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The Development of Smart Solar Tracker (SST) and Charging System by Using Microcontroller

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Abstract: Solar energy, which is a free energy source, plays an important role in the energy industry. Very good to use and available at all times in Malaysia ,it is also environmentally friendly and sustainable to meet the energy needs of mankind. Use of other fuels such as no renewable fossil fuels has many side effects. Combustion products can produce air pollution, acid rain, global warming and also the world's fuel reserves are decreasing. Solar energy is one of important renewable energy source for usage by humankind. However, the efficiency of the solar energy collector can be further improved if it can be tracked by the collector so that photon energy incident on the collector surface is at its maximum. Therefore, the purpose of this project is to Develop Smart Solar Tracker (SST) and Charging System by using Microcontroller. This project will improve the previously constructed projects in terms of how to improve the efficiency of solar tracker and control system to be utilized in this country. A solar tracker system is a combination of design consisting of sensors and stepper motor to mechanically track the sun. This system automatically moves toward the actual position of the sun is used by light sensors as an inputs. By tracking the sun's actual position will increases solar panel efficiency due to the high solar energy absorption which can be stored into the battery. Inaccurate detection of the sun, the panel changing position will interfere with the absorption of solar energy during charging. These will results in a waste of time, energy and costs. To charge the battery will take a long time, solar energy will only be wasted and solar tracker construction cost is also high. When the battery fully charged, the system will automatically cut off. The project will be operated by using their own power supply from the battery that was in charge itself without the use of other power such as electricity. The smart solar tracker and charging system in this project has been successfully design, fabricated and tested.

Keywords: Solar tracker, solar energy, charging, single axis, dual axes

1. INTRODUCTION

Non-renewable sources of energy in the world are coal, oil, natural gas as their main fuel for energy production. Nuclear energy employs the technique of nuclear fission of uranium for electricity generation. **Renewable** sources of energy in the world are hydroelectricity, wind and solar energy. Hydroelectric power plants cannot use water continuously for generating electricity. Solar and wind may not be available throughout the day thereby reducing the efficiency of the system.

A **Solar Tracker** was design to detect the exact position of the sun. The solar tracking system can collect more energy compare than the fixed panel system. Equipped with light sensors for searching sunray directions and positioned the solar tracker with a stepper motor. There are two types of active solar tracking systems:

i. **Single axis**
ii. **Dual axes.**

2. BACKGROUND

Shortage of oil in the world reserved, also resulting in higher oil prices. Fuel or raw material oil also plays a vital issue for energy; the work will be hard to run if the shortage. Countries around the world to finding new areas for oil supply to meet the needs of the world rising oil prices also resulted in impaired energy supply and require the government to act to overcome this problem. Although the nuclear raw material to meet the needs for energy supply, but the side effects resulting from nuclear frightening whole life. Disaster at the Fukushima Daiichi nuclear plant, Japan on 11 March 2011, makes public anxiety about the side effects of the existence of a nuclear plant. With the increasing demand for energy in the international market, the price of fuel continues to rise. In the future energy demand is expected to continue to rise faster than fuel sources currently available. The transition to clean energy sources such as solar energy, allowing the world to improve the quality of life on earth, not only for humans, but also the flora and fauna. Therefore there is a need to develop the conversion of solar energy systems intelligently and then replace fossil fuel applications of weakening. Research and development of solar energy must be carried out using high technology.

3. MATERIALS AND METHODS

The SST was optimized with 1.8^0 stepper motor for double, single and half-stepping capability. Auto cut

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off battery charging system. Charged voltage will converted into digital with on board 10 bit ADC for monitoring the battery charging system. Relay will used to cut off the charging system to prevent battery leakage Two LDR sensors to horizontal (azimuth) control, and two for vertical control. Each pair senses the direction of light from the sun and activates the motor drive to move the solar panel to align parallel to the sun's rays.

