SUPER CAPACITOR BASED BATTERY LIFE IMPROVEMENT IN ELECTRIC VEHICLES

School of Electrical and Electronic Engineering, Lovely Professional University,

Masters of technology on renewable energy engineering

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Abstract: Today's world increasingly showing interest on Electrical Vehicles. From deferent perspectives Electrical vehicles having their advantages over conventional petrol, diesel and gasoline motors and engines, such as highly efficient, lower cost, environment friendly (zero gas emission), fast response, lower maintenance requirement, no sound on working, higher ranges. In addition, higher torque as compare to diesel and SI engine of size of the motor, from application point of view electrical vehicles are occupy less space and less weightage as conventional system do.

Keywords - VRLA (Valve Regulated Lead Acid Batteries), ESR (Equivalent Series Resistance), Super capacitors, DC-DC Converter, NEMMP (National Electric Mobility Mission Plan)

I. INTRODUCTION

This report briefly states the design of super-capacitor base battery life improvement in electric motors (two wheeler) the first chapter of the report gives the entire system's description from battery and super-capacitor to load that is, driving cycle of an electric two wheeler. The second chapter emphases on the literature survey for designing of converter and combined storage system.

I.I INTRODUCTION OF THE SYSTEM

Innovation of two-wheeler vehicles brought ease in our lives and things can be done faster. Although it comes with lots of merits, but has some problem with it. For all vehicles initially we were using gasoline engines for movement power, but gradually upgraded to electrical vehicles which are using batteries and motors.

A significant part of power is used due to speed variation required because of the traffic situation in some urban areas. Recovering such power or energy for improvement of driving range is only possible in electrical vehicles and hybrid electrical vehicles. Electrical and hybrid electrical vehicles are more suitable than conventional vehicles. The electric load profile consists of high spike and steep deeps which overall results generation also a demand surge. They are accountable for generating heat inside battery, by increasing temperature internally increases internal resistance which degrades the performance of battery and finally premature failure of battery will happen. If batteries are fully charged, they are not able to accept any kind of regenerated energy. Super capacitors are tons greatest over batteries while coping with of current surges at some stage in accelerating and decelerating because of their better strength density limits as well as potential to short charge-discharge.

Supper capacitor brought a new era in energy storage. Application of super capacitor gives a better replacement for power source that increases life existing power source, also provides a huge working opportunity. So, connecting a super capacitor with battery will be useful when there is high power needs and its short dynamic reaction, it will rid off the stress on the power storage or battery by catching the optimum regenerative braking energy. Using super capacitors also decrease the size of battery as chemical reactions no longer involved in energy storage technique there is almost not limited number of charge-discharge circle.

Hence, there is no need for maintenance of these devices as they are not using any toxic materials anymore. Although using supper capacitor in battery will decrease the current surge, but effective and beneficial path to utilize super capacitor storage is to control its energy in it thru power electronics converter. Power electronic converter will take control of power content in super capacitor as per status of battery charge. Here we are analyzing the performance of battery after direct connection of super capacitor also through an appropriate power electronic converter using a simulation system of real system.

India has stated National Electric Mobility Mission Plan (NEMMP) 2020 in 2013 to explain the issues of National energy protection, vehicle pollution. The purpose of National Mission for Electric Mobility (NMEM) are national energy protection, decrease the unwanted impact of vehicles to the environment and develop local manufacturing potential in automobile sectors. The NEMMP 2020 has set new vision to achieve in automobile sector for EVs and HEVs.

Manufactures have realized that they need to work of for something which is nature and environment friendly such as EVs and HEVs. In this report I tried to review the direct shunt connection of super capacitor and battery also using power converter in bunk-boost (BB) mode during charging and discharging individually.

I.II LITERATURE REVIEW

The literature review contains explanation of developing better energy storage system for HEVs and EVs using a combination of batteries and super capacitors. Since 1980s the super capacitors are discussed as an application of EV, applications have been slow materializing. However, there are several applications which are commercialized.

Y. Gad et.al [1] they have modeled conventional batteries that were not able to give such energy output and fast reaction in vehicles. As an electrical vehicle needs wave or oscillatory power load, the conventional batteries were not suitable. Battery producers are working hard on producing batteries with better dynamic response for automotive applications. However, to gain a better performance loaded as such to suit its parameters.

S. Pay et.al [2] has tried to improve the range of driving vehicle by presenting technologies that may be applied in a EV battery. They intended to improve performance of acceleration and deceleration and decrease the cost by including supper capacitor in circuit. It discusses a power management system using a high power density super capacitor bank connected to battery system. Current surge of different size introduced in batteries due to regenerative braking will increase internal resistance of battery which causes inefficiency and premature failure [2] and [3].

There are potential future applications for this such as; there could be large scale, mass market and production opportunities for capacitors. Because of some merits of super capacitors over conventional batteries. Super capacitors have thrown light on application of them in automotive industries. These future applications open plug-in hybrid, battery operated vehicle exploitation advanced, high energy density batteries and hybrid electric cell vehicles. May of studies are ready on this case [4]. C. Chen and Barrade et.al [5][6] have also studied some other applications of supper capacitors such as; buffers and elevators.

S. Mith T.A et.al [7] in this article showed many applications requires short power shout periodically and tool or device to store such energy and deliver them when needed. Examples are transmitting of information needs wireless devices working on high power pulses. Super capacitor is able for high power density that satisfy high power demands and they are actually so simple as compare to flywheels and other mechanical arrangements. In this paper DC-to-DC converter and super capacitor are explained and designed. Also, some applications are pointed out. A new multifunctional DC-to-DC converter network (topology) have been estimated for short energy management.

