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IoT Driven Solar Panel Monitoring and Fault Detection System for Enhanced Operation Efficiency

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Abstract: In modern solar power systems, efficient power generation is essential to meet growing energy demands. However, issues such as faulty panels, poor electrical connections, and dust accumulation can reduce output, often going undetected without frequent manual inspections, affecting uninterrupted power generation. Manual monitoring methods are time-consuming, reliant on human intervention, and lack real-time data, limiting their effectiveness in ensuring optimal performance. To address these challenges, we propose an innovative IoT-based solar panel fault detection system that continuously measures essential parameters such as voltage, current, and sunlight intensity using advanced sensors integrated across solar panels, combined with an alert mechanism. The system utilizes voltage, current, and light-dependent resistor (LDR) sensors to monitor key panel parameters in real-time. This data is transmitted to a cloud platform for storage and analysis, while a GSM module provides SMS alerts to users upon detecting abnormal readings like reduced voltage, current fluctuations, or low light intensity. Users can access this data through a mobile app, enabling remote tracking of energy generation, promoting proactive maintenance, enhancing efficiency, and contributing to a sustainable energy future. By automating fault detection, the system ensures early identification of issues, minimizing downtime and optimizing energy output. Consequently, it leads to better panel usage, consistent power generation, and a greater return on investment for users, making solar energy a more viable and sustainable power generation.

Keywords: Solar Panel, Solar Energy, Photovoltaic Monitoring, Light intensity, Internet Of Things, Fault detection, Data Analytics, Remote Monitoring, Solar efficiency.

I. INTRODUCTION

The global shift toward renewable energy has increased the adoption of solar power as a clean, sustainable, and efficient energy source. According to recent estimates, the world's annual consumption of solar energy has reached about 1,033 terawatt-hours (TWh), or almost 3.6% of the world's total electricity generation. This amount is expected to continue growing quickly as solar technology becomes more widely available and effective. Though solar energy is renewable, its generation can be inconsistent and fault-prone due to factors like weather variability, equipment degradation, and system inefficiencies. To maximize the effectiveness of solar installations, continuous monitoring and analysis are essential for understanding energy production, identifying performance issues, and improving efficiency. In order to ensure improved solar power plant reliability and consistent, high-quality power generation, we introduce a comprehensive solution, a real time solar panel monitoring system which continuously monitors the necessary parameters of the panel and determine its performance and transmits the data to the user's mobile phone with a graphical user interface combined with an alert mechanism integrated within the system. This system enables continuous tracking of solar panel performance metrics, prompt identification of any operational issues, and facilitates proactive maintenance to minimize downtime and optimize energy output. The mobile application serves as an accessible platform for users to remotely monitor data, analyse trends and also make data-driven decisions to enhance overall plant efficiency and reliability. The system leverages Internet of Things (IoT) technology to collect and transmit data on key metrics, such as energy output, environmental conditions, and system health. This data is then processed and displayed on a mobile app, providing users with accessible insights into their solar system's performance, efficiency, and potential areas for optimization. By enabling users to track their energy generation remotely, the application promotes proactive maintenance, enhances overall system efficiency, and contributes to a more sustainable energy future This solar monitoring system empowers users with real-time insights and remote access, enabling proactive management of solar installations. By combining IoT and data analytics, it helps maximize energy output, reduce maintenance costs, and enhance system reliability supporting a more efficient and sustainable energy future.

II. EXISTING SYSTEM

The current approach to solar power monitoring predominantly involves manual inspections and basic monitoring techniques, which present several limitations in effectively managing solar energy systems. Operators often conduct periodic visual checks to assess the performance of the solar panel, looking for signs of dirt accumulation, shading, or physical damage. While these inspections able to identify obvious issues, they are inherently time-consuming and may not capture less visible problems, such as internal panel defects or connection failures. In addition to visual assessments, basic monitoring typically employs handheld multi-meters to measure key parameters like voltage and current. However, this method is reactive rather than proactive, as it only provides samples of performance at specific moments. As a result, operators may miss fluctuations in energy generation that occur between checks, leading to inefficiencies and potentially prolonged downtimes.

Moreover, traditional systems often lack real-time data monitoring capabilities and do not facilitate remote access to performance metrics. This means that operators cannot track solar panel performance from a distance, nor can they receive immediate alerts regarding potential faults. As a result, issues such as reduced voltage output, current fluctuations, or insufficient sunlight exposure due to environmental factors may go unnoticed for extended periods. This delay in detection can significantly impact the overall efficiency of solar power generation, leading to lower energy output, increased maintenance costs, and a diminished return on investment. Furthermore, existing solar power monitoring systems typically lack automated fault detection capabilities, which can lead to delays in identifying critical issues such as reduced voltage output or connection failures. Without real-time monitoring, operators may not become aware of these problems until they have already caused significant disruptions in energy production. While these systems can provide fundamental insights into operational performance, they do not utilize advanced data analytics or smart technologies, which are essential for optimizing energy generation and enhancing system reliability. The absence of these innovative features means that operators must rely on manual assessments and periodic checks, resulting in inefficiencies and a heightened risk of prolonged downtimes. Consequently, the overall effectiveness of solar power installations is compromised, limiting their potential to deliver consistent and reliable energy output.

