Design of Hybrid Storage System for Electric Vehicle

A Thesis submitted for the award of the Degree of

DOCTOR OF PHILOSOPHY

In

Electrical Engineering

By:

CHETANKUMAR D. UPADHYAY

Electrical Engineering Department

Faculty of Technology and Engineering

The Maharaja Sayajirao University of Baroda,

Vadodara - 390001

APRIL 2016.

DEDICATED

TO

MY PARENTS

&

GURUS..!

Certificate

This is to certify that the thesis entitled "***Design of Hybrid Storage System for Electric Vehicle"*** submitted by **Mr. Chetankumar Dineshchandra Upadhyay** in fulfillment of the degree of **DOCTOR OF PHILOSOPHY** in Electrical Engineering Department, The Faculty of Technology & Engineering, The Maharaja Sayajirao University of Baroda, Vadodara is a bonafide record of investigations carried out by him in the Electrical Engineering Department, The Faculty of Technology & Engineering, The Maharaja Sayajirao University of Baroda, Vadodara under my guidance and supervision. In my opinion the standarads fulfilling the requirements of the Ph. D. Degree as prescribed in the regulations of the University has been attained.

GUIDE
Dr. Hina B. Chandwani
Electrical Engineering Department
Faculty of Technology & Engineering
The Maharaja Sayajirao University of Baroda
Vadodara, 390001

HOD
Prof. Dr. S. K. Joshi
Electrical Engineering Department
Faculty of Technology & Engineering
The Maharaja Sayajirao University of Baroda
Vadodara, 390001

DEAN
Prof. Dr. S. S. Bhattacharya
Faculty of Technology & Engineering
The Maharaja Sayajirao University of Baroda
Vadodara, 390001
APRIL 2016

Declaration

I, Chetankumar Dineshchandra Upadhyay hereby declare that the work reported in this thesis entitled “Design of Hybrid Storage System for Electric Vehicle” submitted for the award of the degree of DOCTOR OF PHILOSOPHY in Electrical Engineering Department, Faculty of Technology & Engineering, The Maharaja Sayajirao University of Baroda, Vadodara is original and has been carried out in the Electrical Engineering Department, Faculty of Technology & Engineering, The Maharaja Sayajirao University of Baroda, Vadodara. I further declare that this thesis is not substantially the same as one, which has already been submitted in part or in full for the award of any degree or academic qualification of this University or any other Institution or examining body in India or abroad.

MAY 2016 CHETANUMAR DINESHCHANDRA UPADHYAY

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ABSTRACT

Due to the limited power density and energy density, many researches have been done for the Hybrid Storage System. Energy Storage System has become important for the developing and developed countries. Energy Storage System had only one option – Batteries, but due to the benefits of SC (Supercapacitor) the power density has been raised.

The level of charging for the electric storage system is important. Based on the SC model the charging and discharging characteristics varies. It depends on the temperature, voltage window of the SC, No. of Cycle life under work also. SC has various parameters which are indeed responsible for designing the Hybrid Storage System – Equivalent Series Resistance, Voltage Window, State of Charge, Life Cycle, Self Discharge Energy Loss Factor, Energy Density, Leakage Resistance (Equivalent Parallel Resistance), Life Stability and linear as well as non linear capacitance. For Electric Vehicles, Super capacitors are more efficient than batteries for recharging with a limitation of energy density. Super capacitor voltage control algorithm and method of finding optimal system parameters are studied.

Representing a revolutionary change in vehicle design, hybrid vehicles surfaced in many different ways. However, Researches are still on for the hybrid power train that combines multiple power sources of different nature, including batteries, supercapacitors, or fuel cells. This hybrid vehicle with onboard energy storage devices and electric drives allows braking power to be recharged, thus improving fuel economy and reducing pollutants. Thus advanced design philosophy and component technology, the maturing and commercialization of HEV technologies demand improved research and developments.

