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Department of Electronics and Communication Engineering

PROJECT PROPOSAL

for

IEEE Madras Section Student Project Funding (SPF 2022-23)

Title: Battery Management System with Active Balancing

GUIDED BY: Dr. S. Sasikala
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Member (IEEE Computer Society)
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Member IEEE Signal Processing Society,
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IEEE Madras Section Student Project Funding (SPF 2022-23)
STUDENT PROJECT PROPOSAL

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g. Project Details	: Details Attached

CERTIFICATE

This is to certify that **Premkumaar M, Arjun G, Sakthivel P S, Sivasankari T** are bonafide 3rd year UG students. It is also certified that final project report along with utilization certificate signed by the Project guide & Principal will be sent to the IEEE Madras Section in the *.doc format through e-mail.

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1. Abstract:

As the world moves towards a sustainable future, the demand for electric vehicles is increasing rapidly. However, the lack of a universal battery management system is hindering the growth of these industries. This project aims to develop a universal BMS that can be used in both EVs and renewable energy storage systems. The main objectives of the project are to design and develop a BMS that can accurately monitor and control battery performance, provide real-time data on battery health and usage, and optimize battery life and performance. The BMS should also be scalable and adaptable to different battery chemistries, sizes, and configurations. The project will involve a combination of simulation, modelling, and experimental testing. The team will first develop a simulation model to optimize the BMS design and performance. The BMS hardware and software will then be designed and prototyped, followed by experimental testing in both EVs and renewable energy storage systems. The project aims to deliver a universal BMS that can be used in a wide range of applications, including EVs. The BMS should be able to accurately monitor and control battery performance, provide real-time data on battery health and usage, and optimize battery life and performance. The project will also contribute to the growth of the EV and renewable energy industries by enabling the development of more efficient and reliable battery systems. The development of a universal BMS has the potential to revolutionize the EV and renewable energy industries by enabling the development of more efficient and reliable battery systems. The BMS will also contribute to reducing the cost and increasing the safety of these systems, making them more accessible to the general public. The project will help position our organization as a leader in the field of battery management systems for sustainable energy applications.

Keywords: *Battery Management system – Active balancing – Energy converter – State of Charge (SoC) – State of Health (SoH) – Electric Vehicle – Renewable energy storage system*

2. Introduction:

According to a survey by IEA (International Energy Agency), there were more than 10 million cars on the world's roads and by 2030 the global EV fleet is expected to reach 230 million vehicles. This level of increase in EV count also results in several EV accidents worldwide, worryingly most of them end in a tragic manner. For example, about 35,000 to 40,000 vehicle fires are registered in Germany each year, of which nearly half are due to short circuits. Other main reasons for EV accidents are improper cell monitoring and balancing, thermal management, no proper power optimization etc. EVs also play a key role in the domain of fossil fuel depletion [4]. Due to the increase in the number of EVs, fossil fuel depletion has also been reduced. EVs are the key to eliminating 16% of man-made CO2 emissions, but adoption of EV remains as a future task among public due to reliability concerns such as dying mid-trip, battery fire and for some people EV could never match performance of sporty vehicle, etc. Another major problem faced in EV batteries is increasing of temperature which causes thermal runaway which could be reduced by cell balancing techniques which could reduce the overall battery temperature. The reliability and performance of EVs and energy storage systems are highly dependent on battery and its management system. With the technological development in battery system, it is possible to address and solve the worries of public and manufacturers and thus need for robust BMS for robust Batteries.

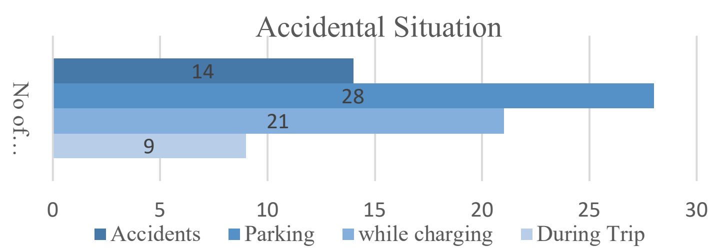

Fig.1. Number of Accidents in EV and their situation

Battery management systems (BMS) are critical components of modern batteries used in electric vehicles (EVs), renewable energy storage systems, and other applications. A BMS is responsible for monitoring and controlling various aspects of battery performance, including state of charge (SOC), state of health (SOH), temperature, and voltage. The earliest battery management systems were simple voltage and temperature sensors that monitored battery performance and alerted users to potential problems. However, as battery technology has advanced, so too have battery management systems. Today's battery management systems use sophisticated algorithms and software to optimize battery performance, prevent damage, and extend battery life.

