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Battery and Supercapacitors Fed Motor Drives for Electric Vehicle Applications

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ABSTRACT

Electric Vehicles (EVs) are good choice for no air pollution, zero roadside emission and higher energy efficiency compared to traditional internal combustion vehicles. Batteries have been used for EV applications because they can store large amount of energy in a reasonably small volume and weight and provide suitable level of power. One of the main considerations for the EV drive is to improve the efficiency of the motor drive. Each components of the power train should be properly designed so as to achieve the maximum efficiency and the desired driving performances. The backward power flow due to regenerative breaking of the EV can be stored provided energy source is receptive. One effort is to combine the high specific energy offered by the battery, with the superior specific power offered by the Supercapacitors. The supercapacitors offer a fast access to store energy and protect the battery from very fast fluctuations thereby increasing battery's capacity and lifespan. The voltage level and dynamic characteristic of the energy storage components are normally different from each other and therefore, a DC-DC converter has been incorporated into the vehicle drive train. In this paper, a prototype model of DC-DC converter fed electric drive system is developed. Battery and Supercapacitor are used as input sources to the system. Power flow from battery to load andSupercapacitor to load are demonstrated.

Keywords—Battery,Supercapacitor, DC-DC converter, Regenerative breaking

I. INTRODUCTION

Conventional engine-drive vehicle uses its engine to translate fuel energy into shaft power, directing most of the power through the drive train to turn the wheels. Much of the heat generated by combustion cannot be used for work and wasted. Implementations of EVs are the good choice for zero emission and reduce energy consumption, by regenerative breaking. [2[Lithium-ion batteries and Lithium polymer batteries are increasingly used in EVs because of high energy densities and long life cycles. [3[Main barrier in implementation of EVs is battery technology and lack of charging facilities. Generally batteries take long time to charge and the life cycles of batteries are shortened in case of fast charging.

Supercapacitors, have fast charge and discharge times and long cycle lives because of its physical mechanisms of charge storage and makes it more appropriate device to pair with batteries. [4]They have fast transient response as compared to commomly available lithium ion batteries (20µs). One of the disadvantage is it has poor volumetric and gravimetric energy density in comparison with batteries or fuel cells. Nowadays, hybrid batteries-supercapacitors are used in a range of industrial, automotive, and other power electronics applications.

[1]EV drive train consists of traction motor drive, electrical energy storage system (ESS), bidirectional DC-DC converters, and vehicle controller. Electric motor is the only source of torque in the electric vehicle. Therefore, high efficiency motor with proper torque-speed profile matching to that of the traction load requirements of the vehicle should be used in the drive train. DC motors are widely employed for traction application in automobiles, as well as for industrial applications where high starting torque might be required. These applications require proper motor operation during startup, speed control and braking. DC motor's torque- speed characteristics are suitable for traction applications, but they suffer from the disadvantages of the low efficiency and periodic maintenance. However, the efficiency of the PMDC motors drive for EV applications can be improved by reducing the losses by boosting up the voltage level and by the inclusion of regenerative braking. DC-DC converter needs to be incorporated to coordinate the power flow between various units of the drive train and load. Hence depending upon the battery and ultracapacitor connection and the bidirectional dc-dc configuration, proper energy management strategy should be developed so as to control the energy flow ensuring the desired performance within the limits of the operational constraints of the ESS devices.

II Simulation of charging and discharging of supercapacitors

An electric drive system is simulated using MATLAB SIMULINK model. It consists of battery and supercapacitor as power source, bidirectional DC-DC converter to match the voltage and power flow, and an electric motor as load. When break is applied in electric vehicle, the kinetic energy of the motor is converted to electric energy which is used to charge the supercapacitor. Fig.1. shows that the voltage and State of charge (SoC) increases with respect to time and the power is flowing from load to supercapacitor which is the charging mode of supercapacitor.

