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Battery-Super Capacitor-based Hybrid E-Vehicle

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Abstract - A growing concern in today's world is environmental protection and energy conservation. Automotive manufacturers are developing alternatives to existing fossil fuel-driven vehicles. This has paved way for the development of Electric Vehicles (EV) and Hybrid Electric Vehicles (HEV). While HEVs tend to reduce the emissions from internal combustion vehicles as a result of greater fuel efficiency, they do not completely solve theproblem. Electric vehicles on the other hand are much more energy efficient, produce absolutely no tail pipe emissions and requires less maintenance as compared to the conventional internal combustion engine (ICE) vehicles. However, the reason the automotive industry has not gone pure electric or able to compete favorably with existing gasoline cars, lies in the inherent problem of existing battery technologies. Presently the only viable solution to this problem is to combine a high energy storage device such as an electrochemical battery or fuel cell with a high-power device such as an Electric Double Layer Capacitor (EDLC) or ultra-capacitor or more often called a super capacitor.

The research work classified in to two different categories, i.e., simulation in MATLAB and its hardware implementation. In this paper Supercapacitor is connected in parallel with Batteries and its comparison is done. These paper presents simulation on BLDC motor with battery and supercapacitor.

Key words – Battery, Super Capacitor, Boost Converter, Electric hybrid vehicles, HESS.

1. INTRODUCTION

To design and implement a small electric vehicle which will be solely powered by a combination of deep cyclelead acid batteries and a super capacitor module. To design and implement an onboard data acquisition system to monitor and log critical data from the electric vehicle.

To prove first hand insight into the interaction between

In the last few years, the pollution problems and the increase of the cost of fossil energy (oil, gas) have become planetary problems. The car manufacturers started to react to the urbanpollution problems lead acid battery pack and super capacitor module connected in parallel. To investigate and justify the reported increase in battery life, range per charge and vehicle acceleration by augmenting the battery pack with a super capacitor module. This is also achieved using real world drive data and results.

Electric vehicle plays a vital role in the energy and environmental impact of an increasing transportation which offers more energy efficient and less pollution over fuel vehicle. Use of electric vehicle increasing day by day because of its benefit. The performance of EV depends upon its storage system. Up to the 2012, only battery is used as a energy storage device. Because of the peak load demand, battery fails to complete the requirement. In the battery-based energy storage system (ESS'S), power density of the battery needs to be high enough to meet the peak load demand. Although batteries are available, but they are costly. It is crucial to have an additional ESS or a buffer that is much more robust in handling the surge current. In order to solve these problems, hybrid energy storage system has been proposed. The basic idea of a HESS to combine super capacitor and battery to achieve a better overall performance. Introduction of super capacitor not only reduces electric stresses but also meet vehicle power demand. It helps to achieve better performance as well as excellent control scheme during motor drive cycle. It also can reduce overall driving cost of the vehicle.

By adding super capacitor module with battery in EV, following are the advantages which improves the performance efficiency of the EV:

1. It improves vehicle acceleration.
2. Reduction in cost and increases life cycle
3. Environment eco-friendly
4. Improvement in driving efficiency thereby increasing in driving range

in nineties by commercializing the electric vehicle. But the battery weight and cost problems were not solved. The batteries must provide energy and peaks power during the transient states. These conditions aresevere for the batteries. To decrease these severe conditions,the super capacitors and batteries associate with a good power management present a promising solution. With such advantage of super capacitors over other conventional capacitor and battery the combined working or individual working of it is of main interest.

