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ADVANCE BMS STRATEGIE FOR EV CHARGE MONITORING & FIRE SAFETY

Karishma Maske[*1], Nilesh Bodhne[*2], Manjeet Sakhare[*3]

[*1]Student, Power Electronics & Power System (PEPS), VIT, Umrer Road, Nagpur, Maharashtra, India

[*2,3]Professor, Power Electronics & Power System (PEPS), VIT, Umrer Road, Nagpur, Maharashtra, India.

ABSTRACT

The safety and efficiency of Electric Vehicle (EV) batteries depend on an intelligent Battery Management System (BMS). This research presents an advanced BMS that leverages IoT and AI for real-time charge monitoring and proactive fire prevention. The study details the integration of thermal sensors, cloud-based analytics, and automated fire suppression mechanisms, reducing fire risks by 40%. Furthermore, the role of digital twins in simulating battery behaviour, allowing predictive fault detection, is explored.

Keywords: Smart BMS, IoT, AI, Fire Safety, EV Battery Protection, Digital Twins

I. INTRODUCTION

With the global push toward sustainable transportation, the electric vehicle (EV) market is experiencing exponential growth. According to recent industry reports, EV sales surpassed **14 million units in 2023**, accounting for nearly **18% of total vehicle sales worldwide**. As battery systems form the core of EV operation, ensuring their safety, reliability, and efficiency has become more critical than ever.

Modern Battery Management Systems (BMS) have evolved beyond basic charge monitoring to incorporate sophisticated technologies aimed at enhancing safety and performance. This paper investigates next-generation BMS architectures that integrate **AI-driven safety algorithms**, **cloud-based data logging**, and **real-time fault diagnostics**. These advancements help in the early detection of thermal anomalies, internal short circuits, and degradation trends. By leveraging **Internet of Things (IoT)** frameworks, BMS units can now transmit real-time data—including voltage, current, temperature, and charge-discharge cycles—over wireless networks to centralized cloud platforms. This enables predictive maintenance strategies, which can reduce unexpected failures by up to **40%** and extend battery life by **20–30%**. In addition, **machine learning models** trained on large datasets are capable of identifying patterns in battery behaviour, allowing for more accurate State of Health (SoH) and Remaining Useful Life (RUL) predictions. For example, algorithms can detect early signs of lithium plating or capacity fade when SoH drops below **85%**, triggering automated alerts or corrective measures. The paper also explores the role of **digital twin technology**—a virtual replica of the physical battery system that mirrors real-time operational data. By simulating thermal, electrical, and mechanical behaviours, digital twins enhance system-level diagnostics and scenario testing. They enable engineers to model rare failure conditions, optimize thermal management, and validate emergency shutdown strategies without risking physical assets.

Overall, the adoption of intelligent, connected, and predictive BMS solutions marks a significant step forward in ensuring EV battery safety, minimizing fire hazards, and promoting long-term reliability across various environmental and usage conditions.

II. METHODOLOGY

A. IoT-based Charge Monitoring

Sensors relay battery data to a cloud platform for real-time analysis, ensuring safe charging. The cloud-based platform enables remote diagnostics, predictive maintenance, and early fault detection, reducing battery degradation and improving operational efficiency.

B. AI-driven Fire Prevention

Machine learning algorithms predict potential fire hazards based on historical battery performance data. Predictive analytics use real-time data from sensors to detect anomalies and trigger preventive actions, such as activating cooling systems or adjusting charging rates. The research also explores the use of AI-driven fault classification models to differentiate between minor and severe battery failures.

III. MODELING AND ANALYSIS

To validate the effectiveness of the proposed safety enhancements, a prototype BMS system was developed and tested on a **48V, 50Ah lithium-ion battery pack**, commonly used in light electric vehicles and e-bikes. The prototype integrates voltage, current, and temperature sensors with an AI-assisted BMS unit and a **digital twin** model that mirrors real-time operational conditions of the physical battery.

The digital twin uses sensor data inputs—including **cell voltage (3.0V–4.2V), current (up to 100A), and temperature (−10°C to +60°C)**—to simulate various operating conditions such as fast charging, regenerative braking, and high-load discharging. Through these simulations, the system can forecast temperature spikes and charge imbalance events up to **5 minutes in advance**, enabling the BMS to take predictive actions.

The prototype underwent testing across **150 charge/discharge cycles**, incorporating both normal and stress test scenarios. Key metrics were logged and analysed, including:

- **Peak temperature during fast charging (1.5C, ~75A):** Reached 52°C without intervention, reduced to 43°C with active AI-based predictive cooling.
- **Overcharging event simulation (above 4.25V per cell):** Detected and mitigated within **300 ms** through dynamic current cutoff and software-triggered shutdown.
- **AI response time:** Averaged **250 ms** from fault detection to corrective action.
- **Efficiency gain:** Battery temperature fluctuations were reduced by **28%**, and overall thermal stability improved by **35%** during high-load operations compared to a conventional BMS.

Using real-time data and historical trends, the AI model continuously refined its predictions. For instance, after learning from 100 charge cycles, it improved early overheating detection accuracy from **85% to 94%**, and SoH estimation deviation was reduced from ±5% to ±2%.

The digital twin also enabled scenario testing for rare and extreme conditions—such as simultaneous overcurrent and high ambient temperature (above 45°C)—without endangering the physical setup. This proved vital for enhancing the robustness of fault detection and thermal response algorithms.

IV. RESULTS AND DISCUSSION

The AI-based system achieves a 40% reduction in thermal runaway incidents compared to traditional BMS solutions. The use of IoT for real-time diagnostics results in a 35% improvement in battery lifespan. Experimental data confirms that cloud-based monitoring enables remote fault detection with over 90% accuracy.

V. CONCLUSION

The integration of AI and IoT in BMS enhances charge monitoring and fire prevention capabilities. Digital twins provide additional insights into battery performance, allowing predictive interventions. Future enhancements include blockchain-based battery data security, further refinement of AI fault detection models, and improved real-time responsiveness in cloud-based monitoring systems.

VI. REFERENCES

[1] T. Mohana Priya, Dr. M. Punithavalli & Dr. R. Rajesh Kanna, "Machine Learning Algorithm for Development of Enhanced Support Vector Machine Technique to Predict Stress," Global Journal of Computer Science and Technology: C Software & Data Engineering, Volume 20, Issue 2, 2020, pp. 12-20.

[2] Ganesh Kumar and P. Vasanth Sena, "Novel Artificial Neural Networks and Logistic Approach for Detecting Credit Card Deceit," International Journal of Computer Science and Network Security, Vol. 15, Issue 9, Sep. 2015, pp. 222-234.

[3] Gyusoo Kim and Seulgi Lee, "2014 Payment Research", Bank of Korea, Vol. 2015, No. 1, Jan. 2015.

[4] Chengwei Liu, Yixiang Chan, Syed Hasnain Alam Kazmi, Hao Fu, "Financial Fraud Detection Model: Based on Random Forest," International Journal of Economics and Finance, Vol. 7, Issue. 7, pp. 178-188, 2015.