Enhanced Battery Management : Thermal Propagation Protection Strategies

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Abstract - *Battery management and thermal propagation protection are critical aspects in the development of robust and reliable energy storage systems. As the demand for efficient and high-performance batteries continues to grow across various industries, the need for advanced strategies to enhance battery management and mitigate thermal propagation risks becomes increasingly paramount. In recent years, battery technology has advanced revolutionized numerous sectors, including electric vehicles, renewable energy storage, and portable electronic .But these developments also present a challenge in terms of managing the complex interplay between performance optimization and safety concerns, particularly regarding thermal issues. Thermal propagation is the quick dispersion of heat in a battery, poses a serious threat to its integrity and overall safety.This involves the integration of sophisticated control algorithms and monitoring systems that actively regulate charging, discharging, and overall battery health. A pivotal aspect of this strategy is the incorporation of thermal propagation protection mechanisms. .This introduction sets the stage for a deeper exploration of the key components and methodologies employed in enhanced battery management with a focus on thermal propagation protection.*

Keywords : Thermal Propagation Protection, Battery Management System, Thermal Management, Energy Storage System, State of Charge

1. INTRODUCTION

[1] Paper 1, Explores a dual functionality battery thermal design. The authors investigate a novel approach to delay battery thermal runaway propagation time, emphasizing the integration of phase change material and pyro block lining. [2] The authors delved into the intricacies of this field, providing insights into crucial aspects of electric vehicle technology. Their work serves as a foundational resource for understanding and developing effective strategies in battery thermal management. [3] The intricate interplay between electrochemical processes and thermal behavior, aiming to enhance battery performance and safety. The paper delves into the complexities of battery temperature regulation, presenting a comprehensive analysis that contributes to advancements in battery technology.[4] challenges and insights related to thermal safety in lithium-ion batteries. The authors delve into current issues surrounding thermal management and provide perspectives on enhancing safety measures. The study contributes valuable insights to the ongoing discourse on battery safety, a critical aspect of advancing energy storage technologies. [5] comprehensive methodology for designing Battery Management Systems (BMS) with a focus on functional safety in automotive lithium-based batteries. They explore key aspects such as reliability, fault detection, and mitigation strategies, contributing valuable insights to the field of electric vehicle safety. [6] existing safety strategies, emphasizing the paramount importance of addressing safety concerns in the rapidly evolving field of energy storage. [7] enhance safety measures, aiming to mitigate the risks associated with thermal runaway events. The results illuminated the possibilities of these interstitial materials in suppressing and controlling thermal propagation within battery modules, contributing valuable insights to the field of battery safety. [8] Prior research has focused on identifying overcharge-induced risks, such as thermal instability and potential fire hazards. have explored various methodologies for predicting and preventing thermal runaway in lithium-ion batteries. [9] Prior research has focused on identifying overcharge-induced risks, such as thermal instability and potential fire hazards. have explored various methodologies for predicting and preventing thermal runaway in lithium-ion batteries.
[10] Explore the critical domain of thermal runaway warning in lithium iron phosphate batteries used for energy storage. Focusing on a safety management system, the authors present insights and methodologies to address the inherent risks associated with these batteries. [11] The integration of temperature monitoring and fire protection mechanisms is pivotal for ensuring the safety and optimal performance of electric vehicle batteries. This study adds valuable insights to the ongoing research in the field, emphasizing the significance of advanced BMS features for the efficient and secure operation of electric vehicles. [12] The authors meticulously explore various dimensions of BMS, offering

insights into its functionalities, challenges, and advancements. The comprehensive overview and developments in BMS technology, shedding light on its role in enhancing the performance, efficiency, and lifespan of electric vehicle batteries.

2. METHODOLOGY

A. System architecture and design

The enhanced battery management system integrates advanced thermal monitoring and control mechanisms. The core components include temperature sensors, a Micro controller. Sure, designing a Battery Management System (BMS) for thermal propagation protection involves several key components:

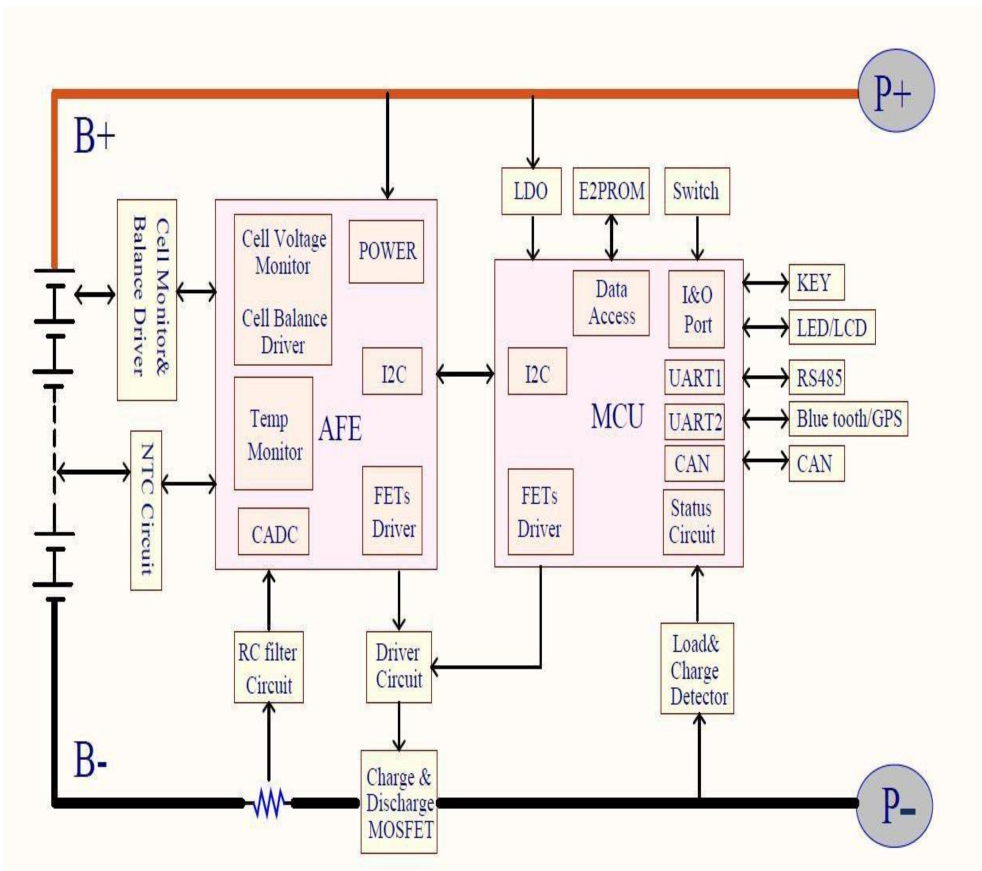

Fig.-1: System Architecture of Enhanced battery management system for thermal Propagation protection strategy

1. Temperature Sensors:-

Integrate temperature sensors (NTC) within the battery pack to monitor individual cell temperatures.

- Use high-precision sensors to ensure accurate Temperature.
- Use high-precision sensors to ensure accurate temperature readings.

2. Control Unit :

-Implement a central control unit responsible for processing temperature data.

- Utilize a microcontroller or FPGA to manage real-time decisions.

3. Communication Interface:

- Establish a communication interface (e.g., CAN bus) to facilitate data exchange between the BMS and external devices.

- Enable remote monitoring and control capabilities.

4. Voltage Monitoring:

- Include voltage monitoring circuitry to track individual cell voltages.

- Implement algorithms to detect overvoltage and under voltage conditions.

- Provide diagnostic information to facilitate troubleshooting..

5. Current Monitoring:

- Integrate current monitoring circuitry to measure charging and discharging currents.

- Implement safeguards to prevent overcurrent situations.

6. State of Charge (SOC) Estimation:

- Develop algorithms for accurate SOC estimation based on voltage, current, and temperature data.

- Use sophisticated models to account for battery aging and temperature effects on SOC.

7. Safety Disconnect:

- Include a safety disconnect mechanism to isolate the battery from the system in case of critical faults.

- Ensure fail-safe designs to prevent unintended disconnects.

8. Energy Balancing:

- Implement energy balancing circuits to equalize charge/discharge among individual cells. - Enhance overall pack performance and longevity.

9. Software Architecture:

- Develop robust and modular software architecture for the BMS.

- Include failover mechanisms and error handling to enhance system reliability.

10. User Interface:

-Provide a user interface for monitoring system parameters and receiving alerts.

11. Redundancy:

-Incorporate redundancy in critical components for increased reliability.

- Implement backup systems to handle failures gracefully.

12. Documentation:

- Maintain comprehensive documentation covering system architecture, design rationale, and operational guidelines.

13. Thermal Management:

- Implement a thermal management system to regulate the battery temperature.

