DEVELOPMENT OF A SOLAR PHOTOVOLTAIC SYSTEM EQUIPPED WITH A SUN TRACKER SYSTEM: A CASE STUDY IN KUCHING, SARAWAK

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ABSTRACT

A solar photovoltaic system consists of photovoltaic panel(s) and it converts energy of sunlight into electricity via photovoltaic effects. Installation of a sun tracker is one of the approaches to improve the performance of a solar photovoltaic system. A sun tracker is a device for orientating photovoltaic panel towards the sun. The aim of this paper is to examine the use of a solar photovoltaic system with a sun tracker in Batu Lintang, Kuching, Sarawak (1º32'09.73''N, 110º20'32.70E). A designed and developed solar photovoltaic system that equipped with a sun tracker is presented. Our developed solar photovoltaic system consists of five modules, i.e., a sensor system, a linear actuator system, a tracking mechanism, a battery storage system and charge controller, and a microcontroller system. The performance of our developed system is further analyzed and evaluated with experiments. Concluding remarks is further presented.

Keywords: *Solar photovoltaic system, Sun tracker, Case study, Sarawak*

1. INTRODUCTION

Solar energy is a clean and inexhaustible source of energy in everywhere of our world [1]. It has been identified as an alternative electricity source [2, 3] with respect to the increase in energy demand and cost [4]. Besides, solar energy is environmental-friendly as compared with other energy sources. In Saudi Arabia, it was reported that average 8182 tones of green house gases could be entering into atmosphere each year with each of 5 MW power plants [5].

Although solar energy offers lots of advantages to the environment, it still remains relatively expensive [6]. A search in literature reveals that many research works have been conducted to identify and to develop alternative approaches to increase the efficiency of a solar photovoltaic system. One popular approach is to keep the photovoltaic panel perpendicularly toward sun's position, thus, reduces the incident angle of radiation. However, the amount of extra energy collected by a tracked photovoltaic panel will be influenced by local condition as well [7, 8].

This line of study is popular and useful, and its importance has been highlighted by several recent publications. From the literature, Al-Mohamad [9] designed a sun tracker with a programmable logic-controller unit. The movement of a photovoltaic panel is further controlled and monitored. It was reported that the daily power output for the developed system increased by 20%, as compared with a fixed photovoltaic panel. Abdallah [10] performed an experimental study on extra power gain of a solar photovoltaic system with four different sun trackers, i.e., two axes, east–west, vertical and north–south tracking. There were increases of electrical power gain up to 43.87%, 37.53%, 34.43% and 15.69%, respectively, as compared with a fixed surface inclined 32° to the south in Amman, Jordan. Besides, Sungur [4] designed a two-axes sun tracker in Turkey and found a increase of 42.6% energy gain, as compared to fixed axes panel. Also, Baltas [11] conducted an experiment to compare the energy consumption between solar photovoltaic systems with continuous and stepwise tracking. It is reported that continuous tacking yields almost same energy as stepwise tracking. It is suggested that tracking motor can idle for 1 or 2 hours, and yet obtain more than 98% of energy as compared with continuous tracking. In [12], a theoretical study on the performance of an east–west oriented single-axis sun tracker in Taiwan is presented.

Motivated from the popularity of solar photovoltaic system, a solar photovoltaic system with a two-axis sun tracker is designed and developed. The sun tracker is able to track the location of the sun and it positions the photovoltaic panel towards the direction of sun. This will further improve the performance of the solar photovoltaic panel. Worth to be mentioned, a search in the literature reveals that no investigation on the use of solar photovoltaic system in Sarawak is reported. Our project started with a simulation of the irradiance of the sun in Kuching, Sarawak, Malaysia. Our developed solar photovoltaic system is further explained briefly. To evaluate the performance of our developed system, experiments are carried out in Kuching, Sarawak. These experiments are meaningful, as performance of a solar system is very much depending on weather and local condition. Our experimental results are further discussed.

The organization of this paper is as follow. In ection 2, our developed system is explained. In section 3, simulated hourly solar irradiance in Batu Lintang, Kuching is presented. Experimental results are presented in section 4. Finally, concluding remarks are presented.

2. THE DEVELOPED SOLAR PHOTOVOLTAIC SYSTEM

Figure 1 depicts the developed solar photovoltaic system, and its modules. In module (A), a sensors system is designed to track the sun's position. In module (B), a linear actuator system is designed to drive the photovoltaic panel. In module (C), a tracking mechanism is designed to hold the photovoltaic panel and allows it to perform two-axis hemispheroidal rotation. Module (D) consists of a battery storage system and charge controller. They are designed to efficiently store the energy generated by the photovoltaic panel. In module (E), a microcontroller system is designed to automatically control the operation of the solar photovoltaic system. Figure 2 further shows a photo of the developed system.

