Development of a Smart Solar Tracking (SST) system as a green renewable energy solution

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Abstract. Renewable energy is a type of energy generated from renewable resources that are naturally generated such as sunlight, waves, rain, wind and geothermal heat. Renewable energy provides energy in different categories such as electricity generation, air and water heating/cooling and transportation. Solar PV cells are the most common method for transforming the sun light to electrical power. But using a standstill PV cells is not very efficient due to sun movement as the PV cells must be perpendicularly aligned to the sun to get its maximum efficiency. Tracking the sun by a tracking system will increase the harvested energy and achieve the maximum power generated from the solar cells. In this work, we develop a solar tracking system that enables photovoltaic cells to continuously track the sun and study the effect of light incident angle on the photovoltaic cell's efficiency. In this study, the use of PV cells with tracking capabilities is 21% more efficient as compared to conventional standstill PV cells.

1. Introduction
Solar power is an energy formed when the sun ray is converted into high temperature (thermal processes) or light energy (electric processes). Solar energy describes many formed energies that custom the ray of the sun. There are some applications of solar energy produced through photovoltaic such as all those involve distillation, evaporation, and photosynthesis which all occur naturally via solar radiation. The traditional types of solar modules/panels are placed in fixed positions and at fixed angles of inclination. The location of the sun changes throughout the day. Thus, these traditional devices cannot face the sun all day long and the angle of the sun ray will not be perpendicular on the solar panel. This work aims to develop a smart system for tracking the sun light. The microcontroller unit of our system allows it to move in two axes as it determines the direction and the angle of inclination of the sun based on the factors in that area. Thus, the system can autonomously track the sun to achieve the best efficiency and generation of energy. This work includes hardware design and implementation together with software programming for the microcontroller unit of the solar tracker. The system has been able to keep the solar panel aligned with the sun or any light source repetitively. Despite being small-scale, a quantitative measurement was also carried out to evaluate how well the proposed tracking system has improved the output power in comparison with the one with fixed mount. This paper also reviews some of the project developments and cites some research review works on the area of solar cell tracking systems.

2. Literature review

2.1. Review of relevant existing research works in Arduino project hub
In this section, several existing solar tracking systems are presented. To improve the readability of the paper, each system is presented in a separate section.

2.1.1. Solar tracker. In [1], a system was developed to increase the solar exposure of a photovoltaic cell. The main attributes of this work is having a servo motor, one axial mechanics, two Light Dependent Resistors (LDRs) and an Arduino platform programmed with a finite state machine in C language. Being a single axis based solar tracking system, the power generation efficiency of this system is poor.

2.1.2. Solar tracker with online data feed – Windows IoT. This system connects between two most important things which we use in our daily live. It ties between windows soft wear and solar energy [2]. This work consists of two main controllers: The Raspberry Pi 2 works as the main controller and the second is the Arduino which is responsible for the movement of the servo and also for light measurement. This system involves several components like Raspberry Pi 2 Proto Board one piece and Raspberry Pi 2 Proto Board one piece. The solar tracker uses online data feed running by the Windows IoT Core running on the Raspberry Pi 2. The Arduino controls two servos when it receives commands from Raspberry Pi and then it translates information into drive commands to the servo motors (vertical and horizontal). The system is in a small scale.

2.1.3. Smart solar tracker. The smart solar tracker was developed in 2015 [3]. It was at first realized exclusively by using mechanical parts but it later was equipped with electronic circuitries. A bundle of wires was then replaced by a plug and play wire. The system control unit is Arduino-based and it is used to plug in servos and sensors. The power generation efficiency of this system requires technical analysis and investigation.

2.1.4. Arduino solar tracker. The system is [4] consists of an Arduino platform, a photo diode and LDRs. The Arduino Nano reads analog values of the LDRs which have a directional motion in north, south, east and west directions, as well as in east-west and north-south directions. The partition between the LDRs shows a shadow if the panel does not look directly to the sun. If one LDR is shaded, the measured analog level will be different from the other pairs. If the analog levels are bigger than five points in a scale, then Arduino Nano sends a command to the servo motor to move 1 degree to the E-W or N-S direction in which LDR has lower level. It rotates until the panel is positioned directly to the sun.

2.1.5. Solar panel sun tracker – phone charger. In [5], the system is used to charge a phone without any external power supply. In fact, there are are some issues with this work as it is obviously requires 5V to power the Arduino and servo motor which are originally used to maximize the power output of solar panels that is at best produces only 3.4V. Thus, it’s definitely not paying itself off. However, the concept is scalable and be modified to be economically efficient. For example, this concept can be extended to an array of 8 panels, producing 12V so that is could power the Arduino platform and charge the phone without an external power source.

