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The Role of Battery Monitoring Systems in Ensuring the Safety and Durability of Industrial Equipment

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Abstract— *Battery monitoring systems play a key role in ensuring the safety and durability of industrial equipment. This study aims to analyze the effectiveness of such systems in industrial operations. The methodology includes the study of temperature, voltage, and resistance of batteries using specialized sensors and controllers, which allows you to monitor the condition and predict possible malfunctions. The results show that the use of these systems significantly reduces the risk of accidents and increases battery life, thanks to accurate monitoring and timely replacement of worn elements. In conclusion, it can be noted that the introduction of battery monitoring systems improves the reliability of equipment and economic efficiency at industrial facilities*

Keywords— *Monitoring systems, batteries, industrial equipment, safety, durability, sensors, temperature control, economic efficiency*.

I. Introduction

Battery monitoring systems are a crucial component of modern industrial infrastructure, ensuring uninterrupted operation and safety of equipment across various facilities. With the rise of automation and the integration of Internet of Things (IoT) technologies, the role of batteries used for backup power and system control is becoming increasingly significant. The reliability of these batteries directly impacts the stability of operations in critical industries such as energy, telecommunications, transportation, and other essential sectors.

The relevance of researching battery monitoring systems is driven by the need to enhance their efficiency and lifespan, which is directly related to the economic and operational performance of enterprises. Implementing these technologies enables early fault detection, preventing emergencies and reducing risks associated with data loss, equipment downtime, and disruptions to production processes. This is particularly important in situations where any malfunction can lead to substantial financial losses and reputational damage.

The purpose of this study is to analyze and evaluate the effectiveness of battery monitoring systems in industrial environments, as well as to examine their impact on the safety and durability of equipment.

II. Materials and Methods

The reliable operation of a battery (hereinafter referred to as BAT) requires continuous monitoring of its condition. The Battery Management System (BMS) is integrated into the uninterruptible power supply and automatically disconnects the BAT in critical situations, preventing damage. These systems enable real-time monitoring of battery status, ensuring prompt detection of deviations from standard parameters and timely measures to prevent emergencies. The main monitoring parameters are shown in Figure 1 below. Thus, by monitoring key parameters, overheating, overcharging, and deep discharge can be prevented, which is essential for extending equipment lifespan and improving efficiency. Additionally, battery monitoring systems enable the accumulation of long-term data on battery conditions

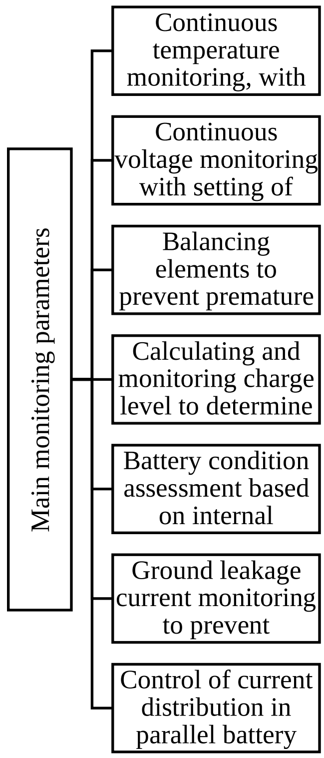

Fig. 1. Main monitoring parameters [1]

This aids in failure prediction and preventive maintenance planning, helping to minimize equipment downtime and reduce repair costs. As a result of implementing such systems, the safety of work processes and the operational reliability of industrial equipment improve, positively impacting overall production process efficiency [1].

The system functions to provide independent regulation and protection for each component within the BAT, extending their lifespan and ensuring operational safety [2]. For greater clarity, the main functions of these systems are shown in Figure 2.

