IOT Based Renewable Energy by Solar Tracking System

Christy Mathew[1], I. Jeya Kumar[2], Dr. M. Babu[3]

[1]*PG Student, Department of Mechanical Engineering, Mahendra Engineering College (Autonomous), Namakkal, Tamilnadu, India-637503*

[2]*Assistant Professor, Department of Mechanical Engineering (Autonomous), Namakkal, Tamilnadu, India-637503*

[3]*Associate Professor, Department of Mechanical Engineering, Mahendra Engineering College (Autonomous), Namakkal, Tamilnadu, India-637503*

Abstract - ***The study introduces a groundbreaking strategy to boost the effectiveness of solar power plants by integrating a horizontal, single-axis solar tracking system, marking a significant advancement in renewable energy. This innovative approach employs IoT technology to meticulously monitor critical parameters like voltage, wattage, current, and solar irradiance. It incorporates a light-dependent resistor (LDR) to precisely detect peak solar power levels. Data from a network of sensors and an ESP32 controller are systematically processed and transmitted to cloud-based platforms for thorough analysis. The ESP32 controller plays a vital role by managing solar panel positioning via a servo motor, utilizing advanced algorithms to optimize energy capture. This dynamic system adjusts panel orientation to match changing solar conditions, ensuring maximum efficiency throughout the day. Moreover, it detects anomalies, such as panel malfunctions or contamination, early, enhancing operational reliability. Overall, this integrated solution marks a new era in solar power generation, promising sustained enhancements in economic viability and operational efficiency. By seamlessly integrating advanced monitoring and control mechanisms, it sets a benchmark for future advancements in renewable energy infrastructure.***

***Index Terms* - ESP32, LDR, Servo Motor, Blynk IoT**

I. INTRODUCTION

Solar power generation has become increasingly important in meeting the world's energy needs due to its renewable nature and environmental benefits. However, optimizing the performance of solar power plants is essential to maximizing energy output and economic viability. Traditional fixed solar panels are limited in their efficiency due to their inability to adapt to changing sunlight angles throughout the day.

This study suggests a solution to tackle this problem by proposing the integration of Internet of Things (IoT) technology with a horizontal single-axis solar tracking system. By utilizing IoT sensors to measure crucial parameters such as voltage, wattage, current, and solar irradiance, along with a Light Dependent Resistor (LDR) to detect maximum solar power, this system aims to dynamically adjust panel orientation for optimal energy capture.

Central to the proposed system is the ESP32 controller, which processes sensor data and autonomously adjusts the panel orientation using a servo motor based on predefined algorithms. This real-time adjustment capability enables the system to continuously optimize solar energy capture throughout the day, enhancing overall plant performance.

Moreover, by leveraging IoT connectivity, the system facilitates remote monitoring and management of solar power plants from any location via the cloud. This enables operators to identify and address performance issues such as faulty panels or surface contamination, thereby ensuring sustained efficiency and economic output.

In this context, the integration of IoT technology with solar tracking systems represents a significant advancement in renewable energy infrastructure, offering automated monitoring, optimization, and maintenance capabilities essential for the sustainable development of solar energy resources. This paper presents a detailed analysis and implementation strategy for the proposed system, highlighting its potential to revolutionize solar power plant operations and enhance the global transition towards clean energy solutions.

A. Objectives

- To implementation of a horizontal solar tracking single-axis system which maximize energy capture.

- To integration of IoT technology to measure key parameters like voltage, wattage, current, and solar irradiance.
- It enabled remote monitoring and management through cloud connectivity for timely interventions and maintenance.
- To automation of panel orientation adjustments using algorithms which analyze sensor data and control a servo motor.
- To Identification and resolution of performance find issues like faulty panels or surface contamination.
- To minimizing maintenance or performance issues.

II. RELATED WORK

Rad et al., (2020) The study explores tracking solar systems in Iran, focusing on integrating them into residential solar installations. The research emphasizes the need for renewable energy sources, particularly solar energy, to address energy demands and environmental degradation. Five different tracking systems were evaluated across eight regions, considering environmental, technical, and economic factors. The most suitable system was identified based on energy cost, reliability, and emission rates. The study highlights the importance of selecting the optimal solar tracking system to enhance power production efficiency while balancing costs.