L. Bertoni et.al [8] have presented scenario of power of EVs also increasing need of power for improving the security and comfort. Control and design requirements for evolution on extra power unit are explained as well. Solectra's DC 400 and DC to DC power converter network (topology) are discussed. There is also explanation of an algorithm for selection of elements from electrical storage system is explained in order to suit load demands, to reduce the size and expenses and improve the efficiency and performance.

After studies and carrying out the detail literature review the problem can be formulated to study the effectiveness of battery and super capacitor combination in EV in order of betterment performance, battery life and efficiency.

I.III PROBLEM STATEMENT

1. When studying the literature number of issues in design and manufacturing of a good storage electrical system to enhance the performance and efficiency driving range of motor bike studied.
2. Therefore, the problem statement can be stated as "Super capacitor-based battery life improvement in electric two-wheeler", considering development the system by using of MATLAB model and analyzing the results.

I.III.I SCOPE OF THE WORK

- ✓ To develop a brief theoretical background for electrical vehicles: Based on knowledge and literature available, theoretic background about working as well as advantages and limitation of an electrical vehicles will be built. It will be used for design purpose standpoint.
- ✓ Modeling: To model an effective storage system for automotive applications we have to consider driving load cycle of two-wheeler first. Then as per load requirements components are chosen to accomplish the requirements.
- ✓ Simulation: After selection of proper components simulation model will be developed by using MATLAB software.
- ✓ Simulation result analysis: Simulation results were compared and analyzed to confirm the calculations and work done.

I.IV FEATURES OF BATTERY-SUPER CAPACITOR COMBINATION

a. Very high efficiency: Super capacitor efficiency is known as columbic, which is greater than 99%. While charging and discharging of a super capacitor even in very high current less amount of charge being lost.

Columbic Efficiency = (Discharging Capacity) / (Charging Capacity)

b. High current surge accepting capacity: Super capacity has less Equivalent Series Resistance (ESR) so they can absorb and deliver high current. Regenerative breaking application and other Quick-charge scenarios is the result of low ESR in super capacitor.
c. Reducing battery size: As super capacitor, has high efficiency and quick response in the system, so it can be used along with batteries as buffer and results the battery size being reduced.
d. Conditioning monitoring: Energy stored in super capacitor can be a function of capacitance and voltage. The capacitance is constant. So, SOC (State of Charge) can be regulate by using voltages of capacitor.
e. Long cycle life: Super capacitor works on process of moving charges and ions only. it does not make or break any mechanical parts. Therefore, they are able to complete unlimited cycles with slightly difference in performance.

f. High operation life: In super capacitor a stable process takes place, as there is not chemical reaction. Hence it has very less maintenance and long operation life.

II. SYSTEM DESCRIPTION

II.I. COPONENTS OF SYSTEM

II.I.I. BATTERY

An electric-bike battery is a battery used for generating traction force in electric bike Battery stores charges by process of chemical reaction. Factors i.e. resistance, temperature, charging and discharging rate effect on performance of the battery. Indefinite model that is commonly used for batteries is Thevenin's equivalent circuit with the open circuit voltage in series with an equivalent resistance. Both resistance and voltage together represents battery SOC (State of Charge). SOC is the amount of charge left in the battery after withdrawing some Amp-Hr. Battery voltage presented by function of SOC i.e.,

$$Voc(t)= a1+a2*SOC(t), \text{ in specific temperature.}$$

Deep-cycle batteries are generally used as compare to SLI battery for automotive applications. Deep-cycle batteries are designed in high charge unit capacity. Batteries for Electrical Vehicle should have high power to weight magnitude relation. Today's electric vehicles and hybrid electric vehicles tend to rising in the markets, it is important to examine their applications where used in public transport systems. The most common energy buffers used in automotive application for their relative low cost are Lead Acid batteries. Till now, chemical properties of lead acids are not permit rapid charging or discharging with no temperature rise that reduces its performances and long term contribution to its degradation. To address to this problem, professionals propose lead acid battery combined with supper capacitor.

II.I.II. BATTERY PRODUCTION

BEVs and PHEVs work with same type of batteries, as lithium-ion is mostly a chemical combination which is common. There are two ways or techniques of extracting lithium used in batteries; mining petalite and spodumene are using pond evaporations in lakes. The popular way or method of lithium brine operation. The batteries are the main technology behind EVs which defines range and other characteristics of a vehicle. The batteries in such a way that generates electrical energy from chemical energy. Lithium-ion is popular chemistry for EVs and HEVs' battery, a lot of research are done in Lithium-ion batteries field. There are three main functional components of a lithium-ion battery such as negative and positive electrodes and electrolyte. In Lithium-ion battery generally the carbon is used for negative electrodes. The positive electrodes are made of metal oxide and the electrolyte is a lithium salt in an organic solvent. The electrotechnical roles of the electrodes reverse between cathode and anode, based on the current direction flow through cell. In a lithium-ion battery the positive and negative electrodes are the reactants of mechanical reactions and the electrolyte providing a medium which is conductive for lithium ions to move between electrodes. The electrical energy flows in and out when electrons flow via a peripheral circuit during charge or discharge, respectively.

Charge and discharge:

While discharge, lithium ions(Li+) carry the energy or current inside the battery from the negative to the positive electrode, through a non-aqueous electrolyte and separator diaphragm.

During charging an outside electrical power source applies an over-voltage, forcing the charging current to go from positive electrode to negative electrode, i.e. in the opposite direction of discharge current. The lithium-ion the moves from positive to negative electrode, where they will be embedded in the absorbent electrode material under intercalation. Loses of energy is arising from electrical contact resistance at interfaces between electrode layers. At the point with current-collectors the energy loses can be high up to 20% of the whole energy of batteries under normal operation situations.

The charging process for a only single cell of Li-ion and a complete Li-ion battery are a bit different.

