Hybrid Energy Storage in EV with Super Capacitor and Battery MATLAB Simulation

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Abstract - *The hybrid energy storage system have been used to improve storage of electrical energy. In this hybrid energy system two sources work together like super capacitor and battery create one superior energy source. In which the super capacitor and battery connected with each other and electrical load connect with battery, in beginning both super capacitor and battery fully charged separately and when load connected with battery the battery discharge but due to super capacitor connected with battery, battery when supplies to electrical load is charge by super capacitor till super capacitor will fully discharge. This think we proved from MATLAB simulation.*

Key Words: **Super capacitor, Battery, Converters, Electrical Load, MATLAB Simulation.**

1. INTRODUCTION

A hybrid combines any two power (energy) sources. The combination of two power sources may support two separate propulsion systems. Both of these power sources can be connected in series, i.e. the super capacitor charges a battery that provides an electrical load, or in parallel, with both supplies electrical load directly. A critical issue for both battery life and safety is the precision control of the charge/discharge cycle. Overcharging can be found as a cause of fire and failure. The application imposes two limits or limitations on the battery. The first limit, which is determined by the battery life, is the minimum allowable state charge. As a result, not all installed battery energy used. The battery feeds energy to other electrical devices, usually an inverter. These devices can use a wide range of input voltage, but cannot accept low voltage. The second limit is the minimum voltage allowed from the battery. So, by connecting super capacitor with battery in this configuration used as high energy density device and super capacitor provides high specific energy and power respectively [1].

1.1 Super capacitor

Super capacitor like batteries store energy in the electrostatic field instead of in the chemical state. No chemical actions are involved, which means that a very long cycle life is possible. They have double layer construction consisting of two carbon electrodes immersed in an organic electrolyte.

During charging, due to the electrical field between charge electrodes created by the applied voltage, the electrically charged ions in the electrolyte migrate towards the electrodes of anti-polarity. Thus two separate charge layers are produces although similar to battery; the double layer capacitor is based on electrostatic action. Since no chemical action is involved, the effect is easily reversible and the typical cycle life is millions of cycles [2].

The difference between simple capacitor and super capacitor is understood by following formula:

$$C = A\varepsilon_0/d$$

In super capacitor the area (A) of two plate is more compare to simple capacitor and the distance (d) between Two plate is less compare to simple capacitor. So, capacitance is more in super capacitor compare to capacitor is shown from above formula.

The internal structure of double layer super capacitor sees below

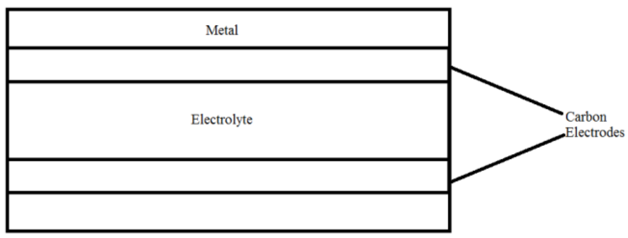

Fig -1: Double layer super capacitor

The super capacitor rating is 2.7V and 500 Farad by using series parallel combination super capacitor we here used 5.4V 750 Farad.

1.2 Battery

Maximum storage condition for the battery demand on the active chemicals used in the cells. During collection cell are subjected to both self-dissolution and possible decomposition of chemical contents. Over time in the electrolyte the solvents can come out of the seal causing the electrolyte to dry out and lose its effectiveness. The level of charge of a battery relative to its capacity is defined by state of charge (SOC). SOC is defined as the available capacity expressed as percentage of some reference, sometimes even its rated capacity even more possibly its current capacity can also lead to this ambiguity confusion and errors. It is usually not an absolute criterion in terms of the amount of energy contained in the clumps, KWh or batteries that would be less confusing. At a given temperature and discharge rate, the amount of active chemicals converted with each charge-discharge cycle will be proportional to the depth of discharge (DOD), the number of cycles charged by the battery increases rapidly over shallow DOD. This holds for most cell chemicals. SOC and DOD are reciprocal of each other. 100% SOC means battery fully charged, where 100% DOD means battery fully empty. SOCs are commonly used when discussing the state of a battery, while DOD is most often used when discussing battery life after reoearted use.

