A review of automatic solar tracking systems

A Mohamad¹, H Mhamdi², NAM Amin¹, M Izham³, NA Aziz¹, and SY Chionh¹

¹ Mechanical Engineering Program, Faculty of Mechanical Engineering Technology, Universiti Malaysia Perlis, Perlis, Malaysia
² Laboratory of Electronic Systems, Information Processing, Mechanics and Energetics, Faculty of Sciences, University Ibn Tofail, Kenitra, Morocco
³ Institute of Engineering Mathematics, Faculty of Applied Sciences and Humanities, Universiti Malaysia Perlis, Perlis, Malaysia

Corresponding author: azizul@unimap.edu.my

Abstract. Solar tracking systems which can track the Sun movement can increase the power generation rate by maximizing the surface area of the solar panels that are exposed to the sunlight. By utilizing a solar tracker, the number of solar panels needed to generate the same amount of electrical energy will be significantly lower. In general, solar tracking systems are classified as single-axis solar tracking systems and dual-axis solar tracking systems. Several researchers had conducted both simulation and experimental work to compare and evaluate the performance of solar tracking systems against static solar panels systems, as well as between different solar tracking system mechanisms. General agreements among the researchers are that the performance of solar tracking systems is always exceeding that of static solar panels. Some researchers also conducted studies on how the weather conditions affect the performance of solar panels, and they concluded that the systems with tracking mechanisms are more resilient toward a variation of weather conditions.

1. Introduction

With the development of society, the topic of environmental protection and energy-saving had become popular and more discussed. One of the ways to reduce the impact of global warming is by minimizing the utilization of fossil fuels by replacing them with natural energy resources such as winds, ocean waves, tides, sunlight, and geothermal heat. To make such changes, scientists and engineers work relentlessly to develop new devices that can convert nature’s available energy resources to more useful electrical energy, such as solar panels for sunlight energy and wind turbines for wind energy.

Despite the significant shift toward renewable energy in recent years, several problems still exist which needed to be solved to fully utilize these energy resources [1]. As an example, solar photovoltaic panels that are commonly available in the market are fixed at a certain inclination angle, thus only facing one direction. Solar panels generate maximum power when the Sun is located perpendicular to the surface of the solar panel. The sun rotates from east to west throughout the day, and most of the time it will not be located perpendicular to the solar panel, thus lead to low power generation. For a large household with high energy consumption, the number of static photovoltaic solar panels that need to be installed to sustain the energy demand is relatively high, which lead to higher start-up cost, which in turn increase the payment period and total cost of electricity, which ultimately make the photovoltaic solar energy option to be unattractive and not economical. To rectify this problem, solar tracking systems which can track the sunlight from east to west are proposed since they can increase power generation rate by maximizing the surface area of the solar panels that are exposed to the sunlight. By utilizing a
solar tracker, the number of solar panels needed to generate the same amount of electrical energy will be significantly lower due to the increase in efficiency of the solar tracking systems, thus reducing the overall performance of the solar photovoltaic system, both technically and economically.

2. Overview of the Solar Tracking Systems

In general, the solar tracking systems could be classified into 2 major groups, depending on their degree of freedom to tilt and rotate. Namely, the classification is a single-axis solar tracking system and dual-axis solar tracking system.

The single Axis Solar Tracking System is used to track the angle of tilt of the sun along a single axis, commonly used in the tropical region [2] since the position of the Sun throughout the year does not differ much. This system consists of 1 linear actuator, with a motor to rotate the panel according to the movement of the Sun [3]. Typically, a set of 2 light-dependent resistors (LDRs) is used, and it is placed on the opposite sides of a solar panel. Its function is to measure the intensity of light by calculating the voltage drop across them. The panel will keep rotating and stop when the voltage drop is equal. Therefore, the solar panel will always face perpendicularly to the sun irradiation.

![Figure 1 Single Axis Solar Tracking system](image1)

Dual Axis Solar Tracking System has 2 axes of rotation that allow it to always track the movement of sunlight, and it is mainly designed to be used outside the tropical region, beyond the latitudes of 10°N and 10°S from the Equator [3][4]. This system consists of 2 actuators, with a motor to rotate the panel by receiving the voltage control signal from 4 LDRs that are placed on all corners of the solar panel. The mechanism of a dual-axis solar tracking system is relatively more complex, and its overall cost is comparatively higher than a single-axis solar tracking system. When the solar panel experiences maximum irradiation, the voltage drops across the 4 LDR will be equal, thus the motion of the panel will stop. This system enables the solar panel to face perpendicularly to the sun irradiation most of the time.