A single cell of Li-ion can be charged in two stages:

1. Constant Current (CC)
2. Constant Voltage (CV)

A Li-ion or a series of Li-ion cells are charged in three states

1. Constant current (CC)
2. Balance
3. Constant Voltage (CV)

In figure 1 while the constant current stage, the charger gives a constant current to a battery and increasing the voltage in a steady manner, till the voltage limit per cell is satisfied. While the balance stage, the charger is reducing the charging current during the state of charge of every single cell is brought to a same level by balancing the circuit, until battery itself is balanced. Some of the fast chargers skip this stage of charging. Some chargers completing the balance stage by charging each of the cell separately.

During the CV stage, the charger gives a voltage which is equal to the maximum voltage of cell slowly decreases towards 0, until the current is lower than a set threshold of about 3% of primary constant charge current. Periodic topping charge about once per 500 hours. Top charging is suggested to initiated when the voltage is going under 4.05V/cell.

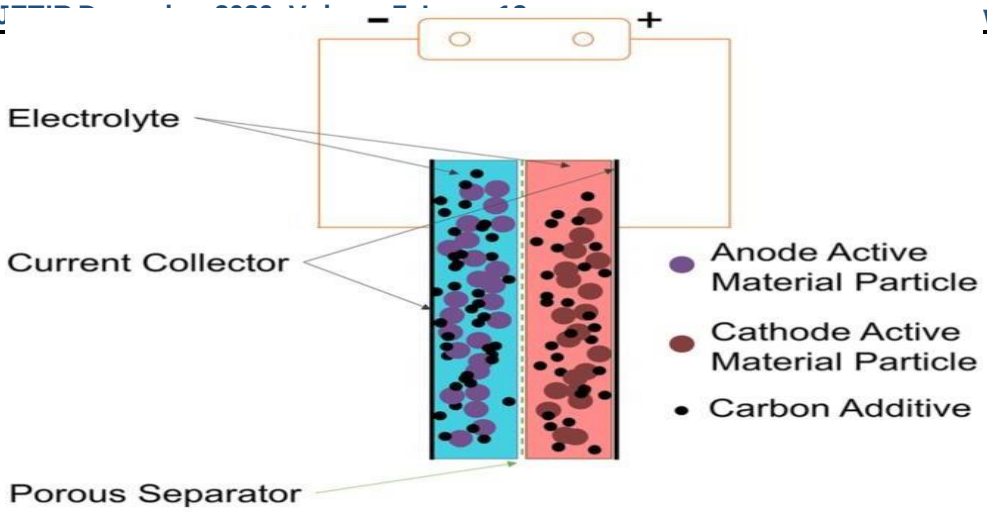

Fig.1: Lithium-ion battery

Different kinds of chemical battery concepts like sodium-nickel chloride (Na/NiCl2), nickel-metal hydride (Ni-MH), and other non-chemical alternative batteries are available in the market like super capacitors, that is allowing fast charging, but it has low energy density. We can say that there batteries with better performance and energy densities are being developed such as Lithium-Metal or Lithium Sulphur (Li-S) or Lithium-Air (Li-air), but there are very from form commercial uses. Lithium-air batteries are able to gain energy densities of almost up to 11700 Wh/kg according to experimental data concerned which is nearly equal to the energy content of gasoline. The most important and highly dangerous pollutants which are produced by the conventional vehicles are sulfur dioxide, Carbon monoxide, Hydrocarbons, greenhouse gases and Nitrogen oxides. So, to prevent producing these gases in environment, researches are going on for producing electrical vehicles (EVs) or hybrid electrical vehicles (HEVs). The EVs and HEVs are using special electric motors (SEM). The lithium batteries are low maintenance which is an advantage that most of other chemistries cannot claim for. There is no scheduled cycling and no memory required to extend the life of battery. Also, the self-discharge is less than half in compare to nickel cadmium, which makes lithium-ion well suited for modern fuel meter applications. lithium-ion cells cause a bit harm once disposed.

Despite of overall advantages, there is some drawbacks of lithium-ions batteries as well. It is fragile which requires the protection circuit to keep safe operation. Built in every pack, the protection circuits are limiting the peak voltage of each cell while charging, also preventing the cell voltages from getting very low on discharge. In addition, temperature of cell is detected to prevent temperature extremes or contrary. The maximum charge and discharge current is limited to 1C and 2C on most packs. With all these precautions taken place, there is the possibility of metallic lithium coating that occurs as overcharge is virtually eliminated. Another big problem with the lithium-ion batteries is the age of battery which is mainly in concern which many of the producers remain silent about this issue. Some capacity failure visible after one year, which includes batteries in use and new batteries. So, the battery will die completely after two to three years of use. We must note that other chemistries also have the same age-related

II.I.II BATTERY PRODUCTION

The batteries used in two-wheeler electrical vehicle must get recharged. There are distributed grid home or stations for recharging which commonly used to recharge the electrical vehicles. To have safe battery charging that will not affect the battery life span a suitable power supply should be used, which may take two to three hours to completely get charged. There is the possibility of fast charging as well which will not harm the battery. Threshold is what we use for fast charging as shown in the figure 2.

The grid capacity limits the time of charging. In countries where supply 110 volt maximum 1.5 kilowatts can be delivered using normal house hold connection, but in countries such as Asian countries with 240-volt single phase power supply maximum 3 kilowatts can be delivered. For current and voltage regulation in battery charging the charger must be equipped with advanced controllers. Without voltage regulation system in chargers the battery life span will get reduced. A battery which is used for an electrical vehicle is made of cells in row that are connected to each other. Battery cells may be subjected to different charges due to unbalancing charge will charging and discharging processes. To overcome battery failure or decreased lifespan, all the battery cells must get fully charged regularly of its SOC. There is another issue to be considered is the overcharging of batteries, they should design a controller for concerning that aspect.