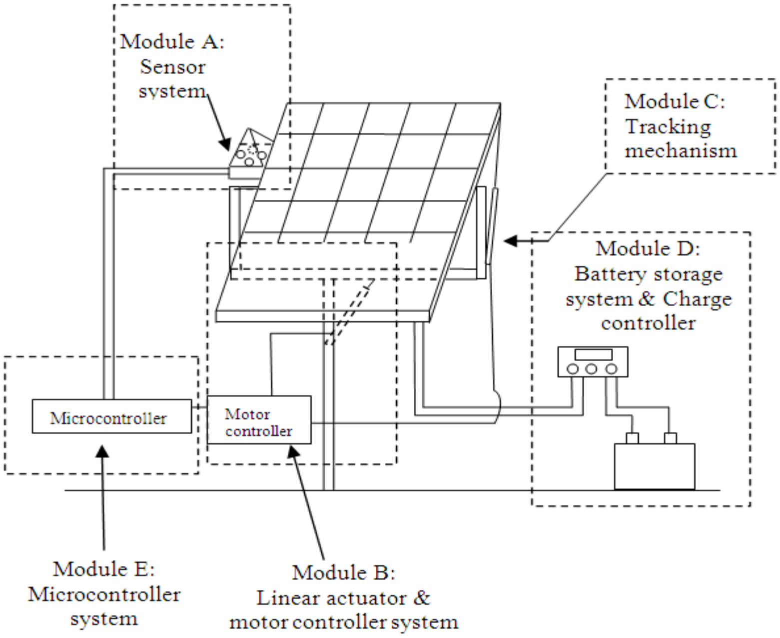

Figure 1. The overall design

Figure 2. A photo of the developed system

In this project, a 175W-Mono-Crystalline Silicon photovoltaic module (NTR5E3E model) is selected as the photovoltaic cell. Details for the modules and the operation of the developed system are further explained as follow.

2.1. The Sensors System

Figure 3 shows the developed module (A): a solar sensors system. This module is used to detect the direction of the light. It consists of four light dependent resistors (LDRs), i.e., east, west, south and north LDRs, which are fixed into a pyramidal block. When the sun is located on the center of the system, these LDRs will receive same amount of light intensity and hence produces the same resistance. However, when the sun is shifted, the cardboard placed in between these LDRs will produce shadow and this causes different light intensity to be received by these LDR sensors. We attempt to adjust the photovoltaic panel is such that resistance for east and west LDRs, and north and south LDRs are equal.

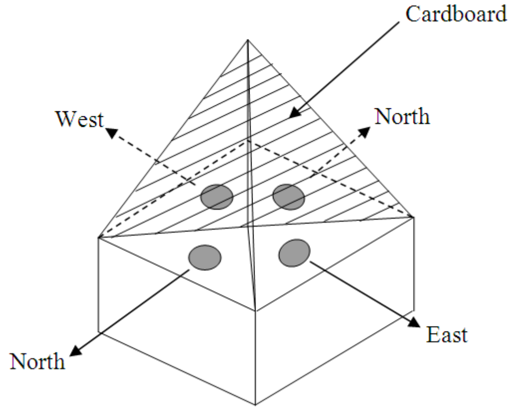

Figure 3 The developed sensors system

2.2. The Linear Actuator System and the Motor Controller System

Figure 4 depicts module (B), i.e., a linear actuator system and a motor controller system. The function of the linear actuator system is to drive the photovoltaic panel to the desire direction. The linear actuator consists of a built in DC Motor with DC worm gear. The DC Motor with DC worm gear is used to allow a smooth and precise extension along the sun tracking process. The motor controller is designed to receive signal from microcontroller to control the position of linear actuator in either to hold, extend or vice versa.

