iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** III **Month of publication:** March 2026

DOI: https://doi.org/10.22214/ijraset.2026.78151

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue III Mar 2026- Available at www.ijraset.com

DC Remote Power Sensor

Aswin Anil[1], Diya Sundus[2], Fidha Habeeb[3], Mariya Sunny[4], Dr Sija Gopinathan[5], Jayan P P[6], Dr. Siny Paul[7]
Department of Electrical and Electronics Engineering Mar Athanasius College of Engineering, Kothamangalam, Kerala

Abstract: Reliable DC power monitoring is important in remote and off-grid areas where AC supply is unstable or unavailable. This project presents a low-cost IoT-based DC remote power monitoring system using the ESP32 microcontroller with built-in Wi-Fi and Bluetooth. A GSM module is included to provide SMS alerts when internet connectivity is not available. Real-time DC parameters are displayed on an LCD screen and can be monitored remotely through the Blynk Android application, which also allows relay control. A buck XL4016E1 DC-DC 10A 300W stepdown module is used to supply regulated power to sensors, buzzer and other system components. A relay and buzzer provide local alerts and manual control for improved safety. The system is suitable for solar-powered, battery-operated, telecom, and off-grid applications, offering a cost effective and reliable solution for remote DC power monitoring.
Keywords: IoT-based DC monitoring, ESP32 microcontroller, Remote power monitoring, GSM SMS alert system, Blynk mobile application, DC-DC buck converter.

I. INTRODUCTION

In today's energy-driven world, industries are increasingly dependent on reliable and efficient electrical power systems. With the rising integration of renewable energy sources such as solar photovoltaic (PV) systems, the need for continuous and accurate monitoring of DC power parameters has become essential [1], [4]. Effective monitoring not only ensures optimal energy utilization but also enhances the reliability, safety, and lifespan of electrical equipment [5].

Traditional monitoring systems often rely solely on online communication platforms that require constant internet connectivity, making them unsuitable for remote or off-grid industrial locations [3], [6]. Conversely, GSM-based systems provide offline monitoring but lack a user-friendly data visualization interface [2]. Therefore, there exists a need for a costeffective, dual-mode monitoring solution capable of operating both online (IoT) and offline (GSM) for uninterrupted data transmission and system supervision [7], [8].

The DC Remote Power Sensor system is developed to address this challenge by enabling real-time monitoring of PV power generation and battery health parameters [1], [5]. The system measures key electrical quantities such as voltage, current, and State of Charge (SOC) for both the solar panel and the battery, ensuring complete visibility of system performance [4]. The proposed project, "DC Remote Power Sensor," addresses these issues by providing real-time monitoring of solar PV and battery performance parameters. The system measures critical values such as voltage, current, and State of Charge (SOC) for both the PV and battery sides, helping detect abnormalities like overvoltage, undervoltage, or discharge conditions.

The hardware core of the system is based on the ESP32 microcontroller, which handles both data acquisition and communication. The measured parameters are transmitted to the Blynk IoT application via Wi-Fi for online monitoring and data visualization [5], [7]. In the absence of internet connectivity, the system automatically switches to GSM-based communication to send alerts through SMS [2], ensuring uninterrupted supervision. Additionally, a local LCD display provides on-site monitoring of PV and battery parameters for immediate reference. This combination of IoT connectivity, GSM alerts, and local display makes the proposed system highly suitable for industrial and remote applications, where maintaining constant visibility of energy flow and equipment health is crucial for efficiency and operational safety [3], [6], [8].

II. METHODOLOGY

The DC Remote Power Sensor system provides a real-time and reliable solution for monitoring solar and battery parameters in both online and offline conditions. It is designed around the ESP32 microcontroller, which offers built-in Wi-Fi and supports GSM communication, making it suitable for remote or industrial environments where connectivity may not always be stable
[3], [5], [7].

The working principle of the DC Remote Power Sensor is based on real-time measurementand transmission of electrical parameters such as voltage, current, and State of Charge (SOC) from both the solar panel and the battery side [1], [4].The voltage and current sensors generate analog signalscorresponding to the measured values.

