Abstract- The evolving global landscape for electrical distribution and use created a need area for energy storage systems, making them among the fastest growing electrical power system products. A key element in any lithium-ion battery is the capability to monitor, control, and optimize performance of an individual or multiple battery modules in an energy storage system and the ability to control the disconnection of the module(s) from the system in the event of abnormal conditions. This management scheme is known as “battery management system (BMS)”, which is one of the essential units in electrical equipment. The battery management system (BMS) plays an important role in ensuring the safe and efficient operation of lithium-ion batteries used in photovoltaic (PV) panels. This paper provides a comprehensive review of the literature related to the development of BMS for lithium-ion batteries used in PV panels. The paper discusses the challenges associated with the use of lithium-ion batteries in PV systems and highlights the importance of BMS in mitigating these challenges. Additionally, the paper presents a research methodology used to evaluate the performance of BMS, presents the results of a study, and discusses the managerial implications, limitations, and future scope of the study.

The battery management system board is used to protect the battery from overcharge, overvoltage, under – voltage, temperature variation, and unbalanced conditions, and also monitor the state of charge of battery, state of health etc.

Key Words: BMS, Lithium-ion battery, Cell Balancing, Charging-discharging, Battery Monitoring, MATLAB, Simulink

1. INTRODUCTION
In recent years, there has been a significant rise in the adoption of photovoltaic (PV) solar systems as a sustainable and clean energy source. PV solar systems utilize solar panels to convert sunlight into electricity, which can be stored in batteries for later use. Among various battery technologies, lithium-ion (Li-ion) batteries have emerged as a popular choice due to their high energy density, longer lifespan, and enhanced efficiency. However, the performance, safety, and overall reliability of Li-ion batteries are greatly influenced by their management during charging, discharging, and storage processes. To address these concerns and ensure optimal performance, a reliable Battery Management System (BMS) is essential. The BMS plays a crucial role in monitoring and controlling various parameters of the battery, such as voltage, current, temperature, and state of charge (SoC).

The objective of this thesis is to design an efficient and robust BMS specifically tailored for Li-ion batteries used in PV solar systems. The BMS will integrate various hardware and software components to provide accurate and real-time monitoring, protection, and balancing of the battery cells. The design will aim to enhance the battery's overall performance, extend its lifespan, improve its safety, and maximize the utilization of the stored energy.

The research will begin with a comprehensive review of existing literature and state-of-the-art techniques related to Li-ion battery management, PV solar systems, and BMS design methodologies. By analysing the current challenges and advancements in the field, the thesis will identify critical areas where the proposed BMS can contribute to overcoming limitations and improving the overall system performance. The design process will involve the selection and integration of suitable sensors, control algorithms, and communication protocols to facilitate efficient battery monitoring and management. Special attention will be given to the development of advanced algorithms for accurate SoC estimation, cell balancing, and fault detection to ensure the safety and reliability of the battery pack.

Furthermore, the proposed BMS will be implemented and tested using simulation tools and prototype hardware to evaluate its performance under different operating conditions. The experiments will include scenarios such as varying solar irradiance, temperature fluctuations, and dynamic load profiles to validate the effectiveness of the BMS design. The outcomes of this research will contribute to the advancement of Li-ion battery technology and PV solar systems by providing an optimized BMS design specifically tailored to their requirements. The proposed BMS will enhance the
reliability, safety, and efficiency of Li-ion batteries in PV solar systems, thereby promoting their widespread adoption and utilization as a sustainable energy solution.

2. LITERATURE REVIEW

The report highlights the significance of battery management systems. It emphasizes the need for a safe and effective BMS to ensure the optimal performance and protection of the battery and associated system. The report provides a comprehensive analysis of various aspects of BMS, including testing, components, functionalities, topology, operation, architecture, and safety. To ensure the safe operation of BMS, the report recommends fully validating the BMS behaviour in the test procedure for overcharge/over discharge. During this process, the BMS active charge control function is inhibited, and the BMS interrupts the overcharge/over-discharge current through an automatic disconnect of the main contactors. The report further suggests four main areas of improvement for BMS safety and performance, including BMS construction, operation parameters, BMS integration, and installation. In conclusion, the report provides a framework for developing a new standard for BMS, with a particular focus on BMS safety and operational risk. [1] Gabbar A. Hossam, Othman M. Ahmed and Abdussami R. Muhammad, Review of battery management systems (BMS) Development and Industrial Standards, MDPI. Technologies 2021,9,28.

The monitoring and prognosis of cell degradation in lithium-ion (Li-ion) batteries are essential for assuring the reliability and safety. This paper aims to develop a reliable and accurate model for online, simultaneous state-of-charge (SOC) and state-of-health (SOH) estimations of Li-ion batteries. Through the analysis of battery cycle-life test data, the instantaneous discharging voltage (V) and its unit time voltage drop, V0, are proposed as the model parameters for the SOC equation. The SOH equation is found to have a linear relationship with 1/V0 times the modification factor, which is a function of SOC. [2] Huang Shyh-Chin, Tseng Kuo-Hsin, Jin-Wei Liang, Chung-Liang Chang and Michael G. Pecht, An Online SOC and SOH Estimation Model for Lithium-Ion Batteries. Energies 2017,10,512.