Jamroen et al., (2020) The research project in Rayong Province, Thailand, pioneered an affordable, automated dual-axis solar tracking system, boosting solar energy production. The system, incorporating Light Dependent Resistor (LDR) sensors, increased energy efficiency by 44.89%. The system required an additional $92 investment for added components but could be recouped within 1130–754 days. Future research aims to optimize tracking components and explore larger-scale PV systems for institutional and commercial use.

Manoharan et al., (2020) The work focuses on power reduction in practical photovoltaic systems, addressing issues such as temperature and irradiance changes, high computation loads from MPPT mechanisms, and increasing PV array output during weather changes. The MPPT approach, which is often used, is improved to avoid drift effects and reduce computational expenses. However, solar PV firms are not yet prepared to use these techniques due to the difficulty of creating controller boards. The work validates the benefits of the proposed methods through mathematical analysis and simulations, demonstrating their efficacy in various operating conditions.

Shang et al., (2020) The groundbreaking study conducted in Rayong Province, Thailand, spearheaded the development of a cost-effective, automated dual-axis solar tracking system, significantly enhancing solar energy generation. It reviews advancements in solar tracking technology, highlighting the evolution of designs and techniques. The analysis acknowledges maintenance requirements due to rotating components and the complexity of design and control mechanisms. The study concludes that dual-axis tracking systems offer superior efficiency but also face maintenance requirements due to their complex design and control mechanisms.

Rokonuzzaman et al., (2023) An inventive internet of things (IoT) integrated maximum power point tracking (MPPT) solar charge controller (SCC) is revolutionizing the management of solar photovoltaic systems. This system addresses the intermittent nature of ambient conditions in solar photovoltaic systems, utilizing IoT-based sensors, a PIC16F877A microcontroller, and a customized buck-boost converter for remote monitoring and control. The SCC's performance is evaluated, achieving an efficiency of 99.74%, highlighting its potential for smart home applications.

Nadia et al., (2020) The research employs the principles of the Adaptive Neural Fuzzy Inference System (ANFIS) to design effective control systems for solar tracking. Its aim is to precisely forecast the movement of the sun through the sky, reducing inaccuracies and optimizing energy generation. The introduced controllers demonstrate impressive accuracy in prediction and minimal error rates, effectively managing both single-axis and dual-axis solar tracking setups. By utilizing five membership functions, ANFIS greatly improves the efficiency of solar energy collection, marking a noteworthy advancement in this technology.

Anshul Awasthi et al., (2020) Solar tracking systems, like those found in grid-tied setups, are both low-maintenance and affordable, making them accessible for many. They operate by storing energy in a battery bank during daylight hours. Dual-axis solar tracking systems are particularly efficient, surpassing both fixed-axis and single-axis systems. They achieve this through the use of shape memory alloys or compressed gas fluid actuators, enabling precise adjustment to maximize exposure to sunlight. With the ability to move independently along both horizontal and vertical axes, these systems offer superior performance. They play a vital role in pinpointing optimal locations and orientations, accurately determining a point's position on the Earth's surface.

Abdul Rahim Pazikadin et al., (2020) Solar grid integration is gaining interest due to its potential to improve power output and economic aspects. Reliable forecasting is crucial for optimal grid control and solar plant design Artificial neural networks (ANN) are gaining traction in the realm of forecasting solar power output, especially when integrated into hybrid systems, which enhance the accuracy of predictions. The rising penetration of solar PV power generation calls for an enhanced forecasting approach. Solar irradiance, a constant at the top of the atmosphere, is absorbed and deflected across Earth's diffuse overhead radiation levels (DHI).