- Include cooling systems (e.g., fans, liquid cooling) activated based on temperature readings.

14. Fault Detection and Diagnostics:

- Integrate fault detection mechanisms to identify and isolate malfunctioning cells.

15. Compliance and Standards:

- Ensure compliance with relevant safety standards and

- Ensure compliance with relevant safety standards and regulations for battery systems.

- Conduct thorough testing and validation to meet industry

requirements.

16. Redundancy :

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3. RESULT DISCUSSION

This comprehensive approach aims to create a BMS that

effectively monitors, manages, and protects a battery pack from thermal propagation and related safety issues.

Material Required:

1. Heating Coil/Filament.
2. DC Power Supply.
3. Data Logger.
4. Thermocouples.
5. CAN Tool for Communication with the Battery.
6. Battery Module/Pack Prepared for the thermal Propagation test.

Step – 1 Prepare the Module or Battery Pack for the test.

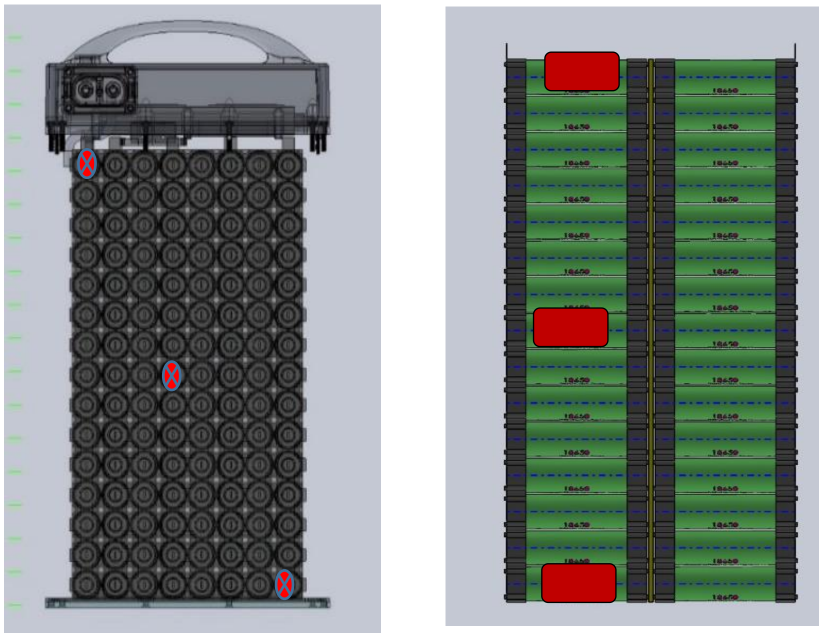

Fig – 2: Targeted Cell Top Corner, Center and Bottom Corner

Step – 2 Prepare Test Setup

Connect the Power supply to the coil terminals and write the program for 100W power. supply in the IT 9000 Application. Voltage = 25 V, A = 4.0A for 10 mins.

Connect the BMS to the PC Master with the CAN tool. Verify the Can Communication established or not

.Once CAN Communicated it display all the BMS data as show below.

Fig -3 : Bi-directional Power Supply delivering > 100W Power

Step – 3 Pre-test requirements/verification

Battery pack fully charged > 90 %.

