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Economics and Environment Assessment for Design and Implementation of An Automatic Solar Tracking System

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Abstract

Our climate system is undergoing severe changes because of a global economy based on fossil fuels and rising greenhouse gas emissions. Furthermore, the use of non-renewable energy will be restricted in the near future. As a result, the use of renewable energy has begun to assist our environment with clean energy. Solar energy is frequently employed since it is a renewable and cost-effective source of power. The objective of this project is to design and implement an automatic solar tracking system by using MATLAB/Simulink and Proteus software to get the maximized power generated from the PV system.

In this project, the inventive of an automated solar tracker benefitting from light dependent resistors added with ultrasonic anemometer as a wind sensor and a rotary position sensor to achieve a fully functioning an automatic solar tracker. The values of irradiance and power generated will be discussed on this paper based on the implementation of the Matlab and Proteus simulation.

Keywords: Solar Photovoltaic (PV), An Automatic Solar Tracker, Maximized Power Generated.

Introduction

An automatic solar tracker is a project to improve the current design of the solar system used especially in Malaysia (Schmid & Behrendt, 2021). Currently the solar panel used is a ground installed with a non-movable panel (Chin et al., 2011). Solar energy, more than any other source, has a unique ability to provide electrical energy at a low cost (Kurian & Nisha, 2015). Solar energy is becoming one of the most favored sources of alternative energy. Solar energy is the energy that markets from the Sun. Mounting solar panels on a stationary assembly is that the easiest method in which alternative energy are often used (Kona et al., 2015). The absorption of sunlight energy is limited due to the change direction of sunlight. Therefore, the main objective for this project is to help to increase the absorption of sunlight as it can move following the direction of the sun. Increasing in sunlight absorption can increase the electrical energy production by the solar panel (Da Silva & Fernandes, 2010). Despite the fact that solar energy is a prominent alternative energy source, most solar panels have a less than 40% efficiency rate. This demands the purchase of expensive solar batteries or the installation of a solar tracking system to meet the energy need (Baskar, Joseph, Narayanan, & Loya, 2013). A comparison study reveals a 40% improvement in energy extraction over fixed panels and a significant benefit of the optimized scheme over continuously rotating panels. The energy savings on the consumption side were found to be just over 20% (Ghassoul, 2018).

To operate the panel according to sun movements, a single straight actuator, such as a motor, is used. Two LDRs on opposing sides of the solar panel can be used to evaluate the intensity of solar irradiation by measuring the voltage drop between them, which is then compared by a drive circuit until the two LDR voltages are equal, and the panel stops moving. As a result, the solar panel is always aligned to the sun's rays (Rani et al., 2018).

In this project, a solar rotating panel which automatic solar tracker used for domestic, industrial, or large-scale solar grid applications has been simulated, which will increase the overall performance of a solar panel by considering the Sun's movement with extreme precision and accuracy (Chang et al., 2020). The Light Dependent Resistor (LDR) is used in the Solar Sensor to monitor the direction of the Sun. A photoresistor, also known as a Light Dependent Resistor (LDR), is an electronic device that can be used in light-sensitive detector circuits as well as light or dark activated switching circuits (Fernandez-Ahumada et al., 2020). The radiation data received by the LDR is sent from the microcontroller to control the brushless DC motor. In other words, when the Sun is at its brightest, the motor drives the panel in that direction (Waibel et al.,2019). The strength of the wind is considered in this system; thus, an ultrasonic anemometer is used as a wind sensor.

Methodology

The entire system as well as the flow of step employed in the solar tracking system will be discussed on how to get the maximized power generated from the PV system. The overall project planning which includes MATLAB and Proteus simulation will be discussed into greater details. The amount of power it produces using the formula and generated by the MATLAB simulation circuit is:

$$P_{OUT} = VI.$$

Where P is power, V is voltage and I is current. This formula gave the power output or the power being produced on the system.

