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4 authors, including:

Nashaat Othman
An-Najah National University

Zulbasri Othman
Universiti Putra Malaysia

Syed Abdul Mutalib Al Junid
Universiti Teknologi MARA

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Performance Analysis of Dual-axis Solar Tracking System

N.Othman
Faculty of Electrical Engineering
Universiti Teknologi MARA (UiTM)
13500 Permatang Pauh, Pulau Pinang, Malaysia
e-mail: halida8142@ppinang.uitm.edu.my

M.I.A. Manan, Z. Othman, S.A.M. Al Junid
Faculty of Electrical Engineering
Universiti Teknologi MARA (UiTM)
40450 Shah Alam, Selangor.
ikhsanmanan@yahoo.com,
zulkifli_othman@salam.uitm.edu.my,
samaljunid@salam.uitm.edu.my,

Abstract — **This paper presents the performance analysis of dual-axis solar tracking system using Arduino. The ultimate objective of this project is to investigate whether static solar panel is better than solar tracker, or the opposite. This project is divided into two stages namely, hardware and software development. In hardware development, five light dependent resistors (LDR) were utilized to capture the maximum light source from the sun. Two servo motors also were employed to move the solar panel to maximum light source location sensed by the LDRs. As for the software part, the code was constructed by using C programming language and was targeted to the Arduino UNO controller. The performance of the solar tracker was analyzed and compared with the static solar panel and the result showed that the solar tracker is better than the static solar panel in terms of voltage, current and power. Therefore, the solar tracker is proven more effective for capturing the maximum sunlight source for solar harvesting applications.**

Keywords- Dual-axis, Solar Tracker, Arduino, Light Dependant Resistor

I. INTRODUCTION

Renewable-energy is energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable (naturally replenished) [1]. It provides 19% of electricity generation worldwide. Malaysia, with its population of about 28 million people, is one of the fastest economically growing countries in Asia. In the last decade, Malaysia managed to achieve almost 20% increase in energy generation which was from 13,000MW in 2000 to 15,500MW in 2009. Under the 8^{th} Malaysia's plan (2001-2005), the government of Malaysia changed the Four Fuel Policy which was based on oil, gas, coal and hydropower to the Five-Fuel Policy with the addition of renewable energy as the fifth element. The demands for electricity keep increasing year by year, but the main resources which are oil, gas and coal are depleting. Solar energy, which is one of the types of renewable energy, has been identified by the government as the best initiative in order to solve this problem.

In the last ten years, many residential areas around the world used electric solar system as a back-up power for their houses. This was because solar energy, which is the energy derived from the sun through the form of radiation, is also an unlimited energy resource and is going to become increasingly important in the long term for providing light, heat and energy to all living things [2]. It is also related to the aspects of deforestation control, protection of ozone layer, reduction of CO_2 emission and so on [3]. In order to utilize the superiority of solar energy, solar tracker was constructed for this project.

Solar tracker is a device used to orient a solar panel towards the sun. Since the sun's position in the sky changes with the time of day, solar tracker is used to track the maximum amount of light produced by the sun. It is discovered that the instantaneous solar radiation collected by the photovoltaic modules, assembled in a tracking system, is higher than the critical irradiance level for longer hours than in fixed systems [4]. Besides, it is estimated that the yield from solar panels can be increased by 30 to 60 percent by utilizing a tracking system instead of a stationary array [5]. Up to 40% extra power can be produced per annum using a variable elevation solar tracker [6]. Nowadays, there are many types of solar trackers invented but the two basic categories of trackers that are widely-used are single-axis and dual-axis tracker. Single-axis tracker can either has a horizontal or a vertical axis, while dual-axis tracker have both horizontal and vertical axis, thus making them able to track the sun's apparent motion almost anywhere in the world.

In this project, the performance of the dual-axis solar tracker was analyzed. It was separated into three parts which were input, controller and output. The input was from the LDRs, the Arduino as the controller and, the servo motor as the output.

Figure 1. Single-axis and dual-axis solar tracker.

II. Methodology

As stated before, the aim of this project is to analyze the performance of dual-axis solar tracking system. It consists of three main structures which are the inputs, the controller and the output. The inputs are from the LDRs, the Arduino as the controller and, the servo motor as the output. The overall system is presented in Figure 2. In this project, the main controller which is the Arduino receives analog input from LDRs and it converts the input into digital signal by using analog-to-digital (A-D) converter. Then the controller sends the signal to the servo motor in order to determine the movement of the solar panel.

