IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 2, April 2026
Impact Factor: 8.2

Design and Development of Smart Battery Monitoring and Maintenance System for Substation DC Power Supply

Himanshu Karale[1], Siddhesh Tambekar[2], Ayush Harne[3], Tushar Kharate[4], Dipak Ingle[5]
Electrical Department[1-5]
Shri Sant Gajanan Maharaj College of Engineering, Shegaon, India

Abstract: *This research provides a simple and effective way of monitoring batteries in the substation using modern technology. This ensures the batteries are always in good condition through the constant monitoring of various factors such as voltage, current, and temperature using sensors such as the ACS712 and DS18B20. This information is then processed by the Arduino Mega and sent using the ESP32 module to the Firebase server for online viewing in real-time.*
This research has shown that the use of IoT in battery monitoring is effective and can be applied in the field. This is because the information is always available in real-time, and any minor issues can be detected in good time. This ensures that maintenance is carried out only when necessary and not on a scheduled routine

Keywords: IoT, Voltage, Current, Real-time

I. INTRODUCTION

In the operation of the power system, the electrical substation is of major importance. In the substation, the protection and control devices require a DC power supply. Normally, the DC power is obtained through the rectification of the AC power using rectifiers. However, in the absence of the AC power supply, the DC power supply may break down unless there is a standby source of power. In this case, the batteries are used as the standby source of power in the protection systems.
However, the batteries are likely to fail over time due to overcharging, deep discharge, and extreme temperatures. In the past, the batteries have been monitored using conventional methods such as inspecting the batteries and tracking the battery parameters. This has been inefficient and has caused the batteries to malfunction unexpectedly. Therefore, the batteries require a real-time monitoring system for efficient and effective battery reliability and performance.
In this study, a Smart Battery Monitoring System is proposed with the aim of monitoring the battery parameters in real-time using sensors and microcontrollers in conjunction with the cloud technology.

II. SYSTEM ARCHITECTURE

The system is structured in a simple way. It starts with sensors that collect battery information such as voltage, current, and temperature. Voltage is measured using voltage divider circuits. Current is measured using the ACS712 sensor module.
Temperature is measured using DS18B20 sensors.
The Arduino Mega 2560 is the central controller of the system. It processes the information and sends it to the ESP32 module for wireless communication. It then sends the information to the Firebase platform for storage in the cloud.
A web-based dashboard is then used to retrieve the information and display it in real-time. This way, the system can be easily monitored in real-time. It is possible to monitor the battery voltage, current, and temperature. In addition, the battery's SOC and health can be monitored in real-time.

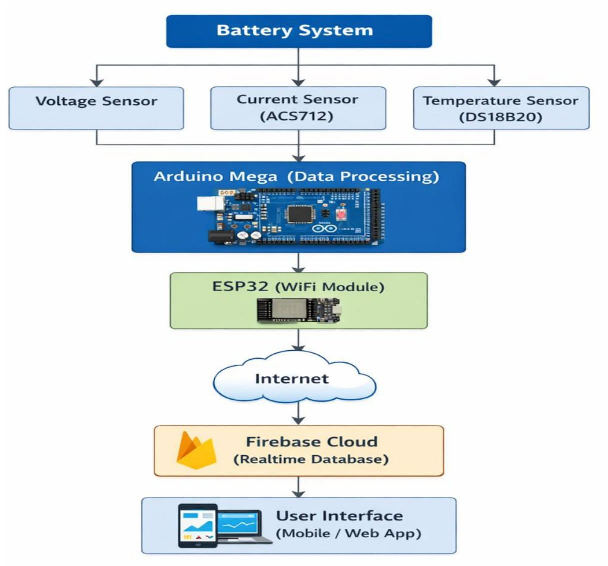

Fig. 1 WORKFLOW MODEL

III. METHODOLOGY

3.1 Voltage Divider

In order to safely operate the Arduino Mega board with the 12V battery pack, a voltage divider circuit was designed to reduce the voltage to a safe level of around 5V. To divide the voltage of the first and second battery of the strings, resistor pairs of 10 kΩ and 20 kΩ are connected in parallel. On the other hand, a resistor pair of 10 kΩ and 33.3 kΩ are connected in parallel with the third battery of the string.

