ANALYSIS OF HYBRID ENERGY STORAGE SYSTEM FOR ELECTRIC VEHICLE

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Abstract – *This dissertation contributes to the problem description of measuring power and energy of multiple energy source for electrical vehicle power system architecture. Electrical vehicle system the one of the challenging task is to improve the performance of the electrical energy storage unit, regarding the electrical power and capacity. The Supercapacitor is the auxiliary storage device connected with battery. The storing electric energy is chemically process in battery, so the power limitation and limited used. By introducing a Super capacitors as aid to system power and mitigate the battery from stresses, the performance of combine energy storage unit is improved.*

This projects aims that problem deposition of managing power and energy management of multiple energy source. The Testing of capacitors different Method, Different type and different ratings and compare charging discharging time. The use of Supercapacitor in application such as pulse power, backup source and other is discussed and their advantages over alternative technologies are considered.

Key words: Hybrid Electric Vehicle, Battery, Super Capacitor, Bidirectional Convertor

I. Introduction

Petroleum resources across the world is depleting at a high rate due to the large dependency of the transportation sector on petroleum as the primary fuel. Also due to this, there is a vast greenhouse gas emission that is degrading the quality of air and causing injury to life and environment.

Electric vehicles attract more and more consideration because of its clean and ecofriendly features. There are two main lines in spread of electrical vehicles: In electric vehicle one of the big issue is the life time of battery and other one is charging time, but new materials are utilized to extend the battery life and also increase the storage density to save weight and space. Besides the new materials, there are still some researches focus on how to form hybrid energy storage system to improve the battery operation condition. Some fast charging schemes and related devices are developed to shorten the charging time. But nowadays condition is change they are widely use in portable electronics, hybrid or electrical vehicles. However the use of batteries as energy buffer is somehow problematic and difficult, it reducing the battery's lifetime. Electrical double layer capacitor (EDLC), or (Supercapacitor) have extremely low internal resistance and high power density so it is help to improve efficiency of Hybrid Electrical Vehicle (EHV). The primary design problems in electrical vehicle having multiple energy storage system in systematic arrangement permit key attributes of individual system to be exploited.

The first Hybrid Electric Vehicle (HEV) car was introduced during 1900 by Lohner Coach Factory, which was driven by a hub motor powered by the generator run through a gasoline engine with a small battery. But since then due to the better development in the Internal Combustion Engine technologies and the cheaper petroleum prices made the Internal Combustion Engine run vehicle a better option than a HEV However for high utilization efficiencies, these energy storage system require interruption of their power sharing, thus a power and energy storage and load. This report alternate propulsion technologies have been increasingly pursued by the automobile industries and this has led to the increased development rate of the Hybrid Electric Vehicle (HEV) technology and a functional implementation.

II. Hybrid Electric Vehicle

As the future of electric and hybrid EVs is evidently becoming promising, significant research efforts worldwide have been directed towards improving propulsion systems and energy storage units. The addition of Super capacitors to the battery in the energy storage system both improves the energy delivery of the system and extends the life of the battery. During peak demands, the Battery deliver high current and load receive the high peak currents. At low SOC, the battery has a higher internal resistance then battery would be overheat and not be able to handle the peak current. Using Super capacitors, which have inherently low ESR, allows a realizable and efficient storage system for these high peak currents, and thus the performance of the energy storage system is enhanced Supercapacitor is with high capacitance than other capacitor it is usually excess of up to 4000 farad.

Supercapacitor do not have a traditional dielectric material like ceramic, polymer films ,or aluminum oxide to separate the electrodes instead a physical barrier mad of activated carbon, the efficiency and operating time improved, and the battery life extended electrically powered systems for commercial and military applications, the need to manage the vehicular power system is imperative. Electrical loads for both traction and ancillary loads are expected to increase as the automotive power system architecture shifts towards a more silicon rich environment. The complex demand profiles anticipated by these dynamic loads require accurate and optimized control of power flow and energy storage subsystems within the vehicle, thus presents a technical challenge and opportunity for vehicular power and energy management research.