3. Objective:

The objectives of the study are:

- To protect and operate lithium batteries for EVs in optimal conditions.
- To enable data acquisition of batteries for continuous monitoring
- To extend battery mileage and life by implementing Active Balancing
- To implement converter-based Active Balancing

4. Literature Review:

a. International status:

The global status of battery management development for electric vehicles (EVs) is rapidly evolving, with significant advancements being made in recent years. Here are some key developments and references in this area: The International Energy Agency (IEA) has identified battery storage as a key technology for the transition to a low-carbon energy system. The IEA's Global EV Outlook 2021 report states that the battery electric vehicle (BEV) market is growing rapidly, with over 3 million new BEVs registered in 2020, bringing the total global BEV stock to over 10 million [1]. This growth has spurred innovation in battery management technologies to improve performance, safety, and longevity [1]. One key area of innovation is the development of artificial intelligence (AI) and machine learning (ML) algorithms for BMS. These algorithms can improve the accuracy of battery state-of-charge and state-of-health estimation, which helps to optimize battery usage and extend its life [2]. A study published in the journal Energy Conversion and Management in 2020 evaluated the performance of various AI and ML algorithms for BMS in EVs and concluded that they can significantly improve the accuracy and robustness of BMS [10]. Another area of innovation is the use of wireless technology for BMS. This allows for real-time monitoring and control of battery performance, which can improve safety and reliability [2]. A study published in the Journal of Power Sources in 2021 evaluated the performance of a wireless BMS for EVs and found that it can provide accurate and reliable monitoring and control of battery performance [3].

Researchers are also exploring the use of new materials and designs for batteries and BMS to improve performance and safety. For example, a study published in the journal Advanced Energy Materials in 2021 reported on the development of a new solid-state electrolyte for lithium-ion batteries, which could improve safety and increase energy density [4]. Another study published in the journal Nature Energy in 2020 reported on the development of a new BMS design that uses a neural network to predict battery performance and optimize charging and discharging. The global status of battery management development for EVs and RESS is dynamic and rapidly evolving, with significant advancements being made in AI and ML, wireless technology, new materials and designs, and other areas. These advancements are helping to improve the performance, safety, and reliability of these systems and are critical for the continued growth and adoption of EVs and renewable energy sources [5].

b. National status:

In India, the battery management development for electric vehicles (EVs) is gaining momentum as the country aims to transition to a low-carbon economy. Here are some key developments and initiatives in this area: The Government of India has launched several initiatives to promote the adoption of EVs and RESS, including the Faster Adoption and Manufacturing of Electric Vehicles (FAME) scheme and the National Electric Mobility Mission Plan (NEMMP) [6],[7]. These initiatives provide incentives and subsidies for EV and RESS manufacturers, which have helped to drive innovation and development in battery management technologies. Indian companies are also making significant strides in battery management development [8].

For example, Tata Motors has developed its own BMS for its EVs, which monitors battery performance and controls charging and discharging. Mahindra Electric, a subsidiary of Mahindra & Mahindra, has developed a BMS that uses artificial intelligence (AI) and machine learning (ML) algorithms to optimize battery performance and extend its life [2]. Indian research institutions are also contributing to battery management development through research and development projects. For example, the Indian Institute of Technology (IIT) Madras has developed a wireless BMS for EVs, which can provide real-time monitoring and control of battery performance. IIT Bombay has also developed a BMS that uses AI and ML algorithms to optimize battery performance and improve safety [10]. Indian startups are also making innovative contributions to battery management development. For example, Exicom Tele-Systems has developed a BMS for RESS that uses cloud-based technology to optimize battery performance and provide real-time monitoring and control. ReNew Power, an Indian renewable energy company, has partnered with battery manufacturer GS Yuasa to develop and manufacture lithium-ion batteries for RESS [11]. India is making significant strides in battery management development for EVs and RESS, with initiatives from the government, innovations from companies, and contributions from research institutions and startups [12]. These developments are helping to improve the performance, safety, and reliability of these systems and are critical for the continued growth and adoption of EVs and renewable energy sources in India [13].

