



IoT Based Dual Axis Solar Tracker Implementation For Polycrystalline Photovoltaic With Energy Storage

Omar Abu Hassan^{1,a,*}, Hazwani Hamdani¹, Hairulazwan Hashim¹, Ahmad Al'abqari Ma' Radzi², Muhammad Shukri Ahmad², Tengku Nadzlin Tengku Ibrahim², Shamsul Aizam Zulkifli³

¹Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia (UTHM) Pagoh, Johor, MALAYSIA

²Center for Diploma Studies, Universiti Tun Hussein Onn Malaysia (UTHM) Pagoh, Johor, MALAYSIA

³Faculty of Electrical and Electronic Eng., Universiti Tun Hussein Onn Malaysia (UTHM) Parit Raja, Johor, MALAYSIA

*Corresponding Author

Email: aomarh@uthm.edu.my

Received 25 September 2020;
Accepted 28 October 2020;
Available online 28 October
2020

Abstract: This project has been identified as IoT Based Dual Axis Solar Tracker Implementation for Polycrystalline Photovoltaic with Energy Storage that has two degrees of freedom that act as axes of rotation, both horizontal and vertical. Polycrystalline panel is great in both diffuse light and specular light and yet known for its minimal cost. This motorized servo-motor system based final year project is a self-orient the solar panel towards the maximum intensity of sunlight using Light Dependent Resistor (LDR) and hence, it will generate supply to the load. The main system that use to control the movement of motor and sense the LDR is Arduino Uno. This portable 10W solar project can be used anywhere at any time as its main concern to educate people of basic solar tracker concept aside to help supplying 5V Direct Current (DC) load. An Internet of Things (IoT) is therefore added as a feature for this project to monitor the performance of photovoltaic voltage through Blynk application in cell phone

Keywords: Dual Axis Solar Tracker, Polycrystalline Solar Panel, Servo Motor, Internet of Things, Blynk deemed necessary

1. Introduction

Nowadays, the use of solar energy to electrify the domestic premises has been widely implemented. The clear benefit of using renewable and clean energy sources accelerate growth in research and development in the area of solar harvesting technology [1]. In Malaysia context, the hot climate season provide big advantages for solar PV installation [2] where the cost of solar installation is still expensive compared to conventional type of energy generation.

The movement of the sun throughout the day lead to static solar PV installation looks less efficient compare to the PV panel that can track the sun movement [2]-[5]. Therefore, the ability of the solar system that can track the sun and move the panel surface to always facing the sun give a lot of advantageous compared to the static system [4]-[8].

Thus, this project exploring and study the different between static solar panel and solar with tracking system. The proposed solar-based project will be in small scale focusing on educational kit to demonstrate how PV system works, with a

connected load which this project connected to RGB strips, along with Internet of Things (IoT) concept for monitoring purposes [9]-[17]. The selection of dual axis system is expected to gain 25% more efficiency compare to single axis system in capturing the solar energy from the sun [6].

1.1 Project Objectives and Scopes

Main objective of this project was to design and study Arduino programming that sense LDR and able to compare the intensity of light. System also need to be able to simulate 0° - 360° rotating servo motor of solar panel upon LDR sensing to obtain the maximum efficiency of solar energy. Finally, construction and validation of a dual axis solar tracker project that has monitoring display for daily monitoring and comparison purposes using Blynk application.

However, some limitation has been set to achieve the project goal.

- a. Designing C++ Arduino uno microcontroller as project controller including interfacing Nodemcu for IoT.
- b. Using light dependent resistor (LDR) as a light sensor where this sensor varies the resistance depending upon the light fall. The converted digital form Analog signal through ADC embedded in Arduino microcontroller will compare the difference LDR voltage level.
- c. By using servo motor to control the solar rotation angle. The difference between LDR voltage level will drives the servo motor towards normal incident of sunlight where it catches the most sunlight. The angle of rotation is set by controller.

