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The charging performance of the battery management system used in the Engineering Department's electric car development

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Abstract: *The increase in global temperatures has driven the automotive industry to transition toward electric vehicles as an eco-friendly alternative. However, the impact of rising temperatures on battery systems has become a key focus in their development. This study highlights the crucial role of Battery Management Systems (BMS) in mitigating these effects on electric vehicle battery performance. BMS can be designed with various configurations and must include essential functions such as charger control, contactor operation, cooling system management, and ground isolation protection. Cell characterization is a vital aspect of BMS development, as test results indicate that cell capacity is directly influenced by the discharge rate, making it a critical factor in State of Charge (SOC) estimation under dynamic conditions like those in electric vehicles. Experimental findings also reveal that during charging, all batteries receive power evenly without significant voltage variations, while the BMS disconnects the load when a battery's voltage drops below its nominal level. Regarding battery health, SOC is consistently maintained between 80% and 100%, and if it falls below 80%, the system will automatically shut down to prevent battery degradation. Moreover, the next step in achieving full potential of this BMS will be the development of the graphical user interface (GUI) used to displays and monitors these performances over time.*
Keywords: *Electric car, Battery Management System, State of Charge*

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I. INTRODUCTION

The global warming poses a serious threat to the environment and the sustainability of our planet. One of the main contributors to the global warming is greenhouse gas emissions from conventional motor vehicles that rely on fossil fuels. Therefore, the shift toward electric vehicles (EVs) is considered one of the solutions to reducing the carbon footprint of transportation. According to a study by the Intergovernmental Panel on Climate Change (IPCC), the transportation sector accounts for approximately 23% of global greenhouse gas emissions, and the adoption of electric vehicles can significantly reduce these emissions (IPCC, 2018).

The electric vehicles, as the future alternative, powered by battery energy, have become the focus of efforts to reduce transportation emissions. Lithium-ion batteries, widely used in electric vehicles, offer efficient and environmentally friendly energy storage. Badrinarayanan et al. (2019) emphasize that the adoption of electric vehicles has great potential to reduce emissions and support the transition toward sustainable mobility.

In the operation of the electric vehicles, the battery is the heart of it, and its operational efficiency heavily depends on the Battery Management System (BMS). The BMS is responsible for monitoring and optimizing battery performance, ensuring a longer lifespan and more efficient charging. Zhang et al. (2020) state that BMS can enhance charging and discharging efficiency, which in turn reduces energy consumption and emissions.

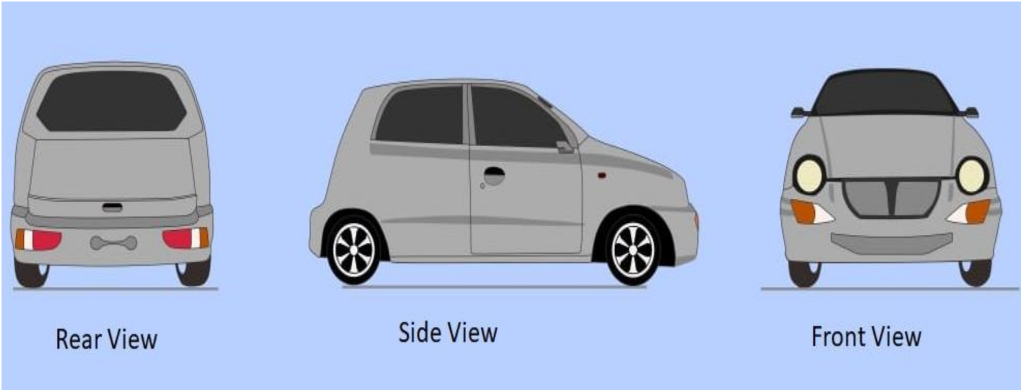
Despite of the significant advancements in battery technologies, there are challenges that need to be addressed regarding BMS, such as effective heat management and accurate monitoring of battery cell conditions. Li et al. (2021) highlight the importance of developing smart BMS algorithms to enhance the efficiency and operational reliability of batteries. By continuing to advance battery and BMS technology, as proposed by Lu et al. (2022) and Liang et al. (2020), we can embrace sustainable solutions to tackle global warming, reduce dependence on fossil fuels, and create a cleaner and greener transportation future.