5. Organization of work elements:

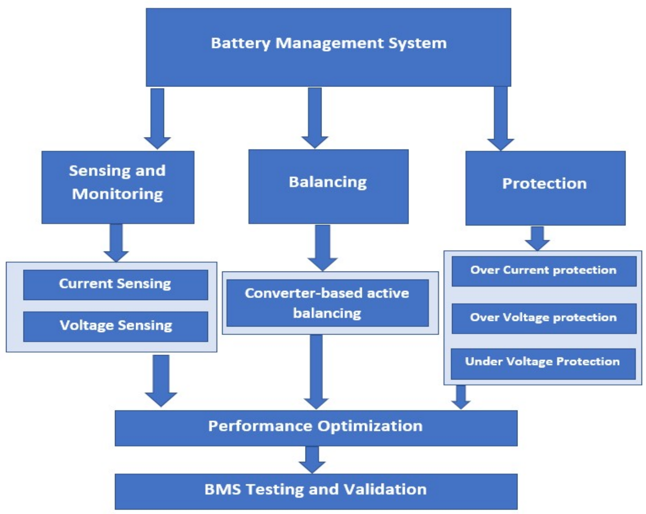

Fig.2. Organization of Work element

6. Methodology:

Our BMS is connected directly to each cell in a battery pack. The building blocks of our BMS are Analog Front End (AFE), Microcontroller Unit, Protection/Circuit breaker, Buck-Boost Converter based Active Cell Balancers, Communication modules (CAN), Data loggers (SD Card), Connectivity via Wi-Fi. The first function of BMS is to measure and monitor the parameters. Analog Front End (AFE) measures Voltage, Current, Temperature and isolates BMS from high voltage side. The cells are multiplexed with analog to digital converter, enabling voltage measurement of all cells using lesser number of components. The voltage is measured using Analog to Digital converters. Shunt based current sensing technique is used to measure current with maximum accuracy to estimate State of Charge (SOC) is the fuel gauge of battery and State Of Health (SOH), indicates the degradation of battery capacity with respect to original or rated cell capacity. Temperature is measured to ensure that battery is operated under safe condition (25° C – 45°C). The second step is to check if all the cells are operated in Safe Operating Area (SOA) of battery.