These signals are processed by the ESP32 microcontroller, which determines the battery's charging or discharging condition [6]. The processed data are then transmitted to the user through two communication modes. Under normal Wi-Fi connectivity, data are sent to the Blynk IoT cloud platform for visualization. When Wi-Fi is unavailable, the system automatically switches to GSM communication, and the SIM800 module sends alerts and readings as SMS messages [2].Additionally, an LCD display shows local readings of the solar and battery sides, providing on-site visibility. In abnormal conditions such as overvoltage, undervoltage, or discharge, the system triggers a relay mechanism and visual indicators to alert and protect the load [8].

A. *Integrated Hardware Framework*

Figure 1 represents the block diagram of remote power sensor. The block diagram illustrates the functional architecture of a DC Remote Power Sensor system designed for real-time monitoring and reliable solution for monitoring solar and battery parameters in both online and offline conditions.

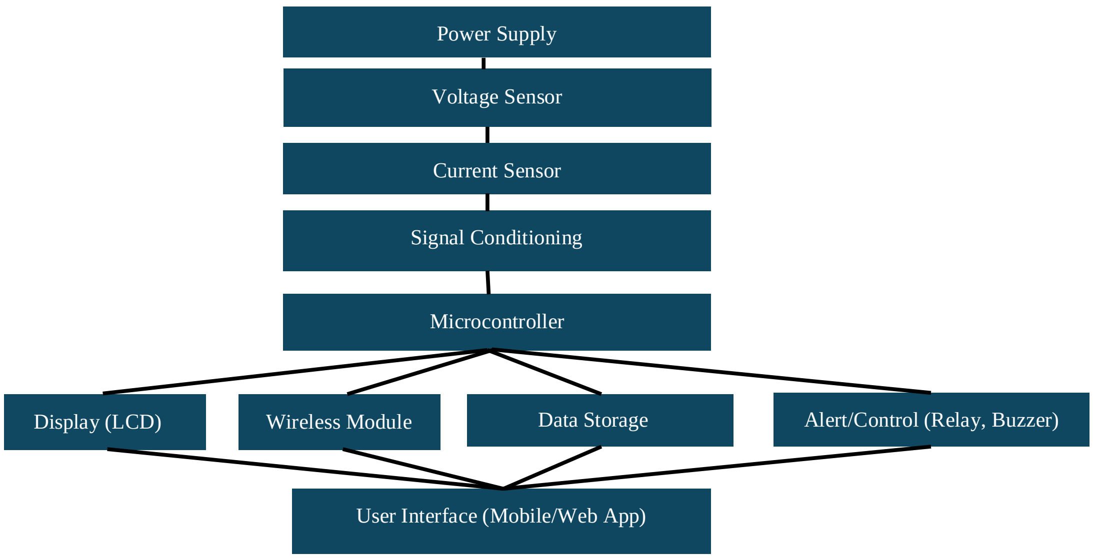

Fig. 1 Block Diagram of DC Remote power Sensor

,

The system begins with a Power Supply, which provides the necessary operating voltage to all components. The voltage sensor measures the DC voltage level, while the current sensor (INA219) detects the flow of current in both directions [1], [6]. These signals are processed through a signal conditioning circuit to make them compatible with the microcontroller inputs. The ESP32 microcontroller acts as the main control unit, processing sensor data to calculate parameters and battery status. The processed data is displayed locally on an LCD display and transmitted via Wi-Fi to an IoT dashboard or mobile app for remote monitoring [5], [7]. A data storage unit (cloud or SD card) logs readings for performance analysis.

For protection, a relay and buzzer are used to provide visual and audible alerts and to isolate the load during abnormal voltage or current conditions. The user interface allows real-time access to system data and alerts, ensuring efficient and reliable power management.