2. Literature Work

Solar Photovoltaic (PV) System is an electrical system that convert light to electricity. The electricity produces from the PV Module in the form of Direct Current (DC). Due to the distribution of the electricity is using Alternating Current (AC), the electricity from PV Module is converting DC to AC using inverter. The transformer is to step-up the voltage level of PV system to match grid voltage level. Basically, the components of Solar PV System are consisting of Solar PV Module, solar charger controller, battery, inverter if needed and load. A PV module is packaged, connected assembly of 6x10 photovoltaic solar cells. Photovoltaic modules There are 3 types of PV Modules which are Monocrystalline, Polycrystalline and Thin Film. These 3 types of PV modules have their own leading characteristics and contrast.

2.1 Solar Tracker in Photovoltaic Application

Normally, the existing system has maximum energy from the sun is received only from morning 11 am to afternoon 2 pm, due to solar panel is always kept tilted 30° facing north and charges a dry cell that normally has a rating of 5V to 24V. Two types of solar tracker consist of single and dual axis tracker. Single axis solar tracking system could improve the incident angle of sunlight. In order to ensure maintain and increase maximum power output from PV cells, the sunlight's angle of incidence needs to be constantly perpendicular to the solar panel. This requires constant tracking of the sun's apparent daytime motion, and yet it will develop an automated sun tracking system which carries the solar panel and positions it in such various ways that direct sunlight is always focused on the PV cell

Single-axis solar tracker rotates with one axis moving back and forth in a single direction. Different types of single-axis trackers include horizontal, vertical, tilted, and polar aligned, which rotate as the names imply, meanwhile dual-axis solar tracker continually face the sun because they can move in two different directions. Types include tip-tilt and azimuth-altitude. Dual-axis tracking usually used to turn a mirror and redirect sunlight along a fixed axis towards a stationary receiver. These both trackers follow the sun vertically and horizontally, so they help gain maximum solar energy generation.

2.2 Project Description

The main objective of this project is to develop an automatic solar tracking system where with the system, the solar tracker will be able to keep aligned with the sun in order to produce as maximum as much power. The system focuses on the controller design and set the rotation of motor upon receiving sun to get the maximum intensity of sun. When the

intensity of sunlight is decreasing, this system automatically changes its direction to get maximum intensity of Sunlight [1]. A Blynk application has been added to monitor the performances of solar panel.

2.3 Solar Panel

The most significance component in the system is the solar panel itself. This project uses Polycrystalline solar panel as it is known as high efficiency type other than thin film. Polycrystalline silicon solar panel are space efficient, which is suitable for this small scale project aside of producing high power. Polycrystalline also live as the longest, hence it can be used for a long period of time. It is easy to get as the manufactured of PV crystalline is worldwide production. Polycrystalline solar panels tend to have slightly lower heat tolerance than monocrystalline solar panels. This project use a panel of 10W, 12V solar panel as on Fig. 1.



Fig. 1 – Polycrystalline Solar Panel

In order to choose the best manufacturer of Polycrystalline solar panel, few calculations of the model efficiency (1) must be considered as follows and further calculation will be demonstrated in part 3.0 onwards:

$$Efficiency = \frac{P_{out_STC}}{P_{in}} = \frac{I_{mp_STC} \times V_{mp_STC}}{h \times A} \quad (1)$$

2.4 Rechargeable Battery

A rechargeable battery dry cell that has function in the same way as primary cell which is non-rechargeable battery. The difference between these two batteries is the chemical reaction that happened in reverse during the recharge cycle. In solar panel, rechargeable battery is used to store the energy collection from the sun that need to be used later by the load and normally use is lead acid type. This battery is a wide deployment due to their cheap and relatively long service life, that can keep up to 15 years. A capacity of 7.2Ah, 12V battery is expected to last for a 8 hours long time (refer to Fig. 2).



Fig. 2 – Lead Acid rechargeable battery

2.5 Servo Motor

Servo Motor or Brushless Servo Motors have windings in the stator and permanent magnets attached to the rotor. No brushes are used. Brushless servo motors provide high acceleration, high torque, and no maintenance [2].

This project has use MG946R Towerpro Digital Metal Servo type that able to carry up to 13KG High torque and load as on Fig. 3. Two similar type of motor is used for rotation angle, horizontally and vertically. Motors are attached at mild steel-based to hold the solar panel and get instructions from Arduino that sense LDR.