MATLAB Simulation

First, the PV array received the solar energy input which are temperature and irradiance. The data of the temperature and irradiance is from a real time temperature and irradiance at Taman Botanical Kuala Lumpur which was taken from SolCast websites. After the data was entered, the DC-to-DC Boost converter will calculate the result. It is made up of a parallel connection of IGBT, Diode, R-C load, R-L load, and a pure resistive load. Temperature and Irradiance are derived as the DC voltage supply from the PV array's output. To maintain the constant value from the PV array, a resistive and capacitive (R-C) load is inserted at the beginning of the boost circuit design. Because the capacitor's principal job is to store energy, it also serves as a battery charger.

Capacitors are electrical energy storage devices that gather electrical charge on their plates. When a capacitor is linked to a power source, it stores energy that can be released when the capacitor is detached from the charging source, and they are similar to batteries in this regard. Then, the output voltage, output current and output voltage is generated. Then, the probe in the simulation shows the waveform of the output. From the result generated, the maximum power point tracking will be generated manually. Figure 2 below shows the MATLAB simulation circuit.

In this MATLAB/Simulink simulation, the result will show on how much the power generated if the solar panel is installed in a static position.

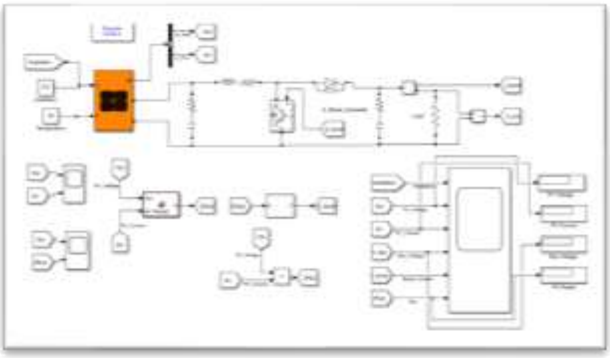

Figure 2: MATLAB simulation circuit.

The graph in figure 3 below is plot from the MATLAB simulation as the guideline of the simulation. The characteristic of PV module is determined by the amount of irradiance and temperature. Figure below shows the relationship between PV voltage and current at different solar irradiance. The highest point is set; the solar irradiance is set to 1000 W/m^2 and temperature at 25-degree C. From this observation as the irradiance is increases, the PV module is able to generate more power.

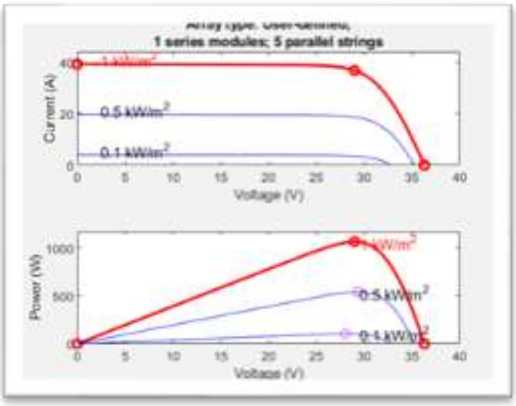

Figure 3: The effect of irradiance on I-V curve and P-V curve.

Proteus Simulation

Figure 4 shows the schematic circuit of the automatic solar tracking system using Arduino Uno board as a microcontroller. The input components used are two light dependent resistors (LDRs), ultrasonic sensor, and a potentiometer. Meanwhile, the output component uses are liquid crystal display (LCD) and a L293D DC motor. The simulation of the system is done on the Proteus 8 Professional software. The program code will be verified in Arduino IDE software and the program code will be uploaded on the Arduino Uno board in the Proteus 8 Professional software in order to run the simulation. The simulation done on Proteus 8 Professional software shows the flow of the system and the components used are only a representation of the real components used for the actual design.

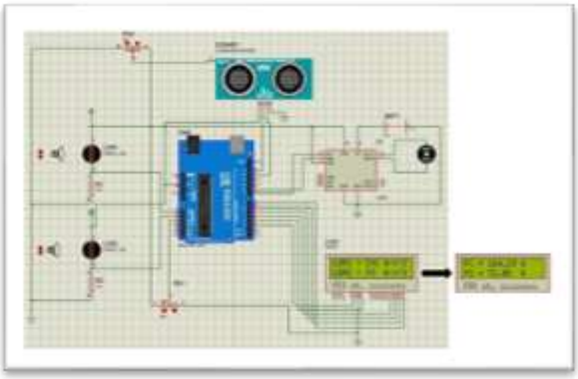

Figure 4: Schematic diagram

Result & Discussion

The result of the simulation from two different software which are MATLAB and Proteus will be discussed. The result of the MATLAB and Proteus simulation data also will be recorded and discusses in this chapter. The result will be divided into three part which are from MATLAB simulation, Proteus simulation and the comparison between two simulations.