B. *Circuit Diagram*

Figure2 represents the circuit diagram of DC remote power sensor. The ESP32 microcontroller functions as the central control unit, processing sensor data to calculate parameters like power, battery health, and SOC. The processed information is displayed locally on the LCD and transmitted via Wi-Fi to an IoT dashboard for remote monitoring. For system protection, a relay and buzzer provide visual andaudible alerts andisolate the load under abnormal conditions. The user interface allows real-time access to all system data and notifications, ensuring efficient and safe power management. This integrated configuration provides both local and remote monitoring, combining safety, automation, and IoT-based control within a single platform and IoT-based control within a single platform.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue III Mar 2026- Available at www.ijraset.com

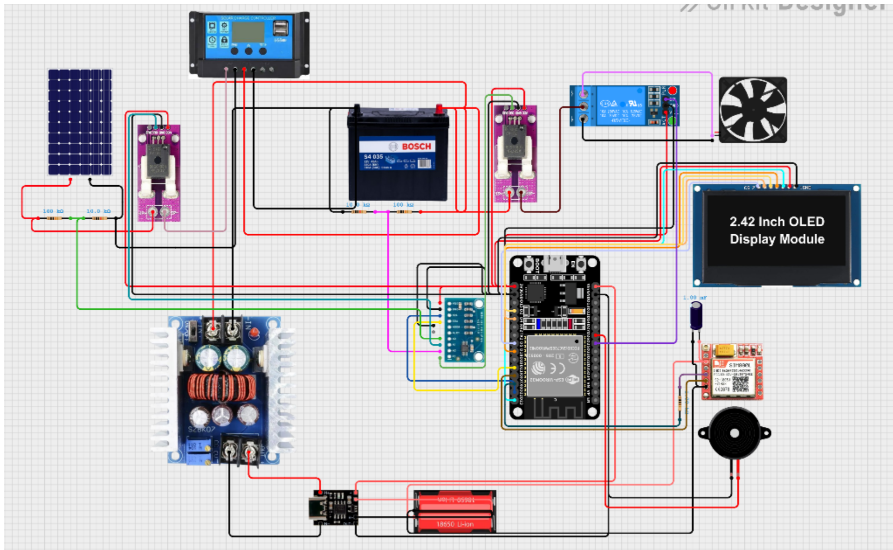

Fig. 2 Circuit Diagram of DC remote power sensor

III. SIMULATION AND RESULTS

The simulation of the proposed system was carried out using Proteus Design Suite, which provides an integrated environment for circuit design, microcontroller programming, and virtual testing. However, due to the complexity of the overall system architecture, the large program size, and the limited memory and real-time communication support avail able within Proteus, it was not feasible to simulate the complete circuit as a single unit. To overcome this limitation, the system was divided into two functional parts for simulation purposes:

- Part (A)–Real-Time Monitoring Module: This section focuses on the core data acquisition and processing functions.
- Part (B)– Alert and Offline Communication Module: This part demon strates the communication and control functionality of the system, including the GSM module and relay unit.

A. Real Time Monitoring

Part (A) focuses on the core data acquisition and processing functions. It includes the simulation of sensors, the ESP32 microcontroller, and the LCD display. The purpose of this part is to validate the real-time monitoring of parameters such as voltage, current, and power, as well as to ensure correct computation and display of the measured values on the virtual interface.

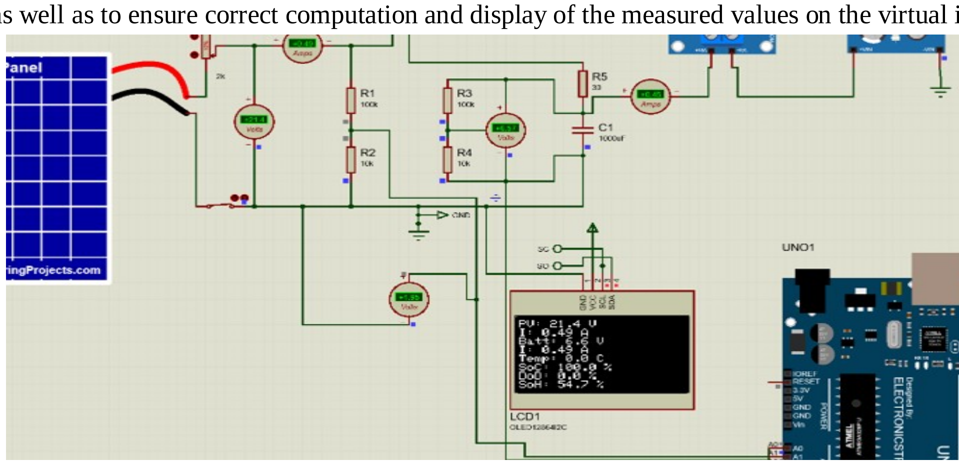

Fig. 5 Simulation Result of part (A)