Fig. 3 – Servo Motor MG946R Towerpro type

2.6 Light Sensor

One of the sensors that detect the existence of sunlight or light is Light Dependent Resistor (LDR) aside of photoresistor. It functions as a resistor, two terminals, no polarity, the resistance decreases when it is expose to higher light intensity and normally use with another resistor as voltage divider. Basically, it is a light sensitive resistor, the resistance will decrease when the surface is expose to light. Total LDR used for this project is four and each LDR will compare the resistance value to give signal to controller and therefore, motor will rotate. Partitions are used to let the LDR sense the highest resistance before it instructed motor to move (Fig. 4).

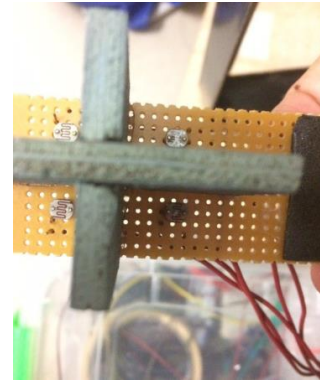


Fig. 4 – LDR for sensing light

2.7 Arduino Uno

Arduino Uno is a type of controlled that use in the project to keep the solar panel aligned with the sun in order to maximise the power efficiency. Arduino Uno is one of the microcontroller that has been selected to convert the Analog signal photocell voltage into digital values and provide output channels for motor rotation. This project connected with Arduino Maker Uno as the brain of project as it is fully compatible with Arduino. It also can share same library and code besides equipped 12 LEDs, 1 piezo buzzer and 1 programmable button on the Maker UNO.

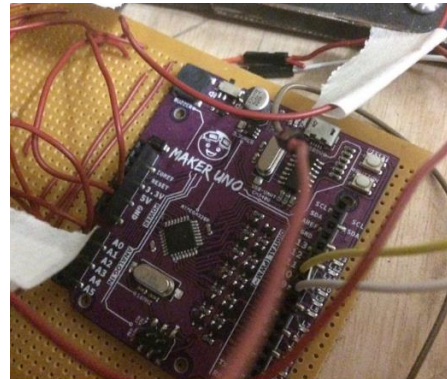


Fig. 5 – Arduino Maker Uno as controller

2.8 NodeMCU Controller

One of the available controller that can be used in the project is NodeMCU. NodeMCU can acts as an interface between hardware and software through Blynk application.

This IoT board is an open source that refers to various firmware. It includes firmware that runs on ESP8266 WiFi and hardware which is based on ESP-12 modules. The languages involving in this firmware are including C and C++ scripting language. The input for this project is sensor voltage and internet, while for the output displayed on smart phone [4].



Fig. 6 – NodeMCU ESP8266-12 type



Fig. 8 – Voltage sensor 0-25V

2.9 PWM Charger Controller

A PWM charge controller or charge regulator is a voltage and current regulator to keep batteries from overcharging (Fig. 7). It regulates the voltage and current coming from the solar panels going to the battery. Solar panel of this project is 12V and need to charge 12V, so if there is no regulation the batteries will be damaged from overcharging. Normally battery need around 12V to 14V to get fully charged. Its purpose is to keep the system batteries charged and safe for a long time. Pulse Width Modulation (PWM) type of solar charger has been selected due to can reduce battery heating and gassing. It also automatically adjusts for battery aging, self-regulate for voltage drops and temperature effects in solar systems.



Fig. 7 – PWM charger controller

2.10 Voltage Sensor

This kind of electronic sensor has its input voltage which is voltage to be measured is restricted to 25V. A simple and useful module which uses a potential divider to reduce any input voltage by a factor of 5 [3]. This allows to use the analogue input of a microcontroller to monitor voltages much higher than it capable of sensing. The module also includes convenient screw terminals for easy and secure connection of a wire (Refer to Fig. 8). It will transmit the data to the Arduino which interfacing with NodeMCU for Blynk.