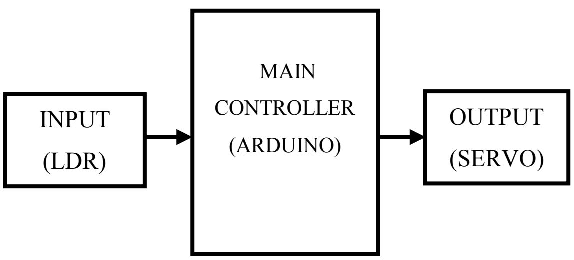

Figure 2. Block diagram of overall system

This project also can be divided into two parts which are hardware and software:

A. Hardware

The components involved in this part are solar panel, LDR, servo motor and Arduino-Uno Controller.

1) Light Dependant Resistor (LDR)

Photoresistor or light dependant resistor (LDR) is a resistor whose resistance decreases with increasing light intensity or it can be said that the LDR exhibits photoconductivity. For this project, the intensity of light sensed by the LDR becomes an input to the main controller.

2) Servo Motor

Servo motor is one of the various types of DC motor available in electronic application. This type of motor requires supply either 4.8V or 6V. This motor consists of three wires namely signal, positive and ground wire. It also comprises several parts which are the motor and gearbox, position sensor, an error amplifier, motor driver and a circuit to decode the requested position. Servo motor only rotates by the maximum of 180 degrees. PWM is used to control the motor. PWM analog signal will go through an electronic circuit and convert the analog signal into a digital signal. PWM in servos is used to control the direction and position of the motor. There were two servo motors used in this project for horizontal and vertical axis respectively.

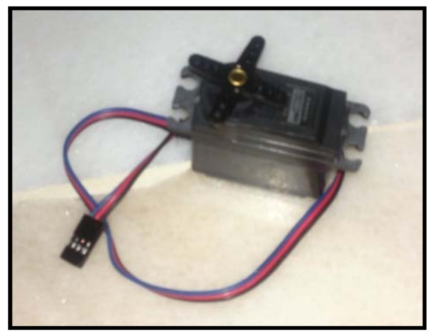

Figure 3. Servo motor

3) Solar Panel

Solar panel, which is also called 'photovoltaic', is a device that converts light directly into electricity. There are many types of solar panel distinguished by their efficiency, price and temperature coefficient that are available in the market. Some of them are monocrystalline, polycrystalline and thin film. The monocrystalline type of solar panel was selected for this project because it has the highest efficiency compared to other types.

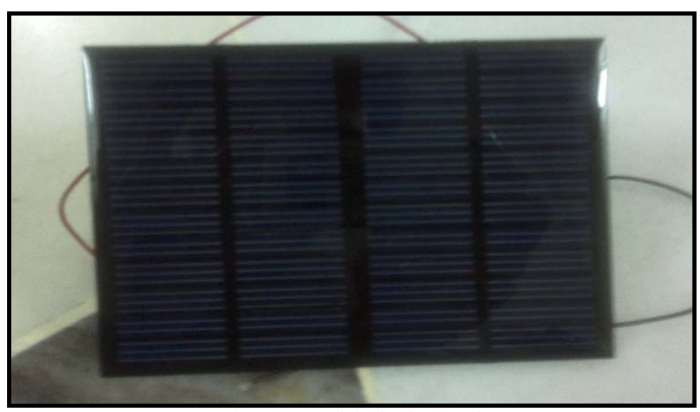

Figure 4. Model of solar panel

4) *Programmer*

Arduino is an open-source electronics prototyping platform based on flexible and easy-to-use hardware and software. Arduino can sense the environment by receiving input from a variety of sensors that can affect its surroundings. Arduino projects can be stand-alone, or they can communicate with software running on a computer. In this development, Arduino is used as the main controller for the project. There are many types of Arduino boards but for this project, Arduino UNO was selected. This is because it satisfies these conditions:

a) Microcontroller board based on the ATmega328.
b) 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header and a reset button.

Figure 5. Arduino-Uno board

B. *Software*

The software part consisted of a programming language that was constructed by using C programming. The codes were targeted to Arduino UNO board to be compiled and uploaded. The flow of the software procedure is shown in Figure 6. The five LDRs were connected to Arduino analog pin A0 to A4 to act as the input for the system. The built-in Analog-to-Digital Converter converted the analog value of LDR into digital PWM. The values of PWM pulse then were <u>applied</u> (exploited?) to move the servos. The maximum light intensity captured by one of the LDR inputs was selected and later the servo motor would move the solar panel to the position of the LDR that was set up in the programming. There were three points of motor rotation; 0, 90 and 180 degrees. The positions of LDRs were divided into five positions which were centre, right, left, up and down. These five positions were the best positions that could detect the highest intensity of sunlight.

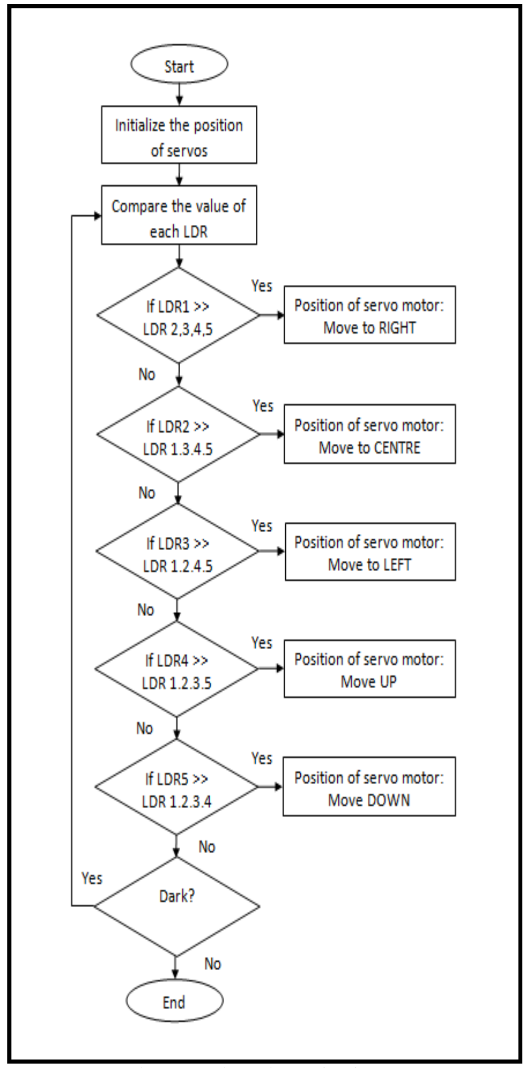

Figure 6. Flow chart of software

III. RESULTS AND DISCUSSIONS

The results revealed that the location of the solar panel was one of the important things in collecting its output voltage and current. It was also discovered that solar panel would perform the best when facing south as this would help to receive the most exposure from the sun as it moved from east to west. For most locations, the peak performance hours of the day were between 9a.m till 12p.m. This was when the sun was at its highest illumination.

The measurements of the data were taken from a wide area where there was no obstruction that would prevent the tracker from getting the maximum sunlight. The measurement of output voltages and currents were taken at two different days from 9a.m until 6.00p.m. The data collected is demonstrated in the graphs below. It was a very sunny day for day 1, but it was quite cloudy on day 2. There were two similar types of solar panels used which followed these conditions:

- Static solar panel with 10 degree of angle facing south
- Solar panel with tracking system facing south

These two conditions enabled the panels to capture the highest and lowest output voltages and currents at the peak performance of sunlight.

TABLE 1. SOLAR PANEL DATASHEET

Model type: SBE15070	
Maximum Power Current (Imp)	0.1A
Maximum Power Voltage (Vmp)	12V
Short-Circuit Current (Isc)	0.11A
Open-Circuit Voltage (Voc)	14.4V

