Study of Hybrid Energy Storage System with Different Configurations of Super Capacitor

S. Sundaramahalingam*, T. Balasubramaniyam, K. S. Prethesh Kumar

Department of Electrical and Electronics Engineering, Mepco Schlenk Engineering College, Sivakasi, India

E-mail: *sundar.eee@mepcoeng.ac.in

Abstract

The main objective of this paper is to study of behaviour of hybrid energy storage system with various configurations of super capacitor. The Hybrid Energy Storage System (HESS) is made up of a variety of energy sources that are typically seen in electric vehicles. The model has been created to study the super capacitor behaviour, charging, and discharging. While the model is being charged, the power is required, and in the discharging state, lithium-ion battery is used. The most important components to be employed as a combo for the proposed HESS are the battery and the super capacitor. When using a supercapacitor in an electric car, the performance is found to be improved. Because of the battery's low power density, rapid draining and charging occurs. Therefore, the battery is alleviated from peak stress with the aid of the super capacitor, which also boosts the efficiency. The concern, however, is to optimize HESS in a way that it is both efficient and effective.

Keywords: HESS, super capacitor, lithium-ion battery

1. Introduction

This generation is driven to create durable, ecologically friendly, and fuel-efficient transportation vehicles due to environmental concerns. The electrification of the power train is one of the significant advances that are currently taking place in the automotive sector. Electric cars are becoming an ecologically friendly technology as a result of today's growth. In a hybrid vehicle, the energy delivered from the fuel cell and the batteries are used. It serves as a source of propulsion power. One of the several advantages of an electric vehicle is

DOI: https://doi.org/10.36548/jeea.2022.3.003
Received: 15.07.2022, received in revised form: 10.08.2022, accepted: 18.08.2022, published: 29.08.2022

reduced pollution levels, however, it faces a challenge in power shortage [1]. One of the most crucial parts of a hybrid car is its battery, and thus it needs specific care. For an increased battery lifetime, the charging and discharging cycles are quite important [2].

1.1 Overview of HESS

A Hybrid Energy Storage System (HESS) combines more than one type of model together to provide better performance than the regular energy storage modules such as fuel cells, batteries, supercapacitors and flywheels [3]. HESS has recently found extensive applications in EVs, smart grids, etc. [4]. Compared to individual energy storage devices, the harmonious integration of various dynamic energy storage methodologies improves overall performance in terms of efficiency, economy and lifetime [5]. This work concentrates on all the areas of energy storage in sophisticated components and their integration into HESS. Both research and review manuscripts on the recent advances and potential research applications in related fields of particular interest have been sought.

1.1.1 Need of HESS

Long-term hybrid energy systems are a promising option for power generation for subsistence applications. Although system design and optimization require complex methods, research and development of these new technologies will almost certainly lead to reduced system cost [6]. Moreover, optimal resource allocation based on load demand and renewable resource estimates, significantly reduces system total cost of ownership. In addition to cost reduction criteria, there are more criteria important to evaluate other essential factors. Advanced models that correctly map the system can help optimize hybrid energy.

1.1.2 Super Capacitor

A supercapacitor is a type of capacitor commonly used in HESS. Its characteristics enable high performance, short charge/discharge time, long life, and high power density. In addition, supercapacitors have higher energy while maintaining performance in discharge situations. Supercapacitors are becoming more popular in the current market due to their superiority over normal capacitors. A supercapacitor is used in this study to lower the peak current. In HESS, such supercapacitors store, and supply peak power when discharged. Compared to standard capacitors, supercapacitors are better and more reliable.

2. Related Work

According to Yanzi & Wang (2014) [11], the new topology improved converter efficiency along with their power rating. In their work, fuzzy logic was used to analyze the power distribution of a supercapacitor. Cultura et al., (2015) [8] proposed that fuzzy logic is advantageous in nonlinear systems, especially for improved energy management and general state efficiency. The technique suggested by [8], improved performance by simulating supercapacitors and batteries using fuzzy logic in Simulink. A relay was included in the Simulink model to prevent overvoltage of the supercapacitor. A resistor was placed to balance the total application, and capacitors provided the flow of electricity.