3. Methodology

This project is designed with solar panel, Light Dependent Resistor (LDR), Arduino Uno controller, Servo Motor and its particular driving circuit. LDR varies the resistance depending upon light fall. The varied resistance is converted into an analog voltage signal. The analog voltage signal from solar sensor is then fed into controller Arduino Uno which ADC (Analog Digital Converter) in it. The converted digital signal is given as the input of Arduino Uno. When there is difference between LDR voltage levels controller program drives the servo motors towards normal incidence of sunlight where it catches the most sunlight. The additional Blynk is for monitoring purpose from distance for solar panel to ensure it maintain optimum performance.

3.1 System Diagram

Based on the diagram in Fig. 9, the process starts with sensing sunlight with Light Dependent Resistor (LDR) and will convey the result to the Arduino Uno. The program works by comparing the resistance of the four sensors and moving the motors. How sensitive those sensors are completely depending on the programming coding. When sunlight falls on the sensors, the value of potential divider circuit will be changed.

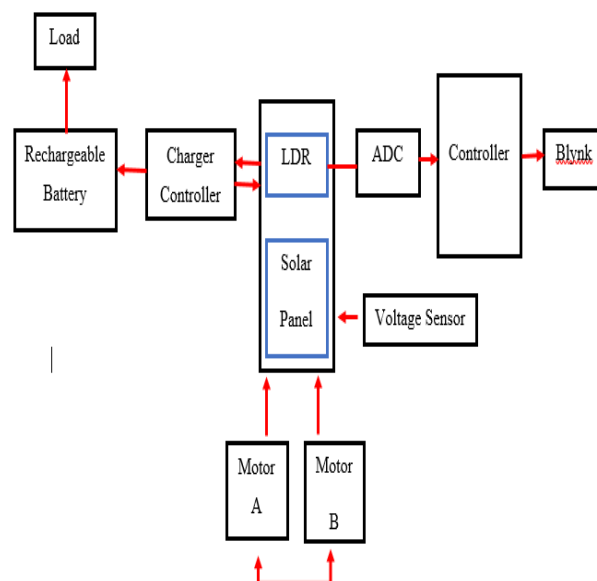


Fig. 9 – Block diagram of the complete system

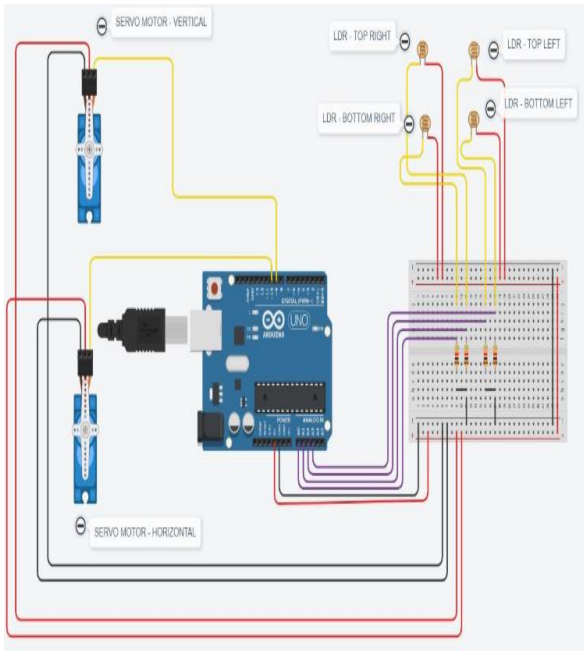


Fig. 10 – Schematic diagram of Arduino connection

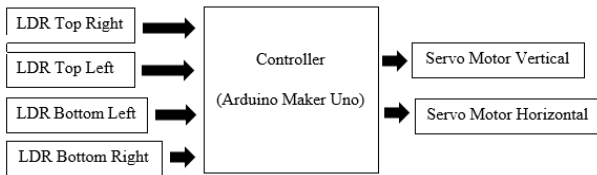


Fig. 11 – Block diagram for controller

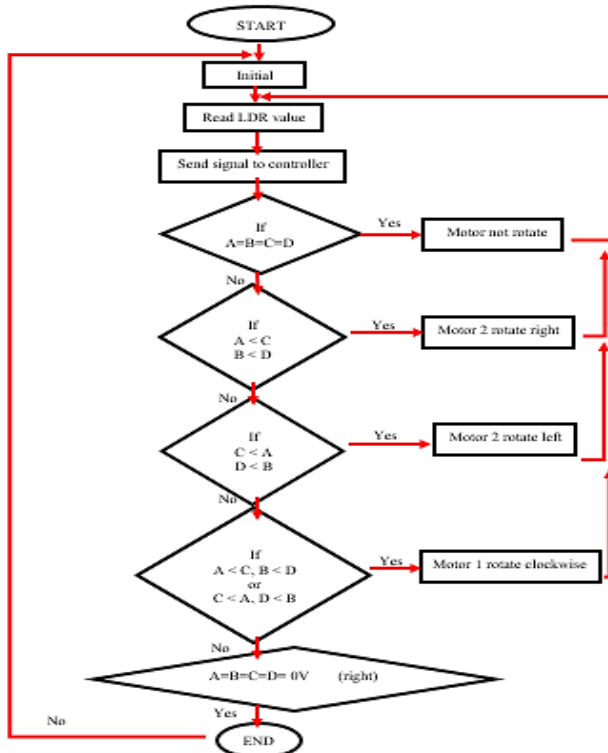


Fig. 12 – Flowchart of the LDR with connection to controller

Fig. 10 and Fig. 11 show input and output sensors connected to the Arduino controller. Firstly, the sensors will

give signal to controller. When sensor is normal to the sun, there is no shadow of object on the LDRs. Then, the light intensity which on the LDRs is same. Therefore, digital values are also same. Thus, the motor will not rotate. If sensor is not normal to the sun, there should be shadow of object on one of the LDRs. Then the digital value of the LDR which get dark is less than the digital value of another LDR.

