Hybridization of Battery and Super Capacitor of an Electrical Vehicle -A Review

Namrata Narayan[1],

[1]Masters in Instrumentation and Control, Department of Electrical Engineering National Institute of Technical Teachers Training & Research, Chandigarh, India,
namratanarayan95@gmail.com

Lini Mathew[2],

[2]Professor and Head of Department, Department of Electrical Engineering ,National Institute of Technical Teachers Training & Research,Chandigarh, India, lini@nitttrchd.ac.in

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Abstract

The goal of this study is to maximise the use of electric automobiles. One of the most essential objectives in improving the efficiency and effectiveness of an electric automobile is to increase the reliability and effectiveness of the electrical energy storage architecture in regards to power densities and energy limitation. In the field of power electronics has research on the hybridization on the energy storage because it is a viable financial solution for further development of energy. Batteries are grouped with SC and hybrid capacitor due to their poor power density and limited charge releasing cycle of energy.Most power research in this area has focused on merging a supercapacitor or hybrid capacitor with a battery, but no researchers have focused on both at the same time.This article manages the mix of supercapacitors and hybrid capacitors with the battery, accordingly, resolving the issues of the absence of pendency between two charging focuses on the supercapacitors, three hybridization methods, battery management system and the equilibrium point of the supercapacitor bank are presented.

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I. INTRODUCTION

The utilization of electric vehicles is steadily expanding because of their expense effectiveness and natural advantages. The Energy Storage System (ESS) [1] utilized in the EV decides the productivity of any EV innovation or technology. Batteries were fundamentally utilized as a storing structure in electric vehicles before 2012, however because of the electric vehicle's conflicting charging profile, battery duration and presentation were diminished as just the batteries needed to give the power in peak load and normal load request conditions. The advantages of lithium-ion technology-based batteries include temperature sensitivity, reduced size, management, highly efficient, and light weight [2-4]. It's the most suitable power source for the 21st century, with a promising future in a diverse range of applications, notably Electric Vehicles (EVs) as well as other portable electronic devices [5]. Hybrid Energy Frameworks based on batteries/supercapacitors have been used in electric cars (EVs) since this type of hybridization can meet EV specifications such as energy density/high power and extended battery lifespan [6] [7].

Many researchers portray that the fuel cell (FC) is the newer technology. Ozone depleting substance outflows and different pollutants come from street transport [8]. The boundless utilization of electric vehicles (EVs) could assist with lessening these fossil fuel byproducts, however they come for an extreme price to replacing the battery throughout the vehicle's existence

One potential answer for the battery substitution problem is to "hybridize" the battery of the electric vehicles with coordinated supercapacitors. Supercapacitors going about as a feature of a hybrid vehicle framework can give huge explosions of force in any event, when the vehicle's battery limit has diminished because of the low State of Charge (SOC), keeping up with increased speed of the vehicle. Supercapacitors may also protect batteries from strong current surges, which can be particularly damaging to batteries [9][10]. Consequently, by supporting the powerful necessities of a vehicle, supercapacitors can expand battery duration. This will be worthwhile assuming that the expense of substitute the batteries is more noteworthy than the expense of the addition of the supercapacitors.

II. LITERATURE SURVEY

Carter demonstrated a direct link among peak current and battery average lifespan [11]. When improved for battery momentum loss, the authors' control method yielded ebb and flow reductions up to 80% for the biggest explored pack of thirty 5000-F supercapacitors, and as much as 49percent of total for the lowest package of thirty 600-F supercapacitors for the drive cycles used in this study.This may result in significant gain in battery life, since almost comparable drops in peak current led to an increase in daily life of 253% for starting lead-corrosive batteries and 137% for auxiliary lead-corrosive foothold batteries. Batteries endurance improvement should be at least 50percent of total in advantage for any supercapacitor packs to be a financially feasible choice for the Cobra given present pricing.. On the other hand, supercapacitors have not been viewed as compelling at expanding vehicle range.

