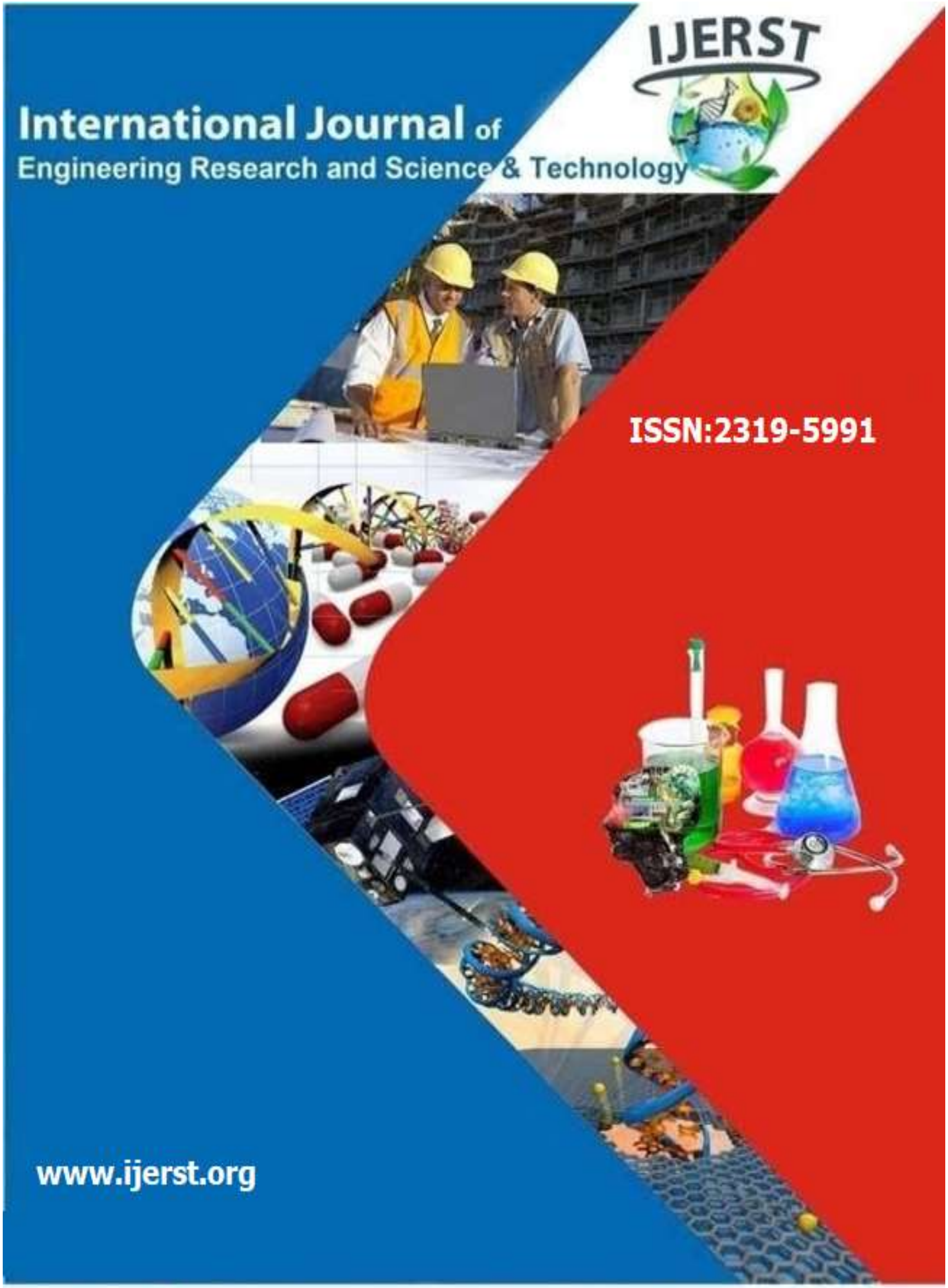

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ENHANCING SOLAR ENERGY EFFICIENCY WITH IOT-INTEGRATED SOLAR TRACKING SYSTEMS

