An investigation of an Arduino-based solar tracking system with panel surface cleaning mechanism

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Abstract - *Solar energy presents a clean, readily accessible, and abundant alternative source of power in nature. Harnessing this energy for electricity generation offers significant benefits. However, fixed Photovoltaic (PV) panels have limitations, as they can only extract maximum energy during a specific time frame, typically from 12 noon to 2 PM in southern parts of India, leading to reduced energy efficiency. Further due to high dust atmosphere the panels are covered with 0.5 to 1 mm thick mud dusts. This will check much of the solar light source reaching the panel. The presence of dust on solar panels can lead to a reduction in their power output. To address this issue, it becomes crucial to enhance the energy efficiency of PV solar panels by implementing a solar tracking system and a cleaning cum wiping system. This study employs an Arduino-based solar tracking system and cleaning model utilizing Light Dependent Resistors (LDRs) to gauge sunlight intensity. The PV solar panel is adjusted accordingly to optimize energy capture as it tracks the sun's movement. The tracking mechanism utilizes a servo motor controlled by a microcontroller, responding to signals from the LDRs. Also motor driven wipers are designed to operate at intervals. The conclusive findings clearly indicate that the solar tracking panel produces a greater amount of energy in comparison to a stationary panel with a pristine surface.*

Key Words: Solar Energy, Arduino, Tracking, Microcontroller, Panel Cleaning

1.INTRODUCTION

South India has a tropical climate with ample sunshine throughout the year. This region receives high solar irradiation levels, making it an ideal location for solar energy generation. Installing solar panels in South India allows harnessing this abundant solar resource efficiently. Solar panel installations promote energy independence by reducing reliance on fossil fuel-based energy sources. South India, like the rest of the country, faces challenges related to energy security and power shortages. Solar power installations can help meet the increasing energy demand, especially during peak hours, and reduce the strain on the conventional power grid. Southern part of India is one of the tropical climate zone with temperatures ranging from 30 to 40 degrees and average of 6.25 hours of sunshine per day. Though states like Karanataka, Tamilnadu and Kerala have significant electrification rate the power cutoff rates are high in rural areas. On this count, only 40% of residences in India currently have access to public power, and this is not always the case. In India, where there is no reliable source of electricity, people have begun to embrace the tradition of producing their own power. Expense of living is quite high, especially in the rural areas of the nation, due to the rising expense of using fossil fuels to generate power. Additionally, the usage of fossil fuels has polluted the environment, which is harmful to human health. The greenhouse effect is brought on by the carbon dioxide released. Deforestation of the land as well as air and water pollution result from this. Because solar energy only comes from the sun, it does not release carbon dioxide, preventing the greenhouse effect. India solar energy development has the potential to provide employment. Particularly as compared to coal mining and oil extraction, employment in the renewable energy sector would lower occupational dangers. Due to its abundance and environmental friendliness, solar energy is becoming one of the most dependable sources of electricity.

Solar tracking systems optimize the positioning of solar panels, maximizing sunlight exposure and increasing energy generation, which is crucial for meeting India's growing energy demand. Solar tracking increases the overall efficiency of solar installations, allowing for higher power output per unit area. This efficiency gain translates into improved cost-effectiveness and a higher return on investment for solar projects. Solar tracking helps align energy generation with peak demand periods, contributing to grid stability and facilitating the integration of renewable energy into India's power grid, reducing reliance on fossil fuels and supporting sustainable energy transition.

Keeping all the mentioned aspects in the mind a system with optimal and effect enhancement of solar panels has be developed. A system that tracks the sun will be able to determine its position in a non-linear way, claims reference [2]. This system's operation ought to be managed independently [3]. A solar PV panel will produce the most electricity when it is angled directly towards the sun and with clean surface the potential can be further enhanced.

2 Literature Reviews

A solar cell is a device that uses the photovoltaic effect to convert light energy into electrical energy. The foundation of photovoltaic modules, or solar panels, are solar cells. In a solar tracking system, the surface of the module automatically tracks the location of the sun during the course of the day. As the sun moves across the sky, its location changes. The solar tracker can boost the effectiveness of such equipment in any given position. For solar powered equipment to function optimally, it must be placed close to the sun, based on performance, price, and sophistication.

Several sun tracking techniques have been studied and assessed in order to keep the PV cells perpendicular to the sunlight. An ideal tracker would allow the PV cells to precisely aim towards the sun, correcting for changes in the sun's altitude angle (during the day), latitudinal offset (during seasonal fluctuations), and azimuth angle. Tracking in relation to latitudinal offset raises the system cost. The altitude angle is tracked using a single axis method. There are two types of sun trackers: passive (mechanical) trackers and active (electrical) trackers [1][6].