The term 'Electric Vehicle' can be identified with any vehicle with an electrical propulsion system. This should encompass land, sea and air vehicles but in fact it has become generally accepted by both the scientific and industrial community that 'EVs' are referenced exclusively to road vehicles unless otherwise specified:

1. Hybrid Electric Vehicle (HEV),

2. Fuel Cell Electric Vehicle (FCEV),

3. Battery Electric Vehicle (BEV)

Capacitive energy storage, two different charging strategies can be used. The storage tank can be either directly coupled to a voltage source or, alternatively, by using a power-electronic converter. In an EV, the energy resources are limited. However it is essential that the power requests from all loads be met. Conversely, with the limitation in energy systems, it is impractical and cost prohibitive to size a single energy storage unit to offer continuous power capacity many times higher than the average power demand, just to meet momentary peaks in power needs. For this reason, employing multiple onboard energy systems that are specialized for the various segments within a vehicular power demand bandwidth becomes a viable solution.

The combination of energy storage devices with high-density specifications such as batteries with energy storage devices having high power density specifications such as Supercapacitor provides such a solution. The task of a power and energy management system then is to suitably coordinate the dynamics of the energy storage systems. This is to be done without compromising the vehicle target performance. Energy storage systems on EVs can be classified as either charge sustaining or charge depleting. The latter refers to a system with a declining state of charge (SoC) as the vehicle operates, thus limiting its operational range. In such systems, power and energy management is even more vital as it contributes to extending the operation range. In the context of this dissertation, the term Hybrid Storage System (HSS) for Electric Vehicle (EV) shall refer to a land vehicle with at least one charge depleting energy storage unit, this baseline vehicle on which the research propositions will be built upon, forms the fundamental configuration of storage system for electric vehicle. The basic configuration of HSS in EV sow in fig.1

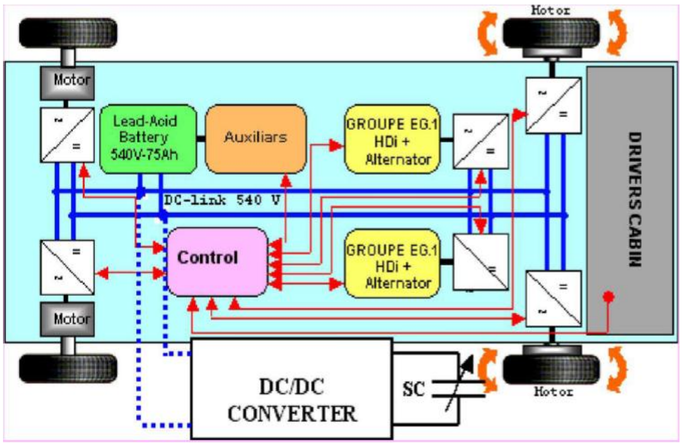

Fig.1 Hybrid Storage System of EV

Hybrid vehicles prepared with batteries and Super capacitors, the Super capacitors let the following:

- Supporting the batteries during hard transient states;
- Increasing the batteries' lifespan and decreasing their size;
- Offering performances independent of the battery state;
- Increasing the available power and, consequently, the hybrid vehicle independence;
- Improving the energetic efficiency while regenerative braking is employed.

III. Battery for Hybrid Storage System

In EV applications, desirable attributes for the battery system are high specific power, high specific energy and a high number of cycle life as well as a long calendar life. Technical challenges exist to meet these performance requirements whilst observing to the initial and replacement costs constraints. Battery systems for EVs requirement to be rechargeable and long backup. There are basically two categories of battery systems that are accordingly termed as primary batteries and secondary batteries. Primary batteries are non-rechargeable and are discarded at the end of a single full discharge. These batteries are commonly found in consumable electronics. Secondary batteries however are rechargeable with the number charge-discharge cycles varying for different battery technology. It is the secondary battery that finds application in HSSs.

A. Basic configuration of secondary batteries

A basic secondary battery cell consists of two electrodes immersed in an electrolyte. The anode is the electrode where oxidation occurs whereby electrons are transported out of the cell to the cathode via the load circuit. The cathode is the electrode where reduction takes place and where electrons from the external load return to the cell. The electrolyte however serves as a path for completing the electrical circuit inside the cell. Electrons are transported via ion migration from one electrode to the other through the electrolyte, thus creating a potential across the cell. During a battery cell charging operation, the process is reversed and the negative electrode becomes the cathode while the positive electrode becomes the anode. Electrons are externally injected into the negative electrode to perform reduction while oxidation takes place at the positive electrode.

The reactions that take place during charge and discharge do not necessary occur at the same reaction rates. The unsymmetrical reaction rates are expressed as the charge acceptance rate during a charging process and a charge release rate during discharge. Generally, the charge release rate of a battery system is higher than the charge acceptance rate, which is why secondary batteries require a longer time to recharge. Figure 2 illustrates the basic battery cell construction and operating principle.

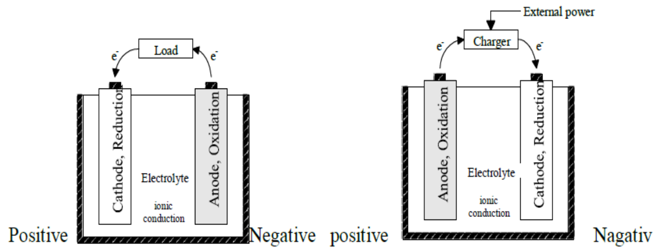

Fig.2 Battery cell basic principal Discharging charging process

Only in an ideal battery cell do electrons only flow when the external circuit is completed. However, in all battery systems, a slow discharge does occur due to diffusion effects. This open circuit discharge is known as the self-discharge of the battery, and is a parameter that is used as one of the long-term performance descriptors of a particular battery type. Figure 3 illustrates the basic equivalent circuit model of a secondary battery, the function of the battery stored charge capacity and the power characteristics. The battery is represented by an ideal open circuit voltage source (Voc) and a series internal resistance (Ri).

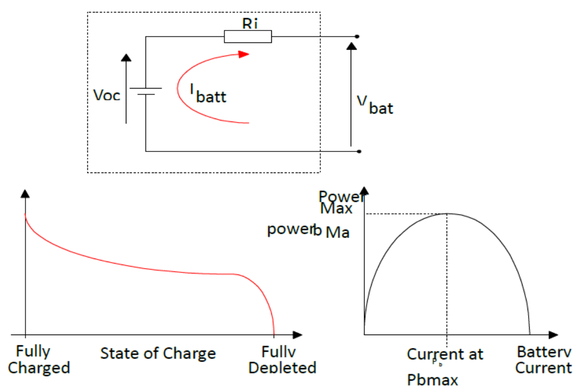

Fig. 3 (a) Battery Basic equivalent circuit (b) terminal voltage vs. charge capacity

$$V_{batt} = V_{oc} - I_{batt} \cdot R_i$$

Where, both *Voc* and *Ri* are dependent upon the battery instantaneous state of charge. The open circuit voltage *Voc* can be obtained from Nernst equations or by empirical methods.

The internal resistance *Ri* can be expressed as a function of the battery state of charge, operating temperature as well as the charge and discharge currents. Extensions to the basic circuit model can be made to account for the difference in charge acceptance and charge release rates. This will be addressed is a later section.

IV. Super-Capacitor

The first supercapacitor based on a double layer mechanism was developed in 1957 by General Electric using a porous carbon electrode [Becker, H.I., "Low voltage electrolytic capacitor", U.S. Patent 2800616, 23 July 1957]. It was believed that the energy was stored in the carbon pores and it exhibited "exceptionally high capacitance", although the mechanism was unknown at that time. The Standard Oil Company, Cleveland (SOHIO) in 1966 that patented a device that stored energy in the double layer interface.

Supercapacitors function as secondary batteries in terms of storing and delivering energy. The charge storage mechanisms itself is very different compared to batteries. As opposed to batteries, which produce electric charge through chemical processes, Supercapacitors store energy in the form of static charge. Since the energy is stored in the same from that it is used, Supercapacitors offer faster charging and discharging rates compared to batteries of similar volume. The energy densities of Supercapacitors are however comparatively less than that of batteries by a factor of 10 to 20. As such, Supercapacitor are not substitutes as secondary batteries but rather regarded as complementary power delivery device.

