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Performance Evaluation of Battery Life Cycle with Supercapacitor Augmentation

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Abstract- **Super capacitors are energy storage density devices with high-power density, electrochemical double-layer capacitors, have attracted a lot of attention recently. These gadgets are perfect for uses like electric vehicles and renewable energy systems, which demand significant energy storage and quick charging and discharging. Super capacitors also have a long cycle life and may be repeatedly charged and drained without noticeably losing performance. However, Super capacitors cannot be used as the main energy storage device in most applications due to their poor energy density, they can be augmented with the existing battery management system to enhance the battery efficiency and life cycle. There are various ways to connect a battery and a super capacitor. Therefore, the proposed work focuses on augmentation of super capacitor with battery either in parallel/series mode to extend the lifecycle of the battery and reduce the overall system cost. The work also presented a buck-boost converter as a control unit to improve the life cycle. The test scenario considered battery test without super capacitor and estimated the number of cycles maximum of 5000. The proposed battery system with augmented Super capacitor demonstrated enhanced performance of 6000 cycles. Therefore, augmentation of super capacitor proved 20% of improved performance of the battery system.**

Keywords: ***Battery Management, Super capacitors, Efficiency, Buck Boost Converter, Battery Life cycle, Optimization***

I. INTRODUCTION

Batteries are becoming an indispensable part of daily life in modern technology era. [1] They are used in electronic consumer products from mobile phones to electric vehicles and are found to be an essential part for the operation of numerous gadgets. Battery efficiency and longevity must be improved for batteries to meet the growing demand for energy storage across a range of industries. [2] Hence, researchers put forth that a super capacitor is integrated into the system could improve the battery system. An energy storage mechanism called a super capacitor has the capacity to store a large amount of electricity and release it gradually. Super capacitor is the perfect addition to a battery system due to its better performance.

Researchers have suggested using super capacitors as a buffer between the renewable energy source and the battery to solve major problems. [3] The author suggested that Super capacitors are electrochemical energy storage systems that provide high power density and quick charging and discharging capabilities. They are especially beneficial for systems that need high power output, such as electric cars and renewable energy sources. Although, there are many advantages to using super capacitors in renewable energy systems, there are several issues that need to be resolved. The cost of super capacitors, which is now higher than that of conventional batteries, is one of the major obstacles. Super capacitors are predicted to become less expensive as technology advances and production levels rise. The lower energy density of super capacitors than that of conventional batteries presents another difficulty. [4] Super capacitors have a high-power density, but their energy density is currently lower than that of conventional batteries. This means that while super capacitors are perfect for applications requiring high power output, they might not be appropriate for applications requiring significant energy storage. Hence, this study will evaluate the battery's durability and effectiveness, by incorporating a super capacitor.

II. LITERATURE SURVEY

The researchers point out that a few elements, like as overcharging and undercharging, voltage imbalances, and temperature changes, can have a detrimental effect on the effectiveness and longevity of super capacitors. The researchers also suggested a control system that manages the super capacitor's SOC and balances the voltage across each cell in the super capacitor bank to address the limitations.

In [5] supercapacitors have been the subject of several research looking at its usage in renewable energy systems, particularly when combined with batteries. The researchers demonstrated the usage of a battery-supercapacitor hybrid energy storage system for a solar power generation system. The results exhibited increased performance of the system, decreased the number of battery charging and discharging cycles, and improved battery's lifespan. The hybrid solution, according to the researchers, decreased the peak power demand on the battery by up to 71%.

In [6] the authors implemented a hybrid battery-supercapacitor energy storage for a wind turbine system. The usage of a hybrid system, according to the researchers, increased system efficiency by 6.5%, decreased the number of times the battery had to be charged and discharged, and increased battery life. The peak power consumption on the battery was also shown to be decreased by up to 62% by the hybrid system.

In [7] presented a power electronics interface to control the energy flow between the two components of the hybrid system, which consists of a battery and a super capacitor coupled in parallel. While the battery manages the low-frequency fluctuations, the super capacitor oversees handling the high-frequency fluctuations. The energy flow between the two devices is controlled by the power electronics interface to ensure that they are used to their full potential.

In [8] the study discovered that the hybrid system boosted the wind turbine system's efficiency by up to 6.5%. This improvement in efficiency is related to the supercapacitor's improved capability to manage high-frequency power fluctuations, which lessens the burden on the battery.

In [9] It has also been demonstrated that the hybrid system may reduce peak battery power consumption by up to 62%. The results impressed that the supercapacitor can handle abrupt surges in power demand better, which lightens the load on the battery. The hybrid technology guarantees that the battery operates within its safe operating limits and lowers the peak power demand on it, extending the battery's lifespan.

