IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Development of a Hybrid Energy Storage System for Electric and Hybrid Electric Vehicle: A Review

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Abstract: **Extensive use IC Engine - based vehicles has contributed to severe adverse impacts on the environment and accelerated depletion of fuel reserves, resulting in considerable rise in price of gas over the past 20 years. These challenges, plus the low efficiency related to the traditional drivetrains, have made the automotive industry seriously consider and move towards drivetrain electrification in vehicular systems. In electrified vehicles, the propulsion is fully or partially provided by electric motors, powered by on-board energy storage systems. In an effort to beat for the boundaries of the present energy storage devices and subsidize to vehicle electrification movement, this paper examines the chance and skill of a Hybrid Energy Storage System (HESS), composed of battery and ultra-capacitor units, through simulation in Matlab/Simulink**

Index Terms - ultracapacitor, Battery Unit, DC/DC converter, EV

I. Introduction

Transportation electrification will cause massive demand for high-performance and efficient energy storage system (ESS) technologies for electric vehicles (EVs) and hybrid electric vehicles (HEVs). "Currently, there's no single variety of energy device which will meet all the necessities imposed by road vehicles. Lithium-ion battery may be a promising technology for vehicular applications thanks to its high specific energy and comparatively higher specific power when put next with lead-acid and NiMH batteries" [12]. However, cycle lifetime of lithium-ion battery are often considerably reduced if the battery is exposed to fast-changing charging/discharging currents so as to fulfill the fast changes within the torque and power of the traction motor. On the opposite hand, ultra-capacitor contains a very high specific power, but is low in specific energy. "Since the capabilities of lithium-ion batteries and ultra-capacitors are complementary, it's worth trying to mix these energy storage devices to attain a high-performance of ESS" [8], [3].

II. HYBRID ENERGY STORAGE SYSTEM (HESS)

"Energy storage systems (ESSs) are of critical importance in electric, hybrid electric, and plug-in hybrid electric vehicles (EVs, HEVs, and PHEVs)" [13],[14]. Additionally to those issues, applications that require instantaneous power input and output typically find batteries affected by frequent charge and discharge operations, which have an adverse effect on battery life [12]. For such systems, it's crucial to possess an extra ESS or a buffer that's far more robust in handling surge current. The half-bridge converter is also a decent portion of the worth. This design solves the matter of the peak power demands, the battery still suffers from frequent charge and discharge operations. to unravel of those aforementioned problems, a replacement HESS is proposed during this paper. Operating principles of both these devices are different which make their characteristics highly different [4], [5]. UC encompasses a far lower energy density and significantly higher power density. UCs have superior low-temperature performance compared to batteries. These characteristics afford an optimal combination so on realize an improved overall performance. "The topologies of HESS are studied over the past few years. A review of the foremost widely used HESS topologies is given".[7]

A. Basic Passive Parallel Topology

Passive paralleling as discussed in [4] is that the simplest method of mixing battery and UC bank together because the two energy sources are hybridized with none power electronic converters/inverters. the most important problem with this topology is that it cannot effectively utilize the UC stored energy.

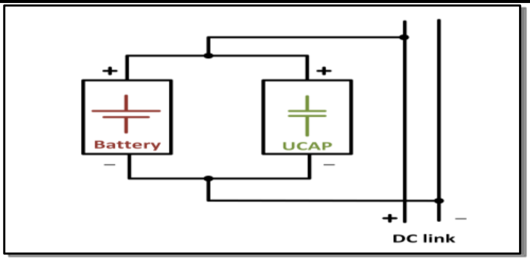


Fig 1. Block Diagram of Passive Topology

B. Cascaded Topology

To make a much better working range of the UC of the battery/UC configuration, another bidirectional dc/dc converter was added between the UC bank and also the dc link. The voltage of the UC can vary in a very wide selection therefore the capacitor is fully used The disadvantage of this method is that two full-size converters are necessary.

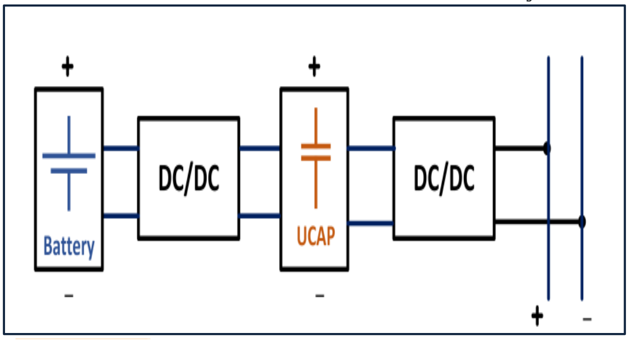


Fig 2. Block Diagram of Cascaded Topology

III. Voltage Strategy of two energy sources

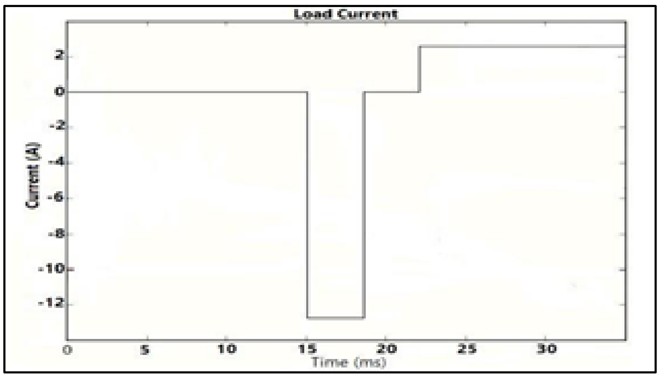
"In scheming a battery/UC HESS, the prime of the voltage approach is strongly allied with the characteristics of the battery and UCs used" [4]. If (Vuc < Vbatt = Vdc), it specifies that electric battery pack is allied on to the dc link and a UC connected to the dc link over a bidirectional dc/dc converter. During this case, the flexibility rating of the dc/dc converter must be correspond to that of UC so on entirely utilize the upper power ability of the UC. The UC bank is connected to the dc link directly, while the battery is connected to the dc link through a dc/dc converter. With this topology, the voltage of the battery is sustained at a lower magnitude so less balancing subjects must be addressed.

IV. Effective Utilization of UC Stored Energy

While energy transfer during a battery isn't a role of voltage, energy storage in a UC follows the law of storage in a standard capacitor as shown in EC a p. Voltage of the UC has to be discharged to half the initial voltage so as to deliver 75% of the energy stored a security sideline is tolerable so as to forestall a reverse charge of unbalanced cells. When a voltage variation of 66% is tolerable, 90% of the UC energy is brought. Even in an destructive discharge, the voltage of the battery pack can drop only up to twenty of the nominal voltage. Assuming that the UC is intended to hide the nominal voltage, Vmax = Vnom , the overall energy which will be delivered by the UC is. the particular energy available is a smaller amount than 36% because a boundary has to be allowed for the UC to hide higher voltage of the battery pack during charging or regenerative braking.

V. Simulation and Results

A study was done on simulation of HESS for hybrid and electric vehicle energy storage system. Given below are the results obtained from the experiment.[2]



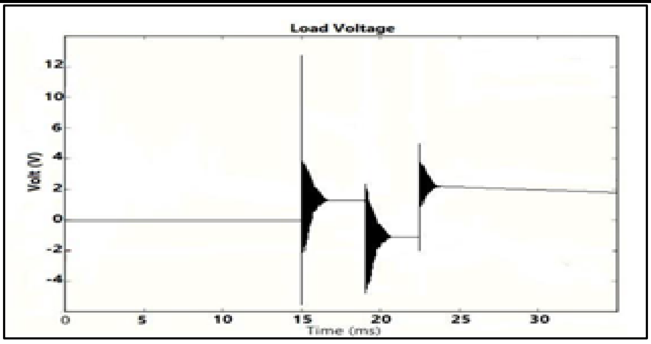


Fig 3. Load current voltage changes

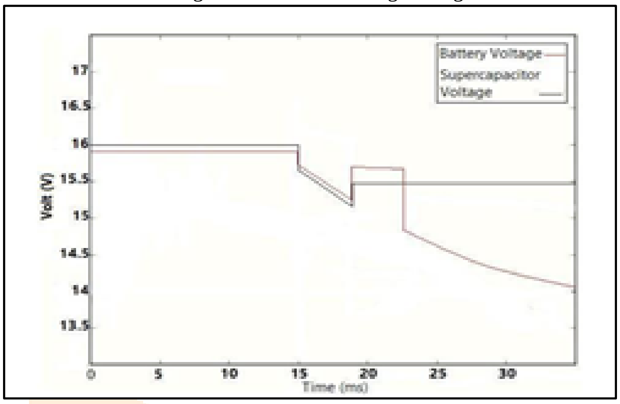


Fig 4. Battery and supercapacitor output voltages

VI. BU/UC CONFIGURATION

"The topologies for connecting components of a Hybrid Energy Storage System (HESS) constituted of battery and ultra-capacitor units to the DC bus of a Plug - in hybrid electric are critically reviewed in this research." [6]. Consumers are hesitant to buy EVs and HEVs until the performance and reliability of those vehicles meet or exceed those of traditional combustion-engine-based vehicles at a comparable price, according to statistical study [11]. They have a much larger capacity than ordinary capacitors [9], [10]. ESS manufacturers are working to close the gap between different storage devices by developing solutions with both high specific energy and high specific power. Among the most common issues with a HESS setup is how to connect the battery and ultra-capacitor. This issue has been extensively addressed within the literature.

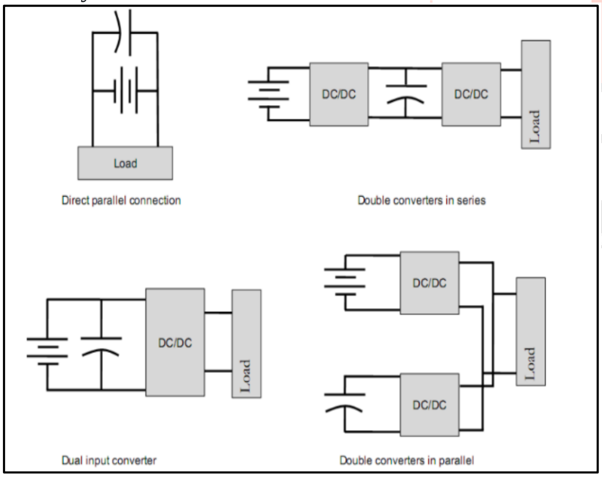


Fig 5. Different configurations of a hybrid battery/super capacitor system

VII. SUPERCAPACITORS

Super capacitors are capacitors which can store a huge quantity of electricity. Super capacitors have a big conducting plate called an electrode, a huge surface area, and a short distance separating them. It is more of an electrochemical device than an electrolyte capacitor because it uses a liquid or wet electrolyte between its electrodes. When it comes to storing electrical energy, there is no chemical reaction. Graphite carbon, carbon gels, and carbon nanotubes make up the two-sided electrodes. Positive ions can travel through while bigger electrons are blocked by the separator. Because of their high capacitance values and short distance amongst electrodes, super capacitors are used in high-energy storage technologies.