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Abstract:- Solar energy is typically the natural source used to produce electricity. This proposal introduces a revolutionary technology called "Solar Tracking Integrated with IoT," which intends to efficiently orient solar panels to follow the course of the sun in order to maximise electricity generation. This integrated system combines precise tracking mechanisms with Internet of Things technology to provide real-time monitoring and control via smartphones. This initiative offers a major step towards achieving solar energy's full potential for a more sustainable future. The previous research works emphasises the value of solar energy, as well as the drawbacks of stationary solar panels. Solar tracking provides an answer to the problem of traditional solar systems not being able to adjust to the sun's shifting location, especially when combined with Internet of Things technologies. The primary objectives of the database collection phase were to organise data, add timestamps for a chronological record, and implement data validation rules to improve data accuracy. These actions allowed for the analysis of the solar output data from the Solar Tracking System Integrated with IoT project and revealed insightful information. The output power varies between 0.97W and 1.81W, with the maximum power being measured at 1:00 pm. Interestingly, after 4:00 pm, all indicators show a discernible decline, indicating a reduction in sunlight

1. INTRODUCTION

1.1 GENERAL

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

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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.

2. LITERATURE SURVEY

1. Author: S. A. Kalogirou
Year: 2013
Title: Solar Energy Engineering: Processes and Systems
Working Methodology:
This work presents a comprehensive study of solar energy systems including fixed and tracking systems. It discusses single-axis and dual-axis trackers, comparing their energy output to static systems. Though not an IoT-focused study, Kalogirou's textbook is foundational. It demonstrated that dual-axis trackers can capture up to 40% more solar energy compared to static panels. This research justifies the need for tracking systems and has influenced the adoption of smart, IoT-based tracking mechanisms in later works.

2.Authors: P. Patel and S. Shah
Year: 2017
Title: IoT Based Dual Axis Solar Tracker
Working Methodology:
The authors used Arduino Uno, four LDR sensors, and servo motors for panel movement. They integrated IoT using the Blynk platform via a Wi-Fi module (ESP8266) to transmit real-time data such as light intensity and panel angles to a mobile app. The tracker adjusts the panel's tilt and azimuth based on sunlight intensity detected by LDRs. The IoT integration allowed real-time monitoring and control via smartphones. Their system improved panel efficiency by approximately 25–30% and introduced user-friendly monitoring for small-scale solar systems.

3.Authors: S. M. Mousavi G and M. Tarokh
Year: 2018
Title: An Intelligent IoT-Based Solar Tracking System Using Cloud Storage and Prediction
Working Methodology:
This system used Raspberry Pi and cloud-based architecture (Google Firebase). Instead of LDRs, a solar position algorithm (SPA) calculated the sun's position based on time, location, and date, enhancing

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precision. The SPA provided better tracking accuracy, especially in cloudy or diffused light conditions. IoT integration enabled historical data logging and visualization on cloud dashboards. Users could analyse trends and schedule predictive maintenance. Efficiency improved by 33%, and the system was more robust than sensor-only trackers.

4.Authors: A. S. Raut and M. G. Shinde

Year: 2019

Title: IoT Based Solar Tracking System Using NodeMCU

Working Methodology:

Used NodeMCU (ESP8266) microcontroller, LDRs, and ThingSpeak for cloud integration. This was a single-axis tracker, which is simpler but effective.Aimed at cost-effectiveness, the system was ideal for rural or residential solar users. The tracking angle was controlled via LDR output differences, and real-time panel data (voltage, angle, light intensity) was uploaded to the Thing Speak platform. Energy efficiency increased by around 20%, and the system was lightweight and easy to replicate.

5.Authors: M. Kumar and A. Jain

Year: 2020

Title: Mobile Controlled Dual Axis Solar Tracker Using IoT

Working Methodology:

The system used an ESP32 microcontroller, a dual-axis movement mechanism, and a custom mobile application for manual and automatic control. Real-time alerts were provided for system errors or deviations. The mobile interface allowed users to override automatic settings, making the system highly flexible. Users could rotate the panel remotely in case of sensor failure or for maintenance. Integration with a solar charge controller allowed performance optimization. The tracker enhanced output by 35%, especially under fluctuating sunlight conditions.

