Design And Development of an Microcontroller Based Automatic Dual Axis Solar Radiation Tracker

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Abstract: Global energy usage is increasing every year due to increase in world population. The need for the use of renewable energy is rapidly growing, as fossil fuels are limited. Solar energy is considered better among renewable energy sources, since it is free and readily available in abundance. Solar tracking system is one of the ways to increase efficiency. Compared to the fixed panel structure, by tracking the sun's position and moving the solar panel in dual axis will be better. Design and development of a dual axis automatic solar radiation tracker to ensure it is always perpendicular to the sun is proposed to increase the efficiency. The Dual Axis Solar Tracker (DAST) and control system is a combination of hardware and software, automatically track the sun's position throughout the day time. Maximum power point tracking (MPPT) charge controller is much more efficient at certain conditions, like cloudy weather or when the intensity of light is not strong. Light Dependant Resistor (LDR) is used to track the sun's position by comparing the output of the sensor from the four directions (North, South, East, West). A mechanical structure developed is used for experimental studies. Dual axis movement is controlled by stepper motor with pulley and belt, while the elevation is control by a linear actuator. Static solar panel with and without MPPT charge controller and tracking solar panel with and without MPPT charge controller results are analyzed and it is proved that the solar efficiency is much improved with design developed. . It has been found that DAST provides 16% more power output compared to static solar panel.

Keywords: Dual Axis Solar Tracker, PV module, MPPT controller, LDR, Microcontroller, Battery

1. Introduction

Exhaustion of natural fossil resources has become a serious global issue in the recent years [1]. The important factors that challenge the world in terms of global economy and planet environment are energy supply security and global warming. To boost regional economic development, renewable energy technologies are being explored. The primary source of human induced greenhouse gas emissions and fossil fuels consumption [2, 3] is transportation. Air pollutants (CO_2 emissions) from an automobile contribute to regional environmental problems as well as global environmental issues like climate change [3, 4].So the future transport systems should have zero emission, no pollution, electric vehicle and/or hybrid/fuel cell vehicle, which uses alternative fuel [5].The market penetration and availability of Plugin Hybrid Electric Vehicle (PHEV)/ Plug-in Electric Vehicle (PEV) are growing quickly due to their benefits like safe, convenient and money saving while slashing emissions and increasing the nation's energy security. PHEV/PEVs have drawn increased attention because of their low pollution and high fuel economy [6].

In the next few years, many automotive OEMs have made their plans to introduce PHEVs and PEVs worldwide. In 2011 General Motors introduced the first PHEV-Volt and Nissan with its electric vehicle LEAF entered in the US market [7].Among the proposed solutions for improving the efficiency of PV conversion, solar tracking occupies the majority of the researcher's choice [8, 9]. Microcontroller based battery charge control system for a PV panel is proposed by Çınar and Akarslan [10]. The efficiency of the PV systems can be improved by the charge controllers. An intelligent charge controller has been designed for battery life extension is proposed by Dakkak and Hasan [11].

Kaur, et al. [12] used LDR sensor to track the sun position and it is also have dual axis movement. Results shows that dual axis efficiency is higher than static solar PV system by 13.44% in term of power generation [12]. Mustafa, et al. [13] had integrated LDR sensor tracking method and detect the tracking error. The LDR sensor is placed in a small pyramid where four holes are evenly cut on each side. This allows the sunlight go through the hold and the LDR sensor inside will receive the light intensity evenly if the sun is directly perpendicular to the sensor. Ten circles are drawn from big to small and the centre of the circle there is a long shaft place on it. If the sunlight is not perpendicular to the system, some shadow will fall on the line of the circle. By observing at the shadow drop on the circle, it can easily detect the level of error of the tracking systems [13].

Gabe, et al. [14] had designed the LDR sensor with four LDRs placed with equal spacing and separated by an extrusion cross section of 90°. As those sensors are equally spaced, when the sun is perpendicular to the sensor unit, each LDR will received the same light intensity. If the sun is not perpendicular to the sun some shades might fall on some of the sensor and result in not even light intensity then the microcontroller identify the error differences and will trigger the motor to move to the position where four sensor receive the light intensity [14].

Mustafa, et al. [15] had designed the Dual-Axis Electromechanical Structure. Electromechanical structure has two degrees of freedom, motorized by two DC motors: a base platform moving around vertical axis and suspended platform with PV panel moving around horizontal axis. Position of the base platform and the suspended frame can vary in the range of ±90∘ ensuring alignment of the panel in azimuth and elevation, respectively. Nallathambi, et al. [16] had presented a dual axis solar tracker using motor with linear motion control. Two DC motors which control the east to west and North to South as the motor receive actuation signal from the control system. They also installed a reduction box for the motor as the motor required a small amount of torque to support the module at the particular position. This could help to save energy as the solar tracker remain in position [17, 18].

The paper is organized as follows. Section 2, Methodology deals with the electronic circuit for automatic tracking. The results and discussion section includes the tabulated experimental results and graphs plotted and the paper ends with conclusion.

2. Design Methodology

The flowchart of programming sequence of tracking is shown in Fig. 1. Whenever the system is started it will go to its initial position and the sensor will start to track the sun. By measuring the light intensity of the sun, the microcontroller will perform the comparison of each sensor values at different direction (east, west, north and south) and decide the action to be taken. If the sensor at east is larger than west, the microcontroller instructs the motor to move east. If the west value is larger than east value, then the motor will move west. Then the sensors will compare the other two values north and south and the motor will move based on the largest value. After the north west movement and the cycle is going to be repeated. The tracking will be turn off once the N(Night) button is triggered manually.

The microcontroller cannot be standalone unit. It should be added with 4 LDR sensors to identify the maximum intensity of sun light. Hence LDR sensors act as input to the microcontroller. The rotation of the motor (counter clockwise /clockwise) is performed by using stepper motor. Since the movement is restricted to certain steps, stepper motor with driver is chosen. Elevation of the panel (up/down) is performed using actuator with driver. Stepper motor rotation and actuator movements are the expected output of the microcontroller. The arrangement of these components and circuit connections are shown in Fig. 2.

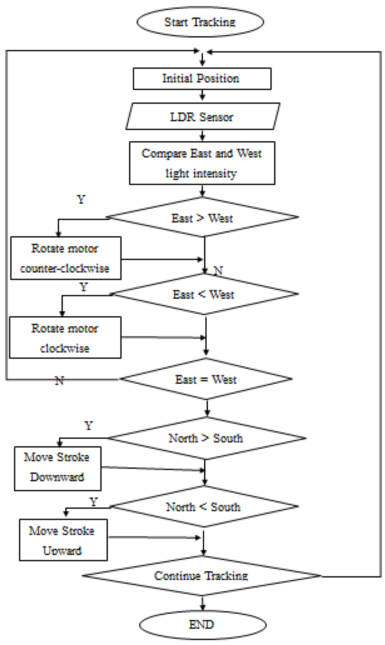

Fig. 1. Programme Flow Sequence

Pin configurations are as follows. The LDR sensor are connected to Arduino pin 1, 2, 3, and 4 respectively. Then followed by the motor connection which is +Dir to pin 2, +En to pin 5 and +Pul to pin 8. All the negative ports are connected together with Arduino ground. Then the linear actuator driver L298N signals ENA IN1 and IN2 are connected to pin 7, 8 and 9 respectively and the negative ports in connected to Arduino ground. The power supply for Arduino is provided by 9V alkaline battery. It is used to power up Arduino by connective the positive to V_{cc} and negative to ground.