The review article by T. O. Soh and M. R. Kamarudin [10] offered a thorough summary of super capacitor technology, its benefits and drawbacks, and its numerous applications. Super capacitors, which offer a high-power density, a long cycle life, and quick charging and discharging, have the potential to revolutionize energy storage. Despite having a lower energy density than batteries, they are still a desirable alternative for a variety of applications, especially those involving renewable energy.

In [11], the prototype system made up of a 12-cell super capacitor bank and a resistive load, the researchers tested their methodology. Even under fluctuating load conditions, they discovered that their strategy could keep the SOC of the super capacitor bank within the acceptable range. Additionally, they discovered that their strategy worked well for balancing the voltage across each of the super capacitor bank's individual cells, which may help to increase the bank's lifespan. The study shown that it is possible to increase the efficiency and longevity of super capacitors by regulating their SOC. Incorporating DC bus voltage variation and a phase-shifted full-bridge converter can help manage the bidirectional energy flow quickly and keep the super capacitor bank from overheating.

In [12] Researchers presented a strategy for enhancing the efficiency and robustness of super capacitors titled "Control of Super capacitor Energy for Enhanced Efficiency and Durability," which was published in the journal Energies in 2018. The method uses a phase-shifted full-bridge converter and is dependent on managing the super capacitor's state of charge (SOC).

III. METHODOLOGY

The following phases make up the methodology for measuring battery life cycle performance with super capacitor augmentation:

Calculate the battery capacity: The first step is to calculate the battery capacity. The battery can be fully charged in order to determine how much charge it can supply.

The variability of the energy supply is one of the main problems with renewable energy sources, though. This variation may result in partial and erratic charge or discharge cycles, which may shorten the lifespan of the battery. The super capacitor will be connected to Buck boost converter 1 and Buck boost converter 2 in order to increase efficiency and it is customized through programmable power supply. To overcome the challenge the super capacitor will be used to store electricity and manage it based on changes in load to get around this problem. The efficiency and lifespan of the EV battery will increase as a result.

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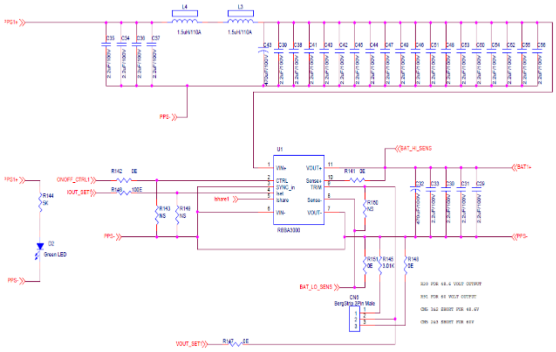

Fig 3.1 First half block of augmentation control unit

Figure 3.1 is the super capacitor's capacity and it described about the schematic model of augmentation module. This can be accomplished by charging the super capacitor to capacity and determining the maximum amount of charge it can produce. Create the system: The super capacitor and battery should be linked in parallel while creating the system. Prior to charging the battery, the super capacitor should be charged.

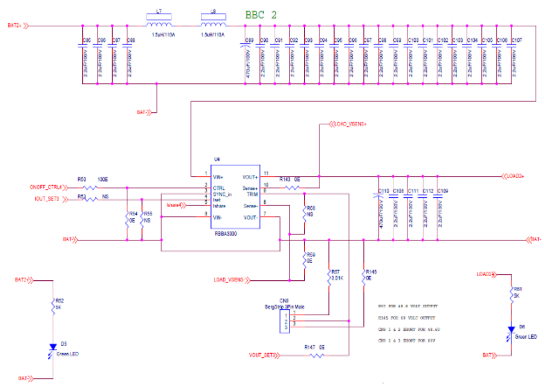

Fig 3.2 Second half block of augmentation control unit

Figure 3.2 defined the charging of system until the battery and super capacitor are both fully charged. Charge the system: The system needs to be charged up till the voltage reaches a specific level. The voltage, current, and time should be noted while the charging and discharging cycles are occurring the effectiveness of applying super capacitor augmentation to lengthen the battery life cycle can be inferred from the findings.

Overall, the method for assessing the battery life cycle performance with super capacitor augmentation entails meticulous experiment design and execution, as well as careful data analysis and interpretation.