3. BLOCK DIAGRAM

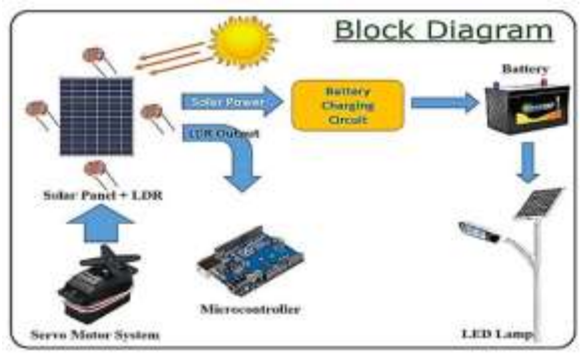

FIG: 1 Block diagram

3.1. HARDWARE COMPONENTS

- Regulated power supply.
- Micro controller.
- Solar panel and battery

3.2. SOFTWARE REQUIREMENTS:

- Embedded C

4. IMPLEMENTATION

The power supply section consists of a step-down transformer (TR1), which reduces the AC mains voltage to a safer level suitable for DC conversion. This is followed by a bridge rectifier (BR1) that converts AC to pulsating DC, and two filter capacitors (C1 and C2) that smooth out voltage fluctuations. A 7805 voltage regulator (U2) ensures a constant 5V output, which is used to power the Raspberry Pi Pico W and other components. A red LED (D1) and resistor (R1) are included to indicate power status.

The central control unit in the system is the Raspberry Pi Pico W (U4), a powerful

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microcontroller with built-in Wi-Fi capabilities. It acts as the brain of the system, receiving data from various sensors and making real-time decisions. The Pico is connected to several peripheral devices through its GPIO pins. These include an LDR (Light Dependent Resistor) for detecting sunlight intensity, a DHT11 sensor for measuring temperature and humidity, and voltage and current sensors for monitoring the solar panel's electrical output. The data from these sensors is used to adjust the orientation of the solar panel and monitor system performance.

5. CIRCUIT DIAGRAM

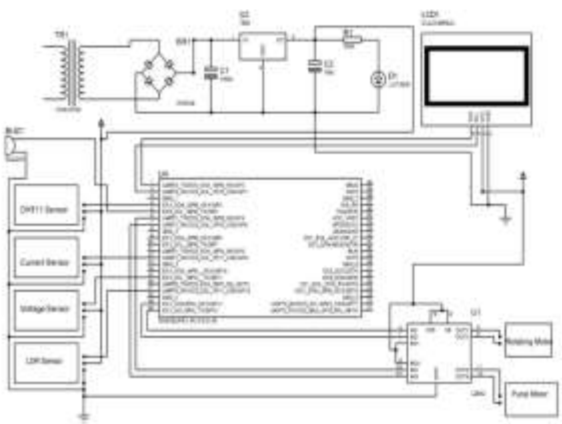

Fig circuit diagram

6. RESULT

This project is well prepared and acting accordingly as per the initia specifications and requirements of our project. Because of the creative nature and design the id of applying this project is very new, the opportunities for this project are immense. The practical representation of an experimental board is shown below:

Fig:3. Project Model

6. CONCLUSION

The proposed IoT-integrated solar tracking system, utilizing the ESP32 microcontroller, represents a significant advancement in the field of renewable energy optimization. By intelligently combining environmental sensing, real-time data analytics, automated motor control, and cloud-based monitoring, the system is designed to ensure that solar panels maintain optimal orientation toward the sun throughout the day. This dynamic alignment leads to a marked improvement in solar energy capture when compared to traditional fixed-panel systems. The integration of sensors such as LDRs for sunlight detection, DHT11 for environmental monitoring, and voltage/current sensors for power analysis enables the system to adapt to changing weather and light conditions with precision.

The inclusion of cloud connectivity through platforms like Thing Speak or

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Blynk provides users with powerful tools for remote monitoring, control, and data visualization. Real-time feedback and historical data trends empower users to evaluate system performance, detect anomalies, and make informed decisions to improve energy output and system maintenance. Additionally, the modular design of the system makes it highly scalable and adaptable for both residential and commercial solar installations.

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