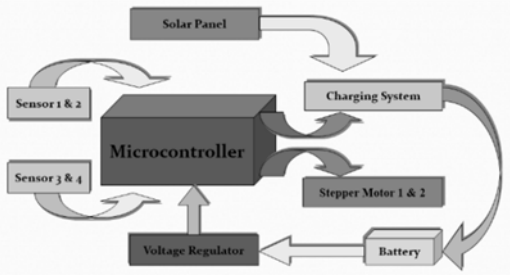


Fig: 1. Block Diagram of SST and Charging System by Using Microcontroller

i. Solar Penal

Solar panel electricity systems, also known as solar photovoltaic (PV), capture the sun's energy using photovoltaic cells. These cells do not need direct sunlight to work; it can still generate some electricity on a cloudy day. The cells convert the sunlight into electricity, which can used to run household appliances and lighting. Solar panels use light energy (photons) from the sun to generate electricity through the photovoltaic effect.

ii. Sensor

Sensor light Dependent Resistors (LDR) will present LDR 1and LDR 2 (S1 & S2) and give a signal to the micro controller to run the steppermotor1(Y Axis), while sensor LDR 3 and sensor LDR 4 (S3 & S4) will give the signal to run stepper motor2(X Axis). When night time, all sensor not received any signal, the motor back to the original position. Sensor LDR is used to produce a signal to the microcontroller.

iii. Microcontroller

Peripheral Interface Controller (PIC) Microcontroller will process all sensor signals and give direction to the motor to move. All automatic processing will be controlled by the micro controller, including the speed of the motor, charging system is cut off, and also the angle of movement motor. In this project microcontroller, PIC-16F877A will used.

iv. Charging System

Charging system circuit is design to control the charging process and auto cut off when battery fully charged. The solar charger circuit system is use to charging the lead acid batteries using the solar energy power. The Charging voltage passes through the diode 1N4007) to the IC voltage regulator (LM 317).

v. Rechargeable Battery

Rechargeable battery is used for storing solar energy has been absorbed. Battery will automatically stop charging when it is fully charged. The proposed solar tracking system must meet certain technical requirements specific to the application for which surveyed minimal energy consumption to maximize global efficiency and optimal installation cost performance ratio, reliability in operation, under different circum stances perturbations the simplicity of the solution movement to reduce the cost and increase the viability and feasibility of system integration in monitoring and centralized control structure, which stands for digital control solutions (Tudorache *et al*. 2010).

vi. Stepper Motor

Stepper motor1and stepper motor 2(M1 &M2) will only move when getting directions from the micro controller. All the details about the motor, everything is determined by the micro controller which has been programmed. Stepper motors have been used in this project because of the speed and angle of the motor simply following the program.

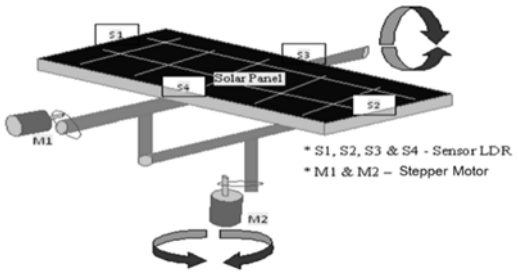


Fig: 2. SST Mechanical Design

This solar tracker has both a horizontal and a vertical axle, so it automatically predict and track the motion of the sun across the sky. The sun will be tracking both angle from East to West and North to South for increase power output, approximately 40% gain and convenience.

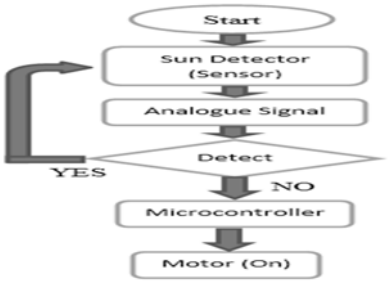


Fig: 3. Solar Tracker System Flow Chart

Flow chart in **(Fig-3)**, describes the operational flow of solar tracker system, starting with the sun must emit light that this system can be operated. If not, the system is in standby mode, while this system cannot operate at night. The microcontroller will recognized the intensity of light based on the data, which was collected from the sensors. The micro controller will activate the motors that move find the exact position (rotate the solar panels in the right direction) of the sun and microcontroller while stop the motor according to the flowchart. The speed of Dc motor will be setting in the programming. The solar panel on the actual position of the sun and the battery is being charged (Jamaludin 2008).

The system then determines the sensor receives light more intensively based on sensor output voltage. The system driver the motor to move towards this sensor orientation. If the output of both sensors are the same, the difference is zero and the output voltage of the motor drive is zero, which means the system has detected the current position of the sun. Sensor north or south detect the position of the sun either. Generally, measured as a continuous signal is a voltage or current analogy signals.

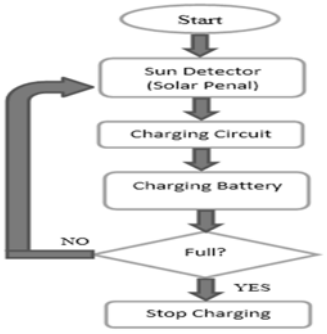


Fig: 4. Charging System Flow Chart

From **(Fig-4)**, is show that the flow of battery charging system. Once the solar panel detects the sunlight, it will absorb solar and sent to the circuit charging system. Circuit charging system will convert sunlight to energy voltage, and will flow to the battery for storage. Energy voltage is stored based on the size of storage space in the battery, if the space is large, so it takes squite along time. If the solar panel receives timely entire panel surface, then multiply the voltage stored energy and fast. This trend will continue to operate until full voltage energy storages, this system will automatically shut down, and will rest art if the voltage energy storage shortage.

By having the battery has been charged, it will be the internal power supply for this entire system. Power supplies were stored in the battery is used in electronics systems, microcontroller, DC motors. If this power supply is required, the system does not need to use an external power supply, the battery has been fully charged, will be used in this system.

Table: 1. Voltage Collecting from Three Different System

Time	Fixed Axis (V)	Single Axis (V)	Dual Axes (V)
1 - 09.00	16.30	17.30	17.64
2 - 10.00	17.02	17.52	17.65
3 - 11.00	17.64	17.64	17.67
4 - 12.00	17.67	17.65	17.67
5 - 13.00	17.64	17.66	17.67
6 - 14.00	17.35	17.65	17.66
7 - 15.00	16.66	17.65	17.66
8 - 16.00	16.37	17.50	17.65
9 - 17.00	16.33	17.30	17.65

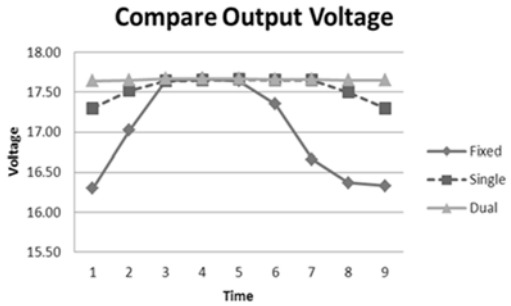


Fig: 5. The Graph Comparison for Voltage Charging

The circuit that has been built and tests were carried out with a decision very encouraging to the system operation, to get results from LDR sensor output signal or voltage. The circuit used a 5V supply voltage and load resistor is equal to 10KΩ. In the measurements conducted, the current of 12.5mA obtained in the circuit, and the resistance of the LDR is equal 400Ω. All the results are recorded in **(Table-2)**.