3. Block Diagram

The figure1 shows the block diagram of proposed HESS. The block diagram consists of the following essential blocks.

- Super Capacitor
- Li-ion Battery
- Voltage Source
- Buck/Boost Converter
- Scope

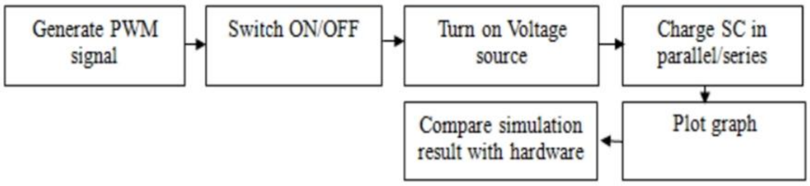

Figure 1. Block diagram of the proposed work

4. Methodology

The super capacitor is linked to the boost convertor/switch as shown in figure 2. The boost converter is also connected to the battery [10]. The voltage power supply is linked to both the circuits. To begin with, the power source provides energy to charge the battery. The battery may discharge through a super capacitor under discharge circumstances to smooth out the current demand. In addition, the charge and discharge conditions of the super capacitor, as well as battery performance, are compared in this simulation. To turn on both circuits, the switch is actuated using pulse width modulation. When the boost converter is turned on, the super capacitor is charged (series or parallel, depending on the desired super capacitor configurations). For this simulation, the voltages used are 24 V and 12 V.