![Figure 2 Dual Axis Solar Tracking system](image2)
3. Comparison of Solar Tracking Systems

Much research had been carried out to study the performance enhancement of different types of solar tracking systems. Tarlochan et al. [5] had carried out experiments on the design and construction of a low-cost dual axis solar tracker and compared the performance of a static solar panel and solar tracker. The design was built up by several components such as Arduino Uno Microcontroller that acted as controller unit, 2 servo motors to rotate the solar panel at horizontal axis and vertical axis, and LDRs that act as light sensors. In this experiment, an automated light source prototype was built to imitate the Sun trajectory. They were using LabVIEW software as a real-time monitoring system to get the instantaneous plots of voltage, current, and power. The researchers found that the solar tracking system was able to achieve an average power gain of 13.44% compared to the static solar panel.

Jamal et al. [6] conducted a study on automatic solar tracking system development and modeling system construction using Labview software. The tracking system that was developed consists of 4 LDRs, an Arduino microcontroller, and a DC motor. The solar tracking system is working by obtaining analog input from LDRs, then the microcontroller converts the analog signal to a digital signal before sending it to the DC motor as output.

NKalo et al. [7] conducted a study to design a dual-axis controller for photovoltaic cells. In this study, they designed a dual-axis controller by using ATMEGA 328P as the microcontroller and servo motor to control the movement of the controller. Two pairs of LDR were placed at all 4 corners of a photovoltaic cell, and they will send signal instruction to the servo motor to rotate the PV cell to make it facing toward the maximum incidence of sun rays. The simulation of the circuit system was performed using Proteus software. Based on the result obtained, it shows that there is an increase of 54.71% in the generated output power for a solar tracking system compared to a fixed solar panel. Figure 3 below shows the plot of the LDRs output voltage against time while Figure 4 shows the plot of solar irradiance against time for both fixed panel and tracking systems.

![Figure 3](image-url)
Figure 4. The plot of solar irradiance against time [7]

4. The Effects of Weather on Solar Tracking System Performances
Sunlight consists of 2 types of radiation, namely beam radiation and diffuse radiation. Beam radiation is the solar radiation received by the surface of the Earth without changing in direction while diffuse radiation is the solar radiation received by the surface of the Earth that had reflected and scattered by the atmosphere [3]. Therefore, the weather condition is playing an important factor that able affects the performance of the solar panel, as the cloud will easily block the sun ray which leads to no beam radiation fall on the solar panel [8].

Lee et al. [8] had carried out an outdoor experiment using a low-cost solar tracker to compare the performance between a static solar panel and solar tracking system in terms of solar irradiance and energy gain in one month. Efficiency and energy gained by the solar panel had measured under cloudy days and sunny days. Table 1 below shows the efficiency and energy gained of solar panels on different days. Based on the result obtained, the efficiency under sunny days had been increased from 24.91% on a cloudy day to 82.12% on a sunny day while the energy generated had increased from 0.108 kWhr/m² on a cloudy day to 0.603 kWhr /m² on a sunny day. The efficiency and energy generated by the solar panel are affected by the weather of the day.

| Weather Condition | Efficiency, η (%) | Energy Generated (kWhr /m²) |
|-------------------|-------------------|-----------------------------|
| Cloudy            | 24.91             | 0.108                       |
| Sunny             | 195.4             | 0.603                       |

Vieira et al. [9] had investigated and compared the performance of solar panels with mobile systems and static solar panels under different weather conditions. The location of this study is the Brazilian semiarid, which is a hot region with high radiation levels. The energy generated by each solar panel and the respective weather condition is given in Table 2. It is observed that the gain of solar panels with
mobile systems comparing with the gain of a static solar panel is a negative value or zero while the weather condition is cloudy. This indicates that the radiation that falls on the surface of the solar panel is diffuse solar radiation, which causes the solar mobile system to lose its path, reducing the performance of solar panels.

Table 2. Performance of mobile system and static system

| Day  | Mobile system energy (Wh) | Static system energy (Wh) | Gain (%) | Weather Condition |
|------|--------------------------|---------------------------|----------|-------------------|
| Day 1| 63.7                     | 68.2                      | -7       | Cloudy            |
| Day 2| 195.4                    | 162.7                     | 20       | Scattered clouds  |
| Day 3| 195.2                    | 166.7                     | 17       | Sunny             |
| Day 4| 177.0                    | 149.3                     | 19       | Sunny             |
| Day 5| 200.7                    | 174.1                     | 15       | Sunny             |
| Day 6| 149.9                    | 159.2                     | -6       | Scattered clouds  |
| Day 7| 100.1                    | 100.5                     | 0        | Cloudy            |
| Day 8| 223.1                    | 189.8                     | 18       | Sunny             |
| Average| 163.1                   | 146.3                     | 11       |                   |

5. Conclusion

This paper reviews previous work on the simulation and experimental analysis of solar tracking systems for both single-axis solar tracking systems and dual-axis solar tracking systems. These researchers compared and evaluated the performance of solar tracking systems against static solar panels system, as well as between different solar tracking system mechanisms, and they agreed that the performance of solar tracking systems is significantly better than that of static solar panels. Similarly, researchers who conducted studies on the effects of weather conditions on the performance of solar panels also concluded that the systems with tracking mechanisms are performing relatively better and they are more resilient toward a variation of weather conditions.

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