By using dual axes solar tracking system, the overall results of the output voltage is almost the same which isapproaching5V. Output voltage (Vo) obtained meet the characteristics of the circuit, Vo is equal the current values multiplies by the resistances of LDR, like the equation:

$$Vo = Current \ X \ LDR \ resistance \quad (1)$$

Table: 2. Light Dependent Resistors Sensors Output

No	Time	RL (KΩ)	LDR (Ω)	Current (mA)	Vo (V)
1	9.00	10	400	12.5	5
2	10.00	10	400	12.5	5
3	11.00	10	400	12.5	5
4	12.00	10	400	12.5	5
5	13.00	10	400	12.5	5
6	14.00	10	400	12.5	5
7	15.00	10	400	12.5	5
8	16.00	10	400	12.5	5
9	17.00	10	400	12.5	5

Analogue Digital Converter (ADC) value is maximum are 1024(2^{10}). The value of this constant physical quantity is converted to a digital number representing the volume's amplitude. The result is a sequence of digital values converted with a constant time and constant-amplitude of the analogy signal into discrete time and discrete-digital signal amplitude. ADC is defined by its bandwidth and signal to noise ratio.

Table: 3. The Value of ADC

No	Time	Vo (V)	ADC
1	9.00	5	1024
2	10.00	5	1024
3	11.00	5	1024
4	12.00	5	1024
5	13.00	5	1024
6	14.00	5	1024
7	15.00	5	1024
8	16.00	5	1024
9	17.00	5	1024

The ADC results can be seen in **(Table-3)**. The values of ADC is equal the voltage output LDR sensor divided by voltage supply and multiplied by 10 bits of intervals (2^{10}), the value was calculated by using equation:

$$ADC = \frac{Vout}{Vcc} \times 2^{10}\,bit \quad (2)$$

$$*\,2^{10}\,bit = 1024$$

While charging percentages were calculated by using the total value of ADC in time, divided by the10bits of intervals and multiplied by one hundred. The recorded of charging percentages is show in **(Table-4)**. Percentages charging were calculated by using equation:

$$\%\ Charging = \frac{ADC}{2^{10}} \times 100 \quad (3)$$

Table: 4. The Percentages of Charging

No	Time	Vo (V)	ADC	Angle (⁰) Y	% Charging
1	9.00	5	1024	18	100
2	10.00	5	1024	36	100
3	11.00	5	1024	54	100
4	12.00	5	1024	72	100
5	13.00	5	1024	90	100
6	14.00	5	1024	108	100
7	15.00	5	1024	126	100
8	16.00	5	1024	144	100
9	17.00	5	1024	162	100

Table-5 is show a digital sequence of LDR sensor output and the solar panel position, if the input signal is equal "1" (high), indicating the charging in the OFF state, the motor will move. To ensure that the charging in the ON state, the sensor is always"0" (low). If all sensors (S1, S2, S3 & S4) in a "0" (low) condition, the motor will stopped and the solar panel facing the sun directly, the system will charge at the maximum level-good condition.

Table: 5. Solar Panel Position vs LDR Sensors output

S4	S3	S2	S1	Output	
0	0	0	0	17.67	←Maximum Charging
0	0	0	1	13.2525	
0	0	1	0	13.2525	
0	0	1	1	8.835	
0	1	0	0	13.2525	
0	1	0	1	8.835	1 = Motor Running
0	1	1	0	8.835	
0	1	1	1	4.4175	
1	0	0	0	13.2525	0 = Motor Stopped
1	0	0	1	8.835	
1	0	1	0	8.835	
1	0	1	1	4.4175	
1	1	0	0	8.835	
1	1	0	1	4.4175	
1	1	1	0	4.4175	
1	1	1	1	0	

When two LDR's are used to detect any relative differences of sunlight receive at the panel's surface axially. Both LDR connected as a voltage divider connection to get the voltage reference for V sense. Formula below will show how to calculate the value of V sense.