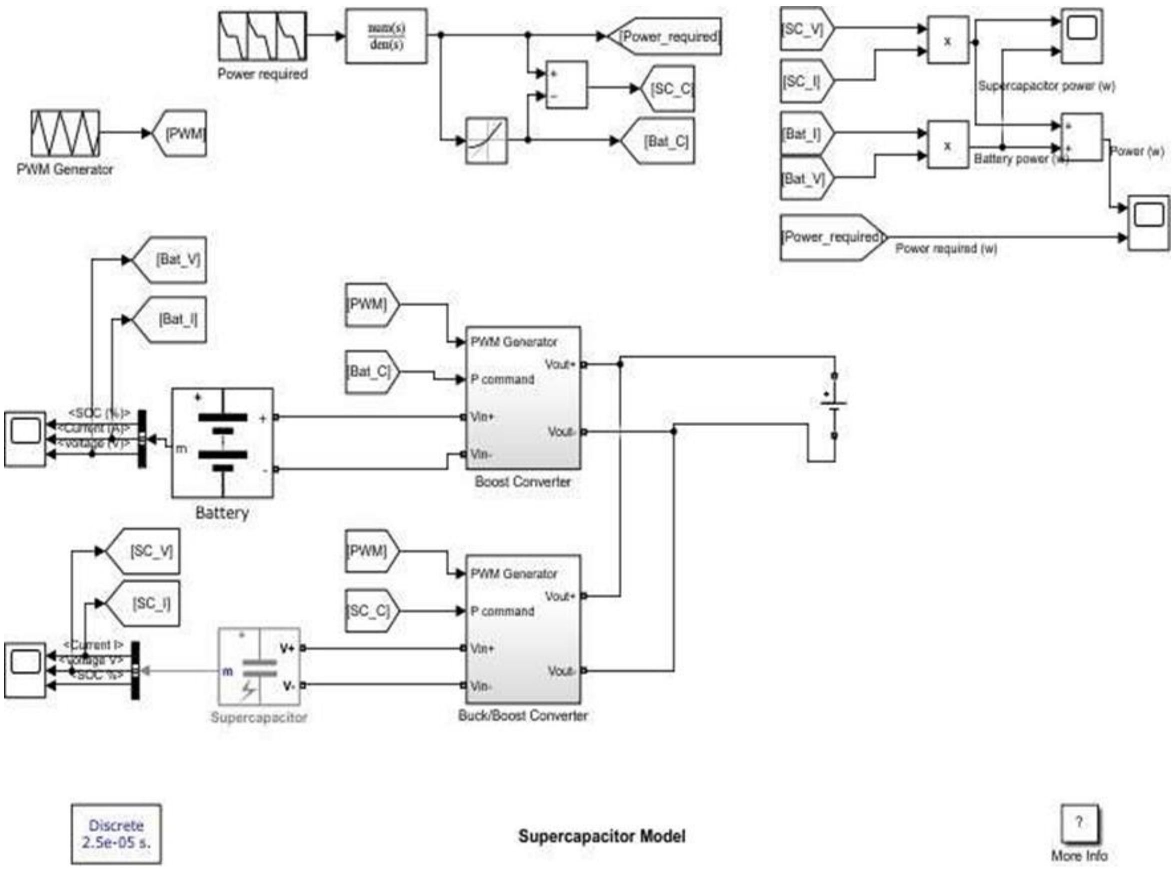

Figure 2. Overall Design of HESS

5. Results and Discussion

In electric vehicles, a supercapacitor is a ubiquitous component. It can store more energy with a greater power density, and it can discharge and charge with a higher power density. The behavior of the supercapacitor during the discharging process is explored and investigated in this chapter. The fundamentals of supercapacitor are also briefly explained.

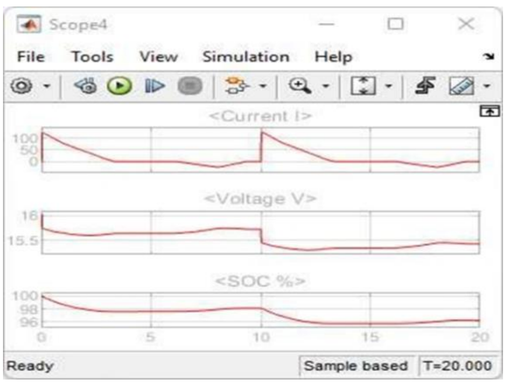

Figure 3. Discharging of supercapacitor

In case of series module [8], the result shows that the DC voltage applied to the supercapacitor is 24 V. The outcome is the same when its SOC is 129.4 and it begins discharging when there is the power is turned off. According to the results, the outcome declines quicker because the signal is turned off, and deteriorates till the end. As a result, the discharge condition may be noticed easily. Figure 3 depicts an ideal outcome, therefore no noise is included despite the fact that the result of the discharge process is being simulated. In case of parallel module, as the number of capacitance increases, the amount of SOC remains the same and constant. Hence, the discharge rate is very less, and therefore for constant SOC, parallel module can be preferred.

Table 1. Comparison of Voltage and Current at various configuration of Super Capacitors

S.no	No. of parallel capacitors	No. of series capacitors	SOC	Current(A)	Voltage(V)
1	1	20	129.4	80	24
2	1	30	123.4	80	24
3	1	40	118.6	80	24
4	1	1	148	80	24
5	30	1	150	80	24
6	40	1	150	80	24
7	50	1	150	80	24

6. Conclusion

In summary, a case study of supercapacitor power requirements and operation has been illustrated. Experimental results show that the discharge rate of the series connected supercapacitor is comparatively faster than the parallel connected module. During the discharge process, the current value and power value of the supercapacitor affect the discharge rate. In supercapacitor, the current decreases as the voltage decreases. This method does not completely discharge the battery, and hence the energy density of the battery does not change. Supercapacitor allows batteries to deliver more energy in less time. As a result, supercapacitor responds in a variety of ways, including high and low power demand, sudden power demand, and steady state. MATLAB Simulink provides optimal results for the current, voltage, and SOC discharge rate encountered during the simulation. Discharge uses Simulink model to mimic the behavior of complex systems. The state of charge and discharge of a supercapacitor is very important. Simulation is used in software. Various discharge conditions with and without supercapacitor are shown. In the scenario without the supercapacitor, the current is shunted to charge the supercapacitor, causing a linear decrease in voltage and a voltage drop. Using the example of a supercapacitor experiment, the simulation model shows that the voltage drops steadily as the energy delivered to the supercapacitor increases. The simulation and real-world results are close, but to have a better and more accurate simulation, the Simulink model results need to be improved, especially in terms of finding each particular point.