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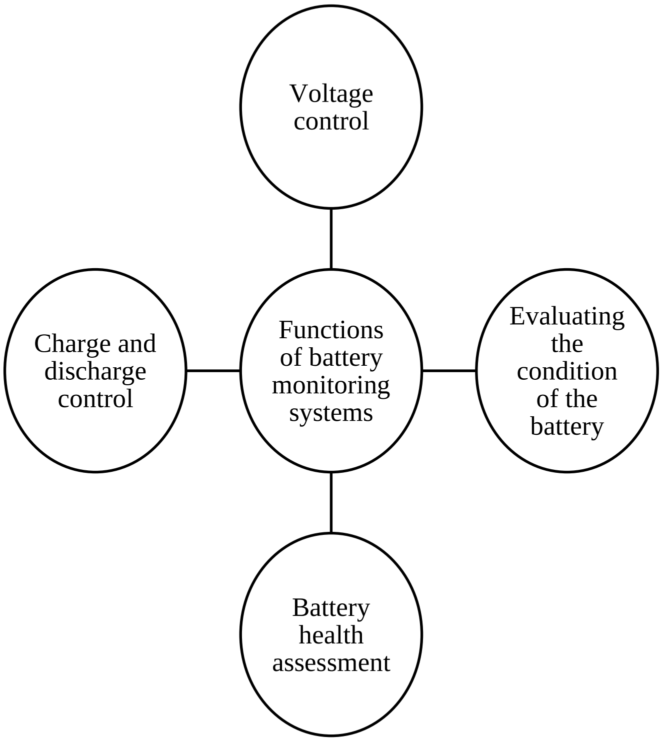

Fig.2. Functions of battery monitoring systems [3]

Currently, through collaboration between Eatron Technologies and Syntiant, an intelligent Battery Management System (BMS) based on artificial intelligence technologies has been developed, achieving a 10% increase in battery capacity and a 25% extension in battery life. This is achieved through high-precision tracking of the State of Health (SoH) and State of Charge (SoC), surpassing the capabilities of traditional BMS.

The NDP120 neural processor, developed by Syntiant, analyzes battery parameters in real-time, applying predictive diagnostics to detect potential faults at early stages. After analysis, the data is used to take measures aimed at preventing failures, optimizing performance, and enhancing battery system safety.

The NDP120 was designed for easy integration into existing BMS used in commercial and household devices. The AI-based BMS microchip, embedded in the battery, eliminates the need for cloud computing, enhancing operational reliability. This type of microchip is particularly beneficial in electric vehicles and electric vertical take-off and landing aircraft (eVTOL) as it extends flight range, improves battery life between charges, and reduces operational costs. The predictive function reduces the likelihood of battery failure in critical situations, which is especially important for small aviation.

Modern lithium-ion batteries typically withstand 500 to 1000 charge cycles before significant degradation begins. However, the use of AI BMS increases this figure to 625–1250 cycles. Eatron is showcasing its AI BMS chip system at The Battery Show Europe 2024, held in Stuttgart, Germany [4].

The intelligent Battery Management System (BMS) developed by Eatron Technologies and Syntiant enhances the safety and longevity of industrial equipment through several key factors.

Firstly, thanks to the NDP120 neural processor, the system monitors battery status in real-time using predictive diagnostic algorithms. This enables early detection of potential faults and deviations in battery performance, allowing timely corrective actions to prevent more serious issues. Such an approach significantly reduces the risk of equipment failures, especially in critical conditions where battery stability is a priority [5].

Secondly, by enhancing the accuracy of tracking the State of Health (SoH) and State of Charge (SoC), the AI BMS enables more efficient battery resource management, increasing capacity and extending battery lifespan. This allows industrial equipment to operate for longer periods between battery replacement cycles, reducing maintenance and operational costs. The extended battery life also contributes to reducing overall waste and increasing production sustainability [6].

In summary, AI BMS integrated into industrial equipment not only increases battery efficiency and lifespan but also minimizes failure risks, which is especially important under intensive use and in challenging or remote locations.

Table 1 below outlines the advantages and disadvantages of battery monitoring systems in ensuring the safety and durability of industrial equipment.