The limitations of existing solar power monitoring systems extend beyond their manual nature and lack of automation. Many of these systems do not provide comprehensive data visualization tools, making it challenging for operators to interpret performance trends and anomalies effectively. This lack of intuitive interfaces can hinder timely decision-making, as users may struggle to identify critical insights at a glance. Additionally, compatibility issues with various solar panel technologies and equipment often result in fragmented monitoring solutions, where different components cannot communicate seamlessly with one another. This fragmentation can lead to inconsistent data reporting and an incomplete picture of system performance. Without this capability, operators may face unexpected downtimes and increased operational costs, as they are unable to priorly address issues before they escalate.Moreover, traditional systems often lack predictive maintenance features, limiting their ability to forecast potential failures based on historical data. The absence of real-time fault diagnosis can prolong troubleshooting efforts, leading to prolonged energy losses and reduced overall efficiency. Overall, these limitations emphasize the need for a more integrated and user-friendly approach to solar power monitoring that leverages modern technology to enhance operational efficiency and reliability

III. DISADVANTAGES OF THE EXISTING SYSTEM

Real-time data collecting, automated fault identification, and predictive maintenance are features that are currently absent from solar panel monitoring systems. These restrictions lead to longer downtimes, less energy efficiency, and delayed problem responses. The lack of remote access and comprehensive analytics makes it even more difficult for operators to efficiently maintain installations and maximize performance. Lack of Rapid decision making, smooth monitoring with timely insights, insufficient data visualization tools and compatibility problems which leads to proactive problems and causes operational inefficiencies in the solar installations, minimizing energy generation and prolonged fault condition. Furthermore, manual inspections which are laborious and ineffective are a major component of older system's detection of external elements like dust and shade. In the absence of predictive insights, malfunctions worsen, increasing repair expenses and reducing equipment longevity. The above mentioned problems leads to the necessity of an integrated solution that lowers operational inefficiencies, improves data insights, and automates monitoring.

IV. PROPOSED SYSTEM

To overcome this crisis and also in response to the growing need for innovative photovoltaic energy solutions, we propose an automated solution which embedded with advanced sensors to facilitate real-time monitoring of solar panel performance. This innovative system continuously measures critical parameters, including voltage, current, and sunlight intensity, allowing for comprehensive assessment of solar panel health and productivity.

The integration of these advanced sensors ensures accurate data collection, providing insights into the operational status of the solar panels. For instance, consistent voltage levels indicate effective power generation, while sudden drops in voltage may signal potential issues, such as faulty panels, poor connections, or obstructions from dust or shading. Similarly, current levels directly correlate with sunlight intensity, with higher readings indicating optimal sunlight exposure, while lower current values may suggest reduced light levels or defects in the solar cells.

The system utilizes three sensors - a voltage sensor, a current sensor, and light dependent resistor to monitor key panel parameters in real-time. Additionally, by facilitating early fault identification and reducing the reliance on manual inspections, the system significantly lowers maintenance costs and enhances the overall reliability of solar installations. The fault detection feature of the proposed solar monitoring system is a critical innovation that significantly enhances the productivity and efficiency of solar panels. By continuously monitoring key parameters such as voltage, current, and sunlight intensity, the system can swiftly identify any anomalies that may indicate underlying issues, such as faulty panels, poor electrical connections, or shading due to dirt and debris. Real-time data is compared to predetermined standards by automated analysis algorithms, which enables the prompt identification of issues such abrupt voltage decreases or current variations. By uploading these data in a cloud platform such as TCP client , the system instantly notifies users when these problems are detected, allowing for prompt intervention. This proactive strategy can maximize energy generation by reducing downtime and guaranteeing that solar panels run at peak efficiency. With the integration of Wi-Fi connectivity, users can access real-time data from anywhere, facilitating remote monitoring that enhances the overall efficiency of solar power systems.

Additionally, the system is equipped with a SIM800L GSM module to provide immediate alerts to users. GSM (Global System for Mobile Communications) is a standard developed to describe protocols digital cellular networks. The SIM800L module allows the system to send SMS notifications directly to users' mobile phones whenever faults, such as voltage drops, current fluctuations, or low sunlight intensity, are detected. This ensures users are promptly informed, enabling quick action even if they are not actively monitoring the system through the cloud. While the Wi-Fi module is responsible for transmitting sensor data to a cloud platform for storage, analysis, and remote access via a mobile app, the GSM module serves as an immediate alert mechanism, ensuring critical issues are communicated instantly through SMS, minimizing response time and reducing potential energy losses.