Figure 3 shows the output of this simulation. In the figure, we can see various parameters displayed on the LCD. The values shown on the LCD and the virtual meters are the same. Apart from voltage and current, other parameters being monitored are SoC, SoH, and DoD.

B. Alert and Offline Communication

Part(B) demonstrates the communication and control functionality of the system, including the GSM module and relay unit. The simulation verifies that the system can generate alerts or send messages under fault or abnormal conditions, and that the relay control logic works as intended.

*1) Case 1:*WiFi available and normal condition.

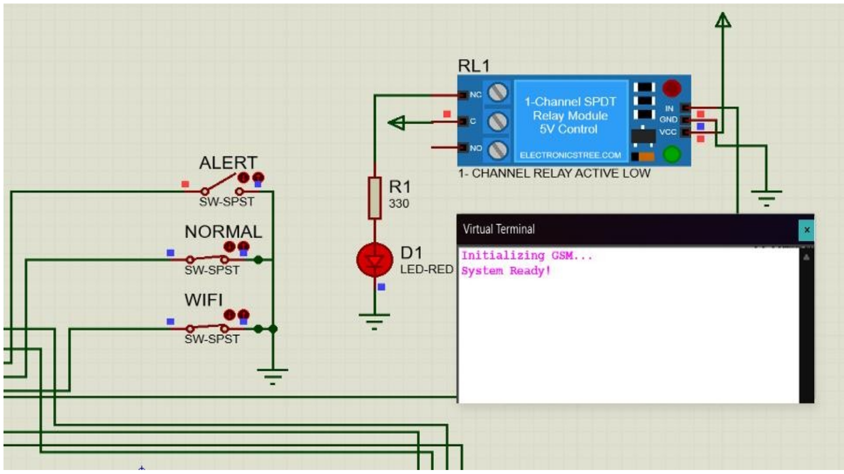

Fig. 4Simulation Result of Case 1

This simulates the online condition of the system. Figure 4 shows the Simulation result of case 1. It shows that the WiFi switch and Normal switch is in the ON state that represents the online and normal condition, so there is no need to monitor offline so no SMS and since it is a normal condition, load is connected to the battery.

*2) Case 2:*WiFi not available and normal condition.

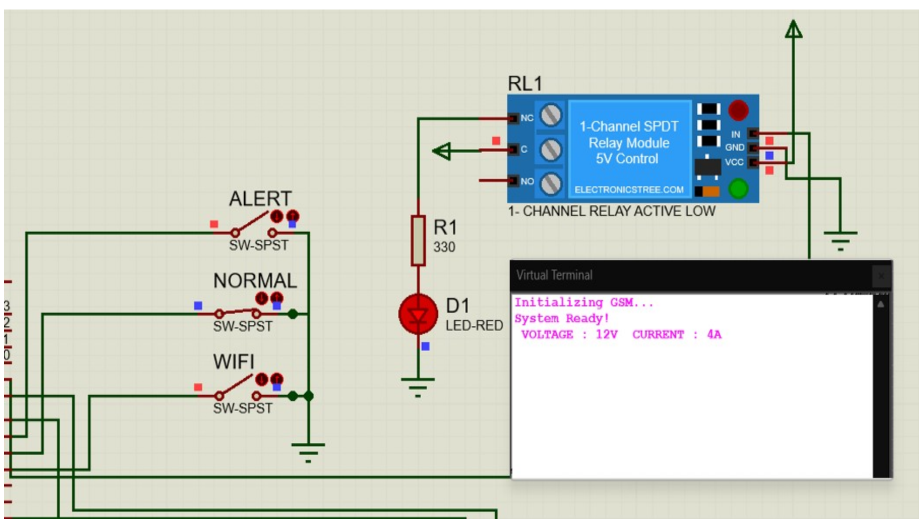

Fig. 5Simulation Result of Case 2

This simulates the offline condition. Figure 5.shows the simulation result of case 2. It shows that the WiFi switch is in the OFF state and the normal switch is in the ON state which represents the offline and normal condition. In this case WiFi is inactive so the GSM module sends the necessary data (voltage and current) as sms for offline monitoring since it is a normal condition Load is connected to the battery.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue III Mar 2026- Available at www.ijraset.com

