***K. Bidenko**, BA student*
***O. Mykhailovska**, lecturer*
Zhytomyr Polytechnic State University

DEVELOPMENT OF A BATTERY MONITORING SYSTEM FOR REMOTE COMMUNICATION NODES BASED ON MICROCONTROLLERS

Modern telecommunication networks strongly depend on the stable operation of remote communication nodes, such as base stations, repeaters, and data transmission points. Continuous power supply for these objects is provided by rechargeable batteries, which work in charge and discharge cycles and gradually lose their capacity over time.

Unexpected battery failure can cause emergency shutdowns, loss of communication, and additional maintenance costs. Therefore, it is important to develop intelligent battery monitoring systems with the ability to remotely control parameters in real time.

The aim of this research is to create a battery monitoring system based on a microcontroller (ESP32 or STM32). The system measures voltage, current, and temperature in real time and sends the data to a server for processing. The main tasks are to improve measurement accuracy, ensure energy efficiency, and create a reliable data transmission channel.

The proposed system uses Hall-effect current sensors for contactless measurement of charge and discharge current, as well as voltage dividers to monitor battery voltage. Temperature control is implemented using digital or analog sensors, which helps to consider the effect of temperature on internal battery processes.

Data is collected using the built-in analog-to-digital converter (ADC) of the microcontroller, which converts signals into digital values for further processing. To reduce measurement errors, calibration algorithms and software filtering methods are used, such as moving average and low-pass filters.

Data transmission is carried out through wireless communication channels such as LoRaWAN or GSM, depending on the location of the node. Communication with the server is implemented using MQTT and HTTP protocols. To ensure data integrity in unstable network conditions, local buffering and delayed data transmission mechanisms are used.

The system continuously collects and stores data about voltage, current, and temperature, and then analyzes changes during charge and discharge cycles. This allows estimation of battery degradation, detection of deviations from normal characteristics, and prediction of remaining battery life using statistical models.

An important feature of the system is automated control of critical battery operating modes. Measured parameters are constantly compared with predefined threshold values. If the voltage exceeds the allowed level, an overcharge condition is detected, which can damage the battery. If the voltage drops below a critical level, the system identifies a risk of capacity loss. Temperature monitoring helps detect overheating, which affects internal resistance and battery stability.

The system also provides real-time alerts that can be sent to a server or directly to technical staff via wireless communication. Notifications can be delivered as push messages, SMS, or other formats in specialized monitoring services. This approach helps reduce the risk of failures and ensures quick response to emergency situations.

As a result, the developed system can operate in remote communication nodes and provide continuous battery monitoring. Its implementation improves the reliability of

telecommunication infrastructure, reduces maintenance costs, and optimizes the operation of power systems.

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