For example, if voltage value of LDR A is less than LDR C and LDR B is less than LDR D, the motor will turn in right direction since LDR C and D has higher amount of voltage. Once all the voltages are the same, the motor will stop rotating. During night time, all the sensor's voltage need to remain all same so that it will not move from its initial position. This can be done by programming. The flowchart in Fig. 12 explained how LDRs working.



Fig. 13 – Block diagram for NodeMCU ESP 8266-12

Fig. 13 above shows how Blynk application is interfacing with NodeMCU ESP 8266-12 which have wifi functionality. This wifi module has 1 input only which is connected with voltage sensor. Therefore, all the voltage performance each time is monitored through the Blynk applications in smartphone from a bit far.

3.2 System Specification and PV Based Modelling

Table 1 shows detailed specifications of the system. The most crucial and hardest part is to assemble the mild steel with the plywood. The mild steel must fabricate nicely according to project and must fit motors well. It requires a lot of time to configure exact dimension and placement of the materials. RGB is place at the end of product to see it works.

Table 1 - Project specification with the list of equipment

Item	Specification
Main Process	To track highest intensity of sunlight and convert into electrical energy by installing controller
Rotation Axis	Horizontal and Vertical, (X and Y)
Solar Panel	Polycrystalline type
System Voltage	GENUINE GP 12V 7.2Ah Rechargeable Sealed Lead Acid Battery
Solar Charger Controller	PWM 12V/ 24V Auto Switch
Controller	Arduino Maker Uno
Motor	Tower Pro RC Servo Motor MG946R (180 degree)
Energy Flow	Solar energy to Electrical Energy
Load	DC load : RGB LED strip (5V)
Material	Mild Steel (holder), Plywood (base) Plastic Conduit Flexible (Cable Trunking)
Feature	Blynk Application (Smartphone)

Fig. 14 shows the model prototype of the system develop in 3D graphic. This model provides the idea on how the system

will look and the arrangement require to construct the actual hardware at later stage.

