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Battery Thermal Management System

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ABSTRACT: A Battery Thermal Management System (BTMS) is essential for ensuring the safe and efficient operation of lithium-ion battery packs, particularly in high-performance and high-energy applications. This project presents the design of a BTMS for a 12V lithium-ion battery pack, consisting of multiple 3.7V cells. The system incorporates a Battery Management System (BMS) for balanced charging, real-time monitoring, and protection against overcharging and high-current discharges. Thermal management is achieved using temperature sensors and an automated cooling mechanism, which activates a water circulation system when the battery temperature exceeds a predefined threshold. An LCD display provides real-time feedback on critical parameters such as temperature, voltage, and current, ensuring comprehensive monitoring and control. The BTMS enhances battery safety, extend lifespan, and ensures optimal performance under demanding conditions. Its applications span electric vehicles, renewable energy storage, portable electronics, and industrial systems, making it a essential technology for modern energy solutions.

KEYWORDS: Electric Vehicles, Lithium-Ion Battery, Battery Management System (BMS), Battery Thermal Management System (BTMS), Temperature Sensor, Cooling System, Microcontroller, Thermal Runaway.

I. INTRODUCTION

The shift toward electric vehicles marks a significant milestone in the pursuit of sustainable transportation, driven by the growing urgency to cut greenhouse gas emissions and reduce dependence on fossil fuels. At the heart of this transition is battery technology—particularly lithium-ion batteries which are favored for their high energy density, reliability, and performance. As electric mobility becomes more widespread, the role of Battery Management Systems (BMS) grows increasingly important. These systems safeguard the battery by overseeing its state of charge, regulating charge and discharge cycles, and ensuring balanced voltage across individual cells. Among the many factors that influence battery health, operating temperature stands out as a critical variable. Thermal fluctuations not only degrade performance but, if unmanaged, can lead to serious safety hazards like thermal runaway—a rapid and uncontrollable rise in temperature that may result in fires or explosions.

Therefore, efficient heat regulation is essential for maintaining battery stability, longevity, and safety in real-world applications. To address these thermal challenges, this project proposes a smart Battery Thermal Management System (BTMS) that incorporates real-time monitoring and adaptive cooling control. By integrating digital temperature sensors with a microcontroller-based logic system, the BTMS continuously assesses the battery's thermal profile and triggers active cooling whenever necessary. This approach aims to enhance battery efficiency, extend operational life, and ensure safe performance under varying load and environmental conditions.

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II. METHODOLOGY

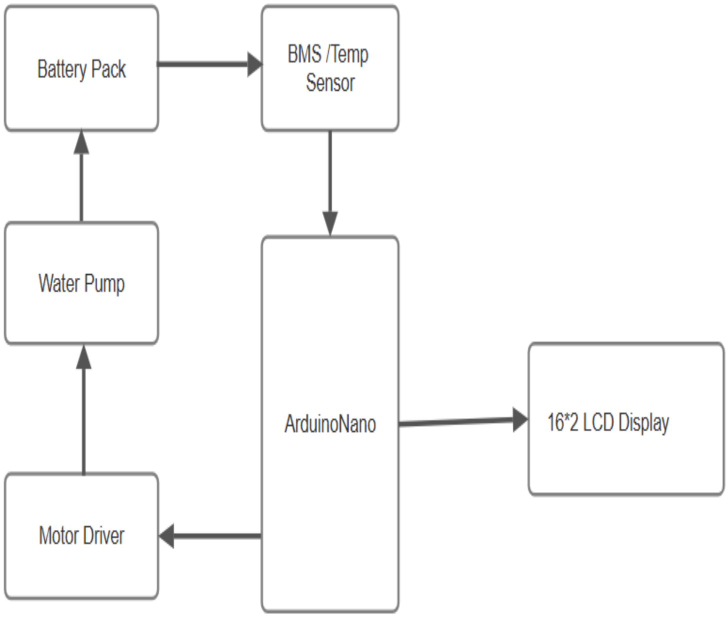

fig 1, is the block diagram of the system

The project focuses on designing a complete thermal management solution for a lithium-ion battery pack. The battery pack consists of 12 cells arranged in a 6S2P configuration, delivering an output of 24V and 4000mAh capacity. A Battery Management System (BMS) is integrated to monitor voltage, temperature, and ensure balanced charging. Temperature sensors are attached directly to the battery pack to detect any rise in temperature during operation. A microcontroller, specifically an Arduino Nano, receives temperature data and processes it to determine whether cooling is needed. If the temperature exceeds the set threshold, the controller activates a relay that powers a water pump. This pump circulates coolant around the battery pack to dissipate heat. Real-time status updates such as temperature, voltage, and cooler activity are displayed on a 16x2 LCD screen. The complete setup includes relay control, pump motor integration, and feedback monitoring, ensuring responsive and efficient thermal regulation.