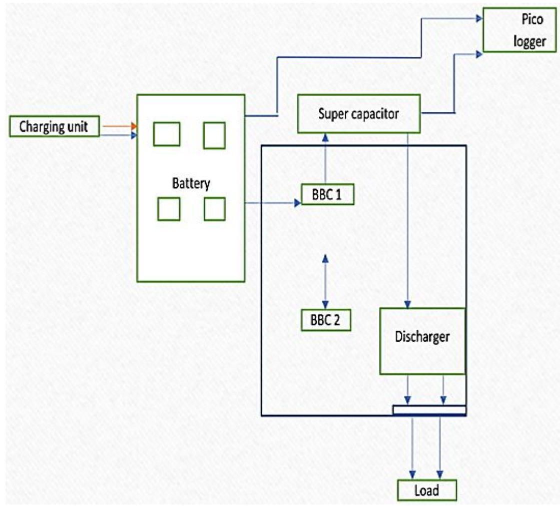

Fig 3.3 Block diagram of a Augmentation control unit

Figure 3.3 is the power source that passes through a fuse before entering the argumentation control unit, which includes capacitors, resistors, inductors, sensing resistors, heat suction materials, diodes, and two buck-boost converters connected in series through the I share pin. The buck-boost converter seems to control the input voltage up to 58V while also charging the battery. To stop current from the discharging unit from going to the load during this charging procedure, it is disabled. The ferrite inductor filters the battery's output when the charge is finished, and the discharging unit then discharges the current to the load. To stop current flow, the charging device is turned off during this discharging.

IV. RESULTS AND DISCUSSION

Voltage and current measurements: During the charge/discharge cycles, the voltage and current measurements are made in real-time. The voltage stability, power density, and efficiency of the charging and discharging processes may all be assessed using this data.

To measure charging and discharging times, time data can be kept track of during charge/discharge cycles. Data on the capacity of the battery and super capacitor can be gathered during cycles to assess the battery's lifespan and the effectiveness of energy delivery and storage.

Fig 4.1

Comparing Super capacitor augmented EV with hybrid battery

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Figure 4.1 is the image to calculate the efficiency data and assess the charge/discharge efficiency, voltage, current, and capacity data are available. The various performance metric data, including voltage and current profiles, capacity versus cycle count, efficiency versus time are measured.

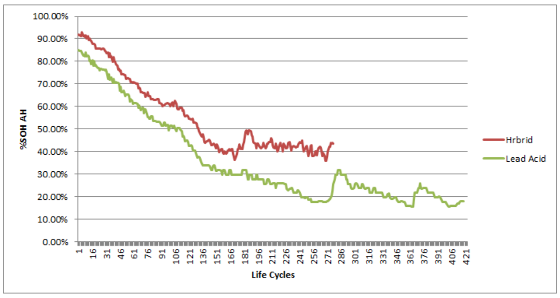

Fig 4.2 Comparing Hybrid battery with lead acid battery

Figure 4.2 is the real-time findings and output data of the performance evaluation of the battery life cycle with super capacitor augmentation provide significant understanding of the system performance and the effectiveness of the super capacitor in extending battery life and boosting system performance.

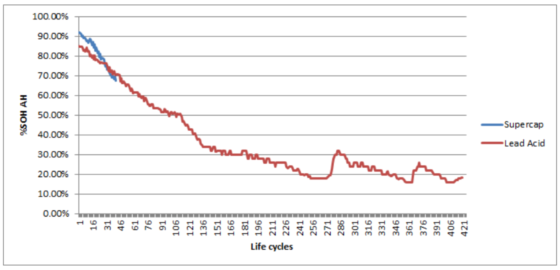

Fig 4.3 Comparing Super capacitor Augmented EV with Lead acid Battery

Figure 4.3 is the image to calculate the efficiency, State of Health (SOH) and analyzed the graph to determine the Ampere Hour (Amp Hr) and Watt Hour (W Hr) which are useful for enhancing the life of EV batteries with constant voltage, constant currents and improve the durability.

Comparing to the normal batteries the batteries with supercapacitor are more efficient. Normally a battery gives 5000 life cycles with original cost, coming to the battery with supercapacitor gives 6000 life cycles in the same cost, so that the battery with supercapacitor gives 20% enhanced life cycles in the affordable cost.

V. CONCLUSION

The use of supercapacitors in conjunction with batteries improved the overall performance and efficiency of energy storage system. The high-power bursts provided the sustained power output over a longer period. The results exhibited the extended life cycle of the battery and reduce the overall system cost with supercapacitor augmentation.

In terms of performance evaluation, efficiency of the system, the power density, the energy density, and the overall system cost metrics are measured to demonstrate the effectiveness of the supercapacitor augmentation. The proposed work evaluated the performance of EV hybrid battery with Supercapacitor augmentation and without augmentation and arrived the efficiency and State of Health (SOH).

The mean and standard deviation of various parameters can be calculated from the data using statistical analysis. This analysis can be used to assess the experiment's dependability and repeatability as a future work.

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