A. Day 1

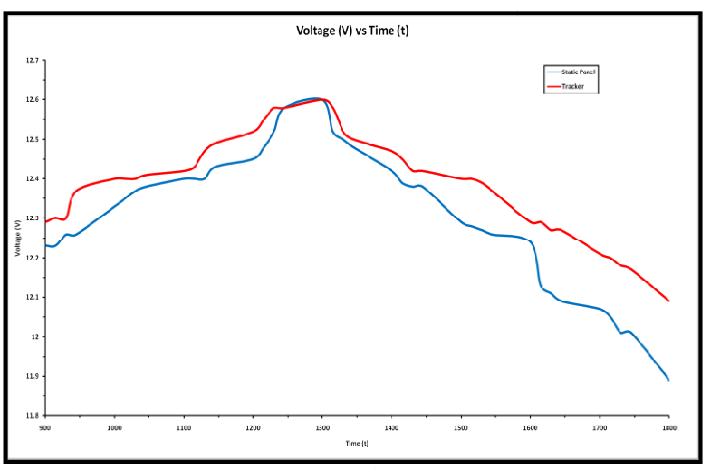

Figure 7. Output voltage comparison between static panel and tracker

Figure 7 shows the graph of output voltage comparison between static panel and panel with tracking system for day 1. As it can be seen in the graph, the output voltage recorded for solar panel with tracking system is higher than the output voltage of static solar panel at most of the time. For the solar tracker, the highest output voltage recorded was 12.6V at 1.00p.m while the lowest output voltage was 12.09V at 6.00p.m. As for the static panel, the highest and the lowest output voltage recorded were 12.6V and 11.89V respectively. The cloud was the main factor that contributed to the instability in the measurement of the output voltage and this was due to its presence that blocked the sun, causing the surrounding to be dim at certain times. As a consequence, the solar panels were not able to obtain the maximum illumination from the sun.

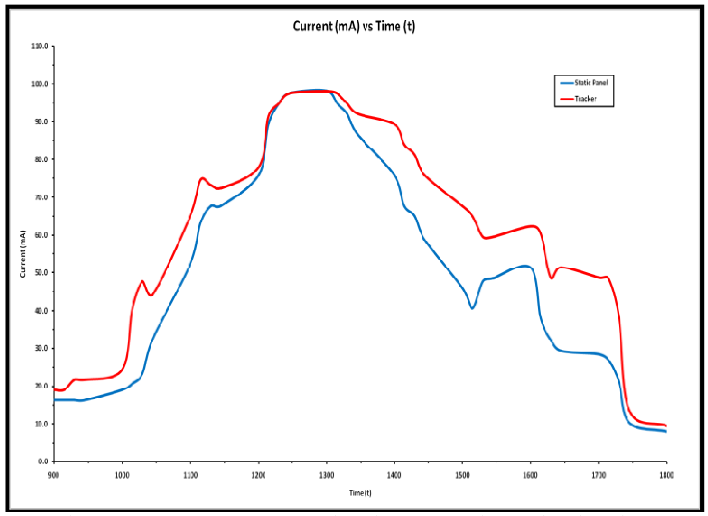

Figure 8. Output current comparison between static panel and tracker

Figure 8 shows the graphs of output current comparison between the static panel and the tracker for day 1. Clearly as illustrated in the graph, the output current recorded for solar panel with tracking system is higher than the output current of static solar panel at most of the times. However, at certain points, the value of output current for both panels recorded similar number. This occurred because during these points, the location of the sun was the same for both panels. The same condition was also employed for the output voltage measurement as presented in Figure 7. For the solar tracker, the highest output current recorded was 98.1mA at 1.00p.m while the lowest output current was 9.5mA at 6.00p.m. As for the static panel, the highest and the lowest output current recorded were 98.1mA and 8.1mA respectively. As shown in Figure 7, the cloud was also the main factor that caused the instability in the measurement of the output current.

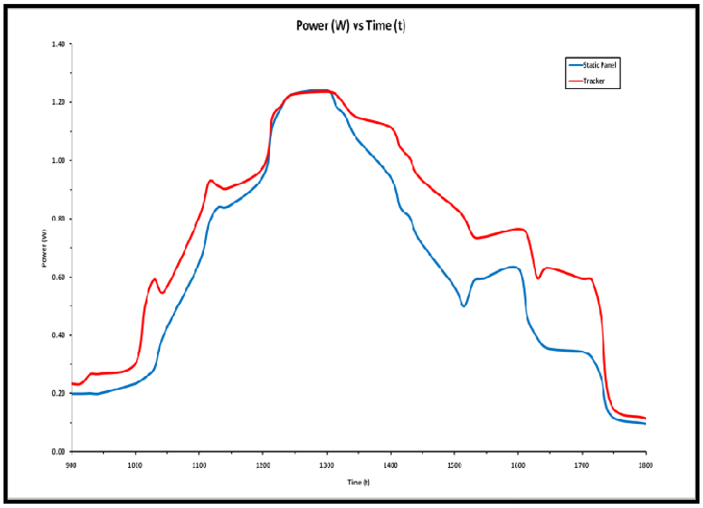

Figure 9. Output power comparison between static panel and tracker

Figure 9 shows the graphs of output power comparison between the static panel and the tracker for day 1. For the solar tracker, the highest output power produced was 1.24W at 1.00p.m while the lowest output power was 0.11W at 6.00p.m. As for the static panel, the highest and the lowest output power produced were 1.24W and 0.10W respectively. As presented in the voltage and current graphs, the output power graph also shows that the output power produced by solar panel with tracking system was higher than the output power of static solar panel at most of the times.

