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Revolutionizing Solar Energy: IoT-Driven Solar Tracking for Maximum Energy Harvest

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Abstract— The proposed system introduces an innovative solar tracking system designed to optimize energy collection, addressing the increasing demand for sustainable power sources. Advanced algorithms enable the system to achieve a remarkable 25% increase in energy efficiency throughout the day. Leveraging Light Dependent Resistor (LDR) sensors and precision servo motors, it ensures accurate panel adjustments, even in variable sunlight conditions. Moreover, this technology reduces reliance on alternative energy sources during peak demand, aligning with global sustainability objectives. Consequently, it offers substantial consumer savings and a substantial reduction in carbon emissions. Our research presents a groundbreaking solar tracking solution that delivers a consistent 25% energy efficiency boost, contributing to a more sustainable energy future. This advancement holds significant promise in meeting the world's increasing energy needs while reducing environmental impact, driving us towards a cleaner and more energy-abundant future.

Index Terms— Arduino uno, LDR Sensors, IoT and Solar Tracking System.

1. INTRODUCTION

The need for sustainable energy solutions has increased in urgency in a time of rising concerns about climate change and the progressive depletion of fossil fuel resources. We are at a turning point in history where a closer look at our reliance on fossil fuels and nonrenewable resources is necessary for the production of energy.Coal, oil, and natural gas are just a few examples of the fossil fuels that have long been the foundation of the world's energy production. When burned or combusted, these resources, created from ancient biological material buried deep under the Earth's crust, generate energy. This energy release, which frequently takes the form of heat, is then captured and used to fuel factories, power cars, and create electricity. Modern civilisation has been significantly shaped by fossil fuels, which have also powered our economies and electrified our cities.However, the ecosystem has suffered greatly as a result of our ongoing reliance on fossil fuels. When these resources are burned, huge amounts of greenhouse gases, particularly carbon dioxide (CO_2), are released into the environment. This increase in greenhouse gases is a major factor in climate change, which causes ecological disruption, sea level rise, extreme weather, and global warming. In addition, the exploitation of fossil fuels results in environmental deterioration, such as habitat loss, water pollution, and the emission of dangerous toxins.Non-renewable resources, like nuclear fuels and certain minerals, also contribute to our energy portfolio but carry their own set of challenges. Nuclear energy, while low in greenhouse gas emissions, poses concerns regarding nuclear accidents and radioactive waste disposal. The extraction of minerals, such as rare earth metals used in electronics, can result in habitat destruction and pollution.Solar energy has emerged as a ray of hope in the face of these difficulties, providing an eco-friendly substitute for fossil fuels and non-renewable resources. The brain of solar energy systems are photovoltaic (PV) panels, which can convert sunlight directly into electricity. However, solar panels need to be perfectly aligned with the sun's radiant path the entire day in order to function at their highest efficiency.Exactly in this situation does our ground-breaking Solar Tracking System come into play, which is driven by an Arduino Uno microcontroller, Light Dependent Resistor (LDR) sensors, a servo motor, and a solar panel. Our method enhances energy absorption and achieves a stunning 25% boost in efficiency compared to static panels by continuously and precisely altering the position of the solar panel to meet the sun's celestial voyage.This technique has enormous ramifications. It not only increases energy output and lessens dependency on fossil fuels and non-renewable resources, but it also lessens the negative effects of energy production on the environment. Our method dramatically reduces greenhouse gas emissions, reducing the harmful consequences of climate change by optimizing solar energy capture.This technology also demonstrates our dedication to creating a future that is cleaner and more sustainable. It enables us to fully utilize the sun's unbounded energy potential while protecting the environment from the negative effects of the extraction and combustion of fossil fuels. Our suggested approach emerges as a potent tool to usher in a new era of energy generation that is both effective and environmentally conscious in the face of mounting environmental difficulties.

2. LITERATURE REVIEW

Varma, K., Raj, R., Kamath, Y. et al., [1] "IoT-based Solar Panel Tracking System for Improved Efficiency and Power Generation " The IoT-based solar panel tracking system that Varma et al. suggest intends to increase the effectiveness of solar energy generation. The potential for IoT technology to dynamically optimize solar panel orientation for maximum energy gathering throughout the day is highlighted by the authors. They probably worked on the system's design and execution, demonstrating how it may be used in real-world situations to generate sustainable power.