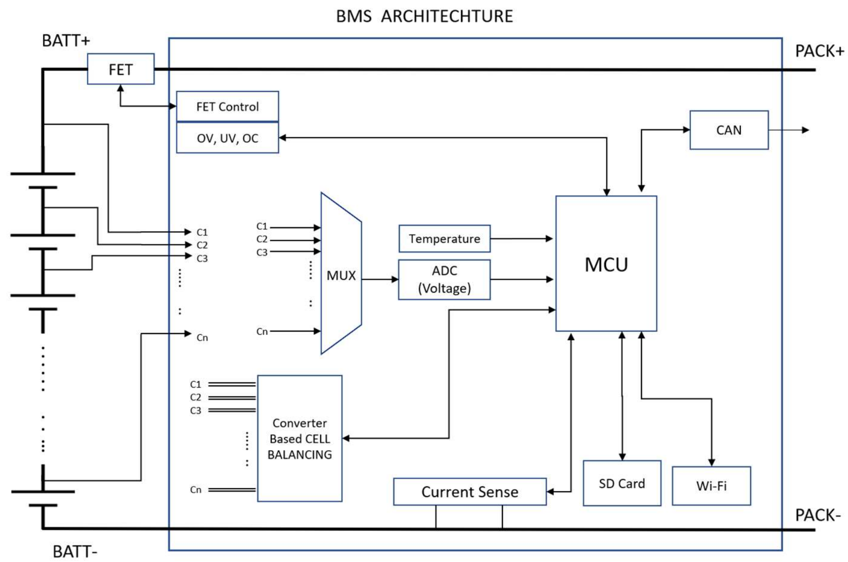

Fig.3. Proposed BMS Architecture

The circuit is disconnected if the cell is experiencing under voltage (UV) or Over Voltage (OV) or Over Current (OC). The request to reduce the stress on battery is sent to other devices such as charger or motor controller is sent via CAN bus if the temperature is not favourable. Further increase in temperature will disconnect battery from other system to prevent fire. While charging/discharging each cell behaves slightly differently due to its inherent properties, this causes imbalance of charge among cells as in Figure 3.a. Therefore, cells should be balanced either by active or passive method. Passive balancing discharges each cell till all cell SOC is equalized (Figure 3.b), this is heating dissipative and waste lot of power. Active balancing takes charges from cell with higher SOC and then delivers it to the cell with lower SOC (Figure 3.c) and repeats till every cell reaches same SOC with help of converter, which is efficient, and less power is wasted.

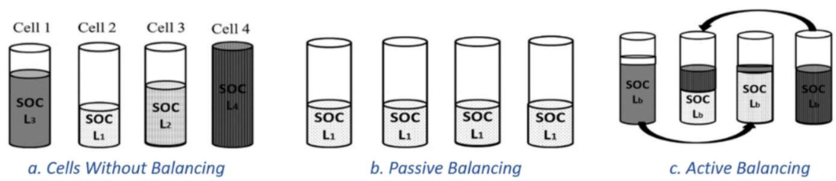

Fig.4. Comparison between passive and active balancing

compared to capacitive active balancing. Converter basically increases/decreases the voltage while maintaining constant power, which is used to control the balancing (current) speed that is optimal for the cell at that time. The speed is controlled by a microcontroller. Next step is to estimate SOC and SOH. SOC tells the mileage and gives user the statistics and alert for timely charging. The voltage, current, temperature data are stored in an SD card and are uploaded to cloud when every BMS connects to internet, thus battery state can be monitored and controlled online. The stored data are used to estimate SOC and SOH using proper algorithms such as Kalman filter. Wi-Fi connectivity sends data to internet/mobile devices which is used to monitor and analyse the data. CAN protocol is used to communicate with other devices such as display in EV, Motor controller, etc. All the above steps are continuously repeated in real-time and facilitated with microcontroller unit. Apart from basic functionality of BMS, there are triggers for fire extinguisher and thermal management.

a. Voltage Sensing

Cell voltage sensing using voltage divider circuit is a popular method used in battery management systems for measuring the voltage of individual cells in a battery pack. The voltage divider circuit is a simple electronic circuit that can be used to measure the voltage of a single cell or multiple cells in a battery pack.

The voltage divider circuit consists of three resistors connected in series between the positive and negative terminals of the battery. The voltage across the second resistor is measured using an analog-to-digital converter (ADC), which provides a digital output that can be used to calculate the voltage of the battery cell.

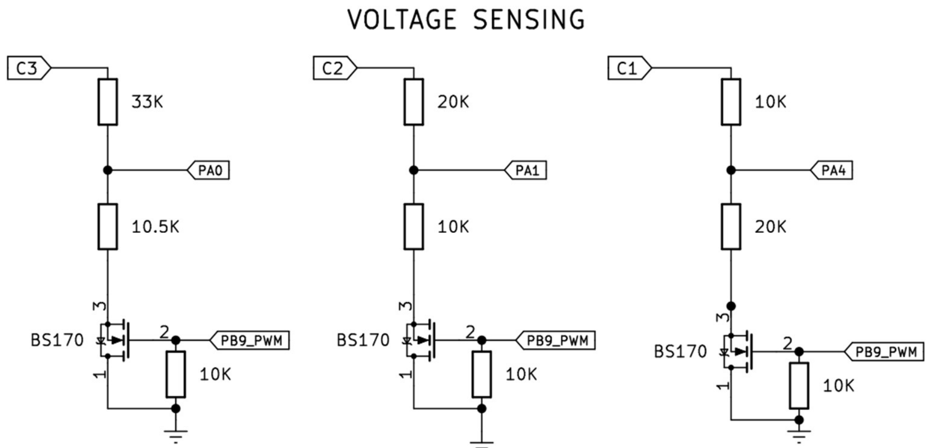

Fig.5. Schematic of Voltage sensing Circuit

b. Current Sensing

Shunt resistor based current sensing is a common method for measuring current in Battery pack. The INA219A is an integrated circuit that provides a simple and accurate way to measure current by using a shunt resistor. The INA219A for current sensing, Connect the shunt resistor in series with the load that measure the current of Battery pack. It will then measure the voltage drop across the shunt resistor and convert it to a digital signal that can be read by a microcontroller via I2C Communication.