2.1.6. DIY solar tracker Arduino work ITA. This work is mechanical automatic system that uses sensors to move with the sun position to store more energy [6]. Simple components are used in the system including Arduino Uno, four pieces of 220 Ω resistors, four photo resistors, two servomotors, breadboard and solar panel. The power generation performance of this system requires an investigation.

2.1.7. Solar battery powered switch for blinds, lights, and charger. The solar tracking system in [7] work acts as a standby in case the normal power drops behind its satisfactory level. In other words, this system works as a charging bank in the house. It operates DIY Window Blinds with stepper motor and uses voice commands with Amazon Alexa to turn on or off an LED, Window Blinds, alarm, charger, and other AC devices. It also has the option to auto close blinds at night and turn on the lights.

2.2. Comparison criteria of solar cell tracking systems
A comparison between the aforementioned reviewed works is presented. The comparison criteria may include the functionality, estimated cost, technology used, design simplicity, reliability and power consumption.

2.3. Research review works on solar cell tracking

In the literature, several research works on the area of solar cell tracking have been conducted in the recent years. In [8], the authors surveyed several open loop and closed loop solar cell tracking systems. In [9], several single axis and dual axis solar cell tracking systems were reviewed, and the authors state that the dual axis systems are much more efficient than the single axis one in terms of power generation efficiency. A more specific review of dual axis solar cell tracking systems is presented in [10]. In fact, the topic of solar cell tracking system is continually attracting the attention of the research community. Recent review works on this area have been published in [11], [12].

3. Development of the proposed smart solar tracking system

In this section, the development of the proposed smart solar tracking system is presented. The system can be divided into three main units namely, the microcontroller as a core control unit via Arduino Uno board, input sensors (LDR), and output signals connected to motors (servo motors). The microcontroller collects data instantly from light dependent resistors, sends control signal to the servo motors to move the solar head towards the light source, and keeps tracking it. The circuit design of solar tracker is presented in Figure 1. Four LDRs and Four 100KΩ resistors are connected in a voltage divider fashion and the output are given to 4 Analog input pins of the Arduino board. The PWM outputs of two servos are used from digital pins 9 and 10 of Arduino board.

![Circuit diagram](image1)

**Figure 1.** Circuit diagram.

The flowchart in Figure 2 presents the operational procedure of solar tracking system that enables the microcontroller to do its intended tasks of data acquisition from the sensors, supplying power to the servo motors and finally positioning the solar panel to the sun adaptively.
The developed smart solar tracking system is presented in Figure 3. Two types of tests can be taken into account to compare the energy harvested by the PV cell; while it is stationary and while it is in a tracking mode.

![Flowchart](image)

**Figure 2.** Flowchart.

The energy levels in both tests are clearly different in terms of the total energy and time of light exposure. As shown in Figure 4, the total energy harvested by the system in the tracking mode has been...
6230.5mWh while it has been 4921.5mWh on the fixed mounting mode. Figure 4 is indicating the effect of light exposure in the two modes. The measurement data reveals that the use of PV cells with tracking capabilities is 21% more efficient comparing to conventional still PV cells. On the other hand, there are some instability in the PV cells output that is due to the manual load adjustment throughout the day. This is necessary to match the variation in the power generated. The results shown in Figure 4 was collected at a building in Nizwa, Governate of Aldhakiliya of the Sultanate of Oman. The test was conducted between 10-13 January 2020 between 0700 to 1800 every day.

![Fixed VS Tracking System](image)

**Figure 4.** Fixed VS Tracking.

4. **Conclusion**
In conclusion, energy usage is dramatically increasing due to more reliance on technology. The future demand for cheap, renewable energy is significant and has been forecasted to grow. The growth rate of solar energy makes up the majority with a yearly rate of 7.5%. In addition, the solar energy is becoming more popular due to the installation and operational costs decrease, making it more practical and allowing for installations in various industries. For example, in the US, the growth rate of solar panel installations is expected to grow by 40% in residential areas. The most common solar panel technologies in market are stationary. Installation and maintenance of these panels are difficult as they must be placed at a fixed angle that optimizes energy absorption. Solar position tracking using electronic systems is not a new concept; is an example of an early microprocessor based solar tracking system. However, in recent years, the escalation of the cost of energy and the reduction in the cost of electronic components have made solar tracking feasible even for domestic applications. Thus, our design goal is to minimize the cost while maximizing the efficiency, so as to make the system commercially viable for domestic applications.

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