Fast charging is the main requirement which a charger must have. Due to lack of grid abilities not everyone is able to chare their vehicles in their home. Therefore outside charging facilities should be available around, otherwise the use of EVs will be limited. The problem with fast charger is, it is charging fast only 80% of the SOC and the rest 20% is charging slowly as normal.

Fig.2 -Household Charger

II.II ELECTRIC MOTORS

The replacement of the internal combustion engines into an electric vehicle battery in core element of the electrical vehicle is called electric motor. The preference of electrical vehicles are few electrical motors such as DC series Motor, brushless DC Motors, permanent magnet synchronous motors (PMSM) three phase AC induction motors, and switched reluctance motors (SRM). The fast progress in areas of power electronics and control techniques has created different kinds of electric motors to be used in electric vehicles.

For our electric vehicle we are using PMSM. PMSM motor is consider the greatest choice for its outstanding performance application, these motors improve the efficiency by reducing the losses.

Both PMSM and BLDC motors has similarities for instance, both has permanent magnet on the rotor and traction features like high efficiency and power density. The difference between PMSM and BLDC is that MSMS has sinusoidal back EMF and BLDC has trapezoidal back EMF. PMSM is consider as best choice to use in cars and buses. PMSM motors are majorly is getting used in the automotive manufacturers for their hybrid and electric vehicle.

The basic construction of PMSM and synchronous motor are also most the same the only difference is in their rotor. We cannot see field winding in PMSM but there is field winding in synchronous motors. The field poles in these motors are created by using permanent magnet. These magnets are made out of high coercively and high permeability like samarium-Cobalt and Neodium-Iron-Boron. Neodium-Iron-Boron is used because of its cost effectiveness and its ease of availability. These magnet are attached on the rotor core.

The working principle of permanent magnet of PMSM and synchronous motors are the same. Here the rotating magnetic field is set up in the air gap when the three-phase winding of stator is energized from three phase supply. The rotor field poles lock with the rotating magnetic field to make torque at synchronous speed; hence rotor continues to rotate.

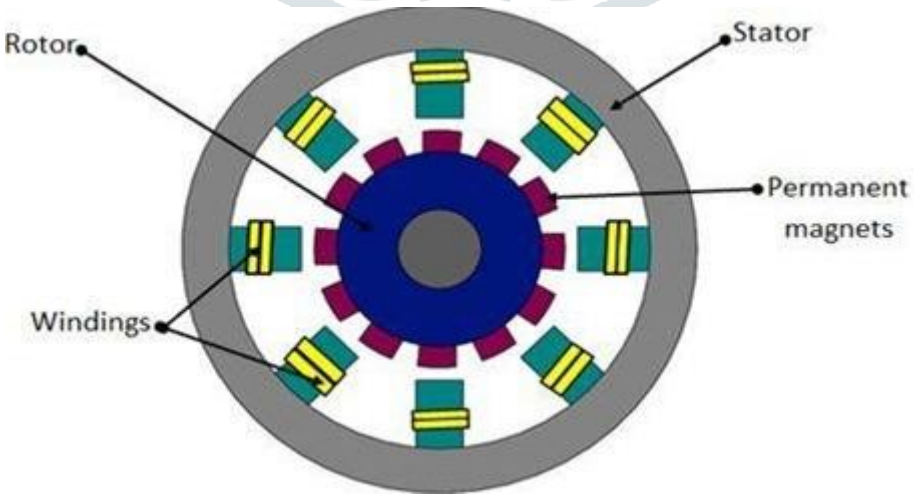

Fig.3: Permanent Magnet Synchronous motors (PMSM)

Since both PMSM and synchronous motors are not self-starting and there is no winding on the rotor, it requires power supply therefore, induction windings for starting is not applicable for such motors. PMSM motor and Brushless DM motors are quite the same, both motors have the same structure and same components. Moreover, both of motors have permanent magnets attached in the rotor which work together with the magnetic field produced by the stator coils. The different between these two motors are that PMSM have a different back-electromotive force (BEMF), since the flux linkage between the rotor and stator is not trapezoidal, the permanent magnet synchronous more is somewhere in between induction motor and brushless DC motor. It has windings on the stator and has a permanent magnet rotor like a brushless DC motor.

Since there is not stator power dedicated to magnetic field production, the density of permanent magnet synchronous motors is higher than induction motors with the same rating.

In today's world, the motors are designed to take lower mass and moment of inertia and in the meanwhile to be powerful. Considering these, permanent magnet motors are more efficient than any other motors. Tesla's chief motor designer was quoted discussing these advantages, saying: "It's well known that permanent magnet machines have the benefit of pre-excitation from the magnet, and therefore you have some efficiency benefit for that. Induction machines have perfect flux regulation and therefore you can optimize your efficiency. Both make sense for variable-speed and drive single-gear transmission as the drive units of the cars." What's important is that what will drive the future of machines.

II.III DC-DC CONVERTER

For the stepping up and down of battery and super capacitor voltage the DC-DC converter is used. The required voltage for motors is 48V, but the battery rated voltage is 24 volts. To overcome the shortage of energy we have to use the boost converter between motor and battery. Once again when the power is given to the system by super capacitor, the boost converter is used. Buck converter is used to charge the super capacitor when the super capacitor discharge. Another converter called two directional buck-boost is also used between battery and inverter in order to feed (PMSM). Buck boost converter has both input and output DC, it is shown in figure 4. The incoming power to converter is always same as the output. The conversion law is shown down below:

Input power (Pin)=Output Power (Pout)

When it comes to the boost mode, voltage for input is less than the voltage we get in output. It is showing that output current is reduced to follow the conversion law. So, the converter is in step up mode.

Vin < Vout and Iin > Iout

In buck converter incoming voltage is more than outgoing voltage. To obey the law of conversion, the output current will be less than input current. Hence, converter is in step down mode.