1.3 Electric Vehicle Motors

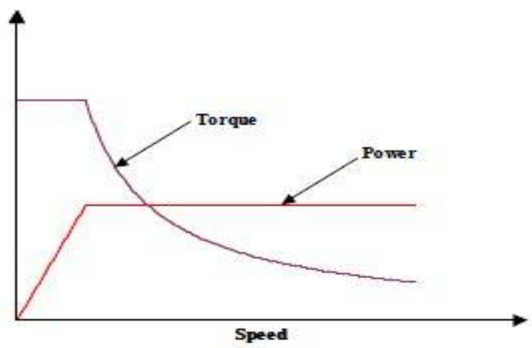

Fig -2: Electric motor characteristic

IC engine cannot operate in wide torque and speed regions on its own. Therefore, it requires the support of clutch and multiple transmission gears to achieve multiple speeds and multiple torque profiles required in a vehicle application. From Fig.-2 electric motor characteristic an electric motor readily provides a high torque at starting and also enables high speed operation at reduced torque. So this operation can be achieved without the necessity of clutch or variable gears.

Requirements of an EV motors are Maximum torque, Maximum speed, high power density, controllability, good dynamic performance, low cost, high efficiency and good voltage regulation.

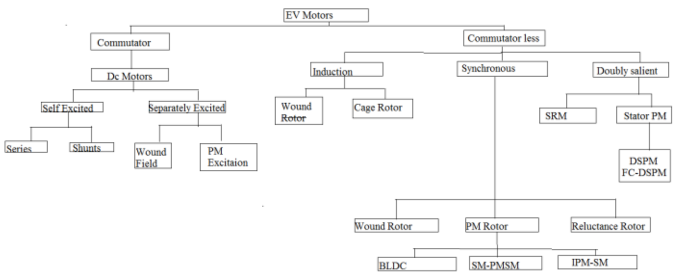

Fig -3: EV motors classification

Technologies used in Electric motors: (1) separately excited DC motor is used since it offers high power density and it is smaller in size. DC motors also provide very simple control since its construction offers orthogonal control of the flux and torque. So PMDC motors are used for low rated two wheeler applications. (2)Induction machine is widely preferred because of its long life and maintenance free operation. The highest efficiency of an induction machine ranges from 85% to 91%. This kind of efficiency can be achieved if rotor copper bars are used in cage rotor motors. So this kind of technology was used in early Tesla car models. (3)Most widely used motor in EV application is synchronous machine. The PM rotor type of synchronous machine is preferred for EV applications since it offers high torque density, high power density, and high efficiency which is the highest among all these motors. (4)Brushless DC machine very popular in two and three wheeler domain. The operation is very simple, similar to a DC machine. (5) permanent magnet synchronous machine(PMSM) in which stator is similar to the one used in induction machine but the rotor is fitted with permanent magnets. So permanent magnets are rare earth magnets pasted on the surface of the rotor such that it offers characteristics very similar to cylindrical rotor synchronous machine without any saliency [4].

1.4 DC-DC Converters

The most commonly DC-DC converters used in an Hybrid EV are:
Unidirectional Converters: They cater to various onboard loads such as sensors, controls, entertainment, utility and safety equipments. **Bidirectional Converters:** They are used in places where battery charging and regenerative braking is required. The power flow in a bi-directional converter is usually from a low voltage end such as battery or a super capacitor to a high voltage side and is referred to as *boost operation*. During regenerative braking, the power flows back to the low voltage bus to recharge the batteries know **as *buck mode*** operation. Both the unidirectional and bi-directional DC-DC converters are preferred to be *isolated* to provide safety for the lading devices. In this view, most of the DC-DC converters incorporate a high frequency transformer.

Classification of Converters
The converter topologies are classified as:
(1)Buck Converter: The buck converter is *step down* converter and produces a lower average output voltage than the dc input voltage. **(2)Boost converter:** In boost converter the output voltage is always greater than the input voltage. **(3)Buck-Boost converter:** In buck-boost the output voltage can be either higher or lower than the input voltage.