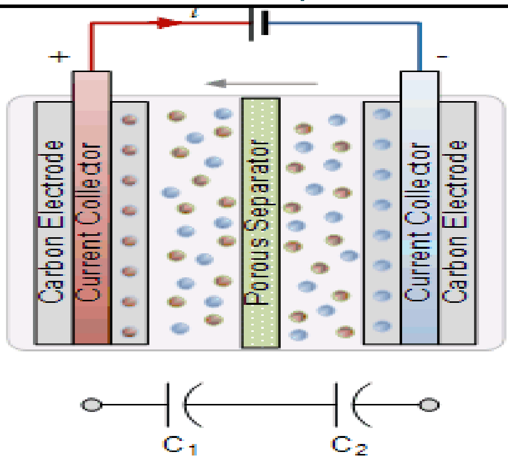


Fig. 7 Construction of supercapacitor

However, because the rated voltage of the ultra-capacitor cell is mostly determined by the electrolyte's decomposition voltage, the voltage across the capacitor can only be very low. Then, depending on the electrolyte employed, a typical capacitor cell has a working voltage of 1 to 3 volts, limiting the amount of electricity it can store. Ultra-capacitors should be connected serially in order to hold charge at an affordable voltage. Ultra-capacitors are distinguished by their low terminal voltage, as opposed to electrolytic and electrostatic capacitors. Ultra-capacitor cells must be coupled asynchronously or in parallel to get greater capacitance values, as indicated, in order to increase their rated terminal voltage to tens of volts.

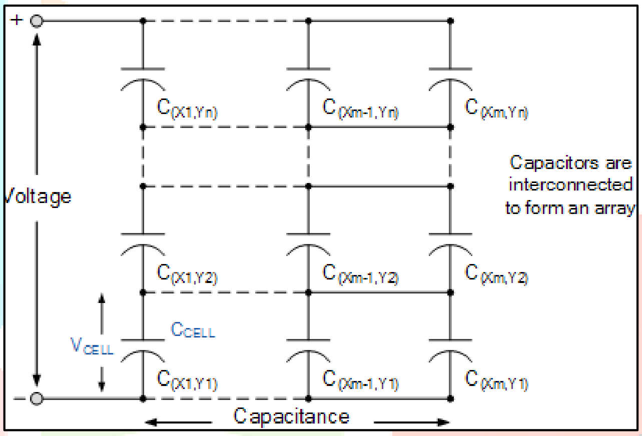


Fig.6 Capacitor array

Where: V_{CELL} is the voltage of one cell, and C_{CELL} is the capacitance of one cell.

Because each capacitor cell has a voltage of roughly 3.0 volts, adding more capacitor cells in series will raise the voltage. The capacitance of a capacitor is increased by connecting several capacitor cells in parallel. The total voltage and total capacitance of an ultra-capacitor bank can then be defined as:

Voltage, $V_{CELL} = V_{CELL} * N$

Capacitance, $C = C_{CELL} * [M/N]$

Where: M is the number of columns.

N is the number of rows.

Like batteries super-capacitors have a defined polarity with the positive terminal marked on the capacitor body.

Abbreviations

ESS = Energy Storage System
EV= electric Vehicle
HEV=Hybrid Electric Vehicle
HESS= Hybrid Energy Storage System
PHEV= Plug-in Hybrid Electric Vehicle
UC= Ultracapacitor
BU= Battery Unit

Acknowledgment

1. *Pooja Chobe, Assistant Professor Department of Electrical Engineering, Sanjivani College of Engineering Kopargaon*

VIII. Conclusion

Because batteries have a low specific power, high-specific-power storage devices, such as ultra-capacitors, must be used alongside them. In an electrical drive train, there are a variety of ways to connect the battery and ultra-capacitor units to the DC bus. The only and most cost-effective option is to link both storage units directly to the DC bus; nevertheless, this plan has numerous downsides in terms of battery life and system efficiency. Structures based on power electronic (PE) converters are frequently used to simplify interface and the construction of efficient energy management algorithms. The temporarily design with the ultra-capacitor unit directly connected to the DC bus and the battery unit connected via a bidirectional DC-DC converter is the most feasible interface topology, according to scientific analysis and literature study. in EV/HEV applications. a whole review of various energy management mechanisms in vehicular applications is included within this paper.

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