1. Location and azimuth elevation range [3].
2. Illumination detected by sensors like photo-resistor [4], [5] light-dependent resistor (LDR)

The fixed solar panel is one type of passive solar tracker. It is positioned horizontally on the solid ground with its face to the sky. However, the majority of passive solar trackers rely on human panel adjustment [1]. Major active trackers are built around a microprocessor, a computer-controlled date and time system, an auxiliary bifacial solar cell, or a combination of these three components. Two frequently used approaches are used to compute the angular steps required for the motor.

The orientation of solar panels plays a crucial role in maximizing their exposure to sunlight [1]. By actively adjusting the panel's position throughout the day to face the sun, solar tracking systems optimize the angle of incidence, ensuring that the panels receive the maximum amount of solar radiation. This leads to increased energy production and higher overall system efficiency. Active solar panel orientation helps optimize energy generation by maximizing the conversion of sunlight into electricity. By tracking the sun's movement, panels can capture sunlight at an optimal angle, increasing the efficiency of the photovoltaic cells[1][2][4]. This enhanced energy generation translates into higher power output, allowing for better cost-effectiveness and a faster return on investment for solar installations.

Keeping the surface of solar panels clean is essential for maintaining their efficiency. Dust, dirt, bird droppings, or other debris that accumulate on the panels can create shading and reduce the amount of sunlight reaching the photovoltaic cells. Regular cleaning helps ensure that panels operate at their maximum capacity, preventing any potential loss of energy production. Clean solar panels also enhance the longevity of the system by preventing damage or corrosion that could occur due to prolonged exposure to debris.

3 Methodology

The solar panel is mounted on a stand, and two LDRs are mounted on opposite sides of the panel. A voltage divider is used to convert the LDR's output, which is in the form of resistance, into voltage. The microprocessor instructs the motor to rotate clockwise or anticlockwise based on the highest voltage from the voltage divider. The power is computed based on the output of the panel and the current sensor. The panel tilts to receive more solar energy depending on the intensity and power ratings. As a result, the sun's location is tracked.

The following are the main components of this system:

1. Microcontroller 8051
2. LDRs
3. Motor driver L293D
4. DC Motors

Software specifications

1. Embedded C
2. Keil

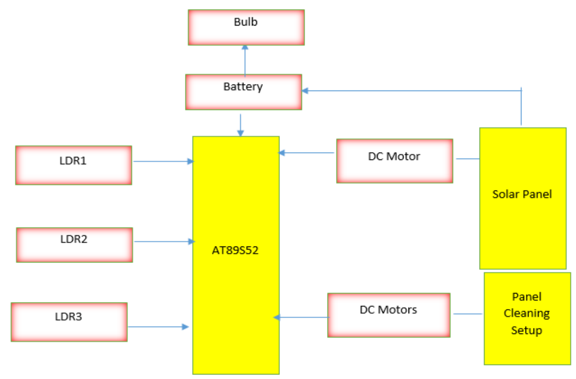

Figure 1. Block diagram of automatic solar tracking system with automatic panel surface cleaner

A solar panel, an Arduino microprocessor, and sensors make up the solar tracking system. Light must be emitted by the sun for this system to function. The LDRs act as sensors, detecting the amount of light entering the solar panels. The LDR then transmits data to the Arduino microcontroller. The servo motor circuit is then built. The servo has three pins, the positive side of which is connected to the +5v of the Arduino microcontroller. The servo's negative is connected to ground. The servo's data point is linked to the microcontroller's analogue point. A potentiometer is connected to control the servo motor's speed. The flow chart and block diagrams of the tracking system are shown in figure 1.

4. Description of Parts

A microcontroller-based solar power tracking system with cleaning functionality is a smart and automated solution to optimize energy generation from solar panels. This system employs a microcontroller, sensors, and motors to track the sun's movement throughout the day and ensure the solar panels are appropriately oriented for maximum energy capture. Additionally, it incorporates a cleaning mechanism to remove dust and debris from the panels, maintaining their efficiency over time. Here's an overview of how such a system might work:

1. Solar Tracking System:

Light sensors (such as LDRs) are placed on the solar panels to detect the intensity of sunlight.

The microcontroller receives input from the light sensors and calculates the sun's position relative to the solar panels.

Based on the position information, the microcontroller controls servo motors that adjust the tilt and orientation of the solar panels to face the sun optimally.