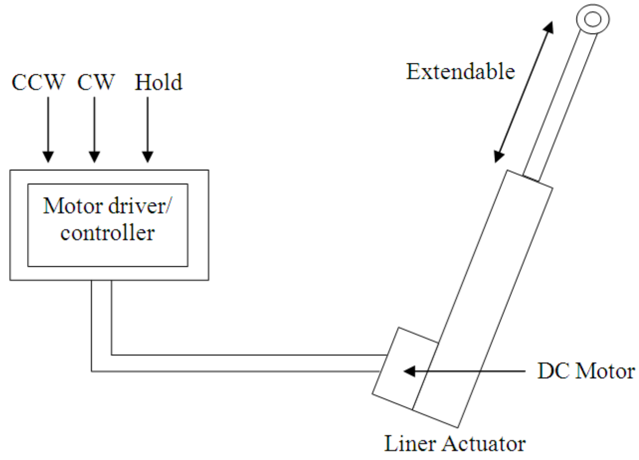

Figure 4 The linear actuator system

2.3. The Tracking Mechanism

Figure 5 shows the operation of the two-axis solar tracking mechanism. The tracking mechanism is used to support and rotate the photovoltaic panel. It performs a two-axis hemispheroidal rotation. A linear actuator is installed to support the rotational motion. Our expeiments shows that a linear actuator can provide enough touque to hold the panel and extend uniformly.

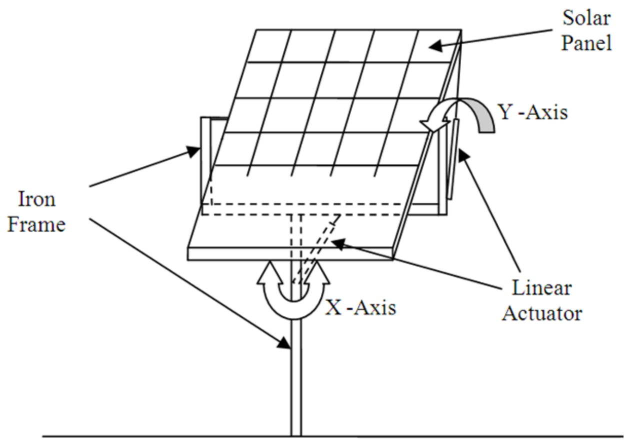

Figure 5 The developed tracking mechanism

2.4. The Battery storage system and the charger controller

Figure 6 illustrates the connection for module (D), i.e., battery storage and a charger controller system. The battery, the photovoltaic panel and the load are interconnected via a charger controller. For a brighter sunlight, more voltage would be produced from the photovoltaic panel and the excessive voltage could damage the battery. The charger controller is used to ensure the proper charging for the battery. While there is a load, charger controller gives priority to the load by switching off the charging.