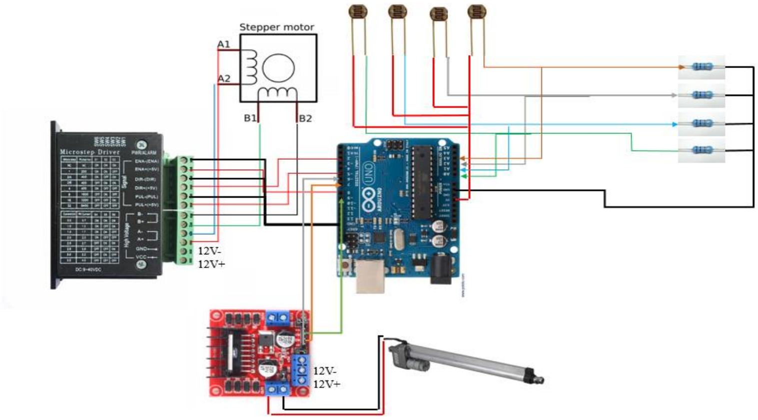

Fig. 2. Microcontroller Circuit

A round plastic bottle cap shown in Fig. 3 is used for placing the sensor unit.Furthermore, plastic card is cut as shown in Fig. 4 is then stick it into the plastic bottle as shown in Fig. 5.The stepper motor(+A ,–A ,+B ,–B) is connected to the TB6600 motor driver. Then from the driver connect –PUL, -EN and –DIR together and ground it to Arduino. Then +Dir to arduino pin 2 and +Pul to pin 5 and +En to pin 8.

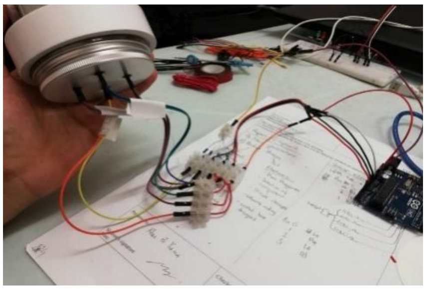

Fig. 3. Installation of LDR sensor

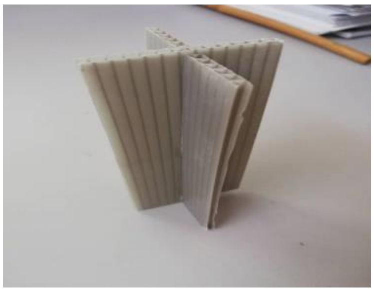

Fig. 4. Plastic Card

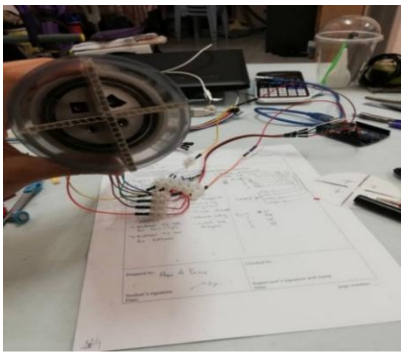

Fig. 5. Complete Sensor Unit

The electronic circuit incorporated with the basic structure is shown in Fig. 6. The parameters measured are voltage and current and the display showing the percentage of the battery charged using battery level indictor.

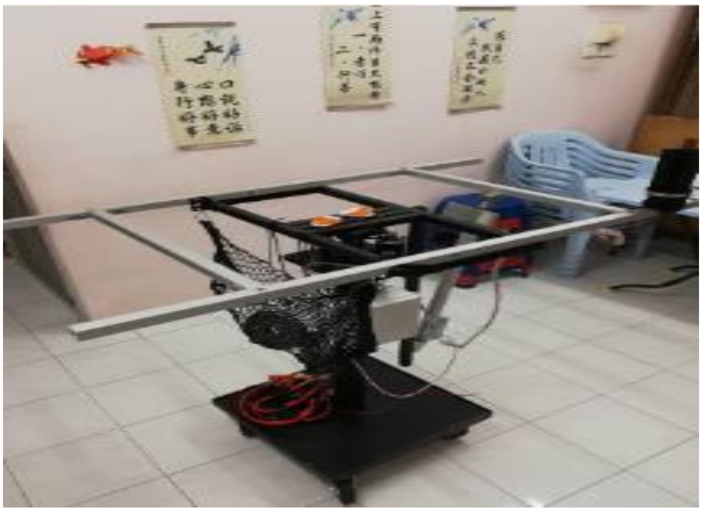

Fig. 6. Complete Structure

3. Experimental Results and Discussion

Case 1

The first case study is with fixed solar PV module. The PV module is placed under the sun at 180 degrees, lying flat on top of a table facing towards the sky.