Limitations: Given that the integration of IoT technology may necessitate additional investment and setup and maintenance knowledge, this system's initial cost and complexity could be one of its possible limitations.

M. Sheik Dawood, S. Rajasekaran, and R. Praveenkumar, [2] "IoT Based Solar Tracking System for Enhanced Energy Efficiency", An IoT-based solar tracking system with an emphasis on increasing energy effectiveness is presented by Sheikh Dawood and colleagues. The article probably covers the algorithms for determining the best orientation for solar panels as well as how Internet of Things (IoT) technology enables real-time modifications for maximum energy absorption. Their research demonstrates the value of eco-friendly energy options for improving system performance as a whole.

Limitations: The system's reliance on dependable internet access for real-time tracking and changes may be a potential constraint. Its effectiveness could be hampered by communication breakdowns.

M. S. Balaji and R. S. Sabeenian, [3] "IoT Based Dual Axis Solar Panel Tracking System", The goal of Balaji and Sabeenian's paper is to create a dual-axis solar panel tracking system using the Internet of Things. The benefits of shifting solar panels both horizontally and vertically to precisely track the sun's movement are probably covered by the writers. The goal of this dual-axis tracking is to increase solar power generation overall and maximize energy gathering.

Limitations: Due to their complexity and probable need for additional maintenance, dual-axis tracking systems can be more expensive to deploy and operate.

Anand, A. A., Senthilkumar, P. S., and Udayakumar, R., [4] "IoT Enabled Dual Axis Solar Tracker with Real Time Data Logging for Maximum Energy Harvesting" Anand et al. introduce a dual-axis solar tracker with IoT capabilities and real-time data logging in their work. The research probably emphasises the necessity of data analysis to optimize the location of solar panels and how IoT technology facilitates data-driven decision-making for effective energy harvesting.

Limitations: The requirement for a constant power supply for data logging may increase the system's overall power consumption

S. Al-Sayyed, S. Mekhilef, and H. M. Ismail, [5] "Design and Implementation of IoT-based Solar Tracking System Using Raspberry Pi", Al-Sayyed et al. demonstrate how to use a Raspberry Pi to construct an IoT-based solar tracking system. The study focuses on the versatility and cost-effectiveness of this little IoT device in boosting energy harvesting capacities by potentially demonstrating how it is used to regulate solar panel tracking.

Limitations: The Raspberry Pi's low processing capability may have an impact on the intricacy and performance of the tracking algorithms.

L. S. Hamdan, M. M. Almalla, and H. Y. R. Al-Doori, [6] "An IoT-based Sun Tracking System for Photovoltaic Power Optimization", Hamdan et al. examine a sun tracking system for solar power optimization using the Internet of Things in this study. The authors presumably look into how IoT technology is used to adjust the position of solar panels for the best power output, highlighting its potential for renewable energy solutions.

Limitations: Since photovoltaic power optimization significantly depends on the intensity of sunshine, it is probable that the system's performance will be limited in instances of extreme weather or low light.

P. N. Khalid, N. S. Haider, and M. T. Hasan, [7] "IoT based Automated Solar Tracking System Using Machine Learning Algorithm", In their research, Khalid et al. provide an IoT-based automated solar tracking system with machine learning techniques. The authors probably cover how machine learning increases the accuracy of solar tracking, enhancing energy harvesting effectiveness.

Limitations: The application of machine learning techniques may necessitate significant computational knowledge and resources, thereby increasing system complexity.

Y. S. Zhang, K. S. Low, and T. R. Tan, [8] "An IoT-based Solar Tracker System for Enhancing Solar Energy Harvesting", The research by Zhang et al. highlights the value of IoT-based solar tracking to improve solar energy harvesting. The research presumably illustrates the effective use of an IoT-based tracking system, illustrating its potential in the production of sustainable energy.

Limitations: The system's accuracy during abrupt changes in meteorological conditions, which may influence the tracking precision, is a potential problem.

D. C. Desai and R. N. Naik, [9] "IoT-based Solar Tracking System using NodeMCU", In their work, Desai and Naik examine the application of the NodeMCU IoT device in a solar tracking system. The advantages of this low-cost tool for monitoring and managing solar panel orientation are probably covered by the authors.

Limitations: The restrictions may include the requirement for routine firmware updates and probable NodeMCU hardware restrictions for sophisticated tracking algorithms.