A. Testing of Super-Capacitor

There are different method of testing of Super-capacitor:

- Constant Power Method
- Constant Current Method

1. Constant Power Method

Constant power operation is often met operating mode of energy storage units. Constant power tests are used to calculate the constant power charging and discharging characteristics of SCs. the help of constant power tests, the cycle efficiency (η) of SCs can be obtained by integrating and proportioning the recorded voltage and current profiles of the discharging and charging phases

$$\eta = \frac{\int_{0}^{\Delta t_{discharge}} v_{UC}(t) \times i_{UC}(t) \times dt}{\int_{0}^{\Delta t_{charge}} v_{UC}(t) \times i_{UC}(t) \times dt}$$

2. Constant Current Method

The charging and discharging characteristics of SCs could be evaluated by means of constant current tests. During constant current tests, SCs are put into constant current charge/discharge cycles within the capacitance (C_{SC}) can be calculated as the linear part of the SC terminal voltage (ΔV1), magnitude of the applied current (I), and time period of the linear voltage variation (Δt).

$$C_{uc} = \frac{I \times \Delta t}{\Delta V_1}$$

$$R_s = \frac{\Delta V_2}{I} = \frac{V_{0+} - V_{0-}}{I}$$

V. Bidirectional Convertor

The main objective is to establish the dynamic control strategy of the dc/dc converters for energy management between the batteries and Super capacitors. This dynamic control strategy is based on current control because the dc-link voltage level is imposed by the battery module. To define the converters control laws and to carry out simulations for a longer period of time, the following assumptions are made a bidirectional buck–boost converter ensures energy conversation between the Supercapacitor and battery modules. This system includes a power source Super capacitors, an energy source batteries, an active load that represents the hybrid vehicle traction mechanisms, and a buck–boost converter.

The Supercapacitor module is connected to the dc link using a bidirectional converter to ensure the charge and discharge of the electric power storage devices. Show in fig. 4 basic diagram of converter topology, hear T1 to T4 switches use and controlled power flow management. Converter operator as controllable step-up (boost) / step-down (buck) converter the nominal terminal voltage and DC bus voltage higher then both battery and Supercapacitor, in boost operation mode switch T2 and Diode D1 active mode and same condition Supercapacitor boost mode Switch T4 and Diode D3 active mode, the swatches T1 to T4 are controlled by variation of duty cycle.

The voltage range of battery is function of state of charge and current drown from it, in electrical battery cell are used in vehicle mode swing of 10.2V to 13.2V.The output to input voltage transfer function of boost converter in continuous conduction mode (CCM). The converter control depends on the energy-management strategy between the hybrid sources and the hybrid vehicle energy application. This converter modeling includes the boost and buck operating modes.

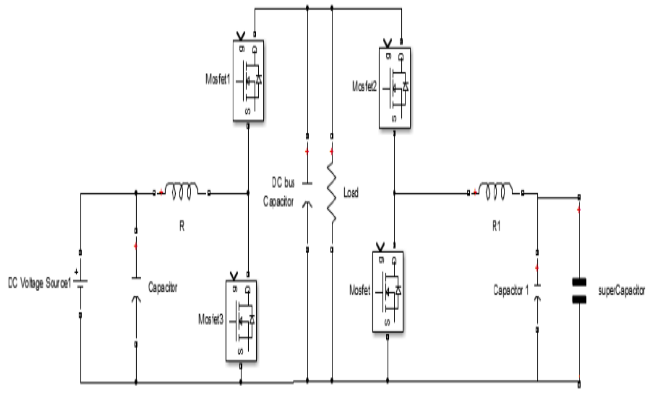

Fig .4 bidirectional convertor topology

A bidirectional DC\DC converter HEV is due to the following reasons:

1. The system is operating at the high power and low voltage making the current to rise too high, which causes high electrical and thermal stresses in the passive as well as the active components of the system, also it increases the ohmic losses and hence decrease efficiency.