The positive and negative terminal of the PV module is connected to the MPPT solar charger controller. The battery is charged through the MPPT solar charger controller and the level of the battery is shown by the battery level indicator connected to the battery.The voltage and current from the PV module (with MPPT charger controller and without MPPT charger controller) are recorded along with battery level indicator for every 30 minutes. Battery level indication stops when the battery is fully charged. PV module voltage and current recording is being record from 8am to 5pm.A graph is plotted from the measured data and analysis is performed on the collected data.

The case study is conducted to compare the efficiency of fixed and tracking solar PV module. Fig. 7 shows the voltage and current output of fixed solar PV module. Fig. 8 shows the charging time between non tracking with and without MPPT charge controller.

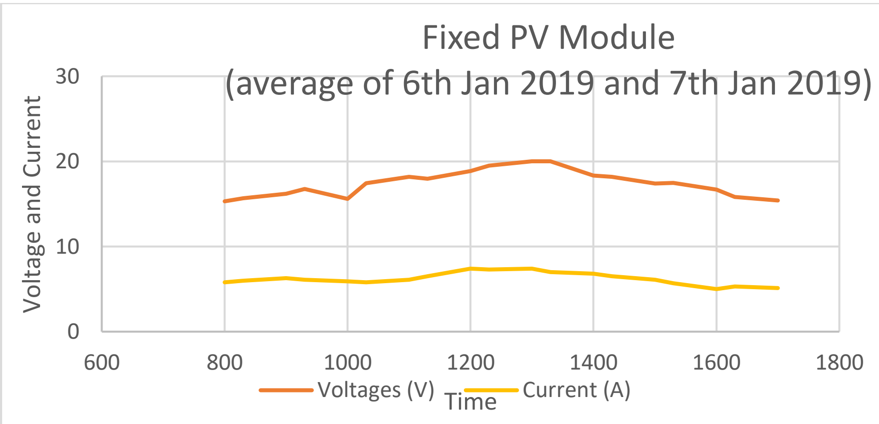

Fig. 7. Voltage and Current Output of Fixed PV Module

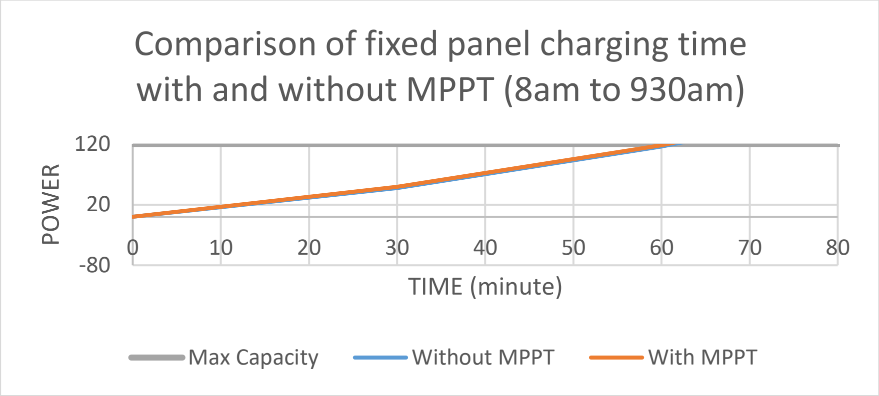

Fig. 8. Comparison of Fixed panel with MPPT and without MPPT (8am to 930am)

Case 2

The second case study is PV module with automatic sun tracking. In this study, the solar PV module is always perpendicular to the sun to get the maximum output. By moving the dual axis solar tracker under the sun and make sure that there is no shadow will fall on the selected location throughout the day. The power supply is provided for the electronic circuit (Arduino and Motors).The positive and negative terminal of the PV module is connected to the MPPT solar charger controller. The battery is charged through the MPPT solar charge controller and the level of the battery is shown by the battery level indicator connected to the battery.

The voltage and current from the PV module (with MPPT charger controller and without MPPT charger controller) are recorded along with battery level indicator for every 30 minutes. Battery level indication stops when the battery is fully charged. PV module voltage and current recording is being record from 8am to 5pm.A graph is plotted from the measured data and analysis is performed on the collected data.

Table 1. Output Voltage Reading from Sensor

Number of Reading	Light Depending Resistor (LDR)			
	Left top (V)	Left bottom (V)	Right top (V)	Right bottom (V)
1	0	0	0	0
2	403	98	98	65
3	98	404	65	97
4	98	64	400	99
5	64	98	98	401
6	401	403	403	402

Fig. 9 shows the voltage and current output of tracking solar PV module. Fig. 10 shows the charging time with and without MPPT charge controller for PV panel tracker.

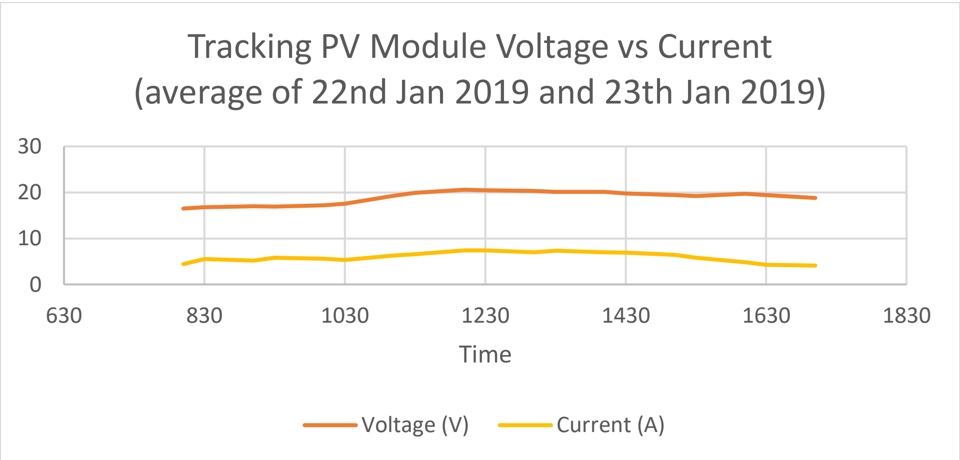

Fig. 9. Voltage and Current Output for Tracking PV Module

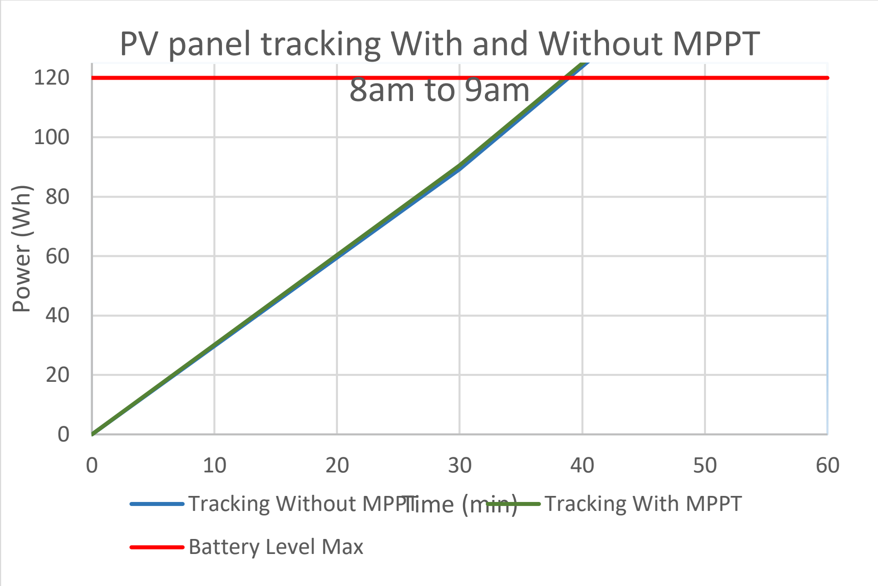

Fig. 10. Tracking with MPPT

Fig. 11 shows the result of fixed solar PV module compare to tracking PV module.