The system starts by drawing power from the battery pack, which consists of a series of lithium-ion cells. The temperature and voltage of the battery pack are crucial factors to monitor for efficient thermal management. A temperature sensor or Battery Management System module continuously monitors the thermal state of the battery pack. It records important parameters to detect any abnormalities. The control unit receives data from the temperature sensor or BMS module. Based on predefined thresholds or conditions, it decides whether to activate the cooling device or issue a warning. If the control unit detects that the battery temperature exceeds safe operating limits, it activates the cooling device. The cooling device works to reduce the battery temperature, maintaining optimal performance and extending battery life. The display shows real-time data. Once the cooling device reduces the battery temperature to a safe range, the BMS module or temperature sensor continues monitoring, creating a feedback loop for continuous thermal management.

III. RESULT AND DISCUSSION

The final implementation of the project achieved all intended functionalities. The assembled lithium-ion battery pack delivered a stable 24V output with 4000mAh capacity. The BMS successfully monitored voltage and temperature conditions, ensuring safe operation and cell balancing. Temperature sensors provided accurate thermal readings, which were processed by the Arduino controller. Once the battery temperature exceeded safe limits, the system automatically activated the cooling pump through a relay. The pump operated until the temperature dropped to a safe range. A 16x2 LCD displayed real-time data including current voltage, battery temperature, and cooling system status (ON/OFF). The entire system operated efficiently and proved reliable under test conditions, validating the effectiveness of the thermal management strategy in maintaining battery health and safety.

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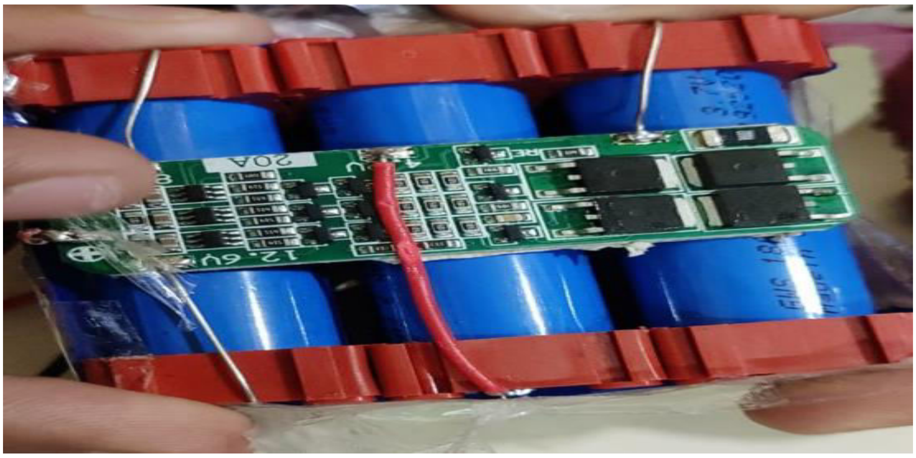

Fig. 2 Battery pack with BMS

In the fig 2, complete battery pack is connected to the BMS (Battery Management Syaytem)