3. DESIGN OF BMS MODULE

When simulating a lithium-ion battery used in conjunction with a photovoltaic (PV) solar panel system, several key components and considerations should be included in the simulation module. Here are the details to consider for simulating the lithium-ion battery module in the context of a PV solar panel system:

1. PV Solar Panel Model: Develop a model to simulate the behaviour of the PV solar panel. This can include modelling the solar irradiance, temperature effects, and the power output characteristics of the panel. Various approaches can be used, such as the single-diode model or the equivalent circuit model for PV panels.
2. MPPT Algorithm: Implement a Maximum Power Point Tracking (MPPT) algorithm to extract the maximum available power from the PV solar panel. Simulate different MPPT algorithms such as Perturb and Observe (P&O), Incremental Conductance (INC), or the Fractional Open-Circuit Voltage (FOCV) method. The MPPT algorithm adjusts the battery charging current to operate the PV panel at its maximum power point.
3. Battery Model: Develop a lithium-ion battery model that accurately represents its electrical behaviour, including voltage dynamics, capacity, and state of charge (SOC). Depending on the level of detail desired, you can use an equivalent circuit model or an electrochemical model. Consider the battery's characteristics, such as charge and discharge efficiencies, self-discharge rate, and aging effects.
4. Charging and Discharging Control: Design control algorithms to manage the charging and discharging of the battery based on the solar panel output and the energy demand of the system. Simulate different charging strategies, such as constant current or constant voltage, and incorporate considerations like battery voltage limits and charge termination criteria.
4. PASSIVE BALANCING MODULE

Passive cell balancing is a technique used to equalize the voltage levels of individual cells within a battery pack without actively transferring charge between cells. When applied to a three-cell battery system connected in series, the working of passive cell balancing can be outlined as follows:

1. Cell Voltage Monitoring: Continuously monitor the voltage levels of each cell in the battery pack. This can be achieved using voltage measurement circuits or dedicated voltage measurement ICs for accurate voltage readings.

2. Voltage Threshold Determination: Define a voltage threshold that determines when cell balancing should be initiated. The threshold is typically set to the maximum allowable voltage difference between cells. For example, if the threshold is set to 50 mV, balancing will be triggered when the voltage difference between any two cells exceeds 50 mV.

3. Balancing Resistors: Connect balancing resistors in parallel with each cell in the series-connected battery pack. The balancing resistors provide a discharge path for the higher voltage cells, allowing them to equalize with the lower voltage cells. The value of the balancing resistors determines the balancing current and the rate at which charge is dissipated from the higher voltage cells.

4. Balancing Current Limitation: Implement a current limiting mechanism to prevent excessive discharge of higher voltage cells. This can be achieved by incorporating series resistors or current-limiting components in the balancing circuitry. The current limit should be set based on the cell specifications and the maximum allowable balancing current.

5. Balancing Duration: Determine the duration of the balancing process. Balancing can be performed continuously or periodically based on the cell voltage differences and balancing current. The balancing duration should be optimized to ensure that voltage imbalances are minimized while minimizing the impact on the battery's overall performance.

6. Monitoring and Control: Continuously monitor the cell voltages during the balancing process. Once the voltage differences between cells fall below the threshold, deactivate the balancing circuitry to prevent unnecessary power dissipation. The monitoring and control mechanism ensures that the cells remain balanced without over-discharging the higher voltage cells.

It's crucial to select appropriate values for the balancing resistors, balancing current, and voltage threshold to achieve effective cell balancing without compromising the overall performance and longevity of the battery pack. Simulation tools such as MATLAB/Simulink can be used to model and simulate the passive cell balancing algorithm for the three-cell battery system, allowing for evaluation and optimization of the balancing technique based on specific design parameters and requirements.
5. RESULT OF SIMULATION

6. FUTURE SCOPE
The future scope for research on Battery Management Systems (BMS) for lithium-ion batteries is extensive and encompasses various areas of optimization, safety, intelligence, and integration with emerging technologies. Key areas for exploration include advanced state estimation techniques for accurate battery characterization, intelligent and adaptive balancing techniques to address cell variations, and the integration of artificial intelligence and machine learning for intelligent decision-making and prognostics. Additionally, research can focus on thermal management techniques to optimize temperature distribution, multi-objective optimization algorithms for comprehensive battery management, and the development of advanced safety systems to mitigate risks. Wireless monitoring and communication, integration with renewable energy systems, standardization, and addressing the specific requirements of novel battery chemistries and technologies are also vital research directions. Advancements in these areas will contribute to improving the performance, reliability, and lifespan of lithium-ion batteries and enable their broader adoption in various applications.

7. CONCLUSIONS
In conclusion, this review has provided an overview of Battery Management Systems (BMS) for lithium-ion batteries and highlighted their importance in ensuring safe and optimal battery operation. The components of a BMS, including the Battery Monitoring Unit (BMU), Cell Balancing Circuit, State Estimation Algorithms, Safety and Protection Systems, and Communication Interface, have been discussed.
The review has also explored balancing techniques, circuit topologies, and balancing control strategies employed in BMS. Active and passive balancing methods, as well as centralized, distributed, and hybrid balancing circuit topologies, were examined. Various control strategies, such as voltage threshold control, SOC-based control, time-based control, priority-based control, and dynamic control, were presented.

Furthermore, the review has discussed the future scope for research in BMS for lithium-ion batteries. Areas of exploration include advanced state estimation techniques, intelligent and adaptive balancing, integration of artificial intelligence and machine learning, thermal management, multi-objective optimization, advanced safety systems, wireless monitoring and communication, integration with renewable energy systems, standardization, and addressing novel battery chemistries and technologies. Advancements in these areas will contribute to improving the performance, safety, reliability, and lifespan of lithium-ion batteries. It will enable the development of more efficient and intelligent BMS solutions, supporting the wider adoption of lithium-ion batteries in various applications, including electric vehicles, renewable energy systems, and portable electronics. The continued research and development in BMS will play a crucial role in advancing the field and driving the future of energy storage technology.

REFERENCES: