A Design Modification to Improve the Charge and Discharge Profile of a Super Capacitor in Electric Vehicles

Kura Ranjeeth Kumar, Rajulapati Sudha, Kunta Srikanth

Abstract: ***As the Super Capacitors have Higher Specific power density, longer life time and safer operation when compared with any other energy source in Electric Vehicles, thus have more attention in the present market. Thus presently Super Capacitors are used to act as intermittent source. This study would deal with the performance analysis of Electric Vehicles by adopting Super Capacitor as the only Energy source without any Backup. The SC can charge and discharge at a very faster rate, the time taken for the charge is also equal to the time taken for discharge. Thus the SC will discharge at a very faster rate, in this regard to improve its discharging rate we would like to do certain Design Modifications. The Main objective of this study is to replace the energy source in the EV's with Super Capacitor Bank which would reduce the weight, Maintenance, and increase the performance of EV's in a long run.***

Keywords: Super Capacitor (SC), Energy Storage, Performance, Design Modifications, Electric Vehicles (EV's).

I.INTRODUCTION

As of today still we see the traditional fossil fuel vehicles, which are responsible for the concern of emitting pollutants in atmosphere. Thus there is more need for clean energy with zero emission. Nowadays, several types of Electric Vehicles such as Hybrid Electric Vehicles, Fuel Cell Electric Vehicle and many more available which are zero emission. The Energy storage Elements in the Vehicles has become a major concern in their performance. The energy storage elements available in the market are Rechargeable Battery (Li-ion, Alkaline etc.), Fuel Cells, Ultra Capacitors/ Super Capacitors, Ultra Flywheels. The charging time and charging infrastructure of the Energy source is the most important concern in the modern world where time is more precious than anything. Thus we need the energy source which can charge at a faster rate and in less time. Among the energy sources available Super Capacitor can charge at a very faster rate, such as ten times faster than the Battery. To make the EV's Compact, the space occupied and weight of the Energy source should be as minimal as possible. The super capacitor will occupy less space and can even be Body Integrated, as well as the weight of the SC bank will be far less than that of a Battery bank for the same vehicle.

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The main demerit of the Super Capacitor is that it gets discharged very fast, thus in this study we would like to make some design modifications such as increasing the distance between the Electrodes, using electrodes with high a high reactive carbon material which could store charge for a long time, using different current collectors, binders and adhesive to store more charge. We shall also do the efficiency prediction of EV's by using the super capacitor as the only energy source. By using Super Capacitor which has static charge rather than current based, the magnetic interference is negligible and therefore it has potential to reduce the electromagnetic interference (EMI) of any vehicle. Generally vehicle in motoring mode will take the energy from the source and when is in Braking or traction mode will give the energy to the source. The source must be capable of charging at a faster rate such that it can gain most of the energy at the time of traction. Super capacitors can charge at a very faster such the other sources, thus can store most of the energy given by the vehicle at the time of traction.

II.LITERATURE REVIEW

A Battery is a volatile device which utilizes electrochemical conversion process. Due to inefficient charge management the concern in present time is Battery life enhancement. SC is an efficient device which can manage the charge and enhance the storage device life. Super capacitors are efficient and reliable energy storage element to compensate the batteries in EV's. The huge power density of super capacitors can significantly reduce the impact of power fluctuations. Electrochemical super capacitors performance is meritorious to conventional capacitors and batteries. The comparisons are like Fast charge and Discharge capability; Higher specific power Density, low operating temperature performance; Million cycles charge and discharge; Good reversibility; free from Electromagnetic interference [1]. From this reference we could analyse the merits of the super capacitors which could be adoptable in the intermittent operations of any systems for energy absorption and utilisation. As in many existing systems there are intermittent loads and source, which are difficult to utilise. Hence SC can play a major role to overcome these difficulties. Super capacitors can supply high power and high current intermittently which could be helpful to absorb the power in traction loads which are intermittent. As SC works on Static Charge, hence the Electro Magnetic Interference (EMI) is negligible when used in the EV's.

By using super capacitors the acceleration performances; Gradient force on the specified slope and the performance of the travelling distance can be improved [2]. As SC have a very high Power Density which makes it to absorb or exhibit the power at a very faster rate which would be nearly 15 to 20 times to that of conventional batteries. Hence we could replace the battery with a SC. Among all the energy storage devices super capacitor is relatively new system that provide higher energy density than dielectric capacitors and higher power density than batteries. As of today's technology the most adoptable charging infrastructure is DC Fast Charging in which the battery is subjected to high inrush of current which is 5 to 7 times to that of rated current for a very short duration which is 15 to 20 minutes. In this method the battery is subjected to very high intermittent load which can reduce the life time of the Battery. As per our observation a SC can be subjected to High intermittent load, they release their stored energy very quickly. Super capacitors have their capability of being charge and discharge constantly without damaging their lifetime. The advantages of using super capacitor are like Efficiency; current capability; lifecycle; Voltage range; Temperature range are more and Maintenance is less [3].

Invention of SC has allowed electronics market to produce portable devices that can charge at a faster rate and have high durability. The main components of a SC are current collectors, Electrodes, separators and electrolyte. The raw material used in manufacturing collectors, separators, adhesive and binders play an important role to improve the performance standards of SC. Hence we can use Graphene and activated carbon as Electrode for high performance, which are capable of huge storage capacity which can help us to replace a Battery [4]. There is still research going on in manufacturing and raw material selection to improve the performance of the SC.

Electric Double layer capacitor (EDLC) is one of the Super capacitor which can rapidly charge within short time because of its large current capability. They are environmentally friendly compared to Batteries, since they won't use heavy metals, and have long durability and reliability. The life of ELDC is nearly 40 to 60 times more when compared to other regular batteries [5]. A SC is a promising solution for high dynamics in charging and discharging. The performance parameters of SC could be like intermittent storage absorption is nearly 60 to 70%. [6]. From these references we can understand that ELDC is widely used for energy storage which is mostly using for two wheelers.

Super capacitors powered buses are running in china. Today range of these buses has gone up to 25 km in one charge. Buses get charge in less than 5 minutes at depots. Today capacitor powered buses are running in few countries even in Europe, Taiwan [7]. Most of the South Asian and European countries are already equipped with electrical buses. ABB had already launched electric buses in countries like Switzerland, where the buses get charged at selected bus depots. China is also took lead in adopting the electrical bus equipped with super capacitors. Super capacitors are then charge on each bus stop with pantograph (like tram). Charge rate with respect to time is as 30 sec –50%, 80 sec – 100% [8].

A. Batteries V/S Super Capacitor's

Parameter	Batteries	Super capacitor
Time	60 – 300 minutes	1-20 seconds
Operating Hours	500hrs and high	>28,000 hrs
Voltage/cell	3.6 to 3.7V	2.3 to 2.75V
Specific energy	100-200	5(typical)
Specific power	1000 to 3000	Up to 10,000
Cost per (Wh)	$0.5-$1.5	$20
Service life(in vehicle)	5 to 10 years	10 to 15 years
Charge Temperature Range	0 to 45^0C	-40^0 to 65^0C
Discharge Temperature Range	-20 to 60^0 C	-40^0 to 65^0C

B. Advantages of super capacitor over batteries

- It has high power density.
- It has high lifecycle.
- It charges instantaneously.
- It has less weight.
- It is environmental friendly.
- It has low internal resistance.
- It has higher efficiency.

III.PROBLEM IDENTIFICATION

A Super capacitor can charge and discharge at a faster rate where charging is an advantage, but discharging is a huge disadvantage. Thus to overcome this problem I want to do certain design modifications which could help to enhance the discharging rate of a super capacitor.

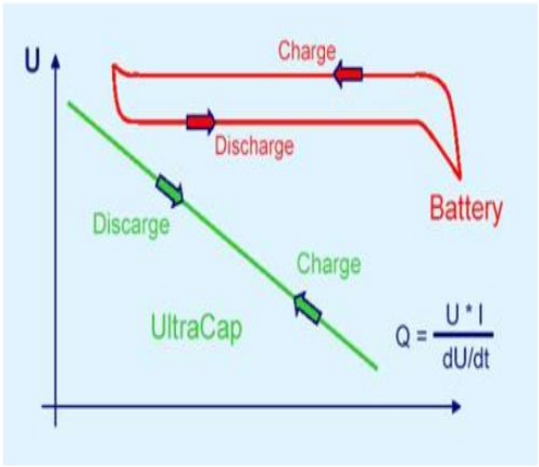

Fig1: Charge and Discharge Profile of a SC

From the above Graphical analysis we can understand that the rate of charge and discharge of a super capacitor is very fast as compared with Batteries.

IV.PROPOSED SOLUTION

There are many advantages by using super capacitor in place of batteries, but the only disadvantage is rate of discharge. Thus to overcome this problem herein I propose a design modification which can improve the discharging rate and can last for a long time.

A. Mathematical Formulation

To improve the discharging rate of a SC, a small mathematical formulation is as follows. Assume C is Capacitance, A is area of plates, d is distance between plates, V is voltage.