Based on the above backgrounds, it is deemed necessary to conduct specific research using of an appropriate design to determine the parameters required as initial data for subsequent testing. The results of this data will be used as a baseline for performance testing of the BMS system, which will be used to assess the feasibility of the development of the electric car.

II. EXPERIMENTAL PROCEDURE

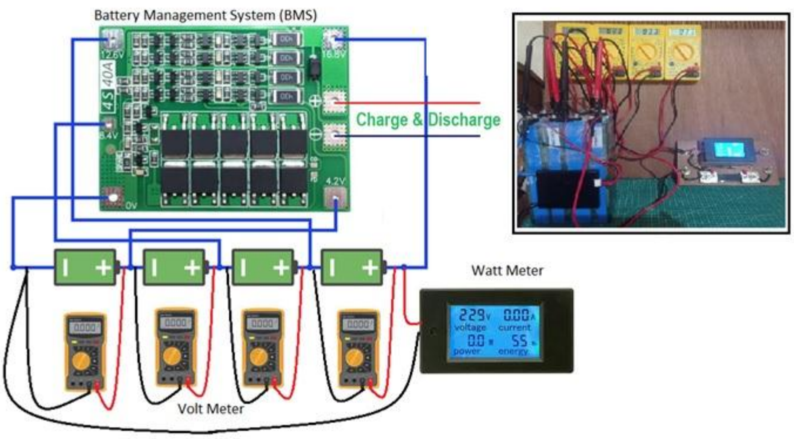
Based on the preliminary research results regarding the dimensions/size of the electric vehicle, which are the subject of analysis in this study is presented in Figure 1.

Figure 1, The Electric car of the University (courtesy of Mechanical Engineering University of Mataram)



In order to get the performance of the Battery Management System (BMS) of this electric vehicle from the Faculty of Engineering, four (4) lithium batteries arranged in series were used. The desired variables, such as the voltage of each battery during charging, were measured using four AVO meters and a Watt Meter to assess the output parameters of the BMS. The setup of the equipment in this study is shown in Figure 2