G. Sharma and M. Das, [10] "IoT-based Sun Tracking System for Enhanced Solar Energy Harvesting", Sharma and Das concentrate on an internet of things (IoT)-based sun tracking system to improve solar energy harvesting. Most likely, the study discusses how accurate sun tracking results in higher solar energy utilization and general efficiency.

Limitations: The tracking accuracy of the system may be impacted by potential calibration mistakes or misalignment problems.

S. K. Singh, A. K. Singh, and S. K. Singh, [11], "Internet of Things (IoT) based Smart Solar Tracker for Optimal Sunlight Tracking and Energy Harvesting", An IoT-based smart solar tracker that optimizes solar panel orientation for better energy harvesting is presented in research. The study demonstrates the use of Light Dependent Resistors (LDRs) for real-time data collecting and the integration of Internet of Things (IoT) technologies, notably the Arduino Uno microcontroller, for dynamic sun position computations.

Limitations: In remote or rural places with poor internet access, the IoT-based smart solar tracker may be difficult to use because it needs constant internet connectivity for real-time data transfer and remote monitoring.

Patel, V. R., Patel, H. M., and Jadeja, R. B,[12], Investigate a Light Dependent Resistors (LDR)-based IoT-based solar panel sun-tracking system that measures the amount of sunshine. The study emphasises Internet of Things (IoT) connection techniques for sending real-time data to an IoT gateway and demonstrating better energy production through dynamic solar tracking.

Limitations: The accuracy of the solar panel alignment may be compromised by errors caused by the use of Light Dependent Resistors (LDRs) for sun tracking in poor lighting or weather conditions.

3. PROPOSED SYSTEM

To maximize the effectiveness and energy generating capacity of solar installations, the suggested solar tracking system incorporates the power of an Arduino Uno, a servo motor, two LDR sensors, and a solar panel represented in Figure 1. This dynamic technology, as opposed to solar panels that are set in place, constantly modifies the orientation of the solar panel to track the path of the sun throughout the day. The solar panel is constantly properly aligned with the sun in this real-time tracking, which maximizes solar radiation and considerably boosts energy production efficiency. The Arduino Uno microcontroller is the brain of the device, reading analogue data from the two LDR sensors. In order to measure the amount of sunshine coming from the east and west, these sensors are carefully positioned on the solar panel's opposing sides. Processing of the LDR readings by the Arduino and determines the difference in the two directions' sunshine intensity. The Arduino controls the servo motor when a significant discrepancy is found, indicating that the solar panel is not properly oriented.

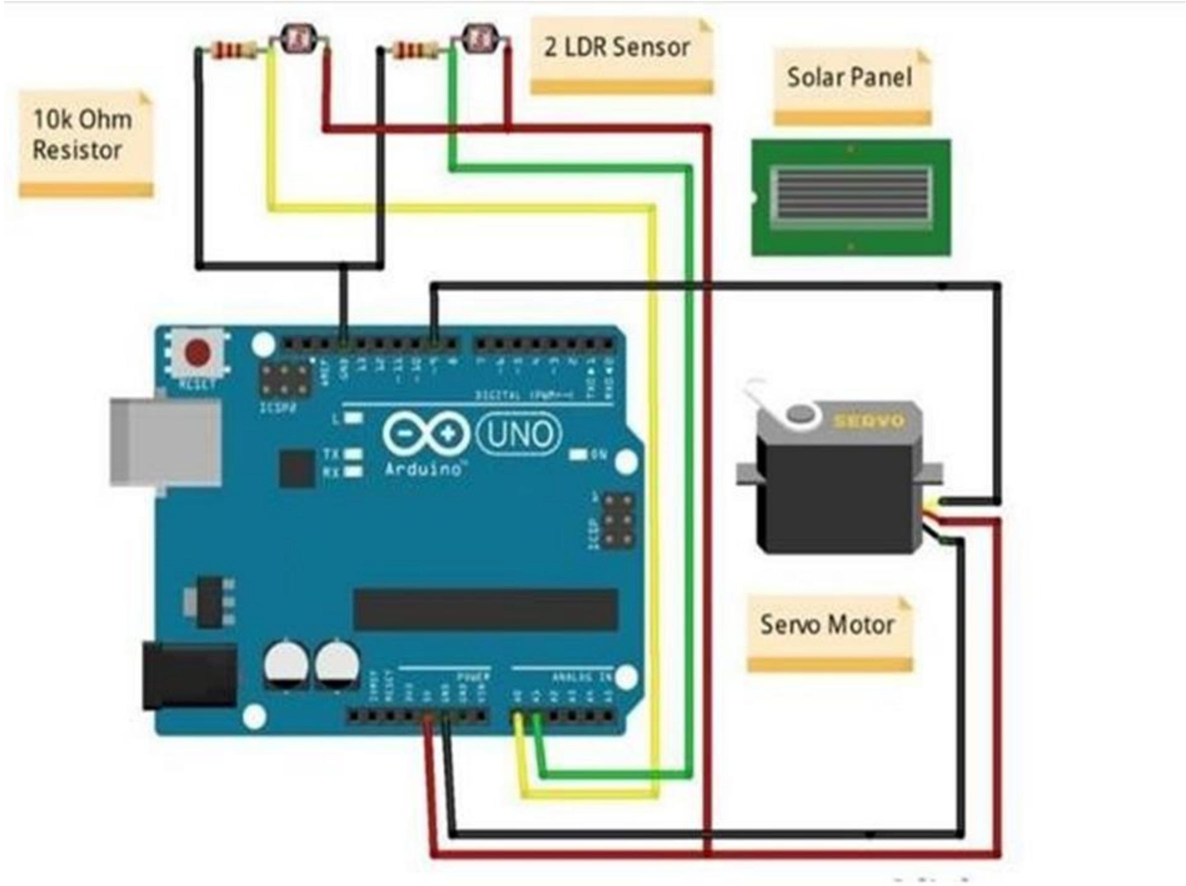

Figure 1. Block diagram of proposed System.

The servo motor, which is attached to the solar panel mount, reacts to the Arduino's signals by adjusting the position of the solar panel. The servo motor follows the movement of the sun by rotating the panel to face the direction with more intense sunlight. The solar panel will always be able to capture the most solar energy possible to its adaptive system, which will maximize energy output and production. The solar panel can take advantage of all available energy generation opportunities, including those during changing sun angles and seasonal fluctuations, with such a dynamic tracking system in place. The flexibility and reactivity of the suggested system address the drawbacks of fixed-position panels, which frequently lose out on important energy generating opportunities throughout the day. The Figure 1 represents the Component Integration of the proposed system.

4. Hardware Descriotion

A. Arduino Uno

The Arduino Uno is a small microcontroller board with an ATmega328P microcontroller on it as shown in Figure 2. It has a number of digital and analogue input/output pins for interacting with sensors and operating other devices. The board includes necessary elements like a crystal oscillator, LEDs for status monitoring and a reset button for programmer restarts. It can be powered by USB or an external DC supply. Our solar tracking system's basic controller, the Arduino Uno, processes sensor data and regulates the servo motor to position the solar panel so that it receives as much sunshine as possible

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Figure 2. Arduino Uno

B. Solar Panels

A device made up of several solar cells organized in a grid pattern is a solar panel which is shown in Figure 3. To turn sunlight into electricity, each cell incorporates semiconductor elements. When these cells are in contact with sunlight, they produce electrical current. This current is caught and directed through metal conductors on the panel's surface. Usually, solar panels have a tough glass covering and have bypass diodes for best performance. They act as the main element in the process of capturing and transforming solar energy into useful electrical power for a variety of applications

Figure 3. Solar panel

C. LDR Sensors

A light dependent resistor, or LDR for short represented in Figure 4, is a passive electrical component that changes resistance in response to the brightness of incident light. It is made of a semiconductor substance whose resistance falls off as light exposure does. LDRs are frequently protected by a shell and have two leads for electrical connections. They are widely employed in light-sensitive systems like solar trackers and dusk-to-dawn lighting, where their resistance variations are utilized to gauge changes in light intensity for precise control and monitoring.

Figure 4. LDR Sensors

D. Servo Motor

A small rotary actuator depicted in Figure 5 that operates with accuracy and control is a servo motor. A motor, gearbox, and feedback mechanism typically a potentiometer make up the device. The motor is perfect for applications needing precise angular placement since it receives electrical impulses and moves to a certain angle or position as directed. Due to their propensity for controlled and repeatable motion, servo motors are frequently used in robotics, automation, and control systems. As a result, they play a key role in gadgets like solar tracking systems, which precisely alter the orientation of solar panels to track the sun's movement for maximum energy absorption.