3) *Case 3:* Alert situation

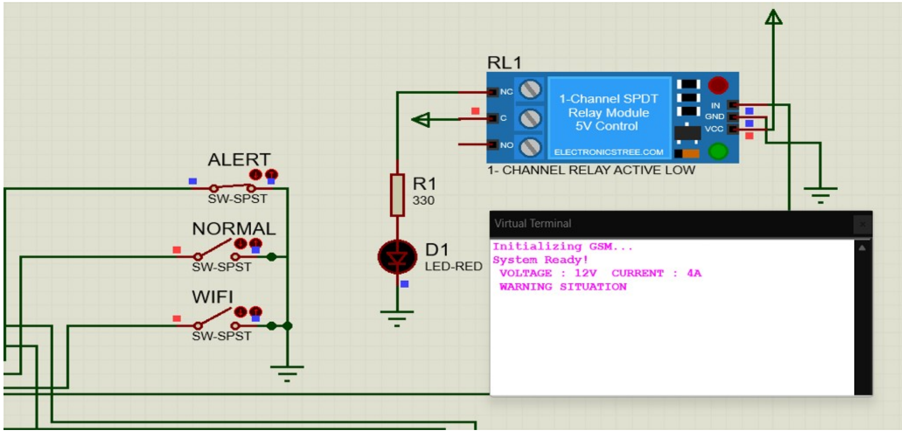

Fig. 6.Simulation Result of Case 3

This simulates the alert condition. In this case the status of WiFi switch is not checked. So when alert happen even though there is WiFi active or not GSM sends the alert msg and load is disconnected from the load. If Wifi is active both online and offline alerts and if there is no wifi offline alert. Figure 6 shows the simulation result of case 3. It shows that the WiFi switch and Normal switch is in the OFF state and Alert switch is in the ON state which that represents the alert condition, GSM module sends warning sms and load is disconnected from the battery.

IV. HARDWARE IMPLEMENTATION

The proposed DC Remote Power Sensor was implemented in a real-time solar-powered environment to evaluate its practical feasibility and operational performance. Figure 7 shows the complete hardware setup of DC Remote Power sensor. The objective of this phase was to validate the integrated monitoring of photovoltaic (PV) parameters, battery electrical quantities, and battery health indicators under realistic operating conditions.

The developed hardware setup consists of a solar panel source, rechargeable battery, voltage and current sensing modules, ESP32 microcontroller, GSM communication unit, LCD display, and IoT-based monitoring through the Blynk platform. The system was tested under varying operating conditions including normal operation, charging, discharging, and abnormal scenarios.