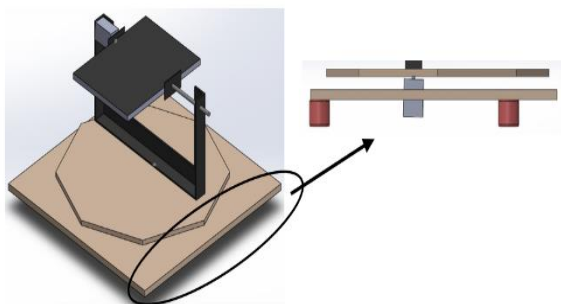


Fig. 14 – 3D model of prototype

3.3 System Algorithm and Project Costing

The system algorithm in Fig. 15 shows the step by step flow in the designed system. System start with initialization of input that power up from powerbank. Once system in ON mode, the location of the solar panel will be adjusted based on the location of the sun detected by the solar sensor.

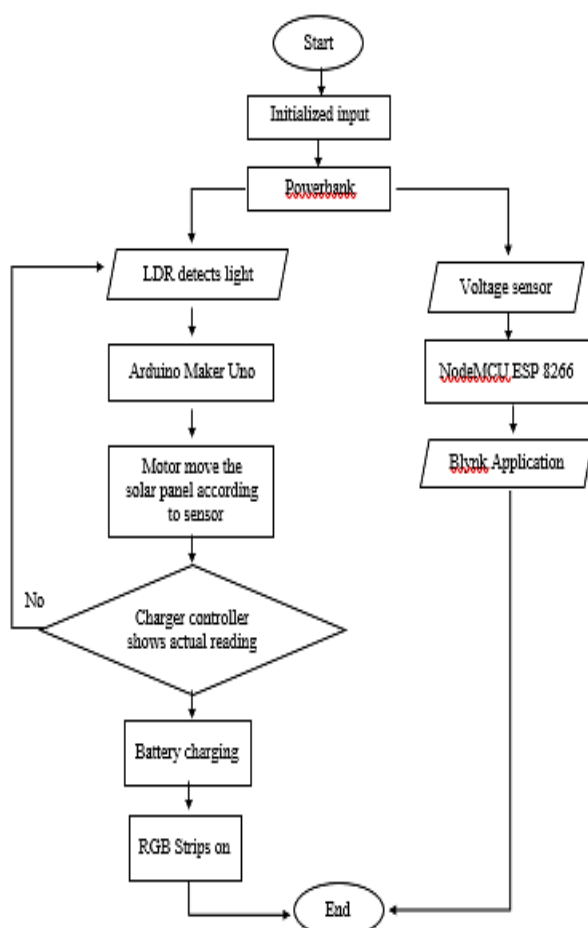


Fig. 15 – System algorithm flowchart

The construction of the hardware prototype requires the purchased of various parts and components. The list of the part for this project and cost incur show in the Table 1.

Table 2 - A summary of project costing for the project

No	Equipment	Specification	Qty	Price (RM)
1	Solar Panel	12V, 10W Polycrystalline	1	80
2	LDR	-	4	2
3	PWM Charger Controller	12V/ 24V Auto Mode	1	14
4	Servo Motor	Towerpro MG 946R	2	50
5	Arduino Uno	Maker Uno type	1	50
6	Battery	Lead Acid 12V	1	70
7	Electronics part	Resistor, cable, jumpers	-	10
8	RGB Strips	5V red, green and blue color	1	10
9	Voltage Sensor	0-25V	1	5
10	NodeMCU	ESP 8266-12 version 9	1	15
Total				304

4. Result and Discussions

Fig. 16 below shows a picture of complete project. The complete system consist of solar PV panel, PWM charger controller, battery, and sensor controller with Blynk system.



Fig. 16 – Dual axis solar tracker complete project

4.1 Functionality Testing

The testing is conducted for 3 consecutive days (Fig. 17). Each day has different time due to unpredictable weather. The project is tested about 10 minutes, within 3-4 hours, put under direct sunlight to gain as optimum as it can. The performance is then monitored through Blynk application. The reading of actual testing with Blynk is almost the same. This is due to formula and declaration numbers in Arduino coding, and hence the reading has slightly different with actual one. The testing is done after near afternoon when the sun almost at the top. The data collection work start around 11 am, finish before 4 pm, on 7 Dec – 10 Dec 2019.