Formula:

$$Vsense = \frac{R1 + LDR1}{(R1 + LDR1) + (R2 + LDR2)} \times Vcc \quad (4)$$

Assuming LDR1 get more light than LDR2,
LDR1 = 1.3kΩ, LDR2 = 19.3kΩ, R1 and R2 = 1kΩ, Vcc = 5V

$$Vsense = \frac{1k\Omega + 1.3k\Omega}{(1k\Omega + 1.3k\Omega) + (1k\Omega + 19.3k\Omega)} \times 5V$$

$$Vsense = \frac{2.3k\Omega}{(2.3k\Omega) + (20.3k\Omega)} \times 5V$$

$$Vsense = \frac{2.3k\Omega}{(22.6k\Omega)} \times 5V$$

$$Vsense = 0.1 \times 5V$$

$$Vsense = 0.5V$$

Table: 6. The Values of Vin, ADC and Hex

Vin	ADC	Hex
0.5	102.4	65
1	204.8	CB
1.5	307.2	132
2	409.6	198
2.5	512	1FF
3	614.4	265
3.5	716.8	2CB
4	819.2	332
4.5	921.6	398
5	1024	3FF

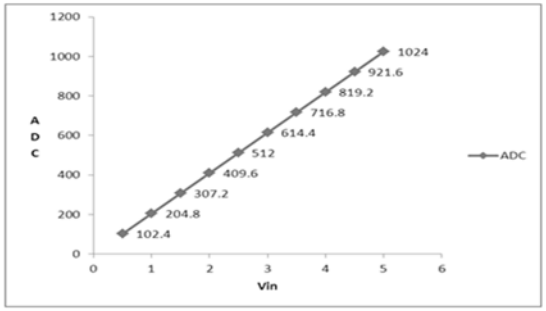


Fig: 6. The relationship between ADC and Vin

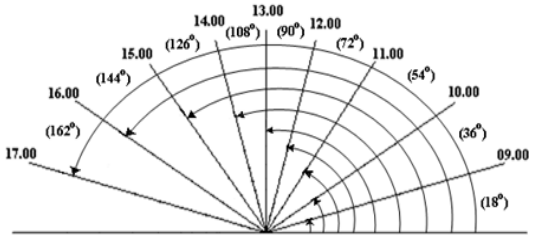


Fig: 7. The Angle Position of Stepper Motor

The movement of the stepper motor is also in accordance with a predetermined angular position in the program. Position angle as shown in **(Fig-7)**, the angle of stepper motor is calculated by using the total number ofangles $180^0(\pi)$ are used and divided into ten his sections, where the ten sections are the fraction of time frame from0900amto 1700pm. All angles of stepper motor are show in table 8. The stepper motors angles were calculated by using equation:

$$Motor\ Angle = \frac{\pi}{10\ sections} X\ No\ of\ time \quad (5)$$

Table: 7. The Value Of Stepper Motor Angle

No	Time	Angle (°)	
		X	Y
1	9.00	1.8	18
2	10.00	1.8	36
3	11.00	1.8	54
4	12.00	1.8	72
5	13.00	1.8	90
6	14.00	1.8	108
7	15.00	1.8	126
8	16.00	1.8	144
9	17.00	1.8	162

The steps values are in accordance with the step motor based on the angle of solar panels. The motor is moved in steps determined by the direction of the PIC programmed. Step that has been used for this steppermotoris1.8. The steps values for both stepper motors have been show in table 8. The Steps values were calculated by using equation:

$$Steps\ Values = \frac{Angle\ Values}{1.8} \quad (6)$$

Table: 8. The Steps Values of Stepper Motor

No	Time	Angle (°)		Steps of Motor	
		X	Y	X (M2)	Y (M1)
1	9.00	1.8	18	1	10
2	10.00	1.8	36	1	20
3	11.00	1.8	54	1	30
4	12.00	1.8	72	1	40
5	13.00	1.8	90	1	50
6	14.00	1.8	108	1	60
7	15.00	1.8	126	1	70
8	16.00	1.8	144	1	80
9	17.00	1.8	162	1	90

Table: 9. The level of battery charging

Vin	Battery Charging	Hex
0.5	2.4	1
1	4.8	3
1.5	7.2	6
2	9.6	8
2.5	12	B
3	14.4	D
3.5	16.8	F
4	19.2	12
4.5	21.6	14
5	24	17

i. Charging System with Auto Cut-Off

The four power diodes are used as a blocking feedback voltage. Charging system used in this project is designed automatically. When the battery is fully charged, the microcontroller gives a signal to their lay to cut off the circuit. This has been programmed in the PIC, the maximum voltage is 24V. Charging circuit will work again after the battery discharge level reaches half (12V). PIC V in will follow the V in signal show in **(Table-9)**.