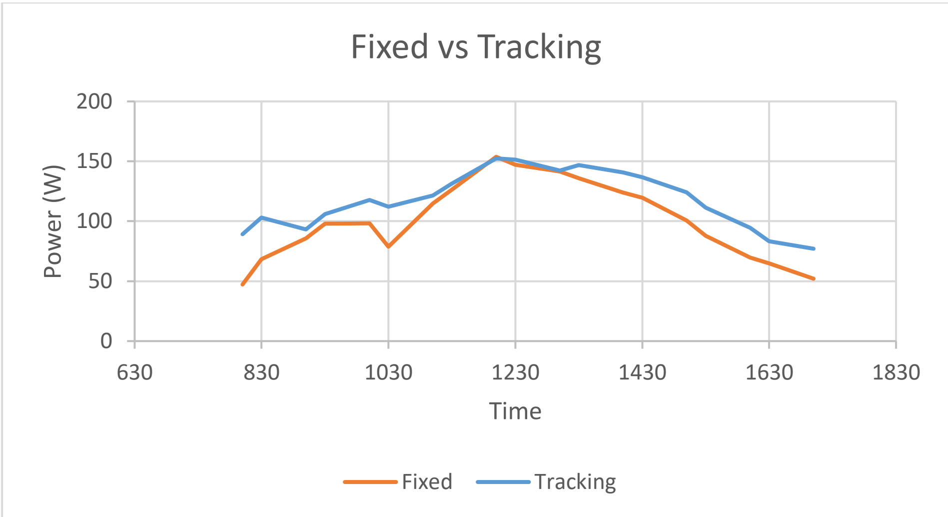

Fig. 11. Fixed vs Tracking

From the case studies of the PV module, as shown in Fig. 7 the power output is increase until 12pm which is the maximum output for fixed PV module then it starts to decrease until 5pm. In short the peak power output happened between 12pm to 1 pm. In addition, the voltage and current varies throughout all the day, this is due to it depends on the sun condition. The brighter and hotter the sun, the higher the current. The higher the current the greater the voltage. Moreover, the power output depends on voltage and current. The higher the voltage and current the greater the power output.

As shown in the Fig. 10 comparing the PV module with tracking had greater power output than the fixed PV module. The total power output for fixed is 1914W while 2235W is the power output for tracking PV module. As result tracking PV module generate 16% more power. As the PV module is perpendicular to the sun, it gives higher output voltage and current resulting higher power output. For fixed PV module it does not always facing the sun perpendicularly, it does not capture as much solar energy as tracking PV module does, therefore it gives lower power output.

Furthermore, Fig. 9 and Fig. 11 shows the result of tracking PV module with MPPT and non-tracking PV module with MPPT. The experiment is carried out in the morning 8am, the time taken to charge the 12V 10A battery is approximate 61 minutes while the charging process without MPPT is about 64 minutes. As for tracking with MPPT and tracking without MPPT are more likely the same as 38 minutes. As the result show there is not much different from tracking with MPPT this may due to the battery capacity is low and the charging current at the particular time had reaches it setting value so that the MPPT charge controller is not needed. However, for non-tracking PV module with MPPT charge controller increase the charging time by approximate 3 minutes. At this case the charge controller had perform because at the particular time the charging current had not reaches its setting condition and the controller help to speed up the charging process.

All the result obtained might not be the actual output because throughout the day the sun is not that consistent. Sometime there are could appearing, 9 hours' daylight data are collected maybe few hours there are cloud appearance that affect the energy generation. As the data collected is every 30 minutes for this 9 hour.

4. Conclusions

Dual axis solar tracker with adriuno microcontroller has been successfully designed and tested successfully at low cost. Dual axis tracking is verified along with MPPT controllers. It is observed that tracking is better than fixed panel. Dual axis tracking is much better with MPPT controller. Furthermore, the efficiency of the PV module might be affected by some condition such as sunlight intensity, humidity, temperature and clouds. Appearance of clouds blockthe sunlight falling on the PV module and decrease the sunlight collection. In addition, the appearance of clouds also reflects the sun rays, so the panels could not absorb it. But when during noon time when the sun it at peak, more solar energy is being collected result in increasing of power output. In addition, if the humidity of the weather is high result in cold weather, the panel performance will reduce.

Nomenclatures

Abbreviations

DAST	Dual Axis Solar Tracker
MPPT	Maximum Power Point Tracking
LDR	Light Dependant Resistor
PV	Photo Voltaic

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