Stefenon et al., (2020) The Neuro-Fuzzy Inference System, incorporating the Wavelet Neuro-Fuzzy algorithm, has been developed to improve solar prediction accuracy. This hybrid model, which considers solar trackers, enhances PV panel efficiency and predicts solar tracking at specific times. The WNF model surpasses the LSTM model in accuracy and performance, boasting reduced computational expenses and quicker convergence. The wavelet transform technique also shows promise when paired with the Neuro-Fuzzy algorithm, outperforming well-established algorithms like LSTM and Nonlinear Auto Regressive.

Hakan Acikgoz et al., (2022) The CWT, a cascading convolutional neural network architecture, was created to extract unique hidden characteristics from solar radiation. The subset characteristic vector is created by concatenating high-performance characteristics, offering precision for forecasting. The fully-trained ELM approach assesses the forecast performance using the chosen characteristics. The CWT uses integrated algorithms for forecasting and feature selection, utilizing the Relief method to identify the most beneficial subset of features. This approach increases the accuracy of solar radiation forecasts by handling chosen characteristics and transforming inputs into equivalent images with time, scale, and amplitude.

III. PROPOSED METHODOLOGY

The proposed method for the renewable energy by solar tracking system integrates various components to optimize solar energy harvesting. The system's foundation lies in employing an ESP32 microcontroller to streamline the transmission of sensor data to the cloud while managing motor drivers. Key components include voltage and current sensors, as well as three Light Dependent Resistors (LDR) sensors strategically positioned to detect the maximum sunlight intensity.

The ESP32 serves as the core unit, gathering information from various sensors and sending it to the cloud for in-depth analysis and monitoring. This constant flow of data allows the system to adaptively align the solar panel to capture the most sunlight efficiently. Through continuous monitoring of the sun's movement, the solar panel can ensure peak energy production from dawn till dusk. Furthermore, the system incorporates Blynk, a user-friendly mobile application, to display essential information such as voltage, current, and wattage values in real-time. This interface enables users to remotely monitor the efficiency of the solar tracking system and make well-informed choices regarding energy consumption.

A servo motor is utilized to precisely position the solar panel based on sensor data, with control managed by the ESP32. This mechanism optimizes the alignment of the panel to harness the utmost sunlight, boosting energy efficiency. The proposed method integrates ESP32-based data acquisition, cloud connectivity, sensor technology, and servo motor control to create an efficient solar tracking system. By harnessing renewable energy through intelligent solar tracking, the system aims to optimize energy generation and contribute to sustainable practices.