V. WORKING PRINCIPLE

The system consists of three sensors - a voltage sensor, a current sensor, and light dependent resistor which monitors the solar panel.

1) *Voltage Sensor:* The system employs a voltage sensor to continuously measure the voltage output from the solar panels with a network of resistors, the voltage divider based sensor lowers the high input voltage to a level that a microcontroller can read also providing real-time insights into their power generation capabilities.
2) *ACS712 Current Sensor:* The sensor used for measuring current in this system is a Hall-effect-based sensor commonly used for measuring current in electrical and electronic systems. Hall effect sensors are appropriate for measuring both AC and DC currents because they use a magnetic field produced by the current-carrying conductor to detect the current without making direct contact. It tracks the flow of electricity from the panel.
3) *Light Dependent Resistor (LDR):* Light dependent resistor gauges the amount of sunlight hitting the panels, ensuring comprehensive monitoring of performance metrics at all times. It is a type of resistor that changes its resistance based on the amount of light it is exposed to. In darkness, its resistance is high, while in bright light, the resistance drops significantly. This property makes it useful in systems requiring light sensitivity, such as solar monitoring. In this system, it helps to assess solar panel exposure by measuring ambient light levels, typically providing an output in lux (lx), the unit for illuminance.

When any issues or abnormalities are identified by exceeding thresholds predefined for each parameter based on the system's configuration and load, the system promptly alerts users through a user-friendly graphical interface on a cloud platform, enabling timely intervention with the help of the Wi-Fi module. Each data reading is uploaded to the cloud platform for continuous storage and analysis. If any abnormalities are detected, an alarm is triggered in the system, which generates a visual alert on the platform. This system is also combined with a GSM-based alert mechanism using SMS notifications to immediately inform users about critical faults, such as voltage drops, current fluctuations, or

low sunlight intensity. This dual-notification system cloud platform visualization and GSM SMS alerts ensures that users are promptly informed, regardless of their internet connectivity status, allowing them to take quick corrective action. This proactive approach minimizes downtime and ensures that solar panels operate at optimal performance, ultimately maximizing energy generation.

VI. HARDWARE IMPLEMENTATION

The Real time Solar panel monitoring and fault detection system's operation can be classified in to three parts:

1) Solar Panel monitoring System
2) Fault Detection
3) Data acquistion and transmission System

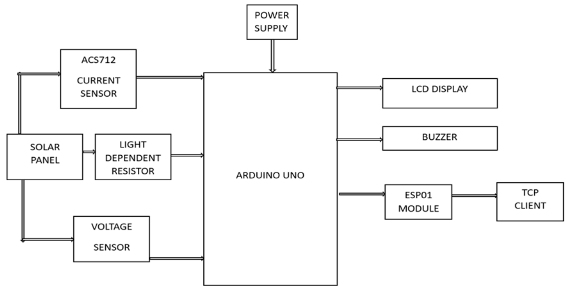

Figure.1 Block Diagram of the Solar panel Fault detection system

A. Solar Panel Monitoring System

Real time solar monitoring and fault detection system is configured by using the above three sensors configured to Arduino UNO microcontroller which measures the crucial panel parameters and detect if any abnormalities gets observed on the key parameters. Parameters to be monitored are listed below:

1) Voltage
2) Current
3) Intensity of the Sunlight

Figure.2 Solar panel's Current, Voltage and Light exposure measurement

The voltage sensor measures the panel's voltage output, the current sensor tracks current flow, and the light dependent resistor (LDR) monitors sunlight exposure. Each of these parameters has specific threshold values based on the system's range, when any parameter exceeds or drops below these thresholds, it indicates potential issues with the solar panel's performance and alerts are displayed on the LCD display as visual feedback, notifying operators of any faults that may require immediate attention.

B. Fault Detection System

1) *Voltage Drop:* Voltage drops in solar panels result from internal resistance and resistance in connecting wires, reducing output voltage. Key faults include damaged panels, poor wiring, and shading or debris blocking sunlight. This system works upon enabling the sensors to measure voltage levels. When voltage levels fall below the expected range, it can indicate hotspots in panels, bypass diode failures, or cracked solar cells. This system enables sensors to measure voltage levels in real-time, with data processed through an Arduino microcontroller to detect deviations from the standard operating range. Early detection of voltage issues helps prevent energy losses and long-term damage to solar panel components.
2) *Current Fluctuation:* Current fluctuations arise from sunlight intensity variations, shading, or temperature changes, causing inconsistent power. Faults include poor connections, solar cell degradation, and intermittent power due to varying load demand. Sudden spikes or drops in current can also signal short circuits, module overheating, or reverse currents affecting efficiency. Sensors continuously monitor current levels, and data is analysed by the microcontroller to detect abnormalities and stabilize output when possible. The system notifies users through cloud alerts and SMS notifications, allowing quick troubleshooting to avoid efficiency loss and potential equipment failures.