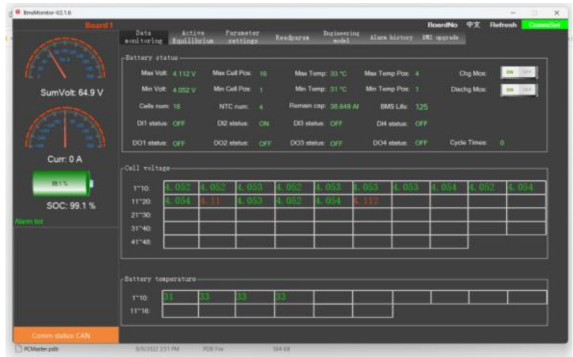

Fig – 4 : BMS data observation in PC master

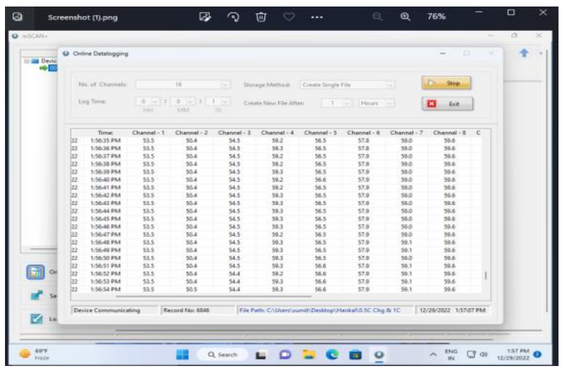

Fig - 5 : Thermocouples temperatures in the datalogger application

Step – 4 Test Procedure

A. Run the power supply program of 100W power to the coil

Fig – 6 : Power supply program of 100W power to the coil

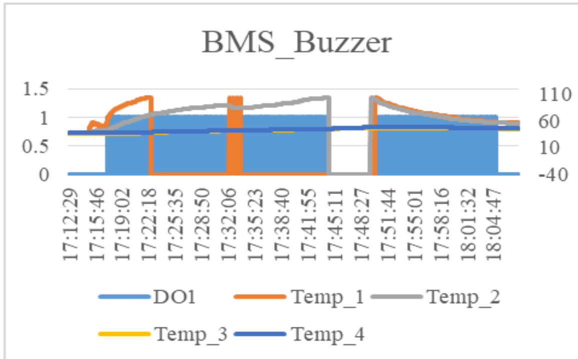

Fig –7: Buzzer performance graph

B. BMS Buzzer Should perform as per the below logic:

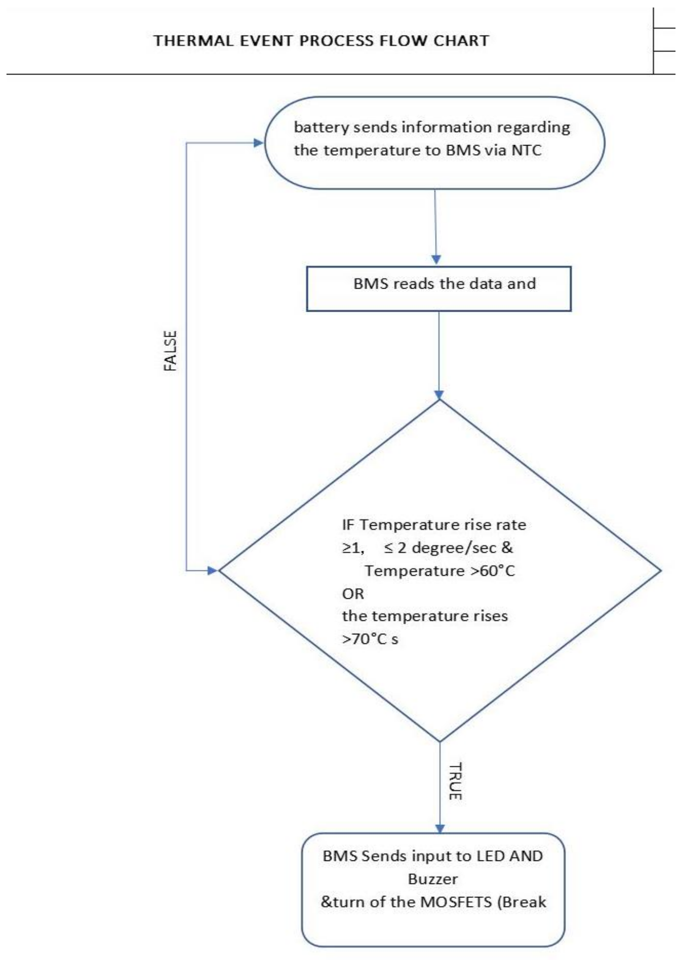

Fig – 8 : BMS alarm buzzer logic with thermal event process flow

4. CONCLUSIONS

The implementation of an enhanced Battery Management System (BMS) incorporating MOSFET-based isolation for load connection proves to be a crucial advancement in ensuring the safety and reliability of battery systems. The MOSFET-based isolation effectively isolates the load from the battery during thermal runway tests, mitigating the risk of thermal runaway propagation and potential catastrophic failures.BMS performed as per buzzer alarm logic, buzzer clearly audible. Alarm are visible on the PC Master screen through CAN Communication and LED also indicate . Through comprehensive analysis and simulation, this test has provided valuable insights into the thermal behavior of batteries under diverse conditions. The integration of advanced protection mechanisms enhances the overall resilience of batteries, safeguarding against thermal propagation and potential cascading failures. This comprehensive approach aligns with the industry's continuous efforts to address safety concerns, fostering the development of more robust and dependable energy storage solutions.

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