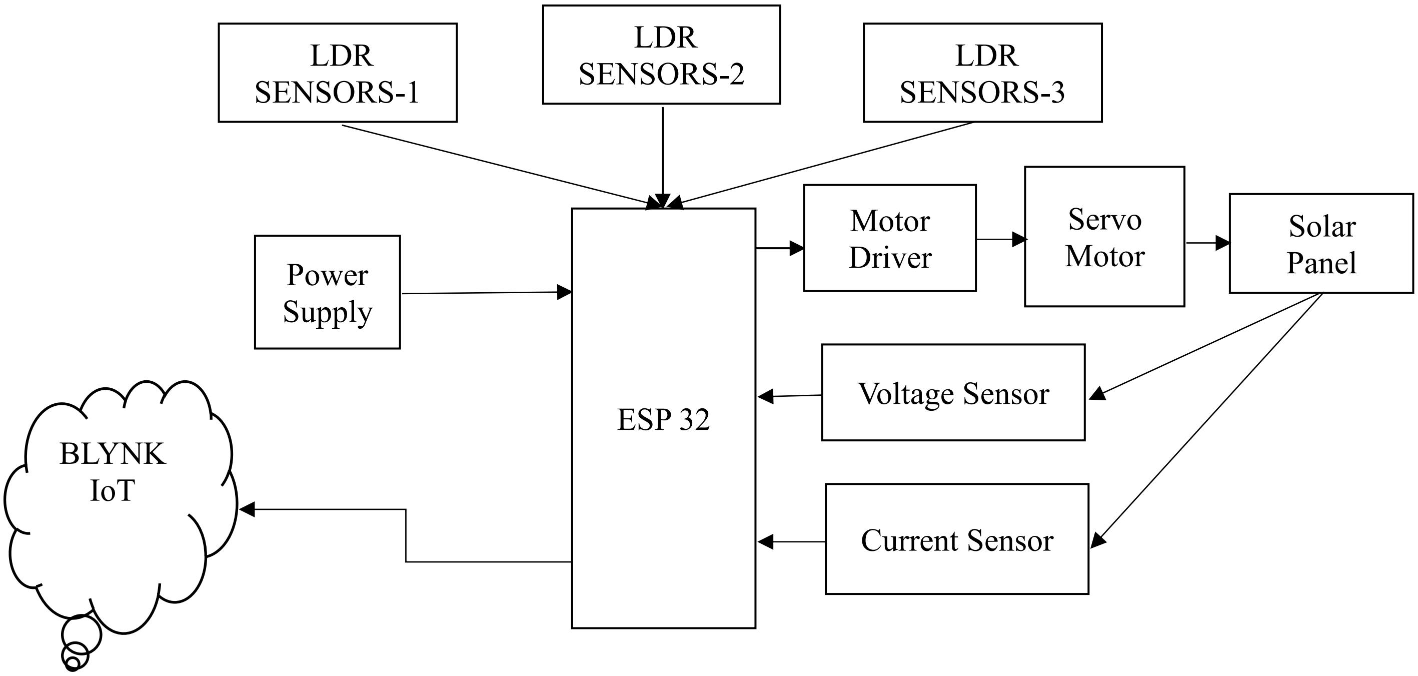

Fig. 1. Block Diagram of Solar Tracking

A. Hardware Description

Power supply

A power supply is an electrical device crafted to furnish electricity to an electrical load. Its main purpose is to transform electrical current from a source into the suitable voltage, current, and frequency needed to energize the load. Hence, power supplies are occasionally referred to as electric power converters.

ESP32 Controller

The ESP32 is a popular SoC microcontroller for IoT devices, offering a wide range of features including integrated crystal, module interfaces, integrated SPI flash, ROM, SRAM, and integrated connectivity protocols like WiFi, Bluetooth, and BLE. Its popularity can be attributed to its ability to interface with various sensors, perform basic processing, store data, and transmit data. ESP32's 520 KB SRAM allows for large data array processing, and its integrated WiFi and Bluetooth stacks make it a game-changer for cloud communication. It also supports BLE and LTE modules, making it a valuable tool for IoT device development.

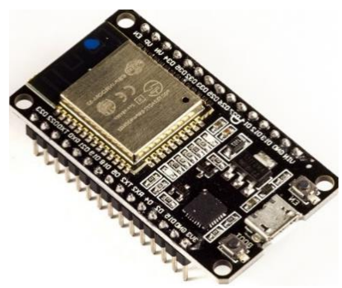

Fig. 2. ESP32 Controller

Current Sensor

Allegro Microsystems' ACS712 is a Hall-effect-based current sensor used in electronic projects and industrial applications. It measures current intensity and generates voltage across a conductor when exposed to a magnetic field. Available in unidirectional and bidirectional versions, it minimizes noise and offset for accurate measurements. The sensor operates across a wide voltage range, ensuring compatibility with power supply configurations. Integrating into IoT-based smart energy meters allows continuous monitoring of energy consumption, facilitating informed decisions to optimize energy distribution.

Fig. 3. Current Sensor

Voltage Sensor

The voltage sensor module, a crucial component in IoT-based smart energy meters, reduces input voltage to a level compatible with microcontrollers. Its resistive voltage divider design allows for accurate measurement of voltages beyond the microcontroller's native sensing capabilities. The module's user-friendly features, such as screw terminals, simplify wire connections, making it an indispensable component for precise voltage monitoring and control.

Fig. 4. Voltage Sensor

Servo Motor

A servo motor is an electric motor designed for precise management of angular or linear position, speed, and torque. It comprises a motor paired with a position feedback sensor and a controller. This controller ensures the motor moves accurately to meet a desired set point.