The solar tracker also detects the highest intensity through LDR and give its optimum value. Its rotate according to the sensing of LDR that gives signal to servo motor. Other than that, in dim weather condition, the sunlight can be replaced with floodlight to replicate the sunlight. Due to unpredictable weather, this experiment only conducted for 10 minutes, repeat

the same experiment after few hours. Fortunately, the result still as expected.



Fig. 17 – Functionality testing under sunlight

Fig. 18 illustrate the PV panel output voltage read from PWM charger controller and from voltage sensor which shown in Blynk application. In dim weather, where the sunlight are covered, the reading of solar panel is however decreasing. This can be seen as in Fig. 18. This concept has been explaining earlier in [1]. Full testing between solar tracker and static solar is done as well at the same time and the result will be shown at 4.2 with further elaborations.

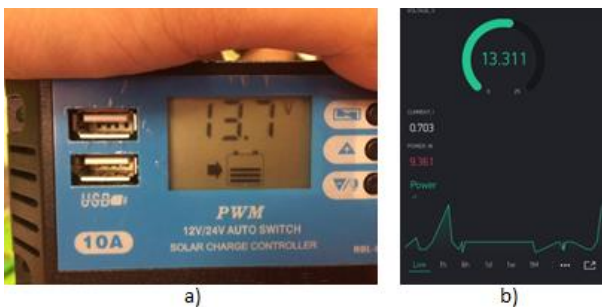


Fig. 18 – a) Voltage output charger controller to the battery, b) Current and power output from Blynk interface



Fig. 19 – Dim weather condition reading, a) Direct voltage output from panel, b) Voltage output from system sensor

4.2 Static Solar and Solar Tracker Performance Comparison

Both Table 3 and Fig. 20 shows the performance comparison of solar tracker versus static solar. It can be observed that the system with tracking function produce higher output voltage compared to the static system. Although, the reading slightly difference, the overall efficiency still within 2% to 9% from total capable efficiency.

Table 3 - Voltage reading between solar tracking and static solar

Date	Time	Solar Tracker Voltage (V)	Static Solar Voltage (V)
07/12/2019	11.30 am	11.89	10.9
	12.45 pm	13.8	13
	2.00 pm	12.21	12.1
08/12/2019	11.00 am	11.5	11.3
	2.30 pm	12.89	12.5
	3.30 pm	11.97	11.5
09/12/2019	12.00 pm	13.98	13.78
	1.00 pm	13.96	13.9
	11.15 am	12.59	12.3
10/12/2019	1.30 pm	13.31	13.2
	2.00 pm	13.9	13.08
	4.00 pm	11.9	9.2

This project prototype can be used as an educational kit to observe some performance behavior in the PV system with or without tracking system. It is proven that the highest of irradiance sunlight can give the highest output performance. However, with the solar tracking system, the performance are slightly increase compare to the system with tracking (Fig. 20).

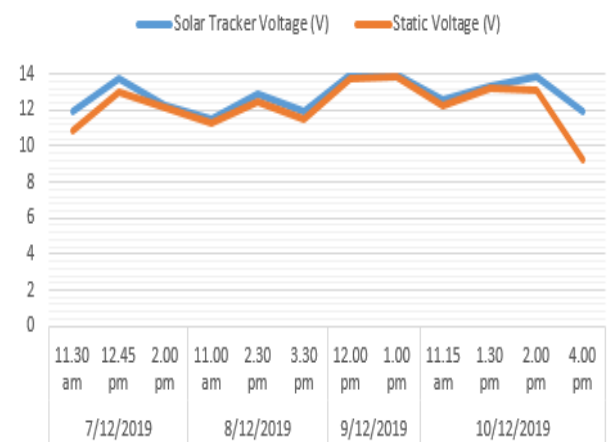


Fig. 20 – Line graph comparison between Solar Tracker and Static Solar

5. Conclusion

This paper elaborates a simple and accurate modeling method of a commercially available photovoltaic panel using both axis of direction. First, this testing is going through a

discussion of an existing modeling methods of photovoltaic panels (actual and simulation). Later, the methodology related to this project and then actual testing of a photovoltaic panel has been described. In methodology also, the main components are discussed in detail with specifications and design related.