In general, energy storage systems capable of delivering continuous power with minimum reduction in their lifespan have greater energy storage capabilities when compared to the pulse power delivering devices. A combinational usage of these energy storage systems in a synergistic configuration exploits the effective use of power whenever necessary whilst maximizing the storage devices operational lifespan.

In electric vehicles, rapid accelerations and decelerations require peak power to be delivered from and transferred to the energy storage system. For a battery sourced EV, augmenting the battery pack with a high power capacity system results in reduced high power stresses impressed on the battery. A typical electric vehicle drive cycle requires short power burst to accelerate the vehicle. During rapid decelerations, kinetically produced energy via regenerative braking, generates currents of high magnitudes. As such, a peak power mitigation device is advantageous. Essentially, peak power can be generated and stored electro-mechanically via a flywheel system, electro-chemically via capacitors or by other forms of peak power buffers.

Although the high capacitance and high power density characteristics of supercapacitors endorses its feasibility in electric vehicle applications, the energy capacity limitation dictates the need for a much higher energy sustainable source, namely a battery bank. The objective of integrating batteries and supercapacitors is to create an energy storage system with the high energy density attributes of a battery and the high power density of a supercapacitor. In essence, the goal is to explore the advantages of both the devices through supercapacitor hybridization of

the two technologies in vehicular power system architecture.

One of the key benefits of integrating supercapacitors with batteries in an electric vehicle propulsion system is the extra ability to harness regenerative energy. It has demonstrated the potential of using supercapacitors as an energy recovery system in larger DC fed applications. By harnessing regenerative energy in a railway vehicle application, the researchers expected to increase energy savings by 30%. This gain is possible for vehicles with very large peak to average power ratios and extended regenerative braking events. For road vehicles, the figures are lower and are heavily influenced by vehicle drive cycles and overriding functions such as anti-lock braking, which pre-empts regenerative braking modes.

A simulation using MATLAB of regenerative energy handling was reported with very promising energy recovery results. The HSS is an unavoidable need of the HEV to improve the overall efficiency of an HEV. The HSS – battery and SC combination has many possible connections and their advantages are discussed here. The Characteristics of the SC charging/Discharging are discussed and various methods are studied. The parameter measurements for the SC have been studied thoroughly and each measurement test has been understood with procedure and data presentation. The various data like ESR, EPR, C_i, C_o, C_{leak}, R_{leak} and its properties for energy density / power density are studied.

Charge management in the battery is performed very effectively by the supercapacitor configuration. In the reference of battery life enhancement, the supercapacitor is most effective device. Using supercapacitors with battery the storage capacity of battery can be improved which is reliable in the emergence. It is worth having the Dempster – Shafer Theory (DST) for implementing to decide the motoring mode and regeneration mode as the decision has to be taken in microseconds for the working of the quadrant of the motor. The variable parameters are based on the historical data of the type of cycle, drivers' decision and the method of driving. The switching signals are generated based on the load current direction, voltage of battery and voltage of SC available. The switching signals of the bidirectional converter is accordingly given such that the driver of EV can charge the SC and Battery without working about the decision for the current, voltage, torque and speed characteristics. The decision can save the energy of the average 1.8 Wh in each braking. An algorithm is developed to meet the requirement of Motoring and Generation using this Evidence Theory.

The evidence theory (DST) is applied to find out the mode of operation for the Electric Vehicle. The data analysis has been done for the motoring mode and generation mode in three different cycles of operation as per Society of Automotive Engineers. The utilization of Electric vehicle with HSS has been proved here analytically that Heavy Electric Vehicles are well suitable for three available cycles – urban, semi-urban & sub-urban. The historical data of all two wheelers and three wheeler, four wheeler and heavy vehicle is analyzed for reliability and cost effectiveness. The data has been obtained by practical measurement of – notching period, running period, coasting period and the braking period. The results are well represented in the form of graph. The concluded efficient vehicle for the highly reliable has been designed structure wise for the location of the battery bank and SC bank. The Center of Gravity has been calculated using AUTOCAD software for location of HSS. The possible charging methods - wireless and with wire are also predicted here.