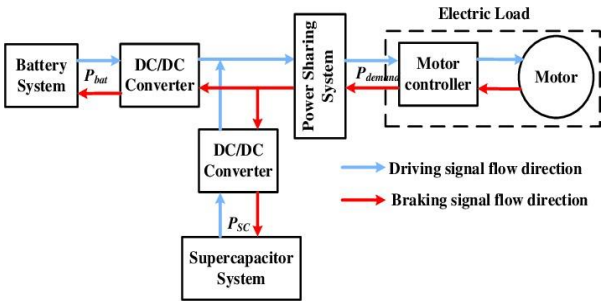


Fig.1. Block diagram of hybrid electric vehicle system

The supercapacitors are mainly used in ride through condition. Ride through condition means the requirement of large amount of power for the short time duration. For the few second of time, we can use supercapacitors. Supercapacitors are storage devices which enable to supply the peaks of power to electrical vehicle during the transient states. During the steady states, batteries will provide the energy requested. This methodology enables to decrease the weight and increases the lifespan of the batteries.

Electric vehicles (EVs) have recently attracted considerable attention and so did the development of the battery technologies. Although the battery technology has been significantly advanced, the available batteries do not entirely meet the energy demands of the EV power consumption. One of the key issues is non-monotonic consumption of energy accompanied by frequent changes during the battery discharging process. This is very harmful to the electrochemical process of the battery. A practical solution is to couple the battery with a supercapacitor, which is basically an electrochemical cell with a similar architecture, but with a higher rate capability and better cyclability. In this design, the supercapacitor can provide the excess energy required while the battery fails to do so. In addition to the battery and supercapacitor as the individual units, designing the architecture of the corresponding hybrid system from an electrical engineering point of view is of utmost importance.

Hybrid combination of battery and super capacitor gives more advantages of both high specific power and high specific energy. The main importance point in hybrid system is to balance the energy between the main source (battery) and auxiliary source (super capacitor). It distributes battery load with supercapacitor having high efficiency and increased battery life and its efficiency. This methodology enables to decrease the weight and increases the lifespan of the batteries.

The main components in the construction of supercapacitors are two charged electrodes, a current collector and a separator that allows for the transfer of ions and prevents direct electrical contact. When an electric charge is collected among the primary electrode and electrolyte, the equal quantity of charges with contrary polarity might be precipitated on the second electrode forming charged layers with minimum separated distance. Supercapacitors are the precise solution when a quick charge is needed to provide a short-term energy. At the same time, batteries are regularly selected to offer long-time period energy as they can be recharged very quickly. Also, they are appropriate and extra robust to bridge power gaps persevering with from some seconds to a few minutes.

To compensate for the challenge discovered in battery powered EVs, SCs are used along with the battery, ensuing in a hybrid ESS(HESS). Their excessive power density and potential characterize the SCs to work on a vast variety of temperature and their potential to respond quickly. The typical characteristics of each battery and SCs are provided. Hence hybrid ESS (HESS) topologies were proposed together with both batteries and SCs.

Properties of super capacitor:

1. Very High Capacity and A Low Internal Resistance
2. Fast Discharge Rates
3. High Power Density
4. Longer Cycle Life
5. High Cycling Efficiency

Advantages of super capacitor over batteries:

1. It offers high energy density and high-power density compare to common capacitor.
2. It offers high capacitance (From 1 mF to >10,000F).
3. It offers fast charging ability.
4. It offers superior low temperature performance (from -40°C to 70°C).
5. It offers longer Service and long life (about 10 to 15 years compare to 5-10 years of Li-ion battery). It offers virtually unlimited cycle life and can be cycled millions of times.
6. It offers higher reliability of performance.

2. SIMULATION AND HARDWARE IMPLEMENTATION:

2.1 MATLAB SIMULATION IMPLEMENTATION:

2.1.1 The permanent magnet dc (PMBLDC) motor is the ideal choice for applications that requires high starting torque, high reliability, better efficiency, and high performance. Generally, a Bldc motor is considered to be high performance motor that is capable of providing large amounts of torque over huge speed range. For the proposed electric vehicle project, BLDC motor is chosen and the model of the Battery-Boost converter and Bldc motor is simulated using MATLAB/Simulation