MATLAB Simulation

Solar panel efficiency depends on several conditions which are location irradiance, temperature, array orientation (direction) and panel tilt angle. Table 1 below shows the result from MATLAB simulation by depending on the temperature and irradiance to find the maximized power generated in the PV system. The perturb and observed method is used in order to maximized the generated power from the PV array. The PV current, PV voltage and power generated from the PV system is recorded on table 1 below based on the simulation.

Table 1
Data collected from Matlab simulation.

Time	Temp ºC	Irradiance (W/m^2)	PV voltage (V)	PV current (A)	PV power (W)
6.00 am	23	0	0	0	0
7.00 am	22	0	0	0	0
8.00 am	23	80	27.54	2.993	82.41
9.00 am	24	304	29.32	11.18	327.90
10.00 am	27	529	29.53	19.16	565.70
11.00 am	29	634	28.39	23.68	672.3
12.00 pm	30	737	28.60	27.19	777.7
1.00 pm	30	777	28.64	85.34	818.9
2.00 pm	30	426	29.21	15.35	448.3
3.00 pm	31	421	28.64	15.47	443.1
4.00 pm	31	290	28.20	10.76	303.4
5.00 pm	30	186	28.49	6.747	192.3
6.00 pm	29	65	25.79	2.474	63.81
7.00 pm	28	13	5.967	0.5116	3.052

The output voltage, current and power of Photovoltaic Array depends on the input which is the temperature and irradiance for the MATLAB simulation. The irradiance and temperature were taken from the website SolCast. The websites will report the weather conditions for the day based on selected place. From the data above, it was taken in Taman Botanical, Kuala Lumpur in December 2021.

P-V and I-V curves have been constructed from the data collected of the MATLAB simulation. The P-V and I-V characteristic curves of the PV module depend on the solar irradiance and module's temperature. The solar irradiance and module temperature varies from 8.00 A.M in the morning until 7.00 P.M in the evening. The value of irradiance and temperature used to plot the P-V and I-V curves are presented below in figure 6 and figure7.

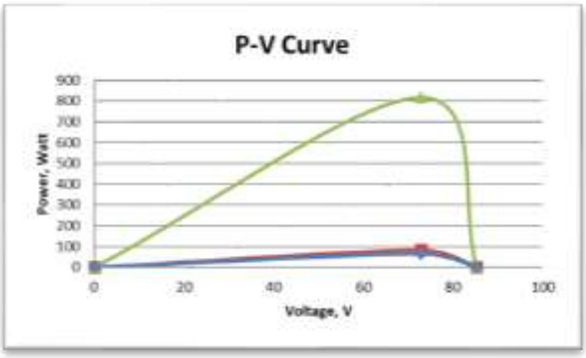

Figure 6: P-V Curve

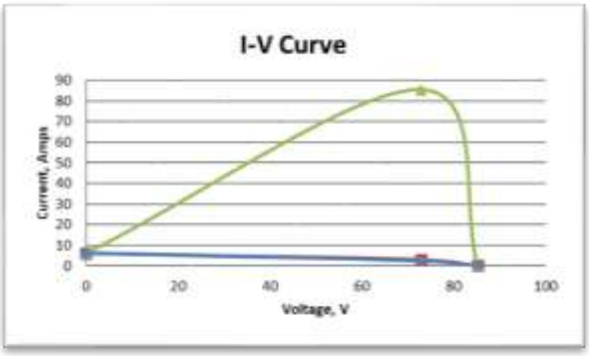

Figure 7: I-V Curve.

Table 2 below shows, in the morning at 8am, the temperature and irradiance received at the PV array are quite low which results an output power generated are also low which is 82.41Watt. Meanwhile, during the afternoon at 1pm, the temperature and irradiance recorded at the highest values which is 818.9Watt because the earth was closest to the Sun at this time and the results of the output power generated at PV Array are also maximum. On the other hand, during the evening time at 6pm, the temperature recorded is high, but the irradiance is low. In this condition, the power generated also low which is 63.81Watt due to the low irradiance received by the PV array.