Fig. 5. Servo Motor

LDR Sensor

An LDR, or light-dependent resistor, is a crucial electronic component designed to adjust its resistance based on the intensity of light it receives. This dynamic response allows it to operate across a wide range of light conditions, making it valuable in various applications. Resistance values can vary significantly, with some being several mega ohms in darkness and others dropping to hundred ohms in bright light. LDR sensitivity also changes with the incident light's wavelength.

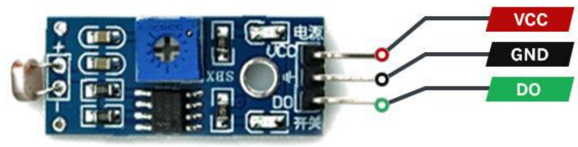

Fig. 6. LDR Sensor Pin Configuration

Solar Panel

Solar panels utilize the photovoltaic effect to convert sunlight into electricity. These devices, made of semiconductor materials like silicon, harness photons from sunlight, causing electrons to flow in specific directions. Solar panels play a pivotal role in renewable energy by transforming direct current (DC) into alternating current (AC) through an inverter.

Fig. 7. Solar Panel

Motor Driver

Fig. 8. Motor Driver

This expansion board, built around the L298N dual H-bridge, is perfect for Arduino and similar microcontroller projects. It empowers you to effortlessly manage the speed and direction of two DC motors, or efficiently control a single bipolar stepper motor.

B. Software Requirements

ARDUINO IDE

The Arduino IDE, short for Integrated Development Environment, serves as a flexible text editor similar to a digital notepad. Its primary functions include coding, uploading code to Arduino boards, and compiling code for error-checking purposes. Furthermore, it boasts cross-platform compatibility, seamlessly running on major operating systems such as Windows, Linux, and macOS.

BLYNK IOT

Blynk offers a comprehensive software solution tailored for the seamless prototyping, deployment, and oversight of connected devices. It empowers users to link hardware to the cloud, develop applications, analyze data, remotely manage devices, and receive real-time notifications. Central to its functionality are Blynk. Console and Blynk. Apps, pivotal tools for administering connected devices, facilitating remote monitoring, and managing controls. Blynk. Apps presents intuitive native mobile applications for both iOS and Android platforms, empowering users to remotely monitor and manage their devices. Conversely, Blynk. Console delivers a customizable, white-label solution ideal for businesses seeking branded management options. Furthermore, its micro-service streamlines device ownership processes, facilitates Wi-Fi credential provisioning, and manages authentication tokens for enhanced security.

IV. RESULT AND DISCUSSION

The prototype depicted in the figure introduces a novel method for boosting the efficiency of solar power plants through its solar tracking system. Utilizing IoT technology and a horizontal, single-axis tracking mechanism, it continuously monitors essential parameters to optimize energy capture. Powered by an ESP32 controller, the system dynamically adjusts solar panel orientation to match sunlight angles, ensuring peak performance and early anomaly detection for enhanced reliability. With its advanced monitoring and control features, this prototype sets a new benchmark for renewable energy infrastructure, promising improved economic viability and operational efficiency.

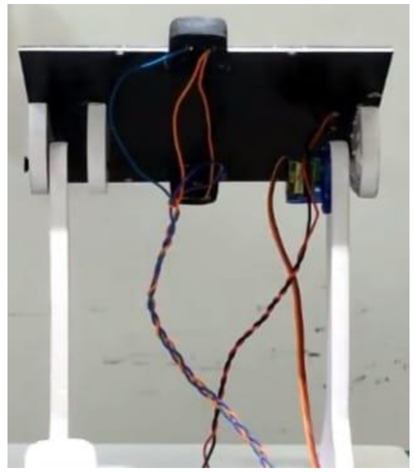

Fig. 9. Solar Tracking Prototype

Moreover, its Internet of Things (IoT) capability allows for remote administration and live tracking, fostering the acceptance of eco-friendly energy solutions and propelling us toward a more sustainable tomorrow.

Fig. 10. Displaying Voltage and Current Output

The figure shows the voltage and current outputs in a mobile app using the Blynk platform, showcasing real-time monitoring and control for enhancing solar power plant efficiency. It integrates a single-axis solar tracking system with IoT technology, enabling continuous parameter monitoring and energy optimization.