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3) *Sunlight Intensity:* Solar intensity impacts power output, with low intensity reducing efficiency. Common faults include panel misalignment, dirt accumulation, and shading from structures or foliage. Long-term reduced sunlight detection may indicate the need for panel cleaning or reorientation. Additionally, irregular patterns in intensity readings can point to environmental issues, such as frequent bird droppings or dust storms in the region. The system employs a Light Dependent Resistor (LDR) to gather solar intensity data, enabling adjustments to ensure panels operate under optimal light conditions. This data allows users to schedule cleaning, repositioning, or trimming of nearby vegetation, ensuring sustained energy production and preventing long-term output degradation.

C. Data Acquistion and Transmission System

This solar panel monitoring system utilizes a TCP client hardcoded to connect directly with Joy S.R.L.'s dedicated server, ensuring seamless and reliable data transfer without the need for dynamic configurations. It incorporates an ESP-01 Wi-Fi module based on the ESP8266 microcontroller, interfacing with Arduino to gather real-time data from sensors measuring current, voltage, and light intensity. These sensors provide performance metrics on the solar panel's status, such as power output, environmental conditions, and potential fault indicators. The ESP-01 features a UART port for serial transmission and GPIO pins for external component interfacing. This connection enables the periodic or event-triggered transmission of performance data, ensuring continuous tracking and reliable monitoring of solar panel performance. Upon power-up, it connects to a predefined Wi-Fi network using authentication credentials, obtaining an IP address via DHCP and establishing a direct TCP connection with Joy S.R.L.'s server. This connection enables the periodic or event-triggered transmission of panel

performance data, ensuring continuous tracking and reliable monitoring of solar panel performance. The received data is processed and visualized on Joy S.R.L.'s server, offering users an accessible interface to monitor solar panel metrics and receive alerts for detected faults or inefficiencies

The system ensures LAN connectivity through Wi-Fi, seamlessly integrating data transmission with panel monitoring to provide real-time outcomes. Detected abnormalities are wirelessly transmitted to users's devices, allowing them to access data through a user-friendly TCP client platform which enables historical data storage and analysis. This robust configuration enhances solar panel management by enabling timely adjustments, improving efficiency, and delivering consistent, real-time insights into system performance. Thus, the system supports seamless integration with existing energy management systems, ensuring compatibility and scalability for diverse applications.

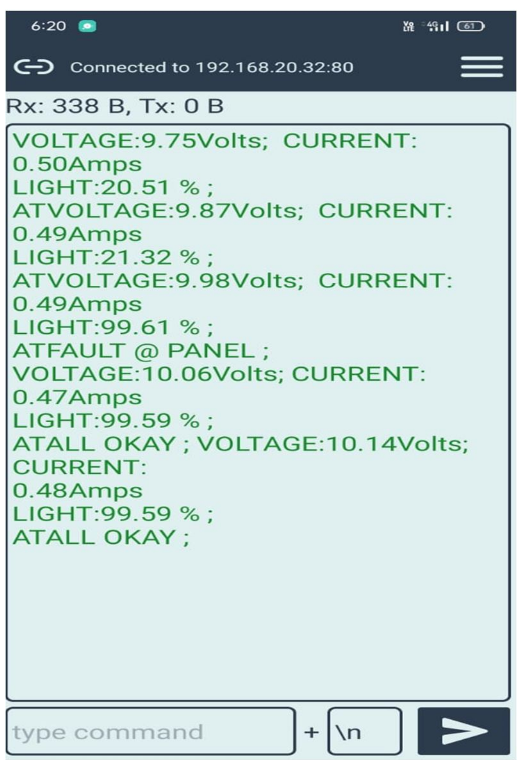

Figure.4 Data transmitted through cloud platform

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Additionally the data acquisted and processed by the microcontroller is fetched by GSM module for remote alert mechanism. The SIM800L GSM module is connected to the Arduino through Software Serial, allowing the Arduino to send commands to the GSM module without interfering with other communication protocols. The TX pin of the GSM module is connected to a digital pin on the Arduino, while the RX pin is connected to another digital pin. When a fault is detected, the Arduino prepares an SMS message containing details like the type of fault, the specific values of parameters, and the recommended action. The Arduino sends commands to the SIM800L module to set it up in text mode which specify the recipient’s phone number and send the SMS content. The SIM800L then uses its cellular network connection to transmit the SMS to the registered mobile number, ensuring users are immediately notified about the fault, allowing for timely intervention and minimizing system downtime. The GSM module establishes a connection with the nearest cell tower using the SIM card, which provides cellular network access. The SMS is delivered directly to the user's mobile device, ensuring fast and reliable communication even in remote areas.