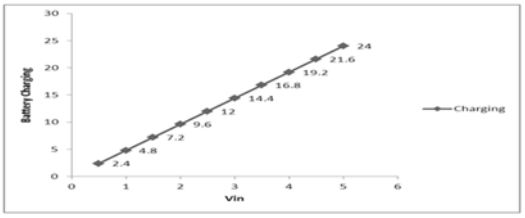


Figure: 8. The Graph of Battery Charging Level

Fig-8 is converted from **(Table-9)**, show the V in signal from circuit versus the level of battery charging. Maximum battery charging is 24V output, it should be changedto+5Vwhich is in the form of digital data, and then will be converted to a hexadecimal number (maximum is 17) that can be read by the Microcontroller. 24v to 5v digital conversion using a scaling circuit, where the input voltage is taken from the value of charging batteries.

4. DISCUSSIONS

The techniques on how to make a solar tracking two Axes conducted or designed automatically. The construction is done carefully and efficiently to produce quality and quantity of the dream. All this hard work pays off with the creation of this project and complete a thesis may be consulted in the future. In the early stages of testing carried out, there are several problems encountered, such as the difficulty to get good sunlight because the weather is always rainy and cloudy. Overheating also affect the production of voltage, if the solar panel overheat the resulting voltage are decreases. In the collection of solar energy heat a barrier to the absorption maximum. The production of solar energy is the solar rays, rather than the solar heat.

Circuit designed also take time to complete due to component failure and not according to the characteristics of the product. Circuit for 12V battery charging voltage also varies with the charging voltage 24V. At first the mighty is not taken note and it affects the test. Finally, this problem can be solved by analyzing the circuit and replace some of the key components in the charging circuit. Zenerdiode rated values important to determine the output voltage for charging. The choice of motor to move the mechanical part should also be noted, in this project the use of a powerful motor. Stepper motors have a choice because it is easy to combine with the microcontroller. Program to control the angle of the motor is also easily done. The Stepper motor used is a sensible proportion ofstep1.8per cycle. The main brain of this project is microcontroller 16F877A it facilitates every course of operation of the project. Besides that by using microcontroller, can save time, reduce space and to make troubleshooting easier. All processing work carried out by the microcontroller was programmed in detail and completed.

SST many were built in the developed countries, but in Malaysia two axis solar trackers are new and hard to find, most of the existing solar farm that uses a fixed axis, as in the solar farm. Solar tracker easy to develop and do not need a wide area, but it requires huge capital. For future development, it is proposed that this system will be improved to become more advanced. The proposed development is first, to increase the number of axis solar tracker that can operate better (3 axis). Second, proposed that the system uses Internet Protocol (IP) base where it can be controlled remotely. Third, proposed that try to use a different control system than the present. Current many advanced control system, easy to use and inexpensive. Fourth, suggested that the design small of DC to AC voltage converter (DAC) can be used by individuals, to save on home electricity bills are rising high.

5. CONCLUSIONS

As a conclusion of this project is a process in which to finalize a complete solar tracker to demonstrate the ability to detect a wide range of sun. To perform the detection process, the motor should move the solar panel facing to the right place where a variety of sun light. To do that, the LDR is needed to track the sun's position. Charge controllers used a dual op amp as a comparator battery and set point. LDR sensors installed at a predetermined position, give a very good action to join the motor to find the position of the sun. When the solar panel towards the sun directly facing the motor will stop and LDR sensor output was low "0" (low resistance). If all the sensors proportionally "0", the stepper motor will be stopped. Yax is stepper motor is most commonly made of movement, while the Xax is stepper motor less movement, can mean not moving. The Yax is stepper motor to move from east to west, follow the movement of the sun. The Xax is stepper motor to move from north to south and it is less moving.

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