Below circuit is of the layout of voltage dividers. This ensures the output voltage of the divided voltage is always within the safe operating limit of the Arduino Mega board.

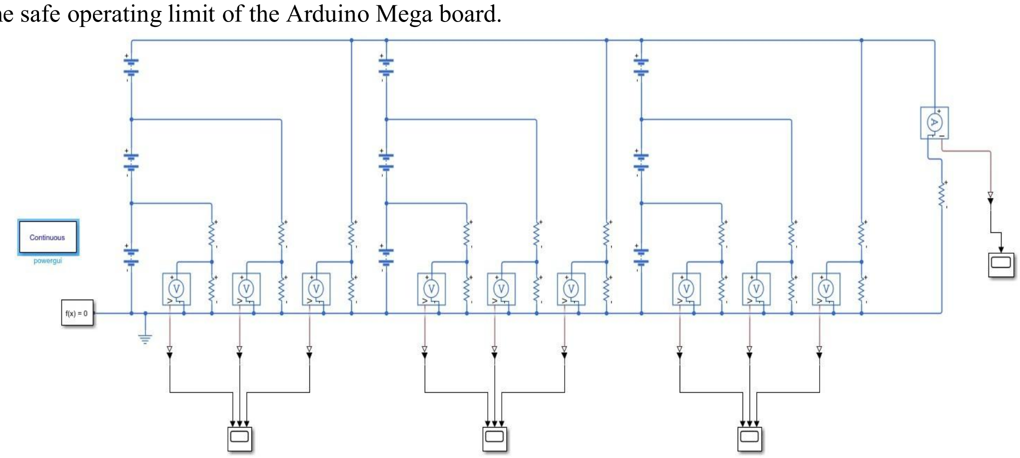

Fig. 2. SIMULATION OF VOLTAGE DIVIDER

Below figure is of the output of voltage dividers.

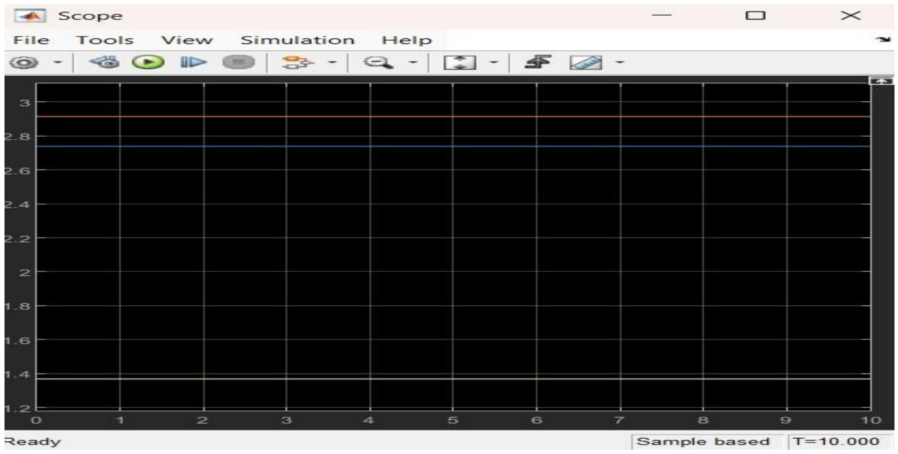

Fig. 3. OUTPUT OF VOLTAGE DIVIDER

3.2 State of Charge (SOC)

State of Charge is a measure of how much battery capacity is left in relation to its total capacity. It is calculated by a technique known as coulomb counting, in which it tracks current flow into and out of the battery.

This technique is reliable, although it has a tendency to incur small errors over a period of time. Therefore, it resets the SOC values when it is fully charged or discharged.

3.3 State of Health (SOH)

State of Health is a measure of how much a battery has degraded in relation to its original condition. It is calculated by comparing its current capacity to its rated capacity.

In addition, it is able to calculate battery internal resistance by detecting voltage drop when sudden current change occurs.

3.4 Data Processing and Communication

The Arduino processes analog signals from sensors and converts them into digital data. The data is processed through calibration and filtering. The data from the sensors is processed by averaging the readings from the current sensors. The voltage is also processed for accuracy.