As we Know

$C=e_0 (A/d)$ -------(1)

And $C=(Q/V)$-----(2)

From equations (1) and (2)

$e_0 (A/d) = (Q/V)$

As e_0 ,A are constants, therefore

$d \sim V$; $d \sim 1/Q$

Distance is directly proportional to voltage.
Distance is inversely proportional to rate of charge/Discharge.

V.DESIGN MODIFICATION

Thus when the distance between the plates is more it takes more time for the capacitor to discharge. Based on this principle I would suggest a design modification,

Step 1: Generally a super capacitor consists of two plates, one cathode and anode. So in this modification we need to place four plates, in which two are anode and two are cathode.

Step 2: The four plates are classified into two pairs. One pair of charging plates and another pair of discharging plates.

Step 3: The distance between the charging plates must be small and the distance between the discharging plates must be large.

Step 4: Relation can be formed how to decide the distance between the plates which should not disturb the stability of the Super Capacitor.

Step 5: First assume the distance between the charging plates as optimal as possible.

Step 6: By taking the reference of charging plates assume a equilateral triangle taking the centre of the plate as the peak of the triangle.

Step 7: Draw a line parallel to the distance between plates where it intersects the two sides of the triangle leading 45 degrees at two ends.

Step 8: Hence this method is used to find the optimum distance between the plates which is drawn in any software and analyse the distance between the plates.

Step 9: Calculate the charging time and discharging time as per given mathematical formulation.

Step 10: At last now we can design a new Super Capacitor whose Charging rate is fast and Discharge rate is slow.

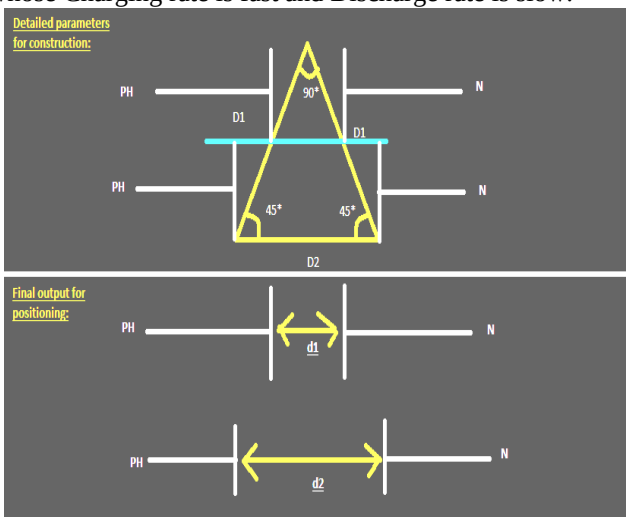

Fig. 2: Design Modification of SC

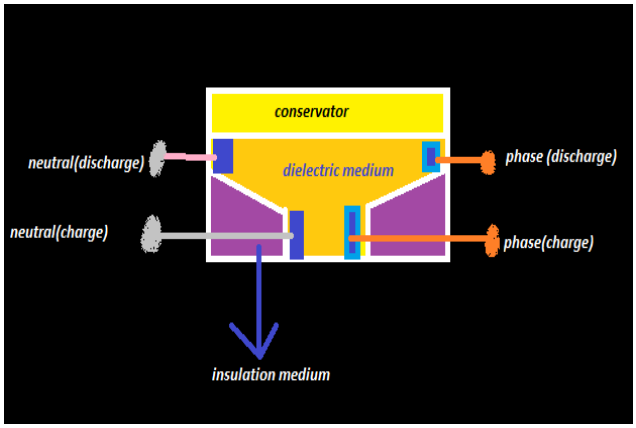

Fig. 3: Four Plate SC

VI.PRACTICAL OBSERVATIONS

1. Whenever the distance between the plates changes the effective series resistance of the capacitor changes.
2. The change in the ESR (Effective series Resistance of capacitor) will affect the performance parameters of the super capacitor.
3. Increase in ESR will lead to high power losses, large noise and higher voltage drop.
4. Thus there is always a need to decrease the ESR which can improve the performance of the super capacitor
5. As to decrease the ESR value we need to decrease the distance between the plates.

VII.CONCLUSION

Super capacitor as an energy source can reduce the size, weight of an Electric Vehicle. It can also improve the performance characteristics such as acceleration, less charging time long discharge time. In this paper I proposed an idea for a design modification which can overcome the disadvantage of faster discharging rate.

Super capacitor after design modification could increase the discharging rate which can make the vehicle to store its energy for longer time and can even travel longer distance. The mathematical formulation can prove that the time constant of the SC can be controlled by modifying the distance between plates. Hence I would conclude that the proposed design modification can improve the charge and discharge profile of a Super capacitor due which It can be used as an energy source.

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