VII. HARDWARE SETUP

The hardware setup for the IoT-based Solar Monitoring and Fault Detection System is centralized around an Arduino microcontroller, which collects, processes, and transmits data from connected sensors to ensure efficient monitoring and fault detection. It includes key sensors include a voltage sensor to measure solar panel output, a current sensor (ACS712) to monitor load variations, and an LDR to track ambient light intensity for evaluating sunlight exposure and Arduino Uno microcontroller read these values through its Analog pins. Actuators and indicators, such as a buzzer and LED indicators, provide immediate alerts for faults or deviations, while an optional LCD display offers on-site visualization of critical parameters. A Wi-Fi module, (ESP8266) enables real-time data transmission to a cloud platform, allowing users to access system performance remotely by UART protocol. This allows the system to transmit data such as voltage, current, and light intensity to a cloud platform in real time. Users can remotely access these parameters via a web application or mobile app, providing flexibility in managing solar energy production. The system’s cloud-based data storage and analysis offer a comprehensive view of long-term performance trends, enabling predictive maintenance and enhancing overall system reliability. The system is powered by a regulated DC supply from the solar panel. By integrating these components, the setup supports continuous monitoring of the solar panel and Proactive fault detection with improved reliability, making it a scalable and practical solution for optimizing solar energy systems. The SIM800L is a quad-band GSM/GPRS module that enables the system to send SMS notifications to users when critical faults are detected. is a standard cellular network technology used for transmitting voice and data over mobile networks. The SIM800L is connected to the Arduino Uno through software serial. It requires a SIM card with an active mobile network to operate. Upon detecting a fault, the Arduino commands the SIM800L module to compose an SMS message containing fault details (e.g., “Voltage Drop Detected” or “Current Fluctuation Identified”) and sends it to the registered user's mobile number. This Hardware setup ensures high reliability by leveraging modern advancements in technology. It offers both on-site visualization and remote monitoring by integrating a local LCD display for on-site visualization, where users can directly view key performance metrics like voltage, current, and light intensity. This enables immediate assessment of the solar panel's status without needing external devices. The system's remote monitoring capabilities through the Wi-Fi module enable users to access real-time performance data from anywhere, enhancing convenience and enabling proactive maintenance. The integration of the GSM module ensures that users receive immediate alerts through SMS for critical faults, reducing response times and preventing potential system failures. This approach of local and remote monitoring provides a comprehensive solution, making the system highly responsive, efficient, and user-friendly. The combination of these features ensures that users can continuously optimize solar panel performance, improve system uptime, and reduce maintenance expenses. By providing real-time insights and prompt fault detection, the system enhances overall energy efficiency and reliability.

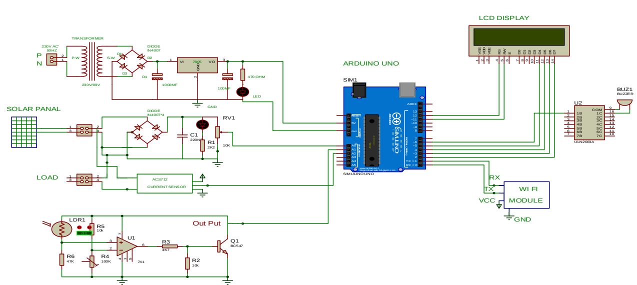


Figure.5 Circuit Diagram of the proposed system

VIII. RESULTS AND DISCUSSION

When the solar panel begins energy generation, the system captures key parameters such as voltage, current, and environmental factors in real time. As sunlight hits the solar panel, it generates a direct current (DC) output, which is measured and monitored by the connected sensors. Once the system's power supply is switched on, the Arduino activates the sensors, initiating the measurement process. These parameters are displayed on the LCD screen at regular sampling intervals, ensuring continuous monitoring of solar panel performance. If any parameter exceeds the predefined threshold programmed in the controller such as abnormal voltage, current, or temperature fluctuations which results in poor sunlight, the system triggers a buzzer alert to notify operators of potential issues. Simultaneously, the IoT module transmits the fault information to the cloud, enabling remote users to receive real-time notifications through the monitoring platform. Faults such as voltage drops, current irregularities, or connection issues can significantly reduce the efficiency of solar panels, leading to energy losses and increased operational costs This system ensures timely intervention to address issues, optimize energy generation, and maintain the reliability and efficiency of the solar panel system.