B. Day 2

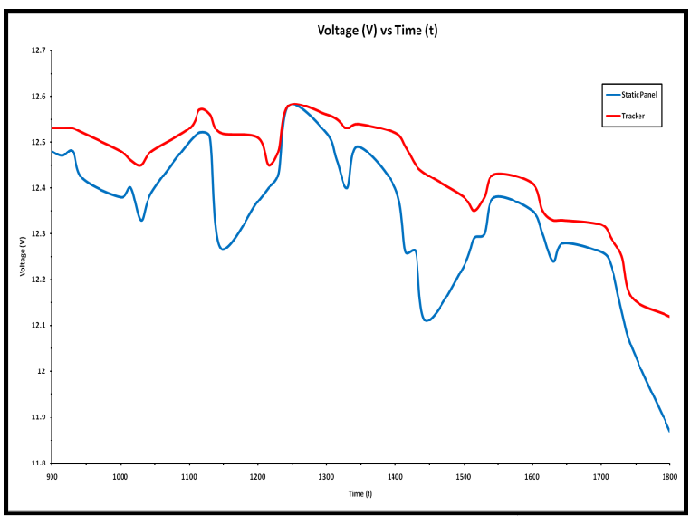

Figure 10 : Output voltage comparison between static panel and tracker

Figure 10 shows the graph of output voltage comparison between static panel and panel with tracking system for day 2. As it can be seen in the graph, the output voltage recorded for solar panel with tracking system is higher than the output voltage of static solar panel at most of the times. For the solar tracker, the highest output voltage recorded was 12.58V at 12.45p.m while the lowest output voltage was 12.12V at 6.00p.m. On the contrary, for the static panel, the highest and the lowest output voltage recorded were 12.58V and 11.87V respectively. As shown in Figure 7, the cloud was the main factor that caused the instability in the measurement of the output voltage because it blocked the sun, causing the surrounding to be dim at certain times. As a result, the solar panels were not able to receive the maximum illumination from the sun.

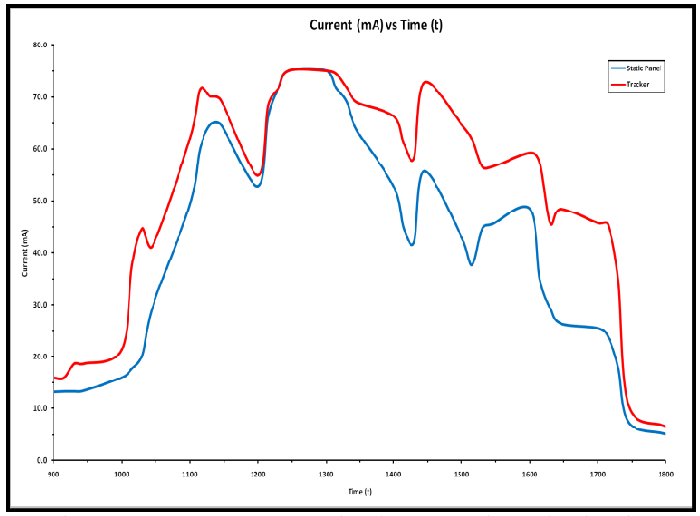

Figure 11. Output current comparison between static panel and tracker

Figure 11 shows the graphs of output current comparison between the static panel and the tracker for day 2. As presented in the graph, the output current recorded for solar panel with tracking system is higher than the output current of static solar panel at most of the times. Nevertheless, as shown in Figure 8, the value of output current for both panels recorded the same number at certain times. This happened because at this point, the location of the sun was similar for both panels. The same situation also occurred for the output voltage measurement as shown in Figure 10. For the solar tracker, the highest output current recorded was 75.1mA at 12.45p.m while the lowest output current was 6.5mA at 6.00p.m. As for the static panel, the highest and the lowest output current recorded were 75.1mA and 5.1mA respectively. As it can be seen in Figure 10, the cloud was also the main contributing factor for the instability measurement of the output current.