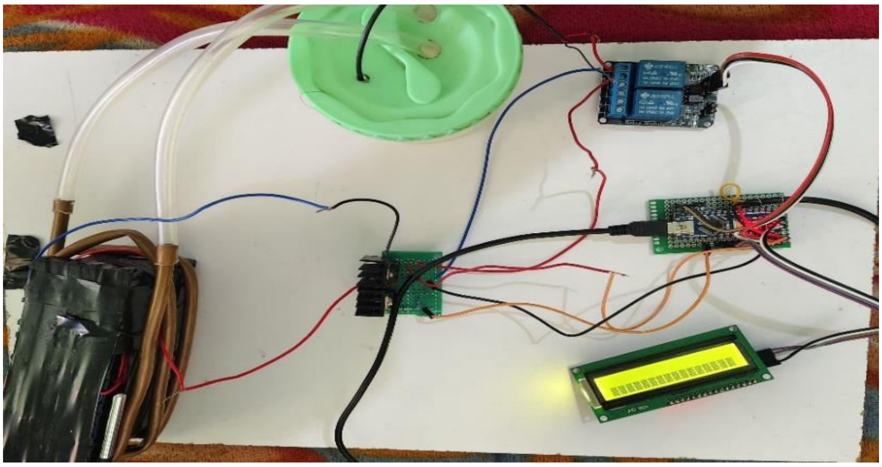

Fig. 3 project process

In the fig 3, complete connection of project and working

Fig .4 Display of the output

In Fig 4, Display the project output through LCD Display

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IV. CONCLUSION

The project successfully achieved the design and implementation of a lithium-ion battery thermal management system using a water-based cooling approach. A 12-cell battery pack configured in a 6S2P layout was constructed, delivering a 24V output with a capacity of 4000mAh. The battery pack was integrated with a Battery Management System (BMS) to monitor voltage, current, and temperature while providing essential protections like overcharge, deep discharge, and cell balancing. Temperature sensors were effectively installed to gather real-time thermal data, which was processed by an Arduino Nano microcontroller. The system was programmed to automatically activate a water pump via a relay when the temperature exceeded the threshold, ensuring safe battery operation. A 16x2 LCD display provided live updates on battery temperature, cooling system status, and alerts, improving system transparency and usability.

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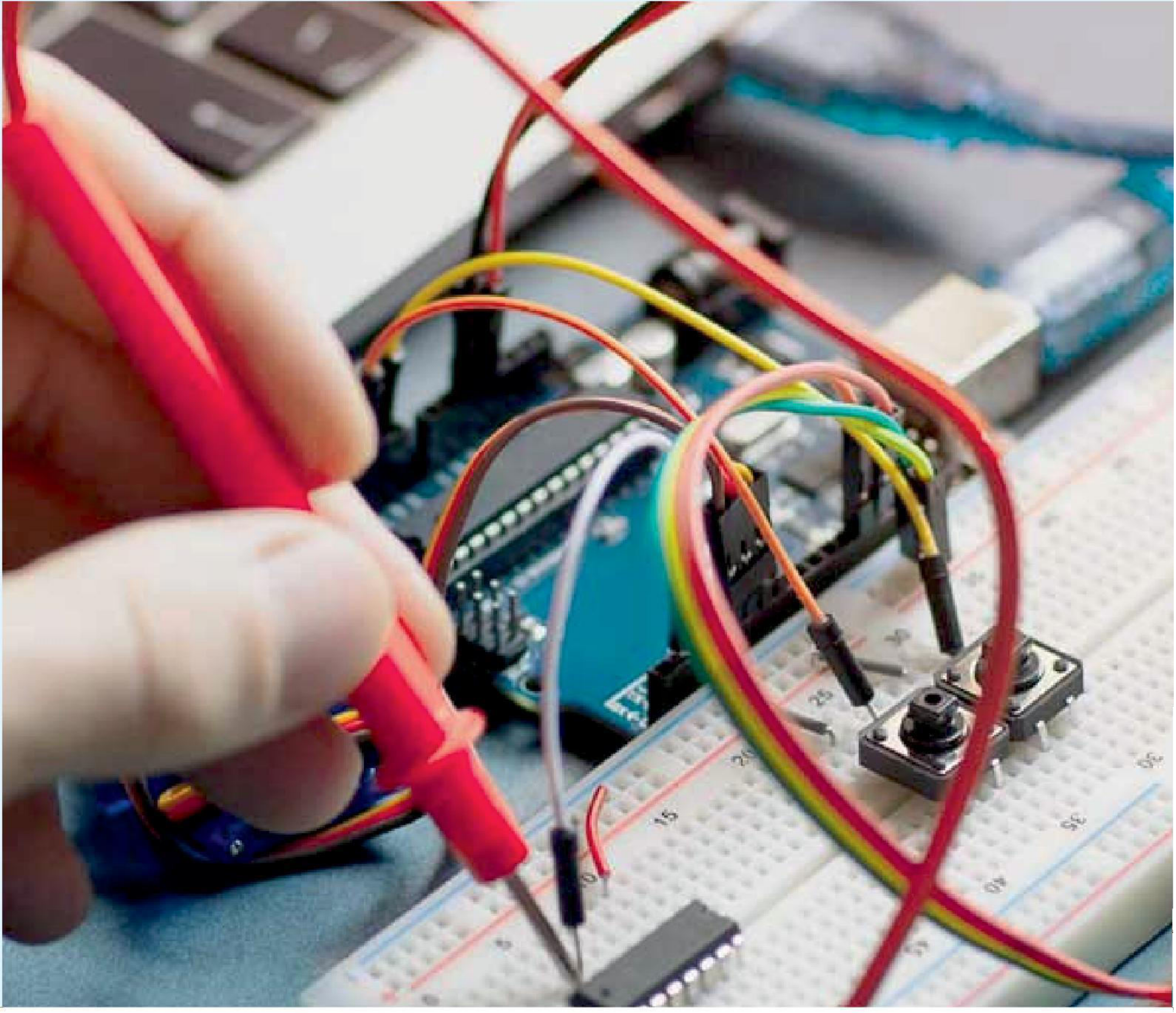

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