Vin > Vout and Iin <Iout

In this type of DC-DC converter, it is able to vary the size of output voltage. It might be low or high than the size of supplied voltage. By using these converters, we can achieve a wide range of output voltage with reference to our input voltage. Topology of buck boost converter:

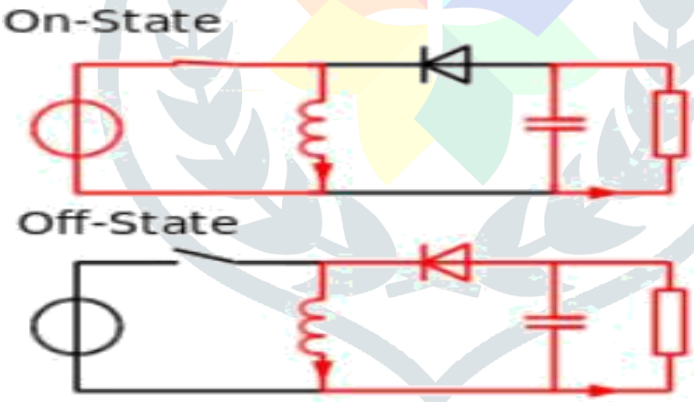

Fig.4 -Buck boost converter

II.III.I CONVERTER MODES

Depending on conduction modes the converters are operating in two different modes.

- ✓ Continuous Conduction Mode: In this mode inductor is always in charged condition maybe full or partially. Here the inductor partially discharges soon than the switching cycle hence maintains the charge.
- ✓ Discontinuous Conduction Mode: In this mode the inductor gets discharged and current through it becomes zero. Here the inductor will totally discharge at the end of switching cycles.

II.III.II APPLICATIONS

- ✓ Self-regulated power supplies
- ✓ Battery power systems
- ✓ Adaptive control applications
- ✓ Power amplification purposes

II.III.II ADVANTAGES

- ✓ Ability of giving higher output volage
- ✓ Operation in lower cycles of duct

III. MODELLING OF SYSTEM

III.I. SYSTEM SIZING ALGORITHM

A suitable size of component is required to fulfill the desired load, furthermore make system most appropriate as a function of size and cost. System performance is depending on selection of component, as its cost and capacity will decide entire vehicle dynamics and economics.

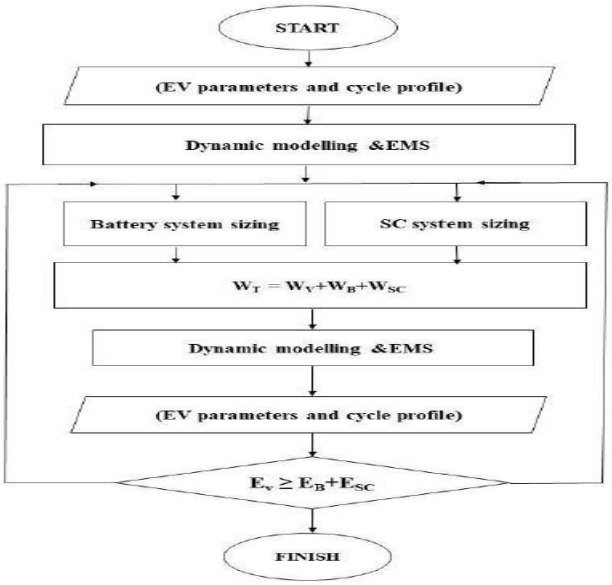

Fig.5 System sizing algorithm

III.II. SYTEM SPECIFICATION

The battery system create pair of banks in parallel. Every battery banks constitutes 24 number of deep-cycle valve-regulated-lead-acid (VRLA) battery cells cascaded together.

Table No.1 – Battery Specifications

Rated voltage	24 V
Capacity	14 Ah
Recharge rated current	14.5 A
Static recharge internal resistance	(SOC ≤ 50%)

Super capacitor

Super capacitor sub system constitutes of series of 12 cells connected in series. Capacitors are connected in series to increase its energy. Super capacitors have very high-power density and low energy density.

Table No.2 – Super capacitor Cell Specifications

Rated voltage	2.7 Volt
Capacitance	350 F
Peak voltage	2.9 V
Series Resistance	1 mΩ

Table No.3 – Super capacitor Subsystem Specifications

Rated voltage	32 V
Capacitance	29 F
Peak voltage	34 V
Energy stored capacity	1.17 MJ

DC-DC Converter

Table No.4- Converter Specifications

Switching Frequency	1 KHz
Inductance	100 mH
Resistance	10 mΩ
Capacitance	100 mF

The size of the switches and diodes used for freewheeling are dominated by the maximum power demand P_{max} from buck-boast converter and the thermal capabilities of system.

III.III. SYSTEM MODELLING

III.III.I DIRECT SUPER CAPACITOR CONNECTION

Combination of super capacitor with load circuit powered by battery is difficult in order to optimize super capacitor sub-system in addition to convenient one. The easy option is to integrate super capacitor is connecting it in parallel with the battery bank, at first it is charged to voltage equal to battery terminals. This connection is given in fig. 7 where the load current is given by il flowing downward that is it will be it gets negative during regenerative breaking and positive during acceleration.

This storage system is given to a specific load which represents some drive cycle of vehicle, super capacitor current ic and the battery current ib, are calculated by basic circuit rules such Kirchoff's current and voltage laws. The ideal component would have a larger energy density than existing batteries and a larger power density than traditional capacitors. At present this component does not exist although super capacitors are heading in that direction. A super capacitor can be thought of as a complementing device that improves the power density of a battery or the energy density of a traditional capacitor.