References

[1] Xiong, Guoping, Arpan Kundu, and Timothy S. Fisher. Thermal effects in supercapacitors. Cambridge, MA: Springer International Publishing, 2015.

[2] Pedram, Massoud, Naehyuck Chang, Younghyun Kim, and Yanzhi Wang. "Hybrid electrical energy storage systems." In Proceedings of the 16th ACM/IEEE international symposium on Low power electronics and design, pp. 363-368. 2010.

[3] Kim, Younghyun, Vijay Raghunathan, and Anand Raghunathan. "Design and management of hybrid electrical energy storage systems for regulation services." In International Green Computing Conference, pp. 1-9. IEEE, 2014.

[4] Durham, 2013. Do Hybrid Electric Vehicles Use Lead-Acid Batteries? Yes! Here’s why. Advanced Lead Acid Battery Consortium (ALABC).

[5] Bocklisch, Thilo. "Hybrid energy storage systems for renewable energy applications." Energy Procedia 73 (2015): 103-111.

[6] Logerais, Pierre-Olivier, M. A. Camara, O. Riou, A. Djellad, A. Omeiri, F. Delaleux, and J. F. Durastanti. "Modeling of a supercapacitor with a multibranch circuit." international journal of hydrogen energy 40, no. 39 (2015): 13725-13736.

[7] Nedyalkov, Ivan, Dimitar Arnaudov, and Nikolay Hinov. "Stand for Testing of Bi–Directional Converters in Photovoltaic Systems." Annual Journal of Electronics 8: 223-226.

[8] Cultura, A. B., and Z. M. Salameh. "Modeling, evaluation and simulation of a supercapacitor module for energy storage application." In International conference on computer information systems and industrial applications, pp. 876-882. Atlantis Press, 2015.

[9] Gao, Chao, Jian Zhao, Jian Wu, and Xiongbo Hao. "Optimal fuzzy logic based energy management strategy of battery/supercapacitor hybrid energy storage system for electric

vehicles." In 2016 12th World Congress on Intelligent Control and Automation (WCICA), pp. 98-102. IEEE, 2016.

[10] Talla, Jakub, Lubos Streiť, Zdenek Peroutka, Pavel Drabek, and Vojtech Blahnik. "Fuzzy energy management strategy for tram with supercapacitors." In IECON 2015-41st Annual Conference of the IEEE Industrial Electronics Society, pp. 003963-003968. IEEE, 2015.

[11] Yanzi, Wang, and Weida Wang. "Energy management strategy based on fuzzy logic for a new hybrid battery-ultracapacitor energy storage system." In 2014 IEEE Conference and Expo Transportation Electrification Asia-Pacific (ITEC Asia-Pacific), pp. 1-5. IEEE, 2014.

Authors' biography

S. Sundarmahalingam received his BE in Electrical and Electronics Engineering from Anna University, Chennai, India in 2010, ME in High Voltage Engineering from Anna University, Chennai, India in 2012 and is pursuing his PhD in High Voltage Engineering in Anna University, Chennai, India. He is currently working as an Assistant Professor (Sr.Grade) in the Electrical and Electronics Engineering department, Mepco Schlenk Engineering College (An Autonomous Institution affiliated to Anna University, Chennai, India). His areas of interests are Power System Protection, and High Voltage Engineering.

T. Balasubramaniyam and K. S. PretheshKumar are pursuing their BE in Electrical and Electronics Engineering in Mepco Schlenk Engineering College (An Autonomous Institution), Sivakasi, Tamil Nadu, India.