Table 2
Values of P-V and I-V curves

Time	**Temp °C**	**Irradiance (W/m^2)**	**PV voltage (V)**	**PV current (A)**	**PV power (W)**
8 AM	23	80	27.54	2.993	82.41
1 PM	30	777	28.64	85.34	818.9
6 PM	29	65	25.79	2.474	63.81

Figure 8 below show the combination of P-V and I-V curve based on data recorded on table 2. It shows that the maximum power point is at 1.00pm which generated the highest power generated from the PV system.

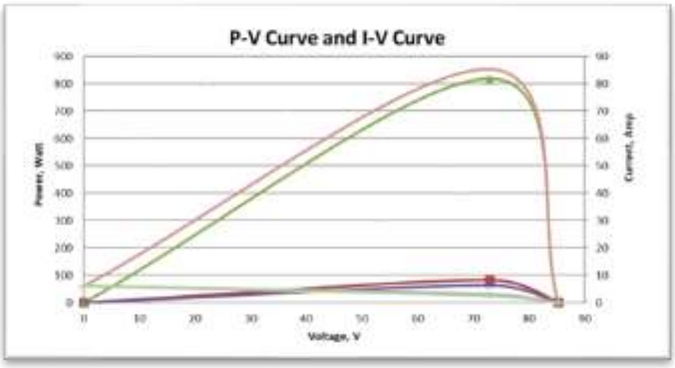

Figure 8: Combination of P-V and I-V curve.

The graph on figure 9 below is generated by the result of the irradiance vs power on the MATLAB simulation. It shows that if there are increasing in irradiance (blue line) W/m^2, the power generated (orange line) Watt will also be increase and vice versa. This is because the higher the irradiance, the greater an output current, as a result, a greater the power generated and vice versa (Motahhir et al., 2017).

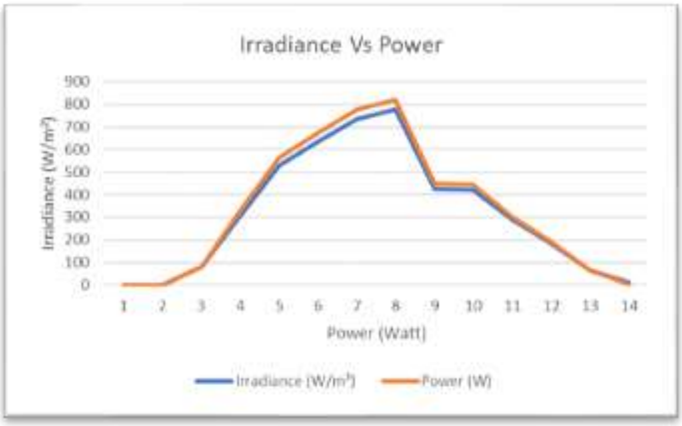

Figure 9: Irradiance VS Power graph.

Proteus Simulation

The simulation was done after completing the schematic circuit in Proteus 8 Professional software shown in Figure 4. For every component used, the library must be specified in the software. After uploading the code compiled and verified in the Arduino IDE software, the simulation will start running. The LCD will display the initial condition of the LDRs where the solar radiance will be 10 W/m^2 and the initial power will be 7.75 W.

The light that comes from the torch indicates the radiant energy that comes from the torch light. When the torch attached with the LDRs is adjusted, the value of the solar radiance and power displayed on the LCD will be as shown in Table 3. The torch is adjusted for either two LDRs. If the light intensity detected by LDR1 is higher than LDR2, the motor will rotate in a clockwise direction whereas if the light intensity detected by LDR2 is higher than LDR1, the motor will rotate in counter-clockwise direction.

Then, the ultrasonic sensor is adjusted to show the simulation of the ultrasonic anemometer. For example, if the motor initially rotates in a clockwise direction, the motor will rotate in counter-clockwise direction when the ultrasonic sensor detects an object at a distance less than 50cm. But the motor will continue rotating in clockwise direction if the ultrasonic sensor detects an object at a distance more than 50cm and vice versa for when the motor initially rotates in counter-clockwise direction.