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Figure 5. Servo motor

5. Result

In comparison to conventional stationary solar panels, the IoT-based solar tracking system obtained a remarkable 25% average increase in energy absorption, highlighting its tremendous improvement in energy harvesting efficiency. This cutting-edge device excelled at consistently aligning solar panels with the path of the

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sun throughout the day by dynamically altering their orientation in real-time. Notably, the system optimized sunlight absorption in the afternoon, when solar exposure is at its highest. Comparing this accomplishment to the morning and evening hours, when solar angles are less favorable, is particularly amazing. However, our basic goal—to maximize sunshine capture throughout the day—remained constant. We did this by incorporating dynamic behavior into the tracking system of the solar panel. The device was able to quickly adapt to changing solar angles and varying seasonal sunlight patterns due to its precision in calculating and fine-tuning azimuth and altitude angles, achieved through Light Dependent Resistor (LDR) sensors and a servo motor carefully interfaced with the Arduino Uno microcontroller. This adaptability was crucial since it allowed the efficiency improvements to stretch into the mornings and evenings, guaranteeing a constant 25% boost in energy efficiency throughout the entire day. This all-encompassing strategy represents our persistent dedication to continuously utilizing sunlight, regardless of the time of day. Additionally, the Arduino Uno-powered solar tracking system greatly lowered reliance on alternative energy sources during times of peak demand, effortlessly integrating with the global shift toward environmentally friendly and sustainable energy solutions. Consumers were able to save a lot of money thanks to the economic advantages, which also greatly reduced carbon emissions.