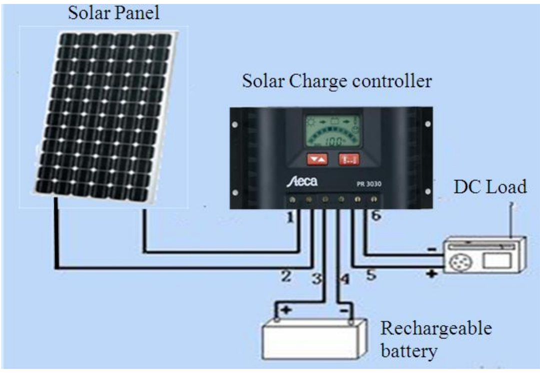

Figure 6 The battery storage system and charge controller

2.5. The microcontroller system and the developed flowchart

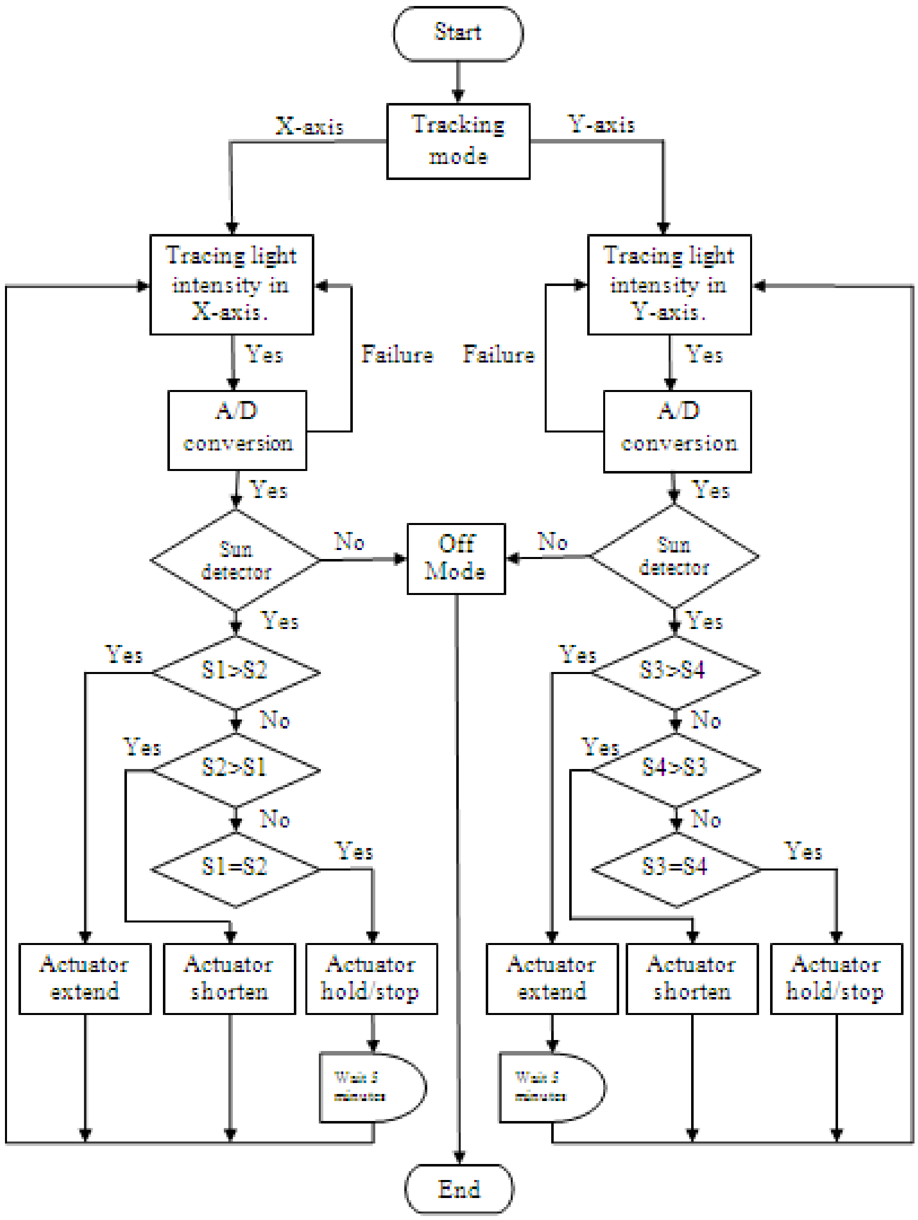

Figure 7 The developed flowchart

In this project, a microcontroller, i.e., PIC16F88 is implemented. Figure 7 illustrates the flowchart for our developed system. The sun's intensity from four different directions are measured by the sensors system, i.e., the east, west, south and north LDRs. For the Y-axis, resistance for south and north LDRs are compared, and a signal is sent to the microcontroller to determine the sun's position for the Y-axis. From this signal, the microcontroller will make a decision and send an instruction to motor controller, i.e., either to remain the position of the actuator, to extend the actuator or to shorten the actuator. If the resistances for these LDRs are not equal, the tracking process would proceed until the same resistances are obtained. The same goes to X-axis.

3. A SIMULATION OF THE IRRADIANCE IN KUCHING

Figure 8 shows the theoretical solar irrandiance falling on the surface parallel to the ground at Batu Lintang, Kuching (1º27'53N, 110º25'58E) on 13 February 2010. The result is calculated based on the earth-sun geomentrical expression.

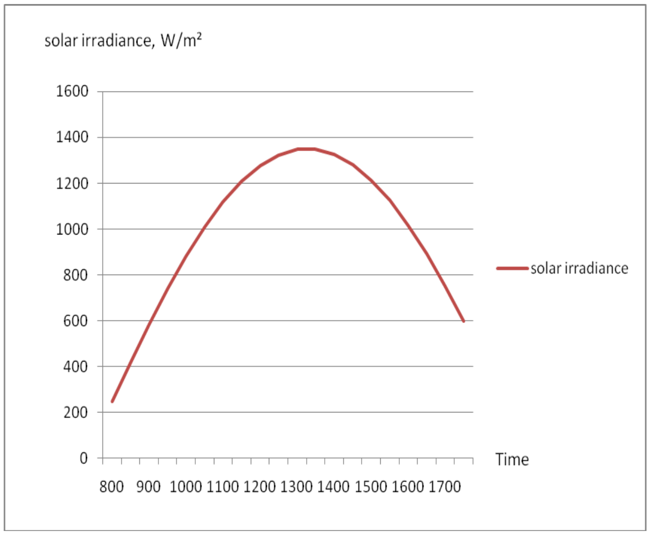

Figure 8 Hourly Solar irrandiance in Batu Lintang, Kuching (1º32'09.73''N, 110º20'32.70E)

4. EMPIRACAL RESULTS

Figure 9 shows the power generated from a static photovoltaic panel which pointed 90º to the sky, while Figure 10 shows power generated from the developed system, both on 13th Feb 2010.