The values of the light intensity obtained by the LDRs on the Proteus software is very limited until a certain value. Table 3 shows the values that can be obtained when simulation is run on Proteus.

It shows that a moving solar tracking system's power output will have increase in the value of data collected. This is because the amount of energy created by solar panels is proportional to the amount of the light. The higher the light intensity, the more the power of the solar panel will create.

Table 3
Solar irradiance and Power values from Proteus simulation.

Irradiance (W/m^2)	**Power (W)**
10	7.75
49	37.98
93	72.08
171	132.53
341	264.29
512	396.82
683	529.35
853	661.11
931	721.56
975	755.66

Based on the figure 10 below, it shows that the higher the solar irradiance, the higher the power generated from the PV system.

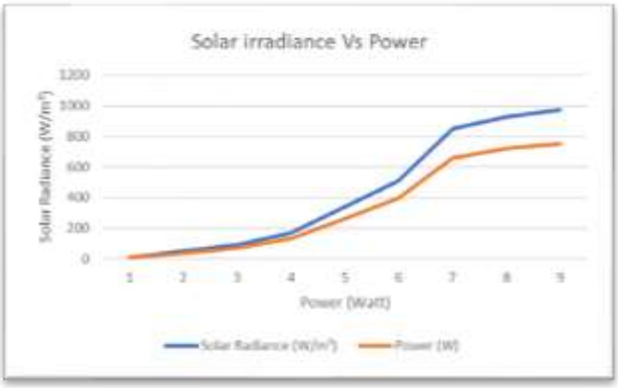

Figure 10: Solar irradiance Vs Power.

Simulation Comparison

The MATLAB/Simulink act as a static solar panel while the Proteus simulation is an automatic solar tracking system. The simulation result obtains from the MATLAB simulation which is a solar tracking system without tracker is compared to the Proteus simulation which is a solar tracking system with a tracker based on the solar irradiance and power versus time. Because of the limitation of the light intensity from the torch in Proteus simulation, data in Table 4 below only recorded from 8 am until 3 pm. The irradiance and power obtained from the Proteus simulation was arranged to match with the time.

Table 4
Comparison of simulation result

	Without tracker		**With tracker**	
Time	**Irradiance (W/m^2)**	**Power (W)**	**Irradiance (W/m^2)**	**Power (W)**
8 am	80	82.41	93	72.08
9 am	304	327.90	171	132.53
10 am	529	565.70	341	264.29
11 am	634	672.3	512	396.82
12 pm	737	777.7	931	721.56
1 pm	777	818.9	975	755.66
2 pm	426	448.3	853	661.11
3 pm	421	443.1	683	529.35

The comparison of the solar irradiance vs time with solar tracker and without solar tracker is shows in figure 11. Both PV solar system show at 1pm has the largest amount of solar irradiance. However, the solar PV system with solar tracker have higher amount of solar irradiance compare to without solar tracker. The comparison graph between solar irradiance displayed in Figure 11 below indicates the solar irradiance reading are related to the amount of power generated by solar PV system.

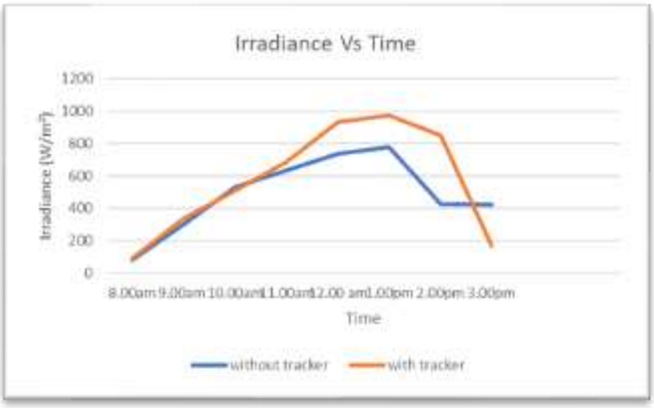

Figure 11: Irradiance Vs Time comparison graph.

Figure 12 shows that, based on the comparison graph Power Vs Time below it shows that the power generated on the PV system without solar tracker is higher compare to with solar tracker. This is because there is a limitation of the light intensity produces by the torch and there is no boost converter on the PV system in Proteus simulation.

Even though the result of solar tracking system is not in a real time or outdoor experiment, the result still shows that by having a tracker on a solar panel can improve the power generated on the PV system. The performance of the solar panel that was controlled by Arduino has been built to compare the result with the previous model which is on MATLAB.

Despite the fact that the numbers compared were not the same, the comparison graph revealed a similar trend, showing that the measured value was correctly obtained. Eventually, the amount of power generated is higher when there is a tracker on the solar panel (Vieira et al., 2016).

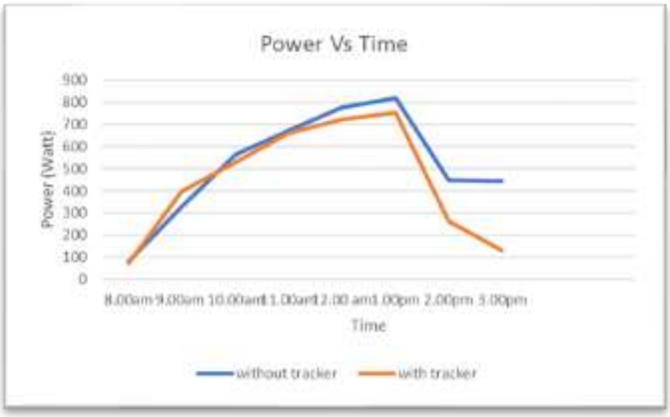

Figure 12: Power Vs Time comparison graph.

Conclusion

The goal of this project is to increase absorption of sunlight to increase the generation of electrical energy. Besides, this project is focused on renewable and affordable energy. This project is proposed to design and innovate an automatic solar tracker which can help to increase the absorption of sunlight. The next objective is to design an automatic solar tracking system using Matlab and Proteus software. Proteus software is the main medium and application to design an automatic solar tracking system. The solar panel can move by following the presence of sunlight with the help of the sensors. The software really helps in developing an automatic solar tracking system. Matlab software is used to show the circuit simulation of Maximum Power Point Tracking for the solar system. It shows the circuit consist of PV array, DC-DC boost converter, Perturb & Observe Matlab function and the display waveforms. The controller for this project will be the Arduino Uno and the simulation will be done by using the Proteus software by using Arduino Uno. The development of a model of an automated solar tracker is made and successfully achieved the objectives of an automated solar tracking system. To conclude that by comparing the simulated solar tracking system, solar system with tracker has produce more power generated on the PV system because it can be moved along with the direction of the sun compared to PV system without tracker.

Contribution of this Research

This project focus in the direction pledged by the Malaysian government for 40% reduction in carbon emissions by 2020 and 45% by 2030 and to date, Malaysia Solar Industry Roadmap 2030 highlights the need on 3rd and 4th generation technologies for solar cell and Green Technology Master Plan (2017-2030) was launched aiming to develop Malaysia to be among the preferred hub for solar cell manufacturing by 2030. The Shared Prosperity Vision (SPV) 2030 was a commitment to make Malaysia a nation that achieves sustainable growth along with fair and equitable distribution, across income groups, ethnicities, regions, and supply chains. SPV highlighted 15 Key Economic Growth Activities (KEGA) and this project is directly related to KEGA 11 that aims to have at least 20% Renewable Energy by 2025 and indirectly related to KEGA 12 that concentrates on the Green Economy in Low carbon activities and green building.

Following the 10-10 MySTIE Framework, it provides a systematic approach to transform Malaysia into a knowledge-based economy by linking science, technology, and innovation (STI) and the economic development of Malaysia and was specifically designed by the Malaysian Academy of Sciences to support the implementation of Dasar Sains, Teknologi dan Inovasi Negara (DSTIN) 2021- 2030. MySTIE Priority areas were divided into Six main sections and this project will contribute to the development of the first section, Energy where the focus is on the diversified renewable energy mainly for solar cell, solar module and solar inverter. The Sustainable Development Goals (SDG) of this project focus on SDG 7 for affordable and clean energy. Switching to renewable power will help to achieve Malaysia's carbon emission reduction goals and manage fluctuating energy costs, while providing better energy security.

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