At the moment super capacitors have about half the power density of the best tantalum capacitors and about one hundred times their energy density. Sources and loads are frequently far from perfection and their tolerable production depends on the application. A super capacitor is a link between source and load. When used in parallel with the battery it flat out the load on the battery whereas improving the source impedance seen by the load. This shows that the battery supplies the energy and the super capacitor supplies the short-term power.

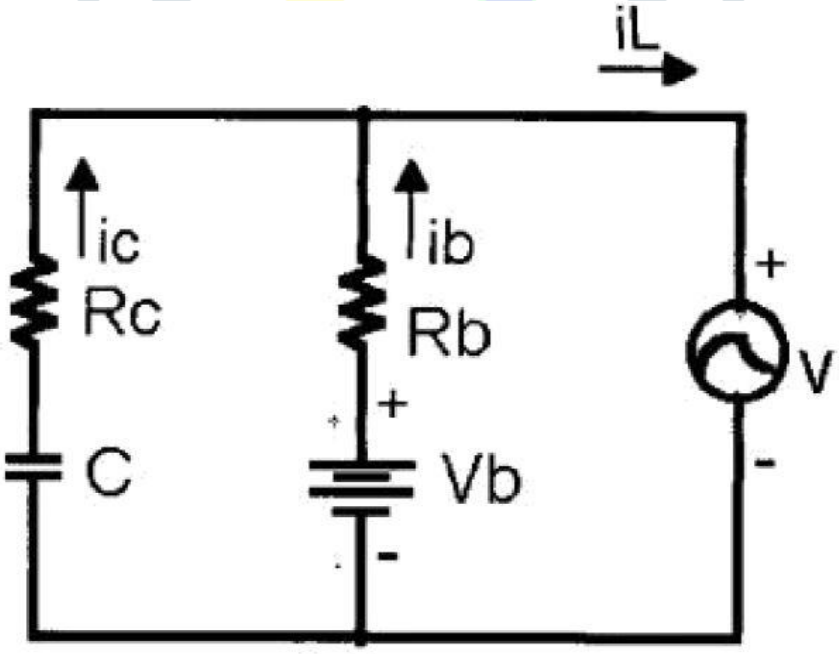

Fig.6 – Super-capacitor bank, battery bank and electrical load in parallel

III.III.II SUPER CAPACITOR CONNECTION THROUGH POWER CONTROLLER

Fig.6 shows direct integration that conclude power flow controller in between storage blocks subsystems is required for maximum use of super capacitor bank. The purpose of such power converter is to obtain the steady state current of battery in order to limit stress on the battery. Whilst, the super capacitor charged quickly from generative direction while breaking and discharge nearly all of its recycled power at time of peak power demand.

III.IV. SIMULATION

Simulation is performed on MATLAB/SIMULINK tool. MATLAB is a higher-performance verbal for technical work out. The simulation models are prepared for power calculations. Vehicle model with power converter are also prepared to show the performance of the combined system with buck and buck/boost power converter. MATLAB models are run in discrete mode for specific load cycle and characteristics where plotted. Following fig. shows power curve of electric two wheeler as well as voltage and current characteristics obtained from MATLAB model shown in figure 9 where supercapacitor and battery are connected in parallel as well as through DC-DC power converter. As indicated by results of simulation on sudden load increase to DC system at typical substation and simulation on sudden load increase, hybrid energy storage system for super capacitor and battery can realize buffered quick discharge of super capacitor and buffered slow discharge of battery, so that both of them can exercise their respective advantages to mutually benefit each other.

Fig.9- MATLAB Model of Super capacitor and Battery

We made different scenarios for both pure electric vehicles and series hybrid vehicles to explore the effect on battery parameters and fuel consumption by using super capacitors with lead-acid batteries, by changing the parameters like capacitance value and battery charge for optimal operation points.

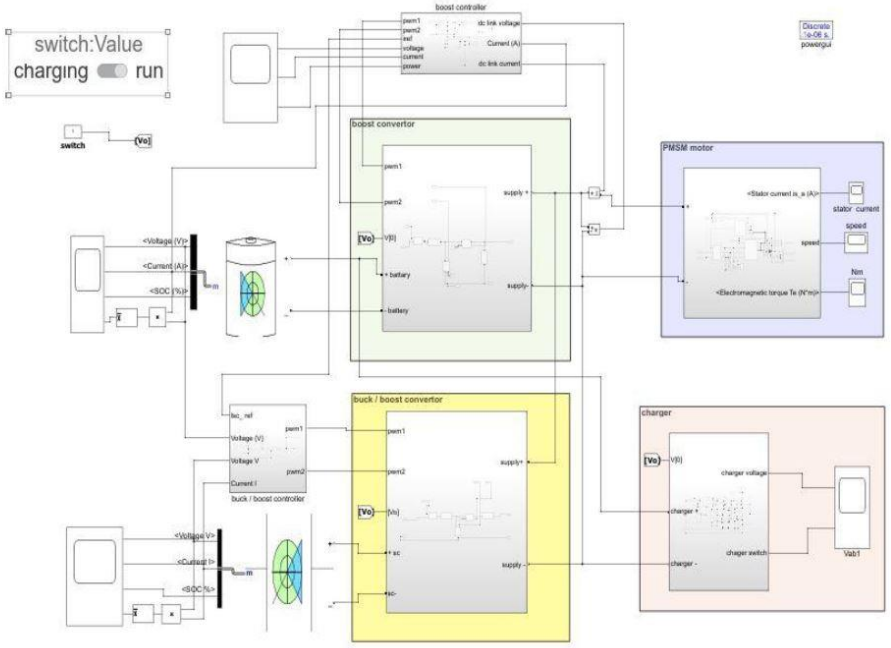

Fig.7- MATLAB Model of Super capacitor and Battery

IV. RESULT AND ANALYSIS

IV.I. MATLAB MODELLING RESULTS

Following figure 8 shows power curve of electric vehicle as well as voltage and current characteristics obtained from MATLAB model where super capacitor and battery are connected in parallel as well as through DC-DC power converter.

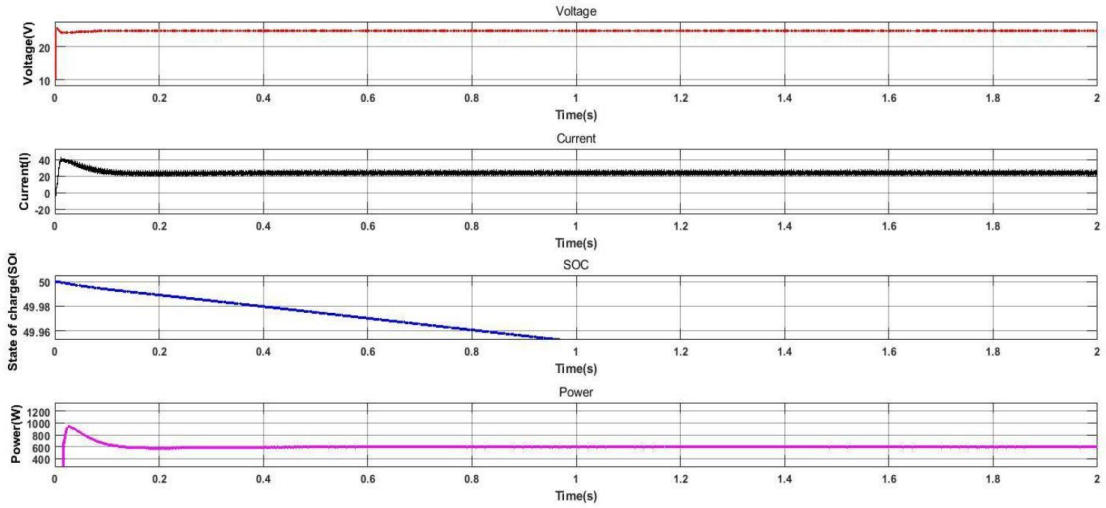

Fig.8 -Battery characteristics of electrical vehicle

Battery voltage is 24V. This is on run mode so battery SOC (State of charge) will decreases as shown in figure 8. In EV drive with battery without using super capacitor. It is seen in the figure 10 without the peak contribution from the super capacitor bank, battery want to provide peak power of 800W.

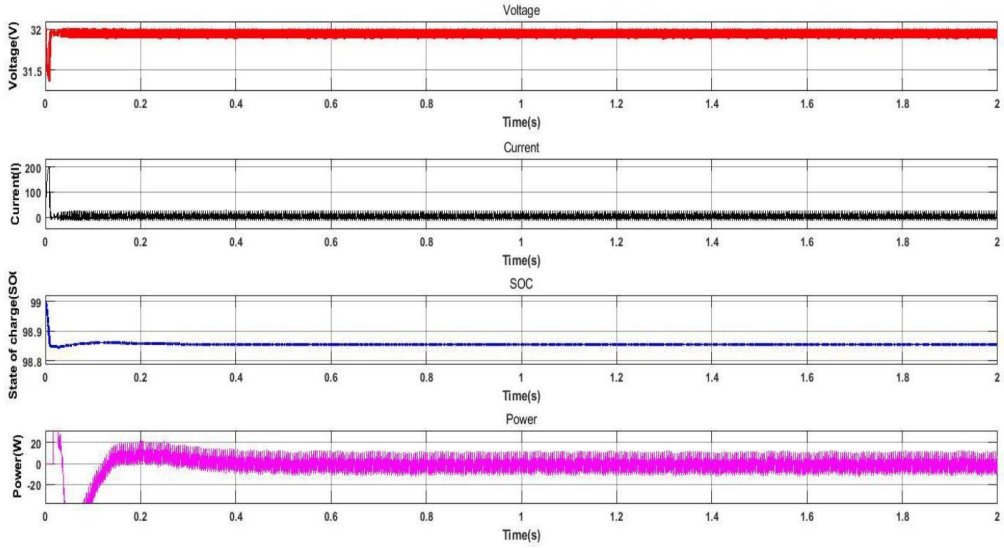

Fig.9 Super capacitor characteristics with Parallel Connection

Above figure 9 shown current and voltage characteristics, when super capacitor and battery are connected in parallel and simulation is run with specific load demand. As we can observe super capacitor provides peak voltage when vehicle is start, and to protect the battery from high peak voltage and current and therefore extend its life time.

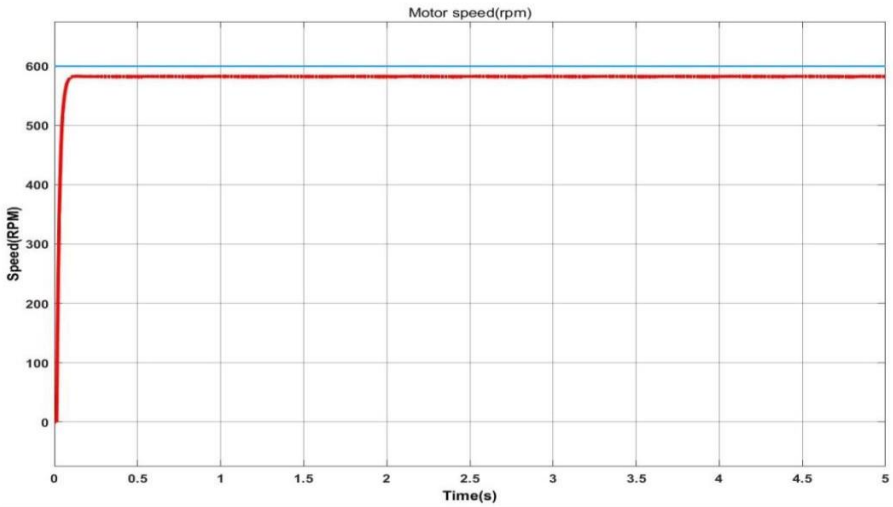

Fig.10 Speed Characteristics from Super capacitor Integrated with DC-DC Converter

Above figure 10 represents speed characteristic for vehicle after introducing power controller for charge control of super capacitor. Our required speed is 600rpm show in blue line and given speed is near about 580rpm. Hence we can observe that curve has become smooth which shows that super capacitor is used optimally.

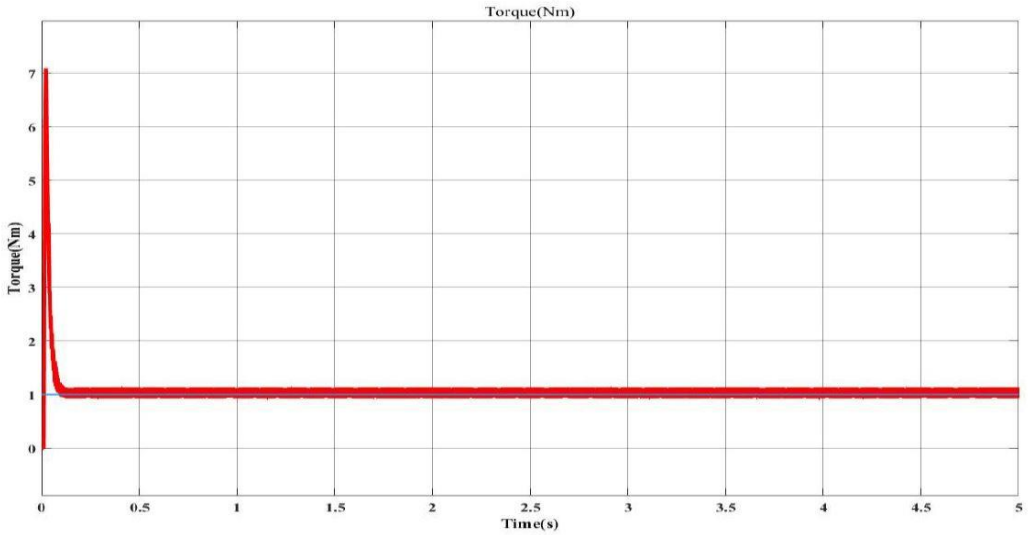

Fig.11: Torque Characteristics of motor

Above figure 11 shows load torque and electromagnetic torque. Motor load is 1Nm this is requirement torque and our system is giving near to 1Nm.This torque characteristics is high in starting time that time vehicle is start by using super capacitor, because of this battery load will be decreases and battery cycle will be increases.

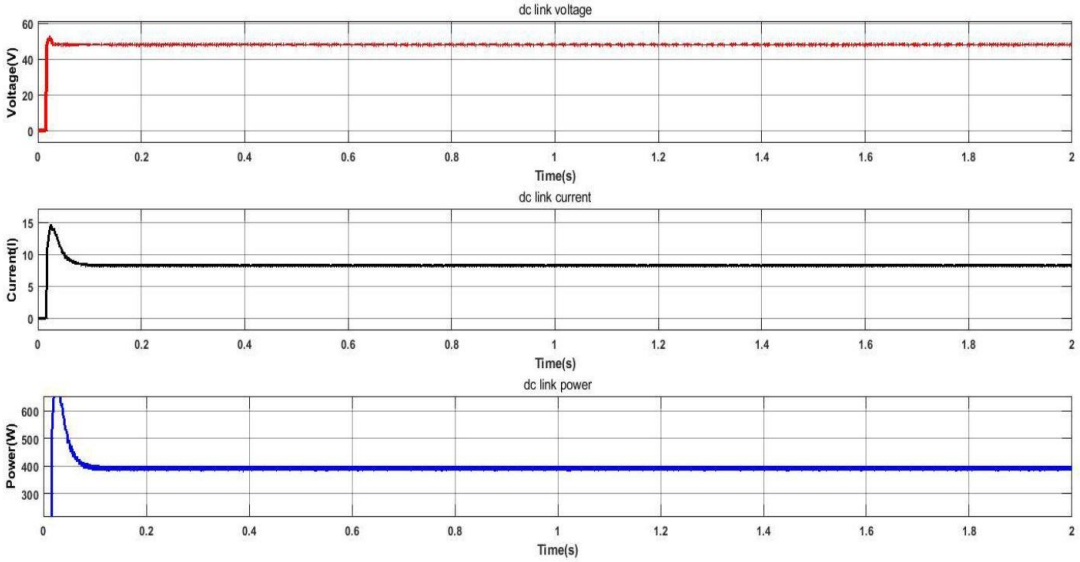

Fig.12 -Motor characteristics of electrical vehicle

Above figure 12 represents motor characteristic for vehicle, Our battery gives 24V to the system and required power is provided from super capacitor In this figure the obtained voltage is 48V which is required for PMSM motor this voltage is given by super capacitor that time our battery will not give any power so Peak current of the battery is reduced by using super capacitor.

V. CONCLUSION

As electrical vehicles are getting more attention due to their advantages and government policies associated with it, they will acquire entire automobile market. Future work will be more focused on advanced control system development, required for the power controller. Performance of the system will be checked for different driving cycles. Though the introduction of super capacitor improves dynamic response of the storage system, effect of them on steady state operation is also checked.

Future work will also be concentrated on development of a storage system which will be effective for all driving modes. Advanced control strategies like fuzzy control will improve our control over energy management. Improvement required for vehicle to grid arrangement can also be area for future work.

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