V. CONCLUSION

In conclusion, the proposed solar tracking system leveraging ESP32 technology offers a comprehensive solution for maximizing renewable energy generation. The system efficiently combines sensor data gathering, cloud connectivity, and servo motor management to enhance the alignment of solar panels, ensuring they capture the highest possible sunlight exposure throughout the day. Real-time monitoring through the Blynk interface empowers users to track energy production and make informed decisions, promoting sustainable energy practices. With its potential to enhance energy efficiency and reduce reliance on traditional power sources, this innovative system represents a promising step towards a more sustainable future powered by renewable energy.

REFERENCES

[1] Rad, Mohammad Amin Vaziri, Ashkan Toopshekan, Parisa Rahdan, Alibakhsh Kasaeian, and Omid Mahian. "A comprehensive study of techno-economic and environmental features of different solar tracking systems for residential photovoltaic installations." Renewable and Sustainable Energy Reviews 129, pp. 109923, 2020.

[2] Jamroen, Chaowanan, Preecha Komkum, Sompol Kohsri, Wuttinan Himananto, Siriwat Panupintu, and Sorawit Unkat. "A low-cost dual-axis solar tracking system based on digital logic design: Design and implementation." Sustainable Energy Technologies and Assessments 37, pp. 100618, 2020.

[3] Manoharan, Premkumar; Subramaniam, Umashankar; Babu, Thanikanti Sudhakar; Padmanaban, Sanjeevikumar; Holm-Nielsen, Jens Bo; Mitolo, Massimo; Ravichandran, Sowmya, “Improved Perturb & Observation Maximum Power Point Tracking Technique for Solar Photovoltaic Power Generation Systems”, IEEE Systems Journal, pp. 1–13, 2020.

[4] Shang, Huilin, and Wei Shen. "Design and Implementation of a Dual-Axis Solar Tracking System." Energies 16, no. 17, pp. 6330, 2023.

[5] Rokonuzzaman, Md, Mohammad Shakeri, Fazrena Azlee Hamid, Mahmuda Khatun Mishu, Jagadeesh Pasupuleti, Kazi Sajedur Rahman, Sieh Kiong Tiong, and Nowshad Amin. "Iot-enabled high efficiency smart solar charge controller with maximum power point tracking—Design, hardware implementation and performance testing." Electronics 9, no. 8, pp.1267, 2020.

[6] Nadia, AL-Rousan, Nor Ashidi Mat Isa, and Mohd Khairunaz Mat Desa. "Efficient single and dual axis solar tracking system controllers based on adaptive neural fuzzy inference system." Journal of King Saud University-Engineering Sciences 32, no. 7 , pp. 459-469, 2020.

[7] Anshul Awasthi, Akash Kumar Shukla, Murali Manohar S.R., Chandrakant Dondariya, K.N. Shukla, Deepak Porwal, Geetam Richhariya, “Review on sun tracking technology in solar PV system”, Energy Reports, pp. 392-405, vol. 6, 2020.

[8] Abdul Rahim Pazikadin, Damhuji Rifai, Kharudin Ali, Muhammad Zeesan Malik, Ahmed N. Abdalla, Moneer A. Faraj, “Solar irradiance measurement instrumentation and power solar generation forecasting based on Artificial Neural Networks (ANN): A review of five years research trend”, Science of The Total Environment, ISSN 0048-9697, Vol. 715, 2020.

[9] Stefenon, StÃ©fano Frizzo; Kasburg, Christopher; Freire, Roberto Zanetti; Silva Ferreira, Fernanda Cristina; Bertol, Douglas Wildgrube; Nied, Ademir, “Photovoltaic power forecasting using wavelet Neuro-Fuzzy for active solar trackers”, Journal of Intelligent and Fuzzy Systems, pp. 1–14, 2020.

[10] Hakan Acikgoz,"A novel approach based on integration of convolutional neural networks and deep feature selection for short-term solar radiation forecasting", Applied Energy, Vol. 305, 2022.