The modeling of this commercially available PV panel is based on specifications given on the manufacturer's plate. Actual testing provides brief idea on how the solar output performance behave with and without the solar tracking system. The output comparison concludes the earlier hypothesis that system with solar tracking provide better output performance. Thus, achieved the main objective of the project.

Acknowledgement

The authors would also like to thank the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia for its support.

References

- [1] Vijay Devabhaktuni, Mansoor Alam, Soma Shekara Sreenadh Reddy Depuru, Robert C. Green, Douglas Nims, Craig Near, Solar energy: Trends and enabling technologies, Renewable and Sustainable Energy Reviews, Volume 19, 2013, Pages 555-564,
- [2] W.X. Shen, Optimally sizing of solar array and battery in a standalone photovoltaic system in Malaysia, Renewable Energy, Volume 34, Issue 1, 2009, Pages 348-352,
- [3] A. Ponniran, A. Hashim and H. Ali Munir, "A design of single axis sun tracking system," 2011 5th International Power Engineering and Optimization Conference, Shah Alam, Selangor, 2011, pp. 107-110
- [4] Yingxue Yao, Yeguang Hu, Shengdong Gao, Gang Yang, Jinguang Du, A multipurpose dual-axis solar tracker with two tracking strategies, Renewable Energy, Volume 72, 2014, Pages 88-98,
- [5] Alexandru C, Pozna C. Simulation of a dual-axis solar tracker for improving the performance of a photovoltaic panel. Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy. 2010;224(6):797-811.
- [6] J. F. Lee and N. A. Rahim, "Performance comparison of dual-axis solar tracker vs static solar system in Malaysia," 2013 IEEE Conference on Clean Energy and Technology (CEAT), Lankgawi, 2013, pp. 102-107
- [7] S. Makhija, A. Khatwani, M. F. Khan, V. Goel and M. M. Roja, "Design & implementation of an automated dual-axis solar tracker with data-logging," 2017 International Conference on Inventive Systems and Control (ICISC), Coimbatore, 2017, pp. 1-4
- [8] Prabodh and S. Kumar, "Design, development and performance test of an automatic two-Axis solar tracker system," 2011 Annual IEEE India Conference, Hyderabad, 2011, pp. 1-6
- [9] Brushed Servo Motors. (n.d.). Retrieved July 1, 2019, from <https://servo2go.com/products/servo-motors-drives/brushed-servo-motors/>.
- [10] 25V Voltage Sensor Module. (n.d.). Retrieved January 15, 2019, from <https://hobbycomponents.com/sensors/389-25v-voltage-sensor-module>.
- [11] Maehlum, M. A. (2018, May 16). Which Solar Panel Type is Best? Mono- vs. Polycrystalline vs. Thin Film. Retrieved February 12, 2019, from <http://energyinformative.org/best-solar-panel-monocrystalline-polycrystalline-thin-film/>.
- [12] Stepper vs Servo. (n.d.). Retrieved February 13, 2019, from <https://www.amci.com/industrial-automation-resources/plc-automation-tutorials/stepper-vs-servo/>
- [13] L. (2016, November 25). Difference between Stepper Motor and Servo Motor. Retrieved February 2, 2019, from <https://www.youtube.com/watch?v=x48ggHZDFLY>
- [14] Worthy, E. (2014, January 25). Dual Axis Solar Tracker. Retrieved February 6, 2019, from <https://www.youtube.com/watch?v=cIC6237TLRA>
- [15] Suzhou Sunlight Well Photovoltaic Technology Co., Ltd. (n.d.). Poly 4W Datasheet. Retrieved February 11, 2019, from <https://www.ensolar.com/pv/panel-datasheet/crystalline/61>
- [16] L. Flysky co., "Digital proportional radio control system Table of contents."
- [17] Cytron Technologies Sdn. Bhd., "SmartDrive160," 2017. [Online]. Available: <https://www.cytron.com.my/p-mds160a>.