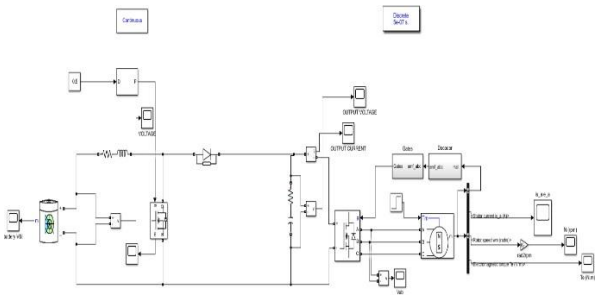


Fig.2. Battery, Boost converter and BLDC Motor

2.1.2 The circuit is connected with a battery with rating of 12V,7A which is connected in parallel with a super capacitor with a rating of 3V, 500F, after that the parallel combination of battery and super capacitor is connected with the boost converter which boosts the voltage from 12V to 24V which is needed to run brushless dc motor.

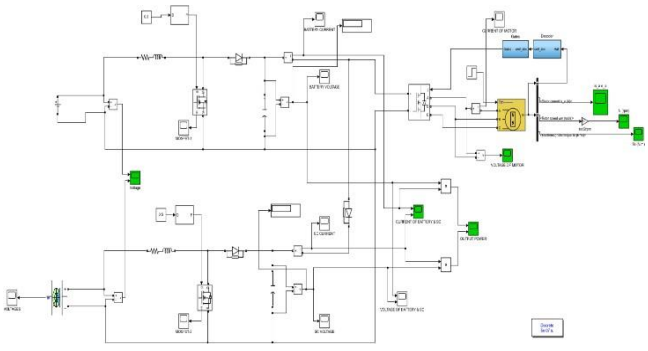


Fig.3. BLDC Motor Drive by using parallel combination of Batteryand Super capacitor

2.2 HARDWARE IMPLEMENTATION

The hardware for the design and implementation of Battery- Super capacitor-based Hybrid E-Vehicle consists of battery, super capacitors, boost-converters, toggle switch, BLDC Motor. The supplyvoltage of BLDC motor is 24 V which will be provided by either battery or Super capacitor based on the conditions.

Fig.4. Complete hardware circuit of Battery Super capacitor-based Hybrid E-Vehicle.

3. RESULT:

3.1 MATLAB SIMULATION RESULT:

3.1.1 Battery, Boost converter and BLDC Motor:

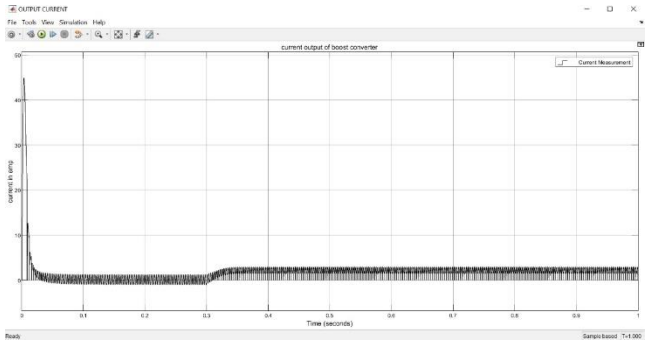


Fig.5. Output current of boost converter

Fig.5. shows the output current of boost converter and its simulation circuit as shown in fig.2. At the starting time motor current reaches to 42 Amp. Within in a fraction of second motor current is decrease after 0.002 seconds, current is in stable condition nearest 2 Amp. When load is given on motor at 0.3 sec. Motor current is increase up to 3 Amp.

Fig.6. Output waveform of stator current

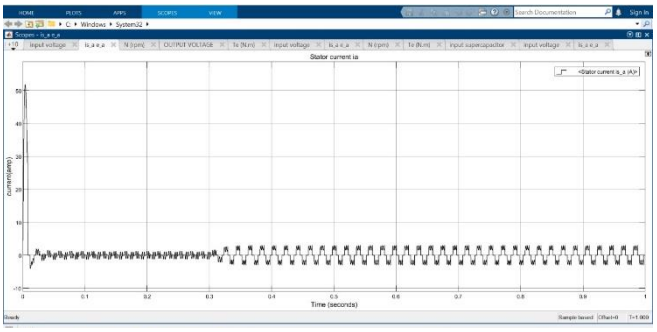


Fig.6. shows the stator current of BLDC motor and its simulation circuit. As shown in fig.2. In starting the motor takes the high starting current which is 52 Amp then it is constant in sinusoidal form, from 2 Amp to -2 Amp for time period 0.3 Sec. After giving load on BLDC motor from time period 0.3 Sec the stator current is observed in sinusoidal form, from 3 Amp to -3 Amp.

3.1.2 BLDC Motor Drive by using parallel combination of Batteryand Super capacitor:

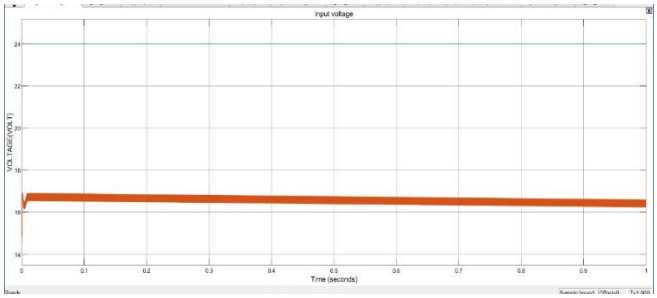


Fig.7. Input Voltage of Battery and Supercapacitor

Fig.7. shows the input voltage of battery and supercapacitor and its simulation circuit as shown in fig.3. In this circuit the blue line shows the input voltage of battery which is 24 V and the orange line shows the input voltage of supercapacitor which is 17 V. Initially consider supercapacitor is in charge condition, at the time of starting it provide voltage to the system. Supercapacitor is fully charge and provide 17 V to BLDC motor in parallel with the battery, when connected into the system its voltage decreases up to 16.8 V.

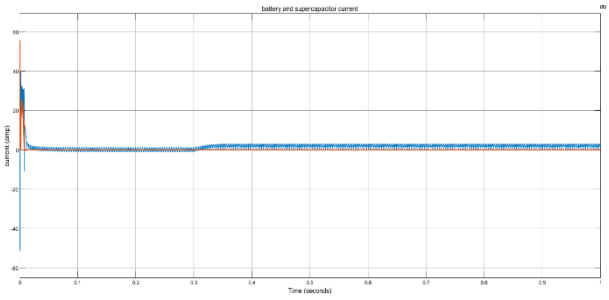
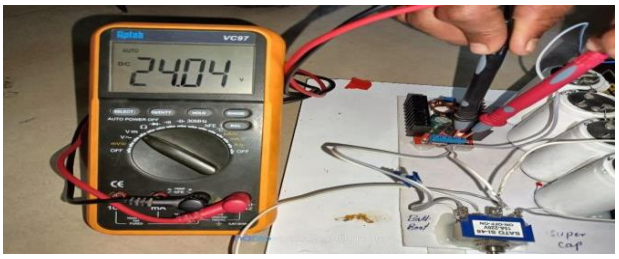


Fig .8. Output Voltage of Battery and Supercapacitor

Fig.8. shows the output voltage of battery and supercapacitor with boost converter and its simulation circuit as shown in fig.3. In this circuit the blue line shows the output voltage of boost converter of battery which is boost up from 24 V to 42 V. The orange line shows the output voltage of boost converter of supercapacitor which is boost up from 17 V to 35 V. In no load condition the output voltage of battery is 42V up to time period 0.3 Sec. After giving load from 0.3 Sec the output voltage of battery is observed 40 V. In case of supercapacitor the starting high voltage of 42 V is provided by supercapacitor for time period 0.02 Sec and then it is constant to 35 V.