The operation of the IoT-based solar monitoring and fault detection system is designed to ensure that each solar panel operates at peak efficiency by continuously collecting, processing, and analysing real-time data. It offers numerous benefits, including continuous tracking of solar panel efficiency, early fault detection, and timely maintenance intervention, all of which contribute to sustainable energy management. The system's remote accessibility ensures users can manage solar energy generation efficiently, even in large or geographically dispersed installations. With remote monitoring, solar panel users benefit from timely alerts and maintenance scheduling without frequent on-site checks, reducing both costs and operational downtime. This proactive approach enhances the reliability of the renewable

energy systems, fostering greater adoption and promoting green energy initiatives. Additionally, the system empowers users to actively participate in their energy management decisions, helping optimize resources and support environmental sustainability. By constantly tracking critical parameters such as voltage, current, and environmental conditions, the system provides a comprehensive view of the solar panel's operational health. Any deviation from normal values, such as sudden voltage drops or current fluctuations, is immediately detected and flagged, preventing undetected performance degradation. This level of real-time, automated oversight significantly reduces the reliance on manual inspections and minimizes the risk of unnoticed issues that could compromise energy output. Furthermore, by integrating data-driven insights, the system helps to identify the exact cause of the problem, allowing for more targeted maintenance and faster issue resolution. This capacity for quick response ensures that solar energy generation remains consistent and reliable, even when external factors like weather or environmental changes impact the panel’s performance.

With the integration of cloud-based data storage and analysis, the system not only provides immediate fault detection but also accumulates historical data that can be used for predictive maintenance and long-term performance trends. This historical analysis allows users to better understand their system's behaviour, optimize panel placement, and make more informed decisions about energy consumption and expansion. Additionally, the remote monitoring capability means that users, even from distant locations, have easy access to system performance data, enabling them to manage energy production efficiently. By offering insights into both current and historical performance, the system allows for better resource planning, reducing potential inefficiencies and ensuring that the solar panels are always working as efficiently as possible. This combination of real-time data collection, fault detection, and long-term performance tracking makes the system an indispensable tool for maximizing solar energy output and promoting sustainability.

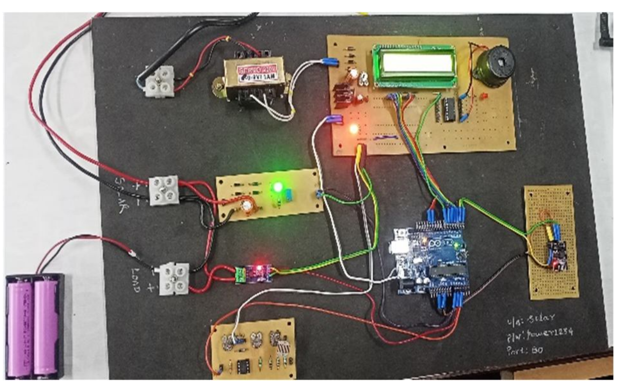


Figure.6 Final Hardware setup

IX. CONCLUSION

The proposed IoT-based Solar Monitoring and Fault Detection System demonstrates a significant advancement in the management and optimization of solar energy systems. By integrating real-time monitoring, automated fault detection, and remote accessibility, the system addresses critical challenges in solar panel maintenance and performance. Continuous monitoring enables the system to provide real-time insights into performance, ensuring immediate detection of abnormalities and continuous optimization of solar energy output. The system's ability to send performance data to central monitoring platforms whichallows for ongoing real time analysis by solar energy professionals, facilitating proactive maintenance and support. By empowering users with real-time insights and remote management capabilities, the system encourages sustainable energy practices, enhances renewable energy adoption, and contributes to a more environmentally responsible future. The integration of smart technologies like this paves the way for innovative solutions in the renewable energy sector, supporting global sustainability efforts. This system not only reduces downtime and maintenance costs but also ensures the reliability and longevity of solar installations. Its scalability and adaptability make it suitable for applications ranging from residential setups to large-scale solar farms. In addition to enhancing operational efficiency, the proposed system plays a crucial role in driving the broader adoption of solar energy by addressing key barriers to widespread implementation. One of the significant challenges faced by solar power systems is the unpredictability of energy generation, which can vary based on weather, environmental conditions, and system performance. By providing detailed, real-time data, this system mitigates the uncertainty surrounding solar energy generation, offering a more reliable and transparent method for managing power output. Furthermore, the proactive fault detection and analytics capabilities help extend the lifespan of solar panels by enabling early interventions, reducing the risk of cumulative damage, and optimizing the overall health of the system. The user-friendly interface ensures that individuals with limited technical knowledge can easily understand and manage their solar setups, fostering wider consumer adoption. This approach to solar system management not only promotes efficiency but also supports the decentralization of energy production, empowering consumers to take an active role in their energy consumption while contributing to the larger goals of sustainability and energy independence. This system represents a significant transformation in renewable and clean energy, driving smarter, more efficient, and sustainable solar energy solutions for a greener, more energy-independent future.

X. SUSTAINABLE DEVELOPMENT GOALS

1) *SDG Goal 7: Affordable and Clean Energy*

The IoT-based solar monitoring and fault detection system advances the shift towards renewable energy by maximizing solar panel efficiency, thereby reducing the cost of energy production. With optimized solar panel operations, the system ensures energy affordability and increases clean energy access, contributing to the global clean energy transition.

2) *SDG Goal 9: Industry, Innovation, and Infrastructure*

This initiative exemplifies the role of technological innovation in enhancing the clean energy sector. By integrating IoT for real-time monitoring, the project fosters the development of next-generation smart infrastructure, which enhances energy systems' resilience, efficiency, and scalability, promoting long-term economic and industrial growth.

3) *SDG Goal 11: Sustainable Cities and Communities*

The solar monitoring system plays a vital role in promoting sustainability in urban areas by improving solar energy reliability and fostering cleaner, more efficient cities. It empowers local communities with the tools to manage their energy resources more effectively, thereby reducing their environmental footprint and promoting energy autonomy.

4) *SDG Goal 13 : Climate Action*

This project accelerates climate action by enabling users to maximize solar energy output, significantly reducing carbon emissions from fossil fuel-based power generation. By empowering individuals and industries with the means to monitor and adjust their energy production, it contributes directly to global efforts to mitigate the effects of climate change.

REFERENCES

[1] Jiao, Xuan, Xingshuo Li, Tangwu Yang, Yongheng Yang, and Weidong Xiao. "A novel fault diagnosis scheme for PV plants based on real-time system state identification." IEEE Journal of Photovoltaics 13, no. 4 (2023): 571-579.

[2] Guerriero, Pierluigi, Fabio Di Napoli, Gianlorenzo Vallone, Vincenzo d'Alessandro, and Santolo Daliento. "Monitoring and diagnostics of PV plants by a wireless self-powered sensor for individual panels." IEEE Journal of Photovoltaics 6, no. 1 (2015): 286-294.

[3] Akram, Mohd Nafis, and Saeed Lotfifard. "Modeling and health monitoring of DC side of photovoltaic array." IEEE Transactions on Sustainable Energy 6, no. 4 (2015): 1245-1253.

[4] Ranhotigamage, Chagitha, and Subhas Chandra Mukhopadhyay. "Field trials and performance monitoring of distributed solar panels using a low-cost wireless sensors network for domestic applications." IEEE Sensors Journal 11, no. 10 (2011): 2583-2590.

[5] De Riso, Monica, Sharmarke Hassan, Pierluigi Guerriero, Mahmoud Dhimish, and Santolo Daliento. "Enhanced Photovoltaic Panel Diagnostics: Advancing a High-Precision and Low-Cost IV Curve Tracer." IEEE Transactions on Instrumentation and Measurement (2024).

[6] Moscatiello, Cristina, Chiara Boccaletti, Adérito Neto Alcaso, Carlos A. Figueiredo Ramos, and Antonio J. Marques Cardoso. "Performance evaluation of a hybrid thermal–photovoltaic panel." IEEE Transactions on Industry Applications 53, no. 6 (2017): 5753-5759.

[7] Wang, Wenguan, Alex Chun-For Liu, Henry Shu-Hung Chung, Ricky Wing-Hong Lau, Jun Zhang, and Alan Wai-Lun Lo. "Fault diagnosis of photovoltaic panels using dynamic current–voltage characteristics." IEEE Transactions on Power Electronics 31, no. 2 (2015): 1588-1599.

[8] Meribout, Mahmoud. "Sensor systems for solar plant monitoring." IEEE Transactions on Instrumentation and Measurement 72 (2022): 1-16.

[9] Jiao, Xuan, Xingshuo Li, Tangwu Yang, Yongheng Yang, and Weidong Xiao. "A novel fault diagnosis scheme for PV plants based on real-time system state identification." IEEE Journal of Photovoltaics 13, no. 4 (2023): 571-579.

[10] Lee, Beomseok, Jinsung Byun, Myeong-in Choi, Byeongkwan Kang, and Sehyun Park. "Degradation diagnosis system of photovoltaic panels with mobile application." IEEE Transactions on Consumer Electronics 60, no. 3 (2014): 338-346.

[11] Abdulmawjood, Kais, Shady S. Refaat, and Walid G. Morsi. "Detection and prediction of faults in photovoltaic arrays: A review." In 2018 IEEE 12th International Conference on Compatibility, Power Electronics and Power Engineering (CPE-POWERENG 2018), pp. 1-8. IEEE, 2018..