Figure 2. Experimental apparatus setup

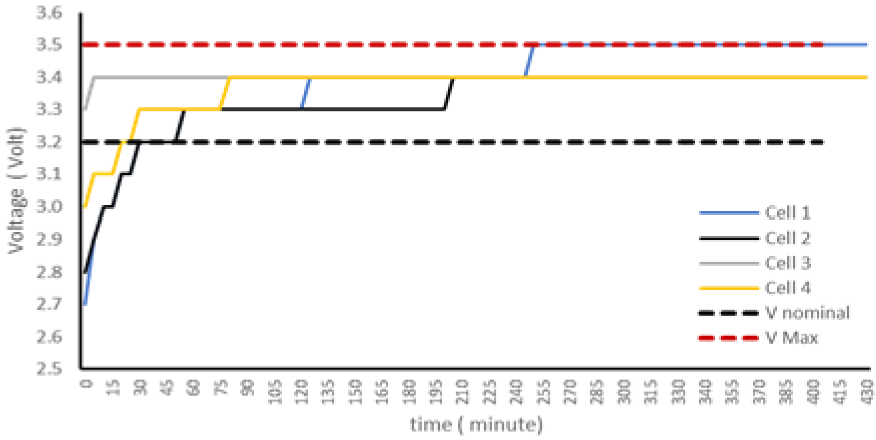


III. RESULTS AND DISCUSSIONS

3.1. State of Charge (SOC)

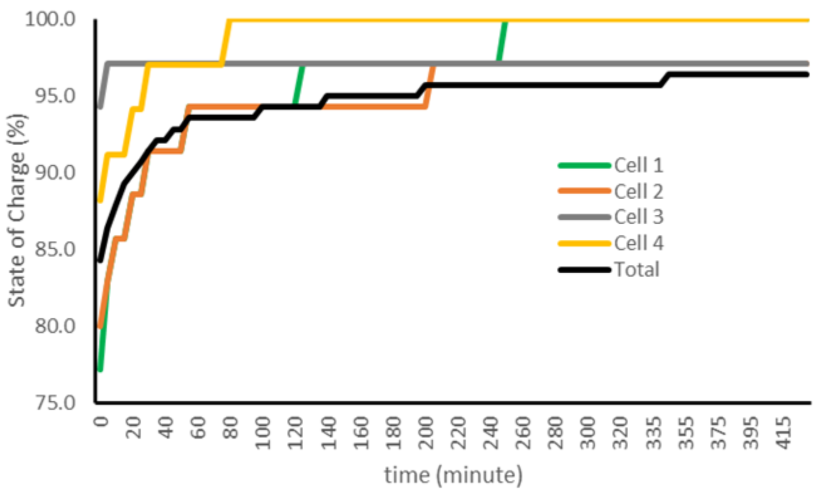
The State-Of-Charge (SOC) is a key parameter in battery management, indicating available energy relative to full capacity (Pillai et al., 2020). Essential for electric vehicles and energy storage, SOC helps optimize performance and extend battery life (Hu et al., 2019). It predicts charge status and operational conditions (Xiong et al., 2017). Estimation methods include mathematical models, experiments, and AI to enhance accuracy (Zhang et al., 2021), ensuring efficient and safe battery management. Furthermore, figure 3 and 4 show the changing voltage of each battery and its SOC during the charging period of 7 hours, respectively.

Figure 3. Battery voltage changes during charging



Based on Figure 3, the charging voltage of each battery shows different trends due to variability in properties and characteristics, as the batteries are designed for general consumers (Linden & Reddy, 2011). These differences may result from manufacturing factors and previous usage conditions. Battery 1 has a higher final voltage, likely due to imperfections in the Battery Management System (BMS) and initial voltage variations. While the differences remain within a healthy range (3.2–3.5V), improvements in BMS are necessary to enhance voltage balance and optimize power input management (Zhang et al., 2020).

Figure 4. State of Charge (SOC, %) of battery during charging

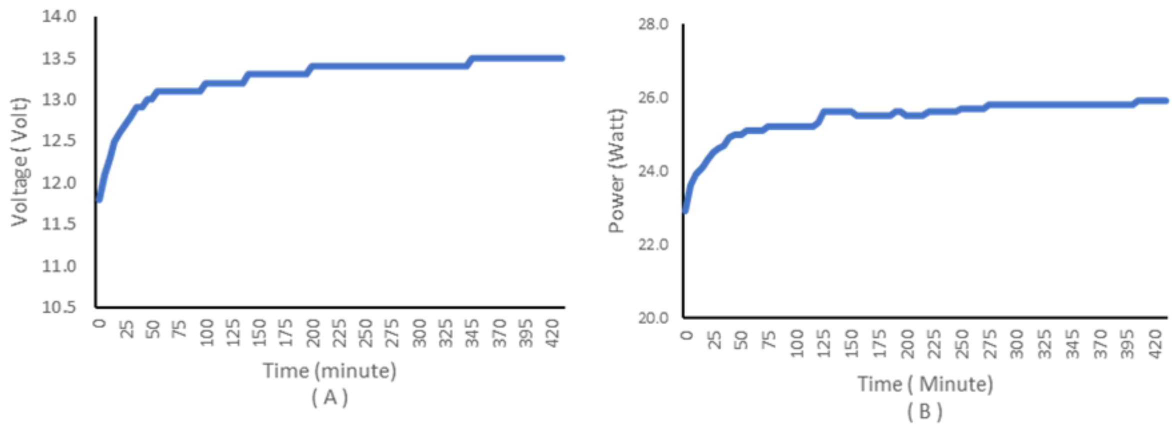


From the perspective of battery health (State of Healt, SOH), the batteries used exhibit excellent SOC, ranging between 90–100%. The highest SOC was observed in Batteries 1 and 4 at 100%, while the lowest SOC was in Batteries 2 and 3 at 97%. After assembly, the overall SOC reaches 95%. According to Zhang et al. (2020), SOC was influenced by charge cycles, operating temperature, and imperfections in the battery management system. Additionally, research by Gao et al. (2021) indicates that optimal SOC contributes to voltage stability and battery durability. Based on the data in Figure 4, the time required to reach 100% SOC for all batteries was approximately 260 minutes (3 hours and 10 minutes). This aligns with the findings of Wang et al. (2018), who state that battery charging duration depends on cell capacity and charging system efficiency. Furthermore, studies by Kim et al. (2019) and Yang et al. (2022) show that high SOC supports energy conversion efficiency and extends battery lifespan. Thus, the battery system used has demonstrated good performance and is suitable for long-term applications.