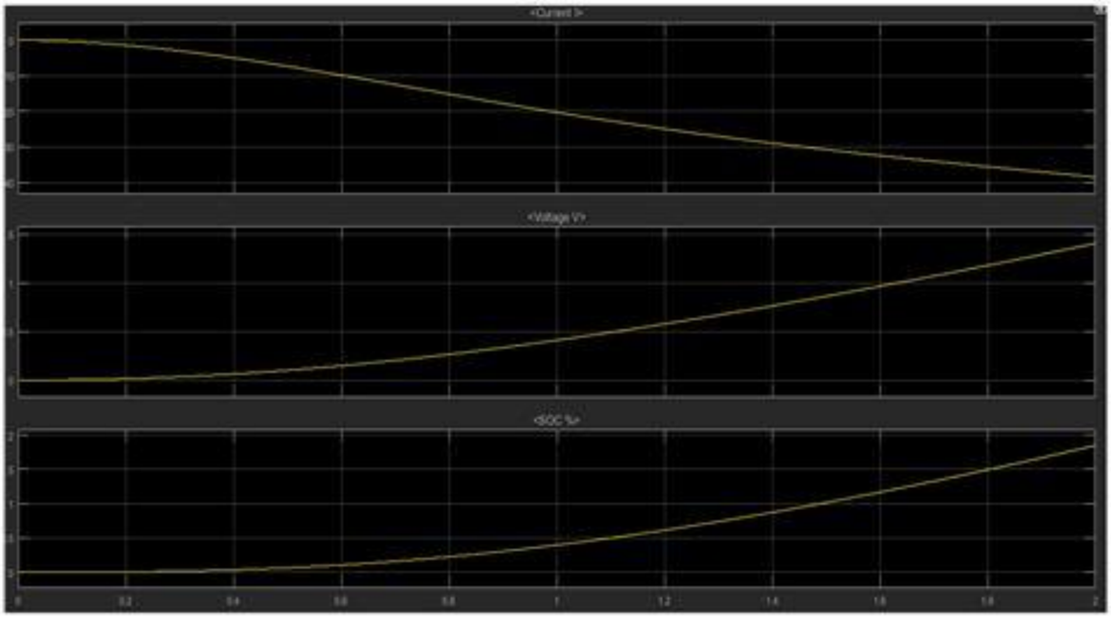

Fig 1.Simulation result for charging characteristics of supercapacitor

Fig.2. shows that the voltage and State of charge (SoC) decreases with respect to time and the power is flowing from supercapacitor to load which is the discharging mode of supercapacitor.

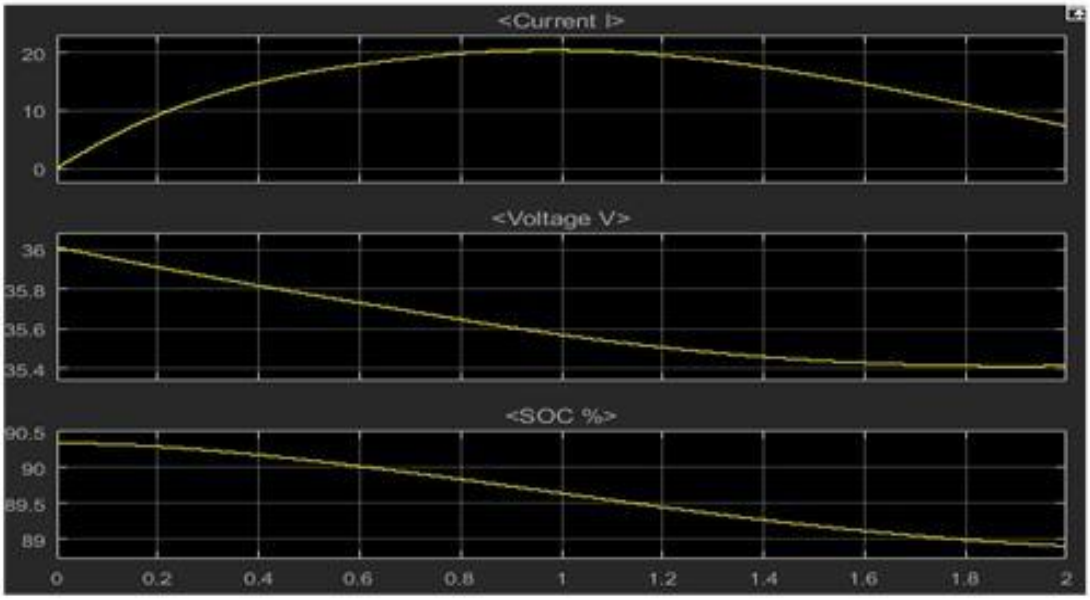

Fig. 2.Simulation result for discharging characteristics of supercapacitor

III