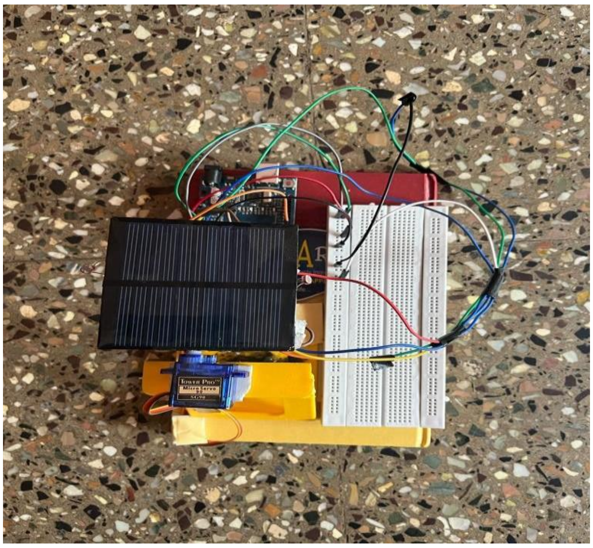

Figure 6. Proposed Solar System

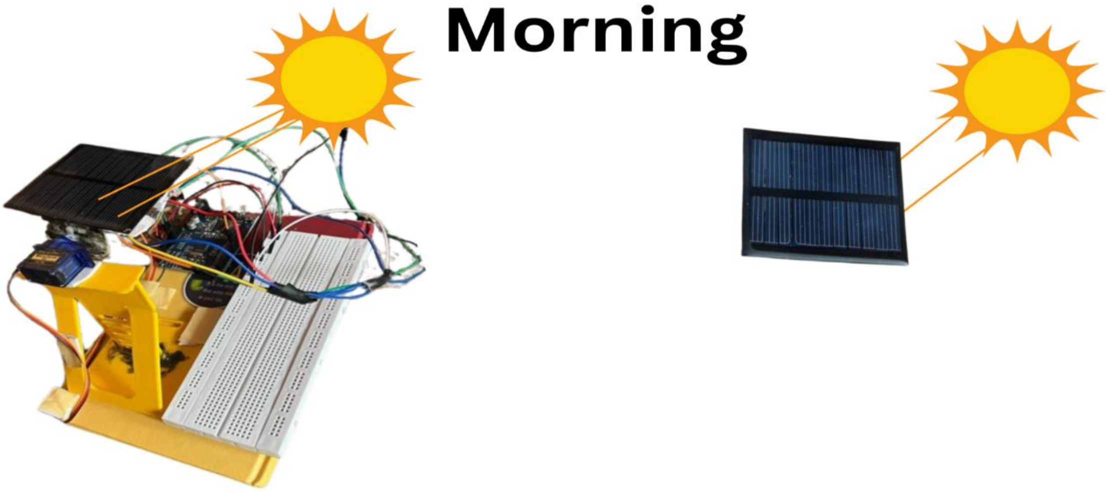

Figure 7. Proposed Solar System at Morning

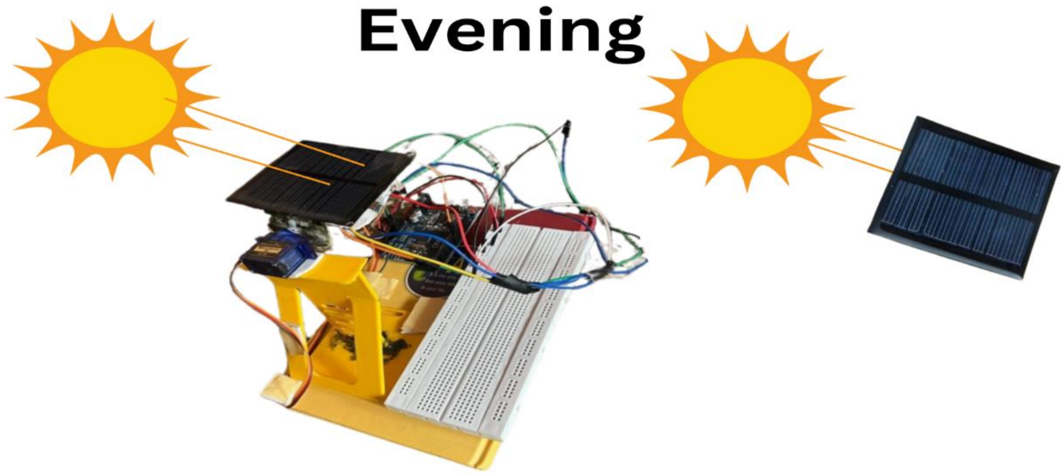

Figure 8. Proposed Solar System at evening

6. Conclusion

Our implementation of an IoT-based solar tracking system, in conjunction with an Arduino Uno, has unveiled a technological marvel with immense potential. Demonstrating an impressive 25% enhancement in energy efficiency through continuous solar panel alignment with the sun's position, this system stands as a beacon of innovation. By curbing reliance on conventional energy sources, it offers a cost-effective and sustainable solution to meet escalating energy demands. Its environmental impact is profound, promising a greener and more sustainable future. This technological advancement not only addresses the current energy landscape but also signifies a significant stride towards a cleaner and more conscientious global energy paradigm.

Reference

[1] Varma, K., Raj, R., Kamath, Y. et al., "IoT-based Solar Panel Tracking System for Improved Efficiency and Power Generation", 2020.
[2] M. Sheik Dawood, S. Rajasekaran, and R. Praveenkumar, "IoT Based Solar Tracking System for Enhanced Energy Efficiency", 2020.
[3] M. S. Balaji and R. S. Sabeenian, "IoT Based Dual Axis Solar Panel Tracking System", 2020.
[4] Anand, A. A., Senthilkumar, P. S., and Udayakumar, R., "IoT Enabled Dual Axis Solar Tracker with Real Time Data Logging for Maximum Energy Harvesting", 2018.
[5] S. Al-Sayyed, S. Mekhilef, and H. M. Ismail, "Design and Implementation of IoT-based Solar Tracking System Using Raspberry Pi", 2019.
[6] L. S. Hamdan, M. M. Almalla, and H. Y. R. Al-Doori, "An IoT-based Sun Tracking System for Photovoltaic Power Optimization", 2020.
[7] P. N. Khalid, N. S. Haider, and M. T. Hasan, "IoT based Automated Solar Tracking System Using Machine Learning Algorithm", 2020.
[8] Y. S. Zhang, K. S. Low, and T. R. Tan, "An IoT-based Solar Tracker System for Enhancing Solar Energy Harvesting", 2018.
[9] D. C. Desai and R. N. Naik, "IoT-based Solar Tracking System using Node MCU", 2020.
[10] G. Sharma and M. Das, "IoT-based Sun Tracking System for Enhanced Solar Energy Harvesting", 2019.
[11] S. K. Singh, A. K. Singh, and S. K. Singh, "Internet of Things (IoT) based Smart Solar Tracker for Optimal Sunlight Tracking and Energy Harvesting," 2021.
[12] V. R. Patel, H. M. Patel, and R. B. Jadeja, "IoT based Solar Panel Sun-Tracking System using Light Dependent Resistor," 2020