3.2. Characterization of battery cells

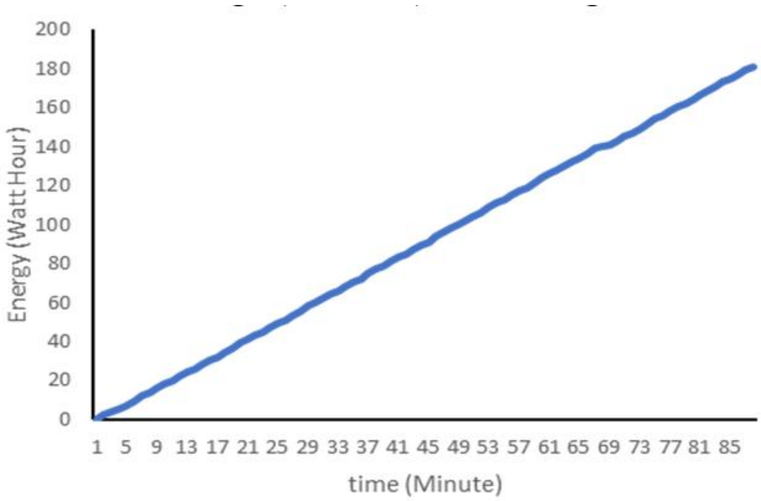
To fully understand the characteristics of the cell, a fully charged Li-ion cell was left to stabilize for one hour. The cell was then subjected to a constant current discharge by applying a specific load. The terminal voltage and discharged capacity (Ah) were monitored until the cell reached the lower voltage threshold. A battery voltage and power change characteristics during charging are shown in Figure 5a and 5b, respectively. Furthermore, figure 6 shows the comparison of energy during charging vs. discharging.

Figure 5 Characteristics of BMS output voltage (A) and BMS output power (B) during battery charging



The comparison of the output voltage from the battery configuration/cells of the BMS used can be seen in Figure 5a. From the figure, it can be concluded that during charging, the battery experiences a constant voltage increase. Moreover, the same phenomenon also occurs in rising the power during charging, where the battery experiences a constant power increase (Figure 5b). The stored power that can be achieved was 26 watts. This was intended to prevent voltage spikes that could lead to excessive heat in the battery, potentially causing fatal damage or even fire. According to Chen et al., 2020, an uncontrolled voltage rise during charging can accelerate lithium plating and thermal runaway, significantly increasing the risk of battery failure. Similarly, Wang et al., 2019 emphasize that maintaining a controlled charging profile helps in prolonging battery lifespan and ensuring safety. The voltage achieved falls within the range of the nominal voltage (3.2 volts) and its maximum voltage (3.5 volts), which aligns with the safe operating limits defined in lithium-ion battery studies.

Figure 6. Characteristic battery based on storage energy



Last but not least, the battery characteristics, as observed from the stored energy, can be said to increase linearly over time (Figure 6). The figure also indicates that the maximum energy that can be stored by the battery configuration was 181 Wh. This maximum capacity can be reached within 430 minutes. This also demonstrates that the performance of the BMS used can be categorized as neither too fast nor too slow in charging (moderate performance).

IV. CONCLUSION

Based on the research of experiment and discussion, it is shown that the Battery Management System (BMS) can be developed with various different configurations. The BMS must have the functionality to control the charger, contactors, cooling system, and ground isolation protection. Characterizing the cells is an integral part of BMS development. The testing provided important findings that cell capacity is a function of the discharge rate. This is a crucial parameter that affects the SOC estimation in dynamic conditions such as Electric Vehicles. Moreover, the test results also indicate that during charging, each battery charges evenly (with no significant voltage differences), while during discharging, the BMS disconnects the load when the battery voltage drops below the nominal voltage. From the perspective of battery health, the SOC is consistently maintained in a good condition, ranging between 80-100%. If the SOC falls below 80%, the circuit will be disconnected. Moreover, after the performance of this BMS design was gotten and gave satisfaction, the next step will be the development of the graphical user interface (GUI) used to displays and monitors these performances over time.

Conflict of interest

There is no conflict to disclose.

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