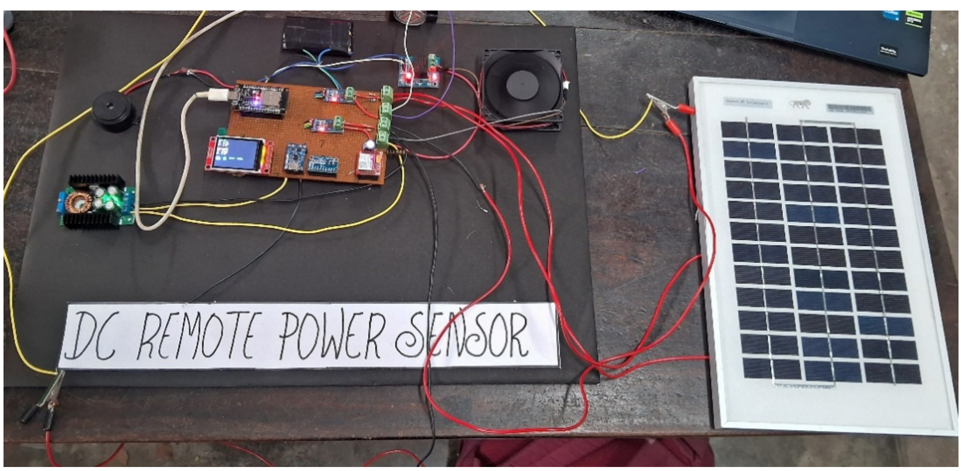

Fig 7 Hardware Implementation of DC remote power sensor

A. *Physical Testbed for PV–Battery Monitoring*

The experimental setup was designed to replicate an off-grid solar DC system under real operating conditions. The solar panel acted as the primary energy source, while the rechargeable battery provided energy storage for supplying the load. Voltage divider circuits and Hall-effect current sensors were used to measure the photovoltaic (PV) and battery voltage and current in real time.

These sensed signals were interfaced with the ESP32 microcontroller and processed through its built-in ADC to enable accurate monitoring of electrical parameters.

An adjustable buck converter (XL4016E1) was integrated to step down and regulate the battery voltage to safe operating levels required by the ESP32 controller and sensing circuits. This regulated power supply ensured stable system performance and allowed continuous monitoring of power flow between the solar panel, battery, and load. The system was tested under both charging and discharging conditions to validate parameter measurement accuracy and battery health estimation. The ESP32 computed key indicators such as State of Charge (SoC), State of Health (SoH), and Depth of Discharge (DoD), which were displayed on the LCD and transmitted remotely via Wi-Fi and GSM, confirming reliable real-time monitoring and stable operation of the solar–battery system. Figure 8 shows the local real time monitoring of parameters through LCD display.

Fig 8 LCD display real time parameters of solar & battery

B. PV Parameter Monitoring Performance

During experimental operation, the system successfully monitored photovoltaic voltage, current, and output power under varying input conditions. Changes in solar input were reflected dynamically in the measured PV parameters, confirming the effectiveness of the sensing and signal conditioning circuits.

The computed PV power values were consistent with the applied load conditions, demonstrating reliable real-time performance of the monitoring framework. This validates the suitability of the proposed system for solar-side supervision in off-grid applications.

C. Battery Electrical Parameter Evaluation

Battery-side monitoring was conducted to evaluate the dynamic performance of the energy storage unit under real-time operating conditions. The proposed system continuously measured battery voltage and bidirectional current using the integrated sensing modules. Based on the polarity of the measured current, the ESP32 controller reliably identified the battery operating mode.

During the charging phase, positive current flowing into the battery was observed along with a gradual rise in terminal voltage, indicating energy absorption from the solar source. In contrast, during the discharging phase, the battery delivered power to the load, resulting in negative current flow and a corresponding voltage drop. This behaviour confirms proper detection of charge and discharge transitions.

The instantaneous battery power was computed within the ESP32 firmware using real-time voltage and current data, enabling continuous assessment of energy transfer. The monitored values were successfully displayed on the OLED and transmitted remotely, demonstrating stable operation and accurate battery parameter tracking under practical conditions.

D. Battery Health Parameter Computation

In addition to electrical parameters, the system computed key battery health indicators including State of Charge (SoC), Depth of Discharge (DoD), and State of Health (SoH) using embedded algorithms. The SoC value increased during charging cycles and decreased during discharging periods, while DoD exhibited complementary behaviour. The SoH parameter reflected the assumed battery condition and provided an indication of long-term battery performance.

The real-time update of these parameters on both the OLED display and IoT dashboard confirms the correctness of the implemented estimation algorithms.

E. Real-Time Cloud Monitoring and Remote Visualization

To facilitate remote supervision, the ESP32 microcontroller was configured to transmit real-time system data to the Blynk IoT platform whenever Wi-Fi connectivity was available. The developed mobile dashboard provided live visualization of key photovoltaic and battery parameters, including voltage, current, power, State of Charge (SoC), State of Health (SoH), and Depth of Discharge (DoD).