The system continuously monitors the sun's position and makes real-time adjustments to ensure the panels are always facing the sun for maximum energy absorption.

2. Cleaning Mechanism:

The system is equipped with a cleaning mechanism, such as brushes or wipers, installed on a separate track or rail system.

The cleaning mechanism is programmed to activate at scheduled intervals or when certain conditions are met (e.g., a predefined level of dust accumulation).

When triggered, the cleaning mechanism moves along the solar panels' surface, removing dust, debris, and other contaminants that may hinder energy production.

The cleaning process can be combined with a water spray or other cleaning agents for more effective cleaning, although water usage should be optimized in arid regions.

3. Integration and Power Supply:

The microcontroller governs the solar tracking and cleaning systems and ensures they work together seamlessly.

The entire system can be powered using a small solar panel and battery setup to make it self-sustainable and independent of external power sources.

5 Experiment and results

The power readings of the fixed solar panel and the tracking solar panel were recorded hourly for three days in March 2022 and are displayed in tables 1, 2, and 3. The efficiency difference between the fixed solar panel and the implemented solar tracker can be seen in the results taken on different days.

Table -1: shows the power readings for a gloomy morning and a sunny afternoon during March 2023 with fixed solar panels.

Power reading of fixed solar panel (6W)			
Time on a day readings made	**11 Mar**	**14 Mar**	**17 Mar**
6:00	0.125	0.566	0.578
7:00	0.176	0.679	0.489
8:00	0.210	0.792	1.061
9:00	0.196	1.779	1.672
10:00	0.567	3.167	1.199
11:00	0.813	3.421	3.226
12:00	2.297	4.604	3.208
1:00	4.941	4.990	4.980
2:00	3.910	4.980	4.990
3:00	4.057	4.888	4.941
4:00	3.846	4.413	3.878
5:00	1.544	3.935	3.824
6:00	1.144	2.639	2.639

Table -2: shows the power readings for a gloomy morning and a sunny afternoon during March 2023 with solar tracking.

Power reading of fixed solar panel (6W)			
Time on a day readings made	**12 Mar**	**15 Mar**	**18 Mar**
6:00	0.566	2.405	2.910
7:00	0.679	2.804	3.280
8:00	0.792	3.203	3.747
9:00	1.779	3.99	4.827
10:00	3.167	4.130	4.749
11:00	3.421	4.800	5.808
12:00	4.604	4.990	6.037
1:00	4.990	4.988	5.736
2:00	4.980	4.976	5.871
3:00	4.888	4.941	5.682
4:00	4.413	4.873	5.847
5:00	3.935	3.964	4.677
6:00	2.639	3.972	4.647

Table -3: shows the power readings for a gloomy morning and a sunny afternoon during March 2023 with solar tracking and cleaning of panels.

Power reading of fixed solar panel (6W)			
Time on a day readings made	13 Mar	16 Mar	19 Mar
6:00	0.578	1.251	1.45116
7:00	0.489	1.487	1.79927
8:00	1.061	2.839	3.29324
9:00	1.672	3.99	4.5885
10:00	1.199	3.99	4.6284
11:00	3.226	4.149	4.77135
12:00	3.208	4.59	5.4621
1:00	4.98	4.99	5.8882
2:00	4.99	4.985	5.8823
3:00	4.941	4.892	5.8704
4:00	3.878	4.79	5.7001
5:00	3.824	3.94	4.728
6:00	2.639	3.65	4.2705

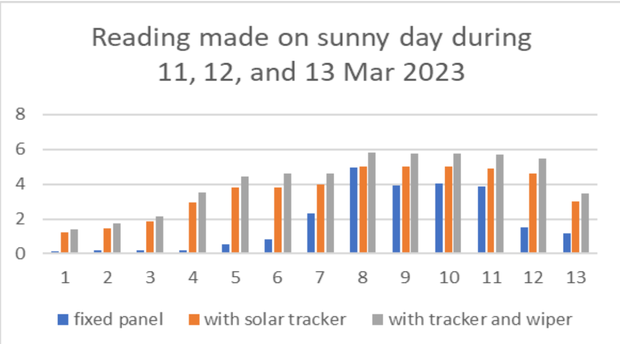

Chart-1: Graph of power readings for sunny afternoon, 11th, 12th and 13th March 2023 .

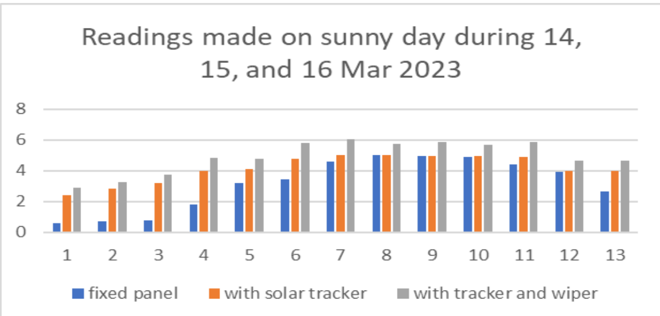

Chart-2: Graph of power readings for sunny afternoon, 14th, 15th and 16th March 2023 .

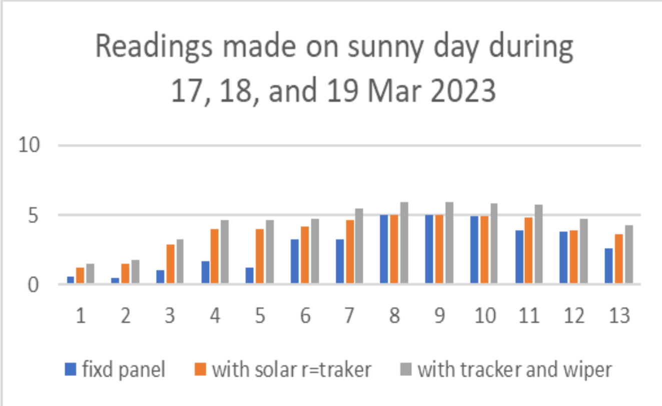

Chart-3: Graph of power readings for sunny afternoon, 17th, 18th and 19th March 2023.

According to the aforementioned tables, the maximum sunshine occurs around midday, with maximum values between 1200 hours and 1500 hours. The intensity of sunlight decreases in the morning and late evening, and the values obtained are lower than those obtained during the day. To save electricity, the tracking system is turned off after sunset. It is then turned on again in the morning to continue tracking. When the numbers are the same, the panel stops moving, indicating that the LDRs get the same amount of sunshine. The wiper is only used once every 1 hour during the day.

5. CONCLUSIONS

The tracking system for solar panels was created and installed. The experimental results reveal that the goal of the solar panel tracking system is to follow the position of the sun in order to improve the efficiency of the solar panel. The implementation of solar tracker reveals considerable increase in the power production. Further, the application of wiper on the panel enhance 20 % power generation. This work can be done on a large scale, which will benefit developing countries like India. Our proposal for future work is to consider using more sensitive and efficient sensors that consume less power and are also less expensive. This would boost efficiency while decreasing costs.

Benefits of this system:

1. Increased energy production: The solar tracking system optimizes energy capture by adjusting the panels to face the sun accurately.
2. Enhanced panel efficiency: Regular cleaning ensures that dust and debris do not accumulate, preventing efficiency losses due to shading.
3. Reduced maintenance: The automated cleaning process reduces the need for manual panel cleaning, especially in hard-to-reach areas.

4. Self-sustainability: The system can operate autonomously, powered by its own solar panel and battery, making it suitable for remote locations.

Implementing such a system requires careful design, programming, and integration of the components. Regular maintenance and monitoring are also essential to ensure the system operates smoothly and delivers the expected benefits over time.

REFERENCES

[1] Adel Abdulrahman et al "Design and Implementation of Solar Tracking System". International Journal of Engineering and Technical Research (IJETR) ISSN: 2321-0869 (O) 2454-4698 (P), Volume-4, Issue-1, January 2016.

[2] MAS Kamala J et al "Solar Tracking for Maximum and Economic Energy Harvesting" International Journal of Engineering and Technology (IJET) ISSN : 0975-4024 Vol 5 No 6 Dec 2013-Jan 2014.

[3] Bingol O, Altintas AO, "Microcontroller based solar-tracking system and its implementation," Journal of Engineering Sciences 2006,vol. 12, pp. 243-248.

[4] Qwq Rumala S, "A shadow method for automatic tracking," Solar Energy 1986, vol.37, pp 245-247.

[5] Palavras I, Bakos GC, "Development of a low-cost dish solar concentrator and its application in zeolite desorption," Renewable Energy 2006, vol. 3, pp. 2422-2431.

[6] Mousazadeh, H., Keyhani, A., Javadi, A., Mobli, H., Abrinia, K., Sharifi, A."A review of principle and sun-tracking methods for maximizing solar systems aoutput," Renewable and Sustainable Energy Reviews, Jan. 2009. vol 13, issue 8, pp.1800-1818

BIOGRAPHIES

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