2. Device voltage and current stresses is even further increased up by the wide variation in the input voltage range of the system. Since device stresses depends on the output to input voltage ratio, input voltage variation further increases the components ratings to be used. Further along with the above two factors

3. To be able to recharge the electrical energy storage system during the regenerative braking, and hence therefore there should be the provision of bidirectional power flow.

Some of the requirements for the Bidirectional DC DC converters design for the HEV applications are as follows:

- High efficiency
- Light weight & compact size
- Lower electromagnetic Interference
- Lower input and output current ripple
- Controlled power flow in spite of wide input voltage variation

A. Bidirectional DC\DC converters operation

Basically, bidirectional DC\DC converters can be classified into two categories depending on the Galvanic isolation between the input and output side:

1. Non-Isolated Bidirectional DC\DC converters

2. Isolated Bidirectional DC\DC converters

The above circuit can be made to work in buck or boost mode depending on the switching of the MOSFET M1 and M2. The switches M1 or M2 in combination with the anti-parallel diodes D1 or D2 (acting as freewheeling diode) respectively, makes the circuit step up or step down the voltage applied across them. The bidirectional operation of the above circuit can be explained in the below two modes as follows:

Mode 1 (Boost Mode): In this mode switch M2 and diode D1 enters into conduction depending on the duty cycle whereas the switch M1 and diode D2 are off all the time. This mode can further be divided into two interval depending on the conduction on the switch M1 and diode D2 as shown in the Fig.

Interval 1 (M1-off, D1-off ; M2-on, D2-Off): In this mode M2 is on and hence can be considered to be short circuited, therefore the lower voltage battery charges the inductor and the inductor current goes on increasing till not the gate pulse is removed from the M2 . Also since the diode D1 is reversed biased in this mode and the switch M1 is off, no current flows through the switch M1.

Interval 2 (M1-off, D1-on; M2-off, D2-off): In this mode M2 and M1 both are off and hence can be considered to be opened circuited. Now since the current flowing through the inductor cannot change instantaneously, the polarity of the voltage across it reverses and hence it starts acting in series with the input voltage. Therefore the diode D1 is forward biased and hence the inductor current charges the output capacitor C2 to a higher voltage. Therefore the output voltage boosts up.

Mode 2 (Buck Mode): In this mode switch M1 and diode D2 enters into conduction depending on the duty cycle whereas the switch M2 and diode D1 are off all the time. This mode can further be divided into two interval depending on the conduction on the switch M2 and diode D1 as shown in the Fig.

Interval 1 (M1-on, D1-off; M2-off, D2-Off): In this mode M1 is on and M2 is off and hence the equivalent circuit is as shown in the Fig below. The higher voltage battery will charge the inductor and the output capacitor will get charged by it.

Interval 2 (M1-off, D1-off; M2-off, D2-on): In this mode M2 and M1 both are off. Again since the inductor current cannot change instantaneously, it gets discharged through the freewheeling diode D2. The voltage across the load is stepped down as compared to the input voltage.

VI. CONCLUSION

This work indicates that it is possible to integrate a Supercapacitor in parallel with the battery in a HEV application. The work has also showed that when installing the Supercapacitor it is preferable to have power control. This power control is applied through a DC/DC converter. Moreover, it was also manifested

that the strategy that has the highest potential to mitigate the battery of stress is the strategy that controls the power drawn from battery in peak demand condition. With this strategy and a suitable Supercapacitor it is possible to relieve the battery from stress and lower the RMS current considerably.

This thesis work has also showed that the Bidirectional DC/DC converter, combined with Supercapacitor and battery, functioned well. The converter is used for discharging (boost mode) voltage 50% of step up to source voltage. While recharging (buck mode) the power forward breaking and reverse braking modes voltage step down 50%, because of Supercapacitor charging very low voltage. Thus power regeneration while braking and cruising is buck boost operation of convertor and power management strategy in MATLAB simulations using variable load condition and hardware implementation.

With a Supercapacitor installed, the performance of the ESU is improved in any given situation with a fixed battery, but Supercapacitor cost is very high so 1F 5.5v Supercapacitor used testing of Hybrid storage system. Combination of the Supercapacitor, battery and convertor has improved efficiency and performance of the Energy Storage Unit.

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