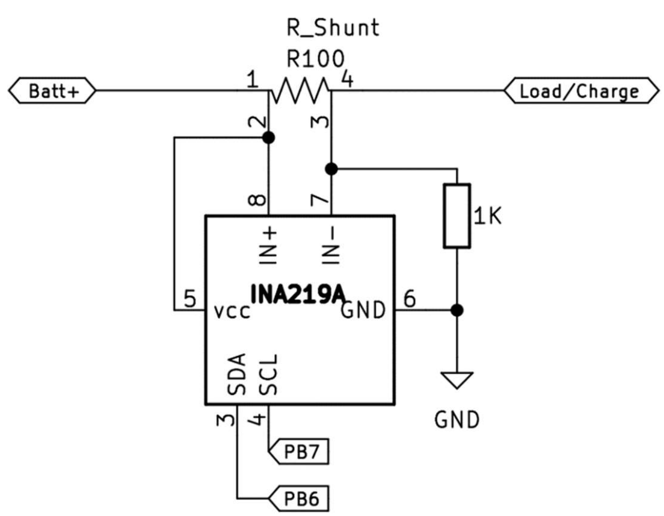

Fig.6. Schematic of Current Sensing

c. Temperature Measurement

Thermistors are temperature-sensitive resistors that change their resistance value with temperature. They can be used to measure the temperature of batteries by sensing the changes in the resistance of the thermistor. Thermistors are commonly used in battery management systems (BMS) to monitor the temperature of lithium-ion batteries.

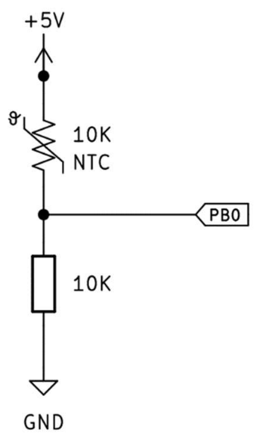

Fig.7. Schematic of Temperature Monitoring

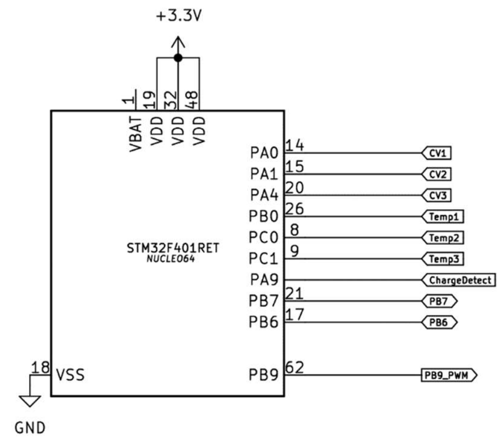

Fig.8. Pin Configuration of Microcontroller

d. Cell Balancing

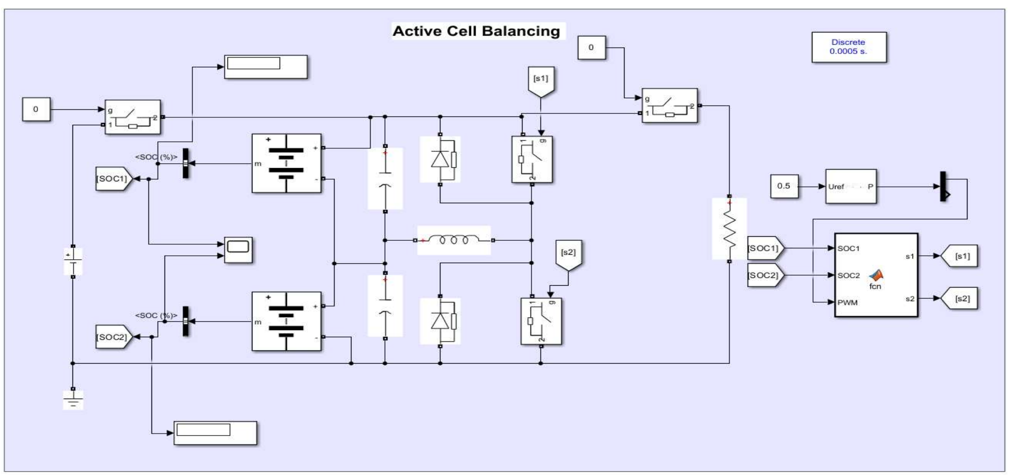

Fig.9. Model of Active Cell Balancing

Converter-based active cell balancing is a technique used to balance the voltage levels of individual cells in a battery pack. Active cell balancing addresses this issue by transferring energy from cells with higher voltages to cells with lower voltages. In converter-based active cell balancing, a converter circuit is used as an intermediary to transfer energy between cells. The converter circuit consists of an inductor, a switch, a diode, and a control circuit. The control circuit monitors the voltage levels of each cell in the battery pack and selectively connects the converter circuit to the cells that need to be balanced. When the converter circuit is connected to a cell, it transfers energy from the higher voltage cell to the lower voltage cell. The converter circuit operates by using the inductor to store energy when the switch is closed, and then releasing the stored energy to the lower voltage cell when the switch is opened. The diode is used to ensure that energy flows in the correct direction, from the higher voltage cell to the lower voltage cell. One advantage of using converter-based active cell balancing is that it is more efficient than capacitor-based active cell balancing. This is because the converter circuit can transfer energy directly between cells, without the need for an intermediate storage device like a capacitor. Additionally, converter-based active cell balancing can handle higher current levels than capacitor-based active cell balancing, making it well-suited for high power applications.

Experimental Results:

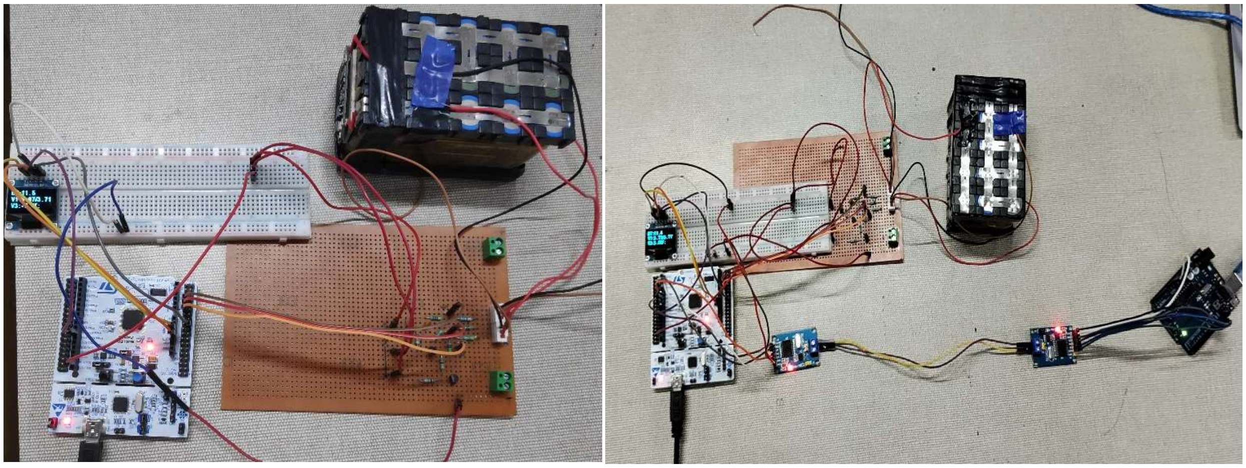

Fig.10. Experimental Setup of Proposed BMS

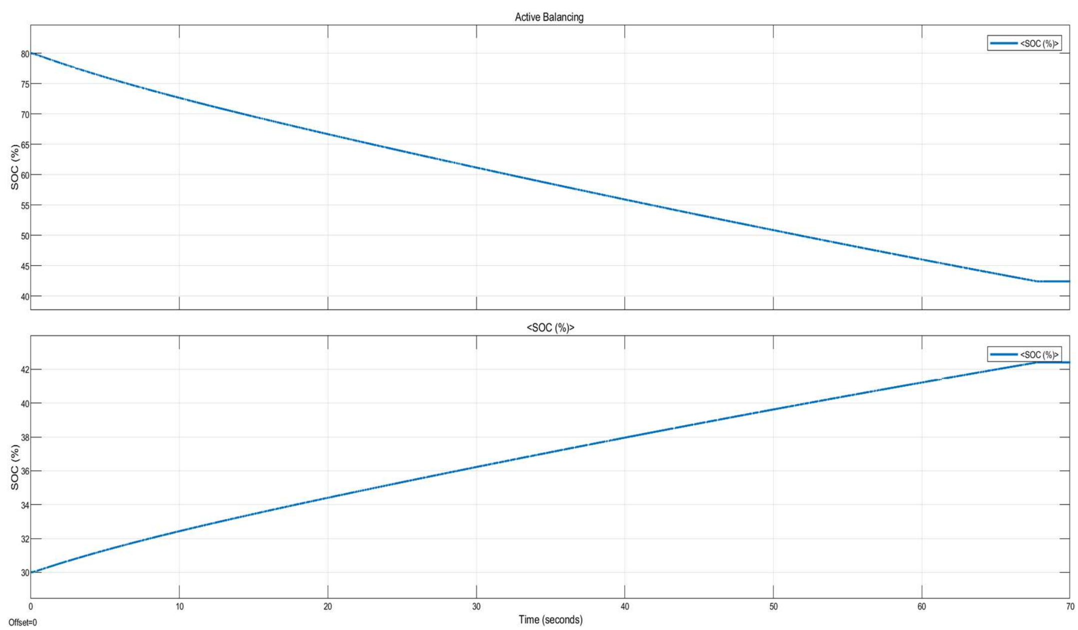

Fig.12.Converter based Active Balancing Results

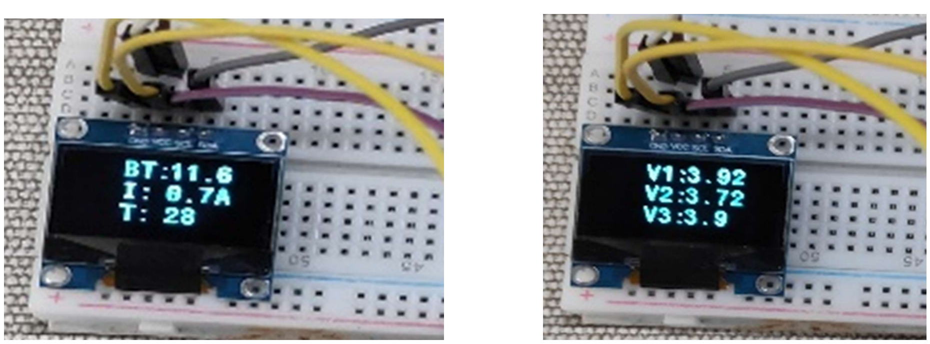

Fig.11.Voltage and Current sensing experimental Result

The BMS is able to accurately monitor and control the battery parameters such as voltage, current, and temperature. **The converter based balancing results show that imbalance of 80% and 30% of SoC is balanced each to 42% SoC at 3Ampere Current within 70sec.** These results ensure that charge and discharge the battery under different conditions and maintain safe operating conditions such as to detect and protect against overcharging, over-discharging, overheating, communicate and display the battery status and alerts.

Conclusion

The development of a battery management system (BMS) for an electric vehicle (EV) is a crucial process that requires careful consideration of several factors. A well-designed BMS is essential to ensure the safe, reliable, and optimal operation of the battery, maximizing its lifespan and minimizing the risk of failure. The development of a BMS involves several key stages, including system requirements analysis, circuit design and simulation, prototype development and testing, and production implementation and testing. Throughout the process, it is important to consider factors such as the cost, weight, and size of the BMS, as well as its compatibility with the specific battery chemistry and configuration used in the EV. By developing a robust BMS, EV manufacturers can ensure that their vehicles deliver the performance, safety, and reliability that customers expect. In addition, a well-designed BMS can help to extend the lifespan of the battery, reducing the need for costly replacements and minimizing the environmental impact of EVs.

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