We calculate the total energy generated for a duration by calculating the area under the graphes, a power unit, i.e., Watt/Hour (W/H) is further used to compare the performance for both the systems. An average of 49.26W/h and 62.46W/h were produced from the static solar panel and the developed system, respectively. Therefore, a extra yield of 26.8% power generation was obtained.

We further compare the performance for both the systems for the morning session (Section A) and the afternoon session (Section B). For the morning session, 44.13W/h and 61.07W/h were recorded, for the static solar panel and the developed system, respectively. In short, about 38.4% of extra power was generated in the tracking sytem in the morning.

For the afternoon session (a cloudy day), 26.94W/h and 31.86W/h were recorded, for the static solar panel and the developed system, respectively. Thus, an extra yield of power generation was 18.3%. A cloudy condition would affected the performance of a solar panel. This explain why the power generated are relatively low, as compared with the morning session. Besides, it is difficult for the developed system to track the sun's position precisely during cloudy day. This is because the sun light was biased by the cloud.

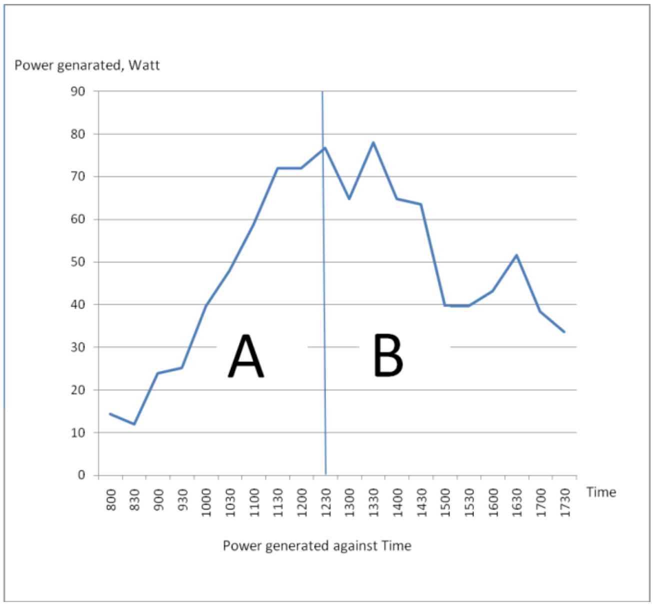

Figure 9 Power generated from a static photovoltaic panel on13th Feb 2010

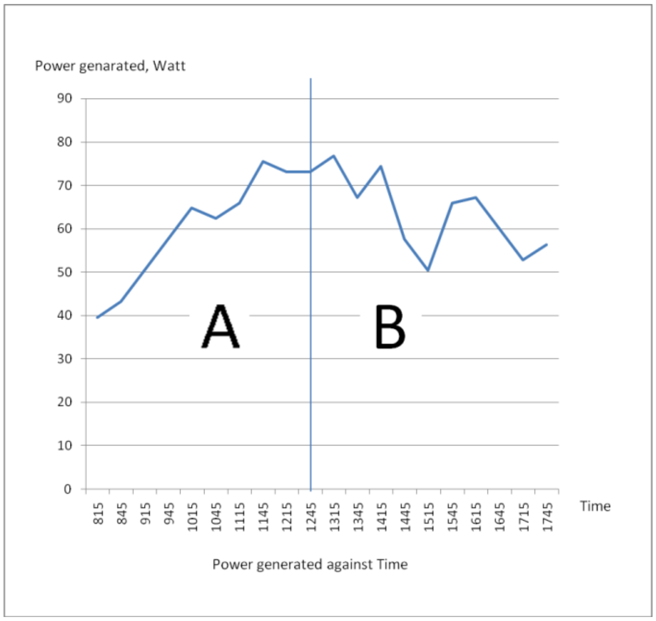

Figure 10 Power generated from a photovoltaic panel with a sun tracking system on 13th Feb 2010

5. SUMMARY

A solar photovoltaic system with a sun tracker was designed and developed. Performance of the developed system is experimented and compared with a static solar system. Experiments were conducted in Batu Lintang, Kuching, Sarawak. The developed system generated an extra of 26.8% power, averagely. Our experiment showed that without much cloud, the developed system could yeild up to 38.4%of extra power generation. In sumary, the developed system has demonstrated the ability to improve the performance of a solar energy system in Kuching.
As future work, we would like to apply Artificial Intelligent (AI) techniques, i.e., fuzzy controller, neural network and genetic algorithms, to our developed system to further improve the overall performance.

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