2. MATLAB Simulation

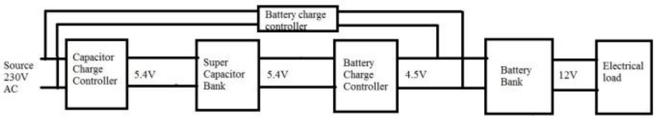

Fig -4: Block diagram

The fig-4 shows block diagram in which the super capacitor of 5.4V/750 farad supplies to battery of 12V, 5Ah and battery connected with resistance of 6 ohm. Initially both charge separately from supply through charge controller converters and when electrical load 6 ohm resistance connect with battery, the battery charge initially from super capacitor till super capacitor fully discharge and supplies to load, after that battery discharge.

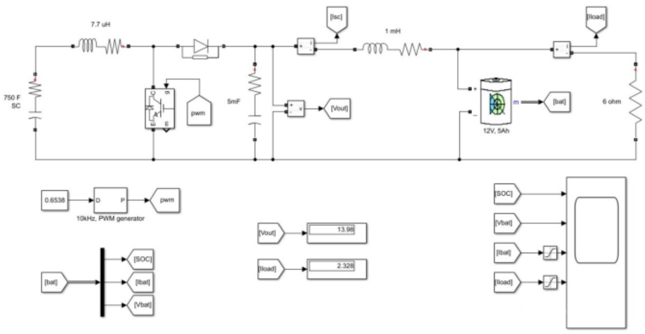

Fig -5: MATLAB Simulation

From fig-5 it is shown that the initially charge 5.4V/750 Farad capacitor is connected to battery through boost converter, we know the input (5.4V) and output(12V) of boost converter from boost converter formula we can find firing angle α=0.6538, after that the battery is connected to the resistive load of 6 ohm. We shows output parameter of circuit with battery initially charge with 80% SOC(state of charge).

The battery voltage and current, and the electrical load 6 ohm resistance voltage and current parameter are taken in scope and that waveform of different parameter for different case shown bellow.

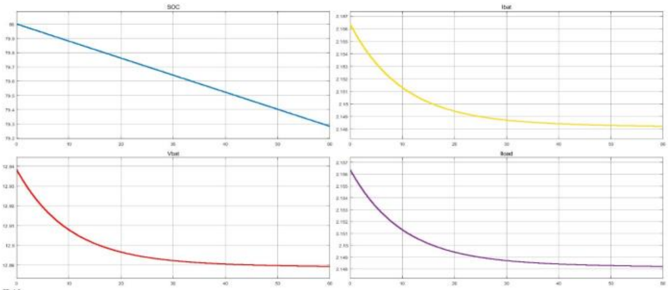

Fig -6: Without super capacitor

The fig-6 shows that battery with initially charged with 80% SOC and no super capacitor connects with battery the battery starts discharging.

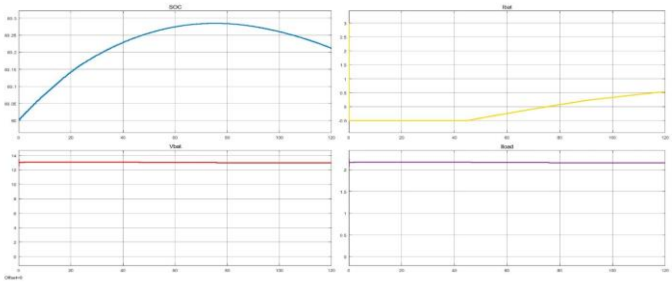

Fig -7: Battery initially charged at 80% SOC and super capacitor connects with battery.

From fig-7 shows that battery initially charged with 80% SOC and super capacitor is connected with battery the super capacitor at beginning charge battery is shown in fig-6 that at beginning the battery SOC increase from 80% to 80.3% and then decreasing. The current waveform shows that at starting the current shows that battery is charging and after some seconds the battery is discharged to load.

3. CONCLUSION

From MATLAB simulation we conclude that when the battery without super capacitor connected to load it will discharge from their initial state, when we connect super capacitor with battery it will charge at begging from their initial state. So, the battery discharge time is increase, battery charging/discharging cycle is increase and due to high super capacitor charging rate the charging time require is less for same output.

REFERENCES

[1] D. Kornack and P. Rakic, "Cell Proliferation without Neurogenesis in Adult Primate Neocortex," Science, vol. 294, Dec. 2001, pp. 2127-2130, doi:10.1126/science.1065467.

[2] M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.

[3] R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.

[4] A.E.Fuhs, Hybrid Vehicles and the Future of Personal Transportation, CRC Press, 2009

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