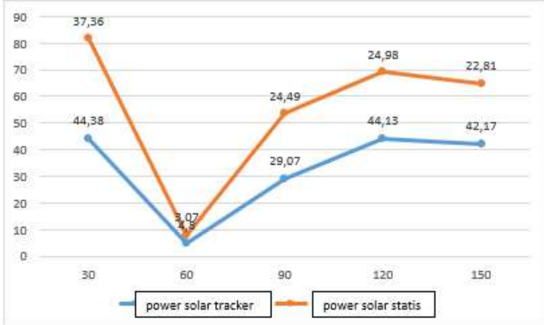

Figure 13. Graph of the tilt angle to the power generated by the solar panel

The graph of the slope of the angle to the power produced the greatest power is obtained when the angle is 30o with 44.38 watts on the solar tracker and 37.36 watts for static diesel. The smallest power is obtained at a 60o angle with 4.8 watts on the solar tracker and power 3, 07 Watts on static/silent diesel. With the direction of the solar panel that is always facing the sun, the power generated is greater than that of static solar. Then the more perpendicular to the sun, the value of the power produced is more optimal.

V. CONCLUSION

The Solar Tracker system built based on the STM32 microcontroller using the BH1750 light sensor gets a maximum light intensity value. It produces a large current so that the power generated is optimal in the direction of the sun and can be monitored via a web server in real-time.

REFERENCES

[1] Marsudi. 2016. "Electrical Energy Generation". Thesis. State Polytechnic of Sriwijaya, South Sumatra. 2016.

[2] Tian, U.Salsabila. 2017. "Prototype of IOT-based PLTS Parameter Monitoring System". Thesis. Yogyakarta State University, Yogyakarta. 2017.

[3] AS Adi, "Analyzing the Performance of Solar Power Plants through Design and Measurement with Solar Irradiance and Temperature Sensors," Sepuluh Nopember Institute of Technology, Surabaya, 2016.

[4] Ponniran, Asmarashid. 2011. "A Design Of Single Axis Sun Tracking System".International Power Engineering and Optimization Conference, Universiti Tun Hussein Onn Malaysia. 2011

[5] D, Saravanan. 2019. "Monitoring Of Solar Panel Based On Internet of Things (IOT) ". Proceeding Of International Conference On System Computation Automation and Networking, Department of Computer Science and Engineering. 2019

[6] RLR Lokesh Babu. 2019. " IoT Enabled Solar Power Monitoring System ". International Journal of Engineering & Technology, 7 (3.12) (2018) 526- 530, India. 2019

[7] Jaya K, W Yudhi. 2015. "Design of Automatic Solar Panel Activator using Photodiode sensor based on Atmega 16 microcontroller". Journal of Electrical Engineering and Technology No.1 Vol. 9.2015.

[8] Tamamy, Aries Jehan. 2019. " Design of Monitoring System for Measuring Solar and Wind Power Potential ". Journal of Electrical Engineering No.1 Vol. 15.2019.

[9] Cholis. 2016. " Designing a Data Recording Device for Current and Voltage Characteristics Curves (IV) for Solar Modules ". Online Journal of Electrical Engineering No.1 Vol.2. 2016.

[10] Myori, E. Dwiprima. 2019. "Solar Light Tracking System in Photovoltaic". Journal of Vocational Innovation and Technology No.1 Vol. 19.2019.

[11] Smeti.A. 2013. "*Implementation of a Predictive controller on the STM32 board* ". IEEE.National School of Engineering of Tunis, Tunisia. 2013

[12] Pamungkas, Muchamad. 2015. "Design and realization of light intensity measurement tools". ELKOMIKA Journal No.2 Vol.3.2015.

[13] Lusita D, Nurul Hidayati. 2019. "Smart Home Prototype with IOT-Based NodeMCU ESP 8266 Module".Online Journal of Electrical Engineering No.1 Vol.2.2019.

[14] Hamid Allamehzadeh 2016. " Solar Energy Overview and Maximizing Power Output Of a Solar Array Using Sun Trackers". IEEE Conference on Technologies for Sustainability (SusTech). Eastern New Mexico University, Mexico. 2016

[15] Gupta.Alok 2019. " IOT based Electrical Device Surveillance and Control System ".IEEE. University School of Information, Communication and Technology (USICT),Delhi.India. 2019

[16] Stoyanov,Todor.2017." Sun Tracker with Sensor – Photovoltaic Cell".IEEE. Technical University of Sofia,Bulgaria.2017

[17] Praci, Rani.2018. "An Analysis on Arduino based Single Axis Solar Tracker".IEEE. Gautam Buddha University Delhi.India. 2018