The data is then sent to ESP32 for further processing. The data is formatted and sent to Firebase for storage. The data is stored in real time and can be viewed anytime through the web interface.

IV. IMPLEMENTATION

The system is implemented by using sensors and Arduino. The sensors are connected to Arduino and ESP32. The voltage dividers are implemented for measuring battery voltage. The ACS712 sensor is calibrated for accuracy in measuring current. The DS18B20 sensors are connected to battery cells for temperature measurement.

The firmware is implemented on Arduino for data collection, processing, and sending data. The ESP32 is used for Wi-Fi communication and sending data to Firebase.

A web interface is implemented using HTML for data representation. The web interface is simple and clear for users to understand battery performance in real time.

4.1 Firmware Development

The role of the Arduino is that of a brain. It is responsible for setting up communication and initializing all sensors when it is powered on. It then goes on to read information from all sensors, including voltage, current, and temperature sensors. It ensures that it gets accurate information by stabilizing the current sensor first.

Once it has this information, it is then sent to the ESP32 in a format, together with a small error check for accuracy. The ESP32 then goes on to connect to Wi-Fi, log in to Firebase, and send the information to the real-time database.

4.2 Web Application Development

The system also has a web interface developed using HTML. This interface shows critical information regarding the battery in a simple manner. The interface updates in real-time using Firebase; i.e., if there are any changes in the values, they are reflected immediately.

There is no need to refresh the page; instead, the values are updated in real-time.

V. RESULTS AND DISCUSSION

5.1 System Performance

The system allows for the monitoring of essential battery parameters such as voltage, current, and temperature. It also allows for the detection of even the slightest changes in the battery voltage, which could be a sign of a faulty battery. The ability of the system to operate at all times ensures that it can detect faults before they happen.

5.2 Real-Time Monitoring Capabilities

The integration of the Firebase system ensures that the information displayed on the online dashboard is updated in real-time. This allows the user to be able to monitor the battery system without having to physically be at the substation.

VI. CONCLUSION

The above research has shown a simple and effective solution for monitoring a substation's batteries using IoT technology. It can continuously monitor voltage, current, and temperature using sensors and send information to a Firebase database using Arduino and ESP32 for real-time viewing.

The solution can greatly ease the monitoring of a battery's condition and can alert if any issues arise. It can be very useful in ensuring that maintenance actions are taken at the right time and based on actual conditions.

The solution is a good and useful one and can be very useful in the future for smart and unmanned substations.

VII. ACKNOWLEDGMENT

We acknowledge the support of the Electrical Department, Shri Sant Gajanan Maharaj College of Engineering, Shegaon, for providing the necessary facilities to carry out this research. We also express our gratitude to our project guide for their valuable guidance and technical support. The contributions of all team members in the development and implementation of this work are duly recognized. We further thank all individuals who provided indirect support during the course of this study.

REFERENCES

[1]. A. Sharma et al., “IoT-enabled monitoring system for battery management in inverter systems,” Next Research Journal, Vol. 6, Apr. 2026.

[2]. M. H. A. Wahab et al., “IoT-Based Battery Monitoring System for Electric Vehicle,” International Journal of Engineering & Technology, Vol. 7, No. 4, pp. 505–510, 2018.

[3]. S. Rajest, “Advanced Battery Monitoring System with Sensor Integration and Remote IoT Access,” Bonfring International Journal, 2025.

[4]. S. Winardi et al., “Battery Power Control and Monitoring System with Internet of Things Technology,” IJCONSIST Journal, Vol. 3, No. 1, 2021.

[5]. C. K. Rajana et al., “Battery Management System Using IoT,” IJRASET, 2024.

[6]. K. Insia et al., “IoT-Based Smart Battery Management and Monitoring System for Electric Vehicles,” AIUB Journal of Science and Engineering, 2023.

[7]. “Internet of Things Based Solar Battery Monitoring System,” Techno Journal, 2025.

[8]. “IoT-enabled advanced monitoring system for tubular batteries,” ScienceDirect, 2024.

[9]. “IoT-Based Smart Battery Monitoring System with Fault Analysis and Battery Life Prediction,” IJIRSET, 2025.