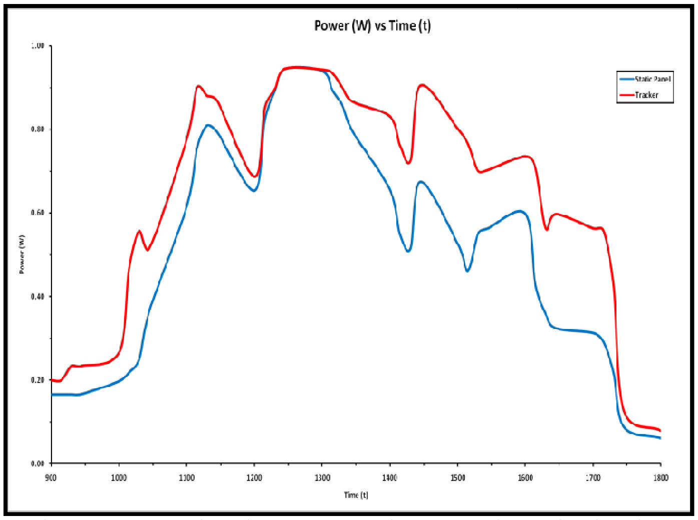

Figure 12 : Comparison the output power between static panel and tracker.

Figure 12 shows the graphs of output power comparison between the static panel and the tracker for day 2. For the solar tracker, the highest output power produced was 0.94W at 12.45p.m while the lowest output power was 0.08W at 6.00p.m. As for the static panel, the highest and the lowest output power produced were 0.94W and 0.06W respectively. As presented in the voltage and current graphs, the output power graph also shows that the output power produced by solar panel with tracking system is higher than the output power of static solar panel at most of the times.

As it can be seen in all the graphs, the data for output voltage, current and power during day 1 is more stable than day 2. This was because day 1 was a very sunny day which this led to the maximum illumination obtained from the sun at most of the times, but for day 2, it was quite cloudy at certain times. The cloud blocked the sun and caused the solar panel not to receive maximum illumination from the sun.

IV. CONCLUSION

In conclusion, the performance of dual-axis solar tracking system was successfully analyzed. Based on the data collected, it can be concluded that the dual-axis solar tracking system is better than the static solar panel in terms of output voltage, current and power. For this reason, the system has been proven effective for capturing maximum sunlight source for solar harvesting applications. The economically and environmentally friendly dual-axis solar tracking system also can be a great technique in utilizing the superiority of solar energy thus solving the increasing demand of electricity problem.

For further research in the future, some improvement to the system can be made in order to improve the outcome. It is recommended that the analysis to be done with a higher intensity solar panel that produces higher output voltage and current. By doing this, the output power will be larger compared to using small solar panel. It is also recommended that the measurement is improved by using a data tracker. All the readings will be automatically recorded in the data tracker.

REFERENCES

[1] Divya, V & Sashanka, P. April 30, 2010. "Renewable Energy". Retrieved June 5, 2012, from http://www.yuvaengineers.com/?p=495

[2] Asmarashid Ponniran,Ammar Hashim,Ariffuddin Joret. "A Design of Low Power Single Axis Solar Tracking System Regardless of Motor Speed".Internal Journal Of Intergrated Engineering,Vol.3 No.2(2011) p 5-9

[3] J.Beltran A.,J.L Gonzalez Rubio S.y C.D.Garcia-Beltran. "Design,Manufacturing and Performance Test of a Solar Tracker Made By a Embedded Control.Fourth Congress of Electronic,Robotic and Automotive Mechanics

[4] O.C.Vilela, N.Fraidenraich& C.Tiba, (2003) "Photovoltaic pumping systems driven by tracking collectors. Experiments and simulation (2003) Solar Energy, 74 (1), pp. 45-52

[5] A.K. Saxena & V. Dutta, "A versatile microprocessor- based controller for solar tracking", IEEE Proc., 1990, pp. 1105 – 1109.

[6] A.Yazidi, F. Betin, G. Notton &G. A. Capolino, July 2006,"Low cost two-axis solar tracker with high precision positioning", Proceedings of the International Symposium on Environment, Identities & Mediterranean Area (ISEIM'2006), July 10-13 2006, Corte-Ajaccio (France), pp.211-216.