Yadav et al. [12] proposed a model and results show the greatest use of supercapacitor energy to run the vehicle in light of the fact that a high current through regenerative breaking can charge SC quicker than the battery, that is the reason more often than not just supercapacitors are being utilized for charging and releasing when its SOC is between 40% to 80% so this diminishes the weight on the battery and battery energy are less used when SOC of the supercapacitor is above 40%. The battery begins releasing when the SOC of the supercapacitor comes to 40% or beneath. At the point when the vehicle is running without a supercapacitor then the main battery is utilized as a stockpile framework. For this situation, the battery releases at the pace of 3.4% in a short time for a particular drive cycle. What's more, the distance went by the vehicle is 6.02 km quickly, so for 90% released, the vehicle covers
159.34 km.

At the point when the mix of battery and supercapacitor is utilized as a cross breed energy capacity framework for electric vehicles, the general distance shrouded by the vehicle in presence of battery and supercapacitor is
173.06 km. It is additionally seen that the scope of the vehicle when with battery and supercapacitor expanded by 8.61% for a similar drive cycle. At the point when a crossover energy capacity framework is being utilized, the size of the battery likewise gets decreased which in a roundabout way influences the general load of the EV that prompting further developed reach and effectiveness of the EV. The supercapacitor and battery-based crossover energy capacity framework with the control rationale, not just assists with further developing the battery duration, and vehicle range yet in addition gives better energy to the battery from high releasing current during regenerative slowing down.

Xiong et al. performed a research on the health of lithium-ion batteries and the usage of a real system for battery management in electric vehicles[13]. It also teaches how to successfully monitor lithium-ion batteries. Experiment data for cells studied at different current rates, like 1C and 2C, as well as temperature, like 25°C and 40°C, are obtained and utilised. According to the implementation findings, the capacity error terms were less than 1.5%. In the final 20percent of the overall battery's lifetime, the mean square root errors of the predictions of the remaining lifespan were within 20 cycles, and the 95% intervals are 20 cycles.

Indra et al. highlighted battery modelling as a concern for battery management systems to safeguard the battery and maximize its lifespan [14]. BMS is an important electric vehicle system for keeping the EV in top condition. This technology protects the battery from overcharging, over-discharge, and overheating, ensuring that it is not destroyed.

Qiang et al. presented the performance of an electric vehicle which was heavily reliant on the performance of its power battery [15]. Accurate evaluation of power battery state was the cornerstone of power battery performing optimally under current technological settings. Based on the order 2RC (second-order resistance- capacitance) model, a standard identification form suitable for gradientadjustment is inferred, and simulation was performed to validate it.

Mahadik and Vadirajacharya, presented a literature survey on enhancement of battery life using hybridization of battery and UC [16]. The authors concluded that the report provides the impression that the battery would provide base demand and UC would manage peaky circumstances. It decreases battery current by nearly half and improves storage system life, endurance, and energy capacity. Hybridization extends a vehicle's driving range. The costof the system is reduced by substituting extra battery storage with an ultracapacitor.

Yaci et al. explored the benefits of employing ultracapacitors (UC) in parallel with the battery in electric cars and established their viability using dynamic modelling [17].The hybrid energy application was explored for possible strain minimization and battery lifetime extension using a DC/DC converter- based design. A basic model was used to run dynamic simulations of two kinds of EVs, a public transportation metropolitan electric buses and an electric automobile. The hybridization studies revealed a significant reduction in battery charging duration. The findings indicated a decrease in the size of the principal energy source of the Electric Vehicle battery.

Camara et al. [18] investigated improved power regulation between lithium ion batteries and supercapacitors for HEV applications. As a result, employing a hybrid source of energy (like UC and battery) and smart energy management improves HEV performance. Two buck-boost converters connect the battery and supercapacitors (10 cells of 2.7V in series) to the DC bus. This study's major contribution is a DC-bus current and voltage control method built on a polynomial controller.The authors have presented improved energy management for HEVs using MATLAB/Simulink simulation and experimental data.

Arefin et al. investigated the advantages of incorporating an ultracapacitor into the battery system of an electrical vehicle's motor train[19]. The simulations are run with two scenarios in mind: new cells and partially battery cells. According to the model, the lesser the temperature, the better the performance of the hybrid system. For light- weight cars, simulations are performed using a modified Bangladeshi driving cycle. The report discusses several difficulties with hybridization, including volumetric, gravimetric, and cost issues. The system's power loss was decreased by up to 10% by using this approach. It has been established that hybridization enhances both the energy storage system's efficiency as well as the effectiveness of the power trains and batteries longevity.

Keil et al. presented an experimental examination of a HESS for electric cars' performance enhancements at subzero temperatures [20]. The authors discussed the distinct microgrid fault location traits and challenges, general fault location methodologies, proposed solutions in the literature, and future directions in this field. The proposed schemes were evaluated and compared to inform future directions of microgrid fault detection and location.

Benela and Jamuna explained design of a solar- powered charging device for electric vehicles [21]. The author tested various plug-in hybrid electriccars. This charging scheme is monitored by an Arduino board. Charging using solar energy reduces emissions from the electricity grid while increasing charging costs. It gives you greater latitude in preparing for technological advancement.

Butterbach et al. [22] discussed the HES idea for an electric garbage collection truck. Lead-acid battery and supercapacitors are used in the hybrid storage. To account for the battery charging during regenerative braking, a thorough lead- acid model was built.A full working day was devoted modelling the automobile on this type of urban driving cycle. The primary benefit of integrating super capacitors and lead-acid batteries in hybrid retention is a reduction in energy usage over the course of a full working day.

Dai et al. [23] described two forms of hybridization of energy storage systems employing ultracapacitors and lead acid batteries. Both power gain as well as the life extension of the hybrid version are explored using simulation and the construction of a modeling of every element in the hybrid system. The findings of the studies show that irrespective of the type of hybridization utilised, power is raised by a factor, and more power lowers battery pack current, increasing the battery's life span.

Galdi et al. proposed a fuzzy-based secure power management solution for electric vehicle energy storage systems [24]. He emphasised the major issue of the electric vehicle's lack of autonomy, which may be overcome with an appropriate FSPM. Whenever the SOC of the batteries falls below a certain level, the fuzzy controller adjusts the torque supplied by the motor. The simulation findings of a virtual EV equipped with a virtual FSPM system show that it performs well in terms of saving energy and autonomy increase, with only a small reduction in acceleration and speed performance.

Afrisal et al. demonstrated multi-battery management control through the use of a bus communication technique based on loop shaping[25]. The electric vehicle model has multiple battery management, and the fundamental control system has been changed to employ the bus communication technology auto tuning based on loop shaping. The vehicle's cost and dependability are improved, and the error equilibrium state is maintained at zero.

Xue et al. proposed the Adaptive Dynamic Modeling Approach for Efficient Battery Management of Battery-electric Vehicles [26]. This solution is intended to tackle the optimal control issue of a battery electric vehicle's battery management. The controller design scheme results demonstrate the efficacy of the BMS and the growth in algorithm.

III. TECHNOLOGIES FOR STORAGEOF ENERGY

This Energy Storage (ES) mechanism is one of the most dangerous components of electric cars (EVs). As a result, numerous innovations in the field of energy storage have been developed, including the lithium-ion battery [27], supercapacitor [28], flywheel [29], and superconducting magnetic energy storage [30]. TheLi- ion battery does have the highest density (70 to 200 Wh/kg) and the lowest running costs per unit of energy consumed. Some have lesser energy densities between 150 to 500 Wh/kg. Supercapacitors are a hybrid of a capacitors and electrochemical batteries which can charge as well as discharge rapidly. Though the Ultra-detailed capacitor's charge storage process is not completely understood at this moment, the following principles related to a electrochemical double layer appear to provide a good summary of the Ultracapacitor's useable capacity. When two distinct materials or phases collide, an interface is produced. An array of particles and oriented dipoles is thought to exist at every interaction. This type of array is referred to as an electric double layer. The supercapacitor should have the highest power density [31] with a power density of 1000-10000 Watt/kg as well as the reduced capital cost per unit. Figure 1 depicts a energy and power density comparison of various energy levels. Every device has a bandwidth, and exceeding this limit leads in significant input/output efficiency losses. Because the addition of an ultracapacitor reduces the bulk of the battery pack by 20%, the usability evaluation compares an electric vehicle with such a 100% battery pack to an EV + ultracapacitor vehicles with an 80%

rechargeable battery.

Both frequency and time-domain input/output evaluations were performed to describe the ultracapacitors and create the dynamic model. For this testing, the second ultracapacitor was pitted against three additional Maxwell Technologies ultracapacitors [32]. Each of these ultracapacitors employ carbon electrodes. Active and passive battery-capacitor hybrid source of power [33]. Active connection are much more efficient and last longer on batteries. Because the voltages of the battery and the capacitor never split, the capacitance array size has a distinct top voltage limit. Because supercapacitors have a high cycle rate of up to 1,000,000 cycles, they can manage the charge/discharge cycles present in a HEV. This notable feature can be used to extend the battery's life by allowing the supercapacitors to handle thousands of exceptionally maximum discharge and charge current flows during HEV's quick acceleration and braking, while the battery is only required to provide markedly less ordinary load current [34].

As a response, FC pair with the battery or even a SC is anticipated to completely use the power density and energy density of each item. Despite having a greater energy content than the supercapacitor, the battery has a reduced power density.Nonetheless, the battery's charging season is delayed by a few hours due to the charging flow restriction; nevertheless, the supercapacitor could be entirely energised in a few seconds, because the supercapacitor can endure a big charge momentum in a very short duration.

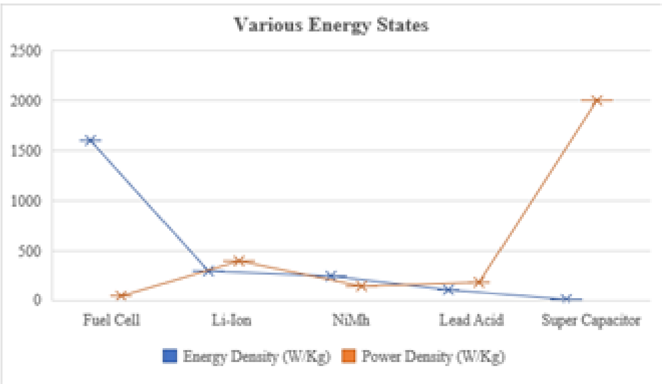

Fig -1: Different energy levels in terms of power and density

As a result,Lithium ion batteries and ultracapacitors are increasingly being employed in electric vehicles which may create the most highly dense qualities of each device, independently, and then the hybridized cell. In automobile power applications, the exhibiting features of an energy storage device may be expressed by two limits, namely power density and energy density [35]. A vehicle's power density is proportional to its velocity or speed; it influences how rapidly the vehicle can go. The energy density, in contrast , is connected to the scope of the vehicle, including how far it can travel. The Ragone plot is the link between these two performance qualities when displayed on a diagram. Tables 1 and 2 compare supercapacitors with other batteries, respectively, and clearly indicate that the Li-Ion batteries has the maximum energy density.

Table-1: Comparison of Different Batteries

Type of Energy Storage	Specific-Energy (Wh/kg)	Energy-Density (Wh/L)	Specific-Power (W/kg)	Energy Efficiency (%)
Lithium-Ion	118-225	200-400	200-430	95
NiMH	50-60	60	100-150	75
Lead Acid	35	100	180	80

Table-2: Comparison of Different Supercapacitors

Super capacitors	Nominal Cell Volt (V)	Internal Resistance (mΩ)	Specific- Energy (Wh/kg)
SKT47F	3	5.2	80
Ness2600F	3	0.25	13850
Panasonic 1200F	3	1	2000
Panasonic 80F	3	2.0	3505
Maxwell 2700F	3	0.5	6428

Figure 2 depicts several key lithium-ion battery as well as supercapacitor limitations, with data standardized to the most severe [36].

The lithium-ion battery has a higher energy density than the supercapacitor due to unique compound responses. This is among the chief factors that it has been recommended to be combined with FC in the field of electric vehicles.

Regardless, the SC has distinct advantages in terms of power thickness and charge/release cycle.Supercapacitors can transport large transient energy in a very brief time frame stretch due to their low internal barrier, and therefore are tempting for power shaving since they are not bound by the charging process. Similarly, the SC has a greater depth of releasing and a longer help lifespan, resulting in an elite presentation of the framework. SC also has the vexing real- world qualities of quick self-release rate and high power cost. The more energy a supercapacitor loses the longer it is kept untouched after being completely charged.The lithium-ion battery has a higher energy density than the supercapacitor due to unique compound responses. The lithium-ion battery has a higher energy density than the supercapacitor due to unique compound responses. This is one of the primaryreasons why it has been suggested that it be paired to FC in the area of electric cars.

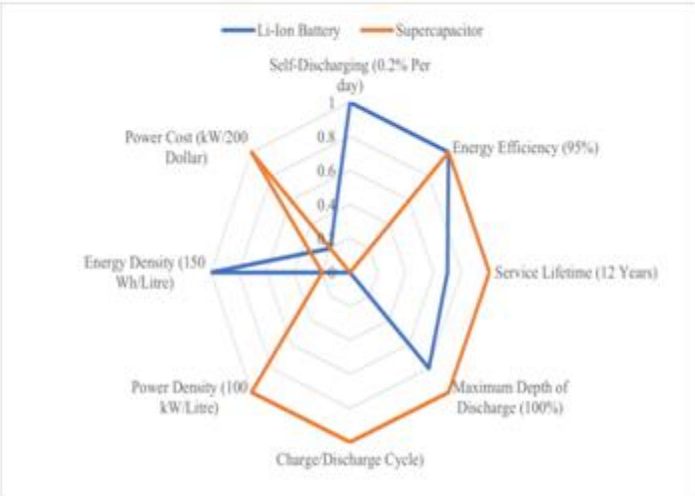

Fig -2: Comparison of some parameter between Li-ion and Supercapacitor [37].

As a result, Each of the three inventions, FC, Li- ion,battery, and supercapacitor, has advantages and weaknesses, and combining them is a fantastic key to maximizing the benefits of each [38].

IV. BMS BUILDING BLOCKS

There are several Battery Management Systems available, classified according to their topology, Modular BMS, Centralized BMS, and Distributed BMS are the three types of BMS accessible. Even though their topologies are different, their core functioning and operation are the same. The structure of a generic BMS is illustrated in Fig. 3.

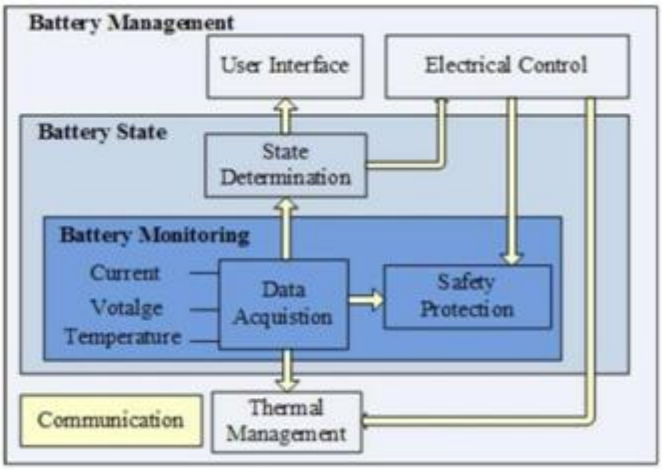

Fig -3: Block Diagram of BMS [39]

The principal purpose or function of BMS is to monitor and analyze three critical parameters from each battery cell: temperature, voltage, and current. As previously stated, battery packs are made up of numerous cells connected in either a series or parallel manner. Whenever cells are linked together in parallel, the voltage is often the sole thing evaluated because it is constant across each of them. When a series of cells is linked, the current flowing through the circuit remains constant across the series, requiring the monitoring of voltage over each cell. In Fig. 4, the cells are connected together in series, and also thecircuit current, and the temperatures and voltages for each cell, are measured once again.each cell, are measured once again .

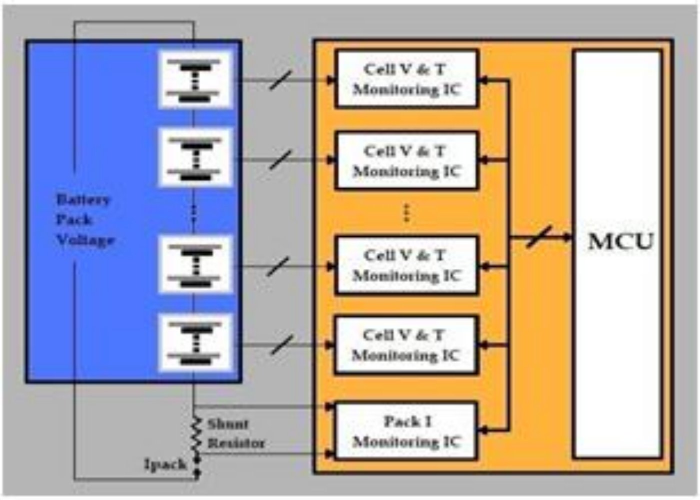

Fig -4: Connection of cells in series [40]

V. CIRCUIT CHARGER

The charger charges the batteries using a basic ac to dc circuit configuration. Around 10 batteries are linked in series and linked to the charging circuit, having power supplied via the charger. A multimeter can measure both charging and discharging current and voltage. A multimeter with red and black probes. For two months, the discharging and charging current and voltage of 100 Ah & 65Ah batteries were monitored continuously. Both batteries contained ten numbers in total.

VI. HYBRIDIZATION TECHNIQUES

Although supercapacitors' high limit and high- power density characteristics demonstrate their viability and the force limit limitation in EV applications requires the use of much greater practical supportable source, particularly a battery bank [41]. To develop an energy storage system that combines the high energy density of a battery with power density of a supercapacitor, batteries and supercapacitors are combined. In essence, the goal is to combine supercapacitors from the two developments in the power system architecture of the vehicle to harness the benefits of the two devices.

In this case, the battery serves as the primary power source, while the supercapacitor serves as that of the buffer system. Clearly, when the supercapacitor works with the battery, the supercapacitor will offer most extreme power requirement, while the battery will provide the normal power request. As a result, there is no risk of unanticipated battery cheating, which increases battery life and the overall efficiency of the energy storage structure [42].

The primary rationale for introducing a hybrid powertrain is to reduce fuel consumption and further enhance the IC Engine. There are numerous techniques and solutions that are used to exploit a vehicle's hybridization and to increase the energy efficiency of the storage design used in the EV.

This survey is primarily focused on the three primary hybridization procedures (i)direct hard wiring,

(ii) hybridization through individual power regulatory authorities as DC-to-DC converters and includes the same layout of Hybrid Capacitor (HC) as well as SC while conveying a power regulator coupled to the battery pack via DC-to-DC converters.

(i) **Direct Hard Wiring:** Direct or plain association is the sort of hybridization of energy storage that is the easiest [43]. When a load is applied to the hybrid storage capability terminals, the internal protections of each device define how well the device will be split in the future. It is expected that the current delivered by super and hybrid capacitors would be significantly larger than the current given by the battery because they both have lower interior safeguards than the battery. When connected the components according to the Fig. 5, the result shows the high current when calculated on the SC is about 200A within 5s, at the same time the HC shows 90A and the battery shows 150A. Similarly, when the time is about 10 seconds the current of SC and HC is about 1-3A and thebattery shows approximately 140A [41].

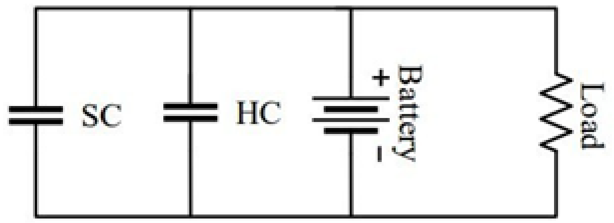

Fig -5: Hybridization of Battery using Hard wiring of SC and HC in parallel [41]

Hybridization by individual power regulator: Because the voltage there at SC and HC terminals varies with the SOC, connecting them to DC transport via DC converters allows for additional capacity to be extracted from the capacitors. Also, framework productivity and battery duration would be moved along. Fig. 6, shows the hybridization of energy storage device represented with every a gadget equipped with its own Power converter This method demonstrates the regulation of energy flow using energy capacity devices through DC converters. Because the SC and HC have significantly greater power densities than that of the battery, it is efficient to deliver just the high flows that are required in high power density. The point at which an electric car advances to meet another vehicle is an illustration of this power density [37].

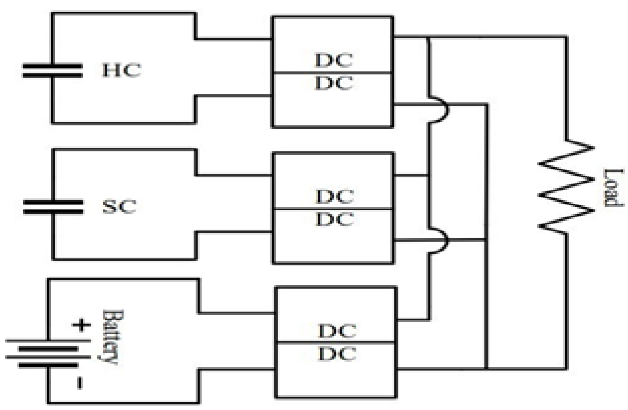

Fig -6: Hybridization of Energy Storage Devices

This procedure leaves space for control and greatest utilization of the energy created during regenerative slowing down. Because regeneration slowing action is likely to occur on a regular basis in the driving behavior of electric cars, batteries have a realistically limited charge/release cycle. To extend battery life, it is highly cost effective to store the energy generated during regenerative slowing in the HC and SC because their charge/release cycle is much higher than that of the battery. The hybridization approach, in which every energy storage devices includes its own DC link, is quite complex. Using a new converter fundamentally reduces the expense while expanding the converter's productivity and uniformity [44]. A Multi-Input DC-to-DC converters comprising 3 input structures: batteries, ultracapacitor, and hybrid capacitor can use the figure above.

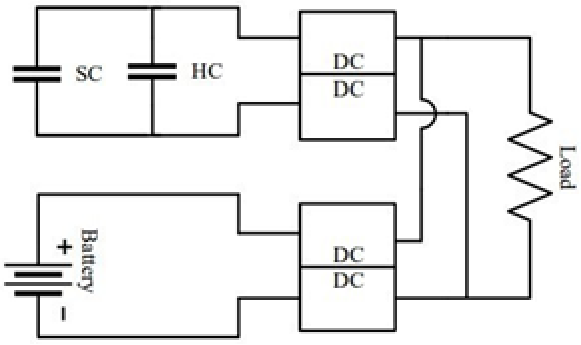

Fig-7: Innovative Hybridization Techniques

VII. CONCLUSION

Scientists are interested in hybrid vehicle frameworks that use renewable energy. With such a single energy device, the HESS has shown to be a potential option to an energy problem of electric automobiles. While battery and supercapacitors cannot meet all of the demands of electric vehicles on their own, HESS may compensate for their shortcomings.For HESS to turn out to be more serious, future exploration endeavors ought to be committed to bringing down the expense and expanding the limit and productivity of batteries and supercapacitors, as well as their HESS, through the presentation of adaptable materials and groundbreaking power gadgets. Furthermore, unique interest’s ought to zero in on more exact determining of future energy interest by joining continuous data and authentic driving information, so that better control of energy can be accomplished. the ability to further develop HESS execution. Right now, not many undertakings on the planet are engaged with the advancement of this innovation. The motivation behind this survey article is to make sense of mixture vehicle advances and their weaknesses exhaustively. Simultaneously, draw in scientists required to this field to track down new arrangements. A few related examinations that have been talked about are environmentally friendly power innovation, energy the executive’s framework, and other related points. Different types of models and portrayals examine the HEV framework overall as opposed to as a particular innovation.

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