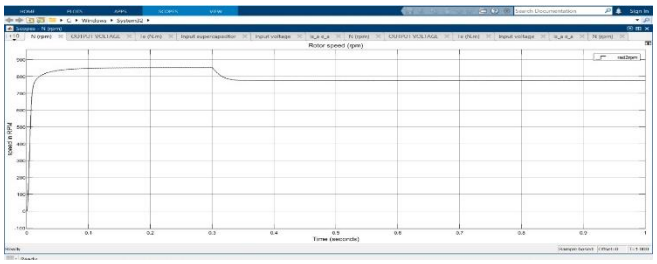


Fig.9.Output Waveform of Stator Current

Fig.9. shows the stator current of BLDC motor and its simulation circuit as shown in fig.3. In starting the motor takes the high starting current which is 52 Amp then it is constant in sinusoidal form, from 2 Amp to -2 Amp for time period 0.3 Sec. After giving load on BLDC motor from time period 0.3 Sec the stator current is observed in sinusoidal form, from 3 Amp to -3 Amp.

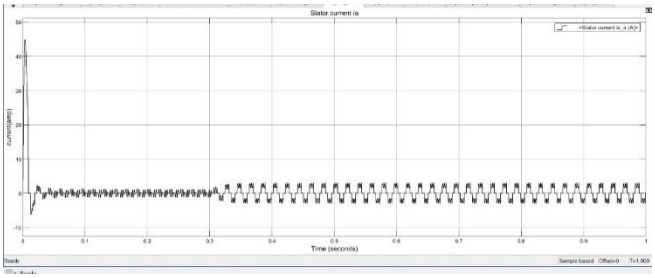


Fig .10. Output Waveform of Speed of BLDC Motor

Fig.10. shows the speed waveform of BLDC motor and its simulation circuit as shown in fig.3. In this circuit at no load condition speed increase linearly up to 0.002 sec. After that speed of the motor is constant from 0.001 to 0.3 sec. When the load increase on motor speed of motor decreases up to 790 rpm up to 1 sec.

4. HARDWARE RESULT:

4.1 The circuit is consisting of series combination of super-capacitor andboost-converter as from the series connection of 4 capacitors with the voltage ratting of 3 V each the total output voltage getting is 12 V but to drive the BLDC motor of 24 V, 24 V is needed so the boost-converter is used which boosts the 12 V from the supercapacitor to 24 V.

Fig.11. output voltage Super capacitor and boost-converter

4.2 The circuit is consisting of series combination of Battery and boost-converter as from battery, voltage getting is 12 V but to drive the BLDC motor of 24 V, 24 V is needed so the boost- converter is used which boosts the 12 V from the battery to 24 V.

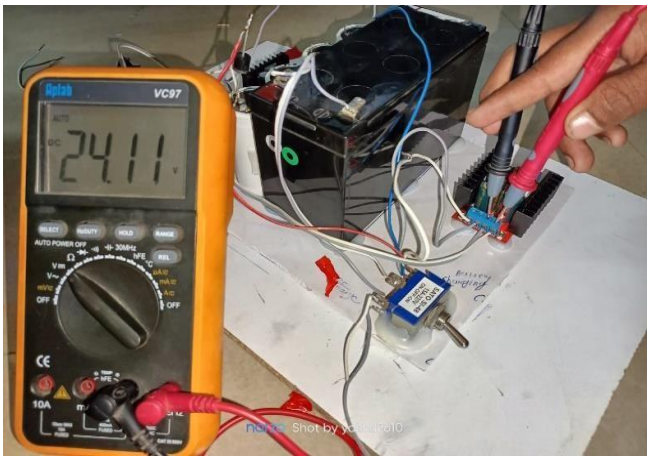


Fig.12. output voltage battery and boost-converter

5. CONCLUSION:

In this study the EV simulation is carried out that determines the energy flow among the EV component are integrated.
By combining SC parallel with Battery, we can improve the performance of EV and also reduce burden on battery at the time of starting of BLDC motor.
This work has successfully implemented a battery/Super capacitor hybrid power source for an electric vehicle geared BLDC motor.

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