TABLE 1. Advantages and disadvantages of battery monitoring systems in ensuring the safety and durability of industrial equipment [7]

Category	Description
Advantages	
Increased safety	Monitoring systems promptly detect parameter deviations (overheating, gas leakage, excessive voltage), reducing accident risks.
Extended lifespan	Monitoring charge levels, temperature, and other indicators allows for timely maintenance, extending battery life.
Reduced maintenance costs	Early fault detection minimizes downtime and expenses for unscheduled repairs, improving economic efficiency.
Optimized equipment operation	Maintaining optimal battery conditions supports the stability and efficiency of the production process.
Disadvantages	
High implementation cost	Installing and configuring monitoring systems requires significant financial investment, especially when retrofitting existing facilities.
Integration complexity	Integrating systems into existing processes may be challenging due to equipment or software incompatibility, requiring additional resources.
Need for maintenance	Monitoring systems require regular maintenance and calibration, increasing personnel workload and operational costs.
Potential malfunctions and errors	Technical limitations of sensors or algorithms may lead to false alarms or missed critical deviations.

Thus, it can be concluded that the use of modern BMS systems contributes to improved production processes and enhanced equipment safety.

III. Results and Discussion

Battery monitoring systems play a key role in ensuring the safety and longevity of industrial equipment. With the intensive use of batteries in various sectors, such as energy, transportation, and manufacturing, continuous monitoring of their condition is essential to prevent failures and emergencies. Monitoring systems enable the tracking of crucial battery parameters, including voltage, temperature, charge level, and internal resistance, facilitating the timely detection of anomalies and potential malfunctions. This, in turn, minimizes the risks of fire or explosion, especially under conditions of high temperatures or overloads.

Moreover, the use of such systems extends battery lifespan and reduces operating costs. Continuous monitoring allows for the optimization of charging and discharging cycles, avoiding deep discharges and overvoltages that can significantly reduce battery life. Intelligent algorithms embedded in modern monitoring systems analyze data and recommend optimal operating strategies, which not only extend equipment life but also enhance energy efficiency. Thus, battery monitoring systems are a critical element in integrating modern technologies to improve the reliability and sustainability of industrial equipment [8].

In Ukraine, several industrial enterprises are already actively using battery monitoring systems to enhance the efficiency and reliability of their production processes. The following examples demonstrate how these systems impact operations and provide advantages in battery management.

ArcelorMittal Kryvyi Rih, the largest metallurgical complex in Ukraine, actively uses battery monitoring technologies to manage energy systems at its production sites. The implementation of specialized battery monitoring systems has allowed the company to reduce operating costs associated with battery maintenance on large-scale installations. The use of predictive analytics and remote monitoring has been a significant step in ensuring production continuity and reducing equipment downtime [9].

DTEK Energy, a coal mining and electricity production company, also actively uses battery monitoring systems to manage backup power sources at its facilities. In particular, the company's power plants are equipped with systems that monitor the condition of batteries used for emergency power supply. The intelligent BMS installed at DTEK sites provides not only battery condition monitoring and analysis but also failure prevention, which is especially crucial for facilities critically dependent on stable power supply [10].

Metinvest, the largest Ukrainian mining and metallurgical holding, has integrated battery monitoring systems to ensure stable power supply at its plants. As part of its energy infrastructure modernization programs, Metinvest utilizes AI-based solutions for battery diagnostics and failure prevention. This enables the company to maintain high levels of safety and reliability for critical equipment [11].

Battery monitoring systems play a key role in ensuring the safety and longevity of equipment at Ukrainian enterprises. The examples of companies demonstrate how effective use of such systems not only extends battery life but also minimizes the risks of accidents and failures. Implementing these solutions enables Ukrainian enterprises to improve the efficiency of their operations and reduce operating costs.

IV. Conclusion

The study showed that battery monitoring systems play a crucial role in ensuring the safety and longevity of industrial equipment. Analysis results demonstrated that implementing such systems significantly reduces the risk of emergencies by continuously monitoring key battery parameters, such as temperature, voltage, and internal resistance. The use of specialized sensors and automated control systems enables timely fault detection, preventing equipment failures and minimizing economic losses.

It was also found that battery monitoring systems increase battery lifespan and production efficiency by optimizing maintenance and planning battery replacements based on their current condition. This contributes to reducing operational costs and improving overall infrastructure reliability. Future advancements in IoT-based technologies and predictive analytics will further enhance monitoring systems, providing more accurate forecasting and automation of battery management processes.

Thus, the research objectives have been achieved, confirming the importance and potential of using battery monitoring systems to improve the safety and durability of industrial equipment.

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