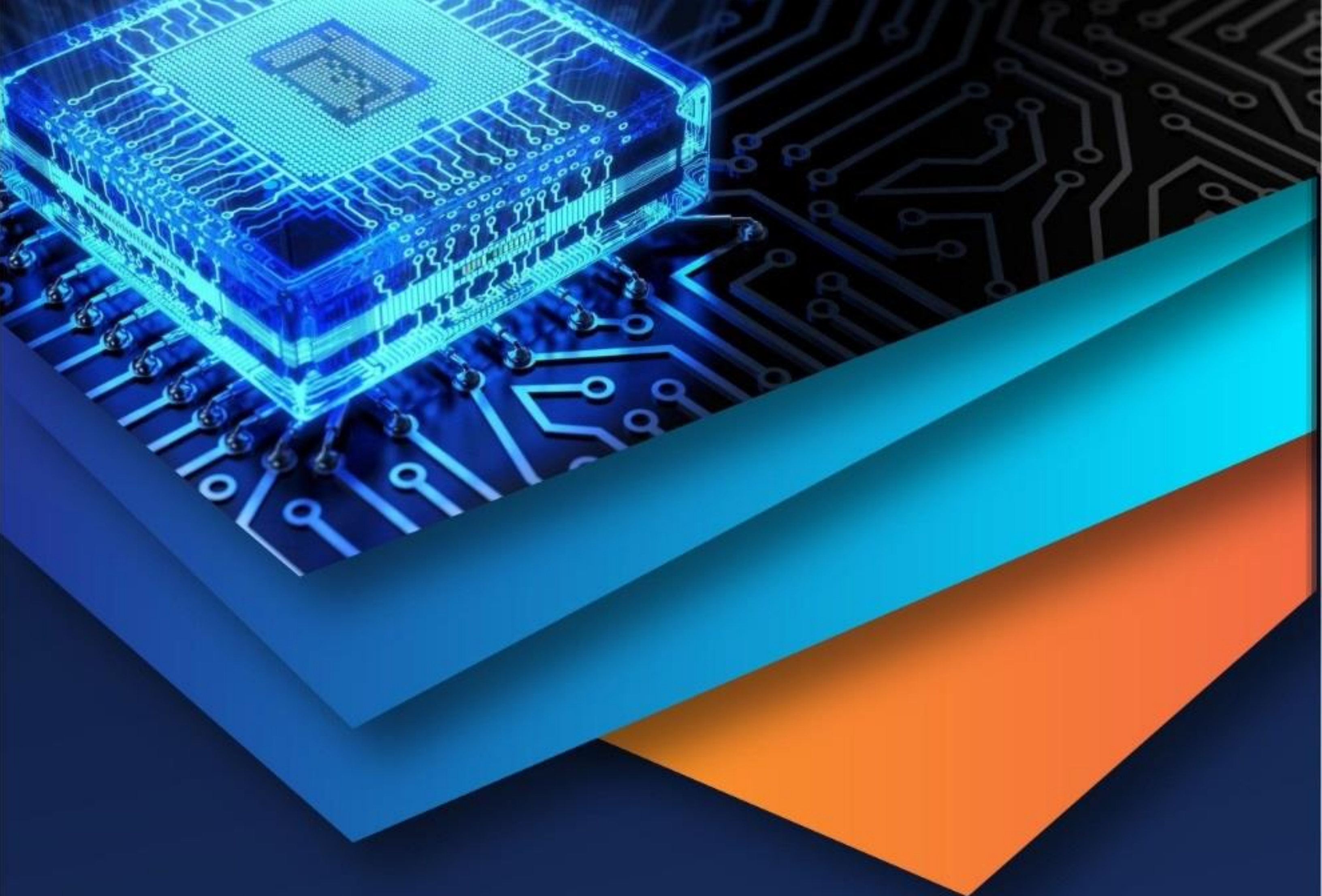
[12] Merza, Bashar Noori, Ahmed Ghanim Wadday, and Ahmed Kareem Abdullah. "Study and analysis of fault detection in solar array system based on internet of things." In AIP Conference Proceedings, vol. 3092, no. 1. AIP Publishing, 2024

[13] Mridul, Mridul, Bhuvnesh Vashishat, Anil Kumar, Rohit Kumar, and Supriya Jaiswal. "IoT based Solar Photo Voltaic Fault Detection System." In 2023 International Conference on Computer, Electronics & Electrical Engineering & their Applications (IC2E3), pp. 1-5. IEEE, 2023.

[14] Bhatane, Ganesh Asaram, Vitthal Janardhan Gond, Sachin Vasant Chaudhari, and P. William. "Real Time Performance Monitoring of Solar PV Panel IoT System for Energy Optimization." In 2024 4th International Conference on Innovative Practices in Technology and Management (ICIPTM), pp. 1-4. IEEE, 2024

[15] Lee, Jihyun, Youngmee Shin, and Ilwoo Lee. "Cloud-based application platform for smart monitoring & management of photovoltaic generation systems." In 2018 International Conference on Electronics, Information, and Communication (ICEIC), pp. 1-3. IEEE, 2018.

[16] Al-Naib, Ahmed MT Ibraheem, and Majeed Ismail Mohammed. "IoT-Based Real Time Data Acquisition of PV Panel." In 2023 International Conference on Engineering, Science and Advanced Technology (ICESAT), pp. 169-173. IEEE, 2023.



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TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

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