The cloud-based interface enabled users to monitor system performance continuously from a remote location without requiring physical access to the hardware. Parameter updates were observed with minimal latency, indicating efficient data acquisition and wireless transmission.

The successful integration of the ESP32 with the Blynk platform demonstrates the suitability of the proposed system for intelligent remote energy management, particularly in off-grid and distributed solar applications where continuous monitoring is essential. Blynk interface is shown in Fig. 9

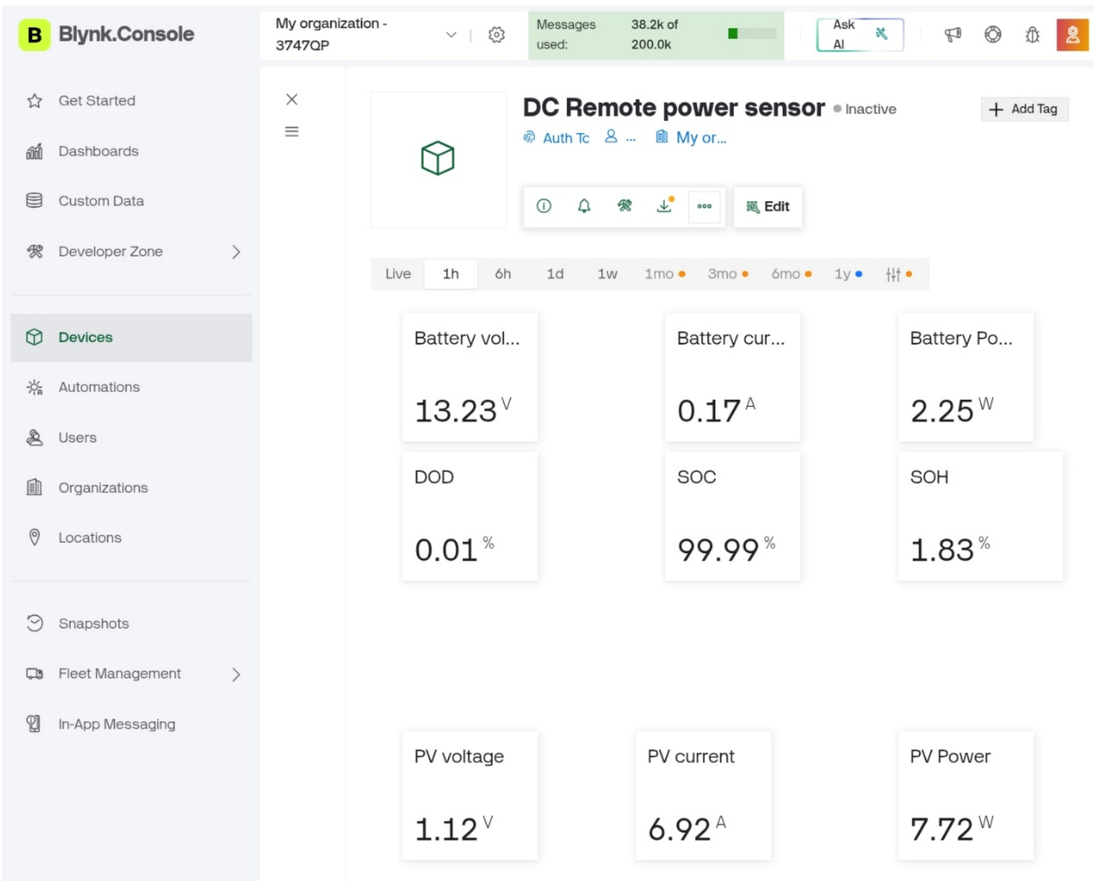

Fig. 9Blynk Interface for remote data monitoring

F. GSM-Based Alert and Fault Notification

To maintain system supervision during network failure conditions, a GSM-based communication module was integrated into the proposed system. This module provides an independent offline communication path, ensuring continuous data availability even when Wi-Fi connectivity is not present. In the implemented setup, the ESP32 transmits not only fault alerts but also key real-time battery parameters to the registered user via SMS. During abnormal conditions such as battery under voltage or overcurrent, the transmitted message includes both the alert status and the corresponding measured values, enabling meaningful remote diagnosis.

Experimental verification confirmed reliable SMS delivery under offline conditions. The successful transmission of real-time data along with fault notifications demonstrates the robustness of the dual-mode communication approach and enhances the suitability of the system for remote solar DC applications. Sample SMS alert during all conditions is shown in Fig. 10

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue III Mar 2026- Available at www.ijraset.com

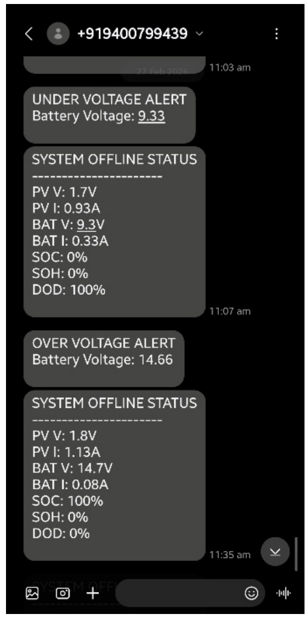

Fig. 10 GSM-based SMS alerts for solar PV and battery monitoring

G. Protection Response and System Reliability

The relay-based protection mechanism was validated by intentionally introducing abnormal operating conditions. Upon detection of unsafe voltage levels, the controller activated the relay to isolate the load and prevent further battery degradation.

Simultaneously, visual and remote alerts were generated, ensuring timely user awareness. The coordinated operation of sensing, processing, communication, and protection modules confirms the robustness of the proposed DC Remote Power Sensor.

V. CONCLUSIONS

The developed prototype demonstrated accurate monitoring of PV and battery parameters, along with reliable computation of battery health indicators such as SoC, SoH, and DoD. Both online monitoring through the Blynk platform and offline data transmission via GSM were verified, confirming the effectiveness of the dual communication strategy. Overall, the experimental results establish the functional correctness and practical feasibility of the proposed system for remote supervision of solar-powered DC installations, thereby providing a strong foundation for further optimization and large-scale deployment.

REFERENCES

[1] R. Murugesh, A. Humatnhaiah, U. Ramanadhan, and N. Vasudevan, “Designing a wireless solar power monitor for wireless sensor network applications,” in Proc. IEEE Int. Conf. Systems, Man, and Cybernetics (SMC), 2018, pp. 79–84.

[2] C. Ranhotigamage, S. C. Mukhopadhyay, S. N. Garratt, and W. M. Campbell, “Measurement and monitoring of performance parameters of distributed solar panels using wireless sensor network,” in Proc. IEEE Instrum. Meas. Technol. Conf. (I2MTC), 2011, pp. 1–6.

[3] O. Ben Belghith and L. Sbita, “Remote GSM module monitoring and photovoltaic system control,” in Proc. First Int. Conf. Green Energy (ICGE), 2014, pp. 188–194.

[4] S. Durgadevi, S. Shalini, T. Sundari, and A. K. R. Hari Shanker, “A smart solar monitoring system using IoT,” in Proc. Int. Conf. Communication, Computing and Internet of Things (IC3IoT), 2020.

[5] S. M. Patil, M. Vijayalashmi, and R. Tapaskar, “IoT based solar energy monitoring system,” in Proc. Int. Conf. Energy, Communication, Data Analytics and Soft Computing (ICECDS), 2017, pp. 1574–1579.

[6] A. Abu Al Aish, W. F. Abu Shehab, M. I. Alshrari, and S. Nabhan, “Real-time performance monitoring of PV solar module based on wireless data acquisition system,” ResearchGate, 2019.

[7] M. I. Rusydi, R. Putra, and M. H. Putra, “Real-time measurement of grid connected solar panels based on wireless sensors network,” in Proc. Int. Conf. Sustainable Energy Engineering and Application (ICSEEA), 2016, pp. 95–99.

[8] A. Ghosh, G. Konar, and N. Chakraborty, “Online monitoring of power data through wireless sensor network,” in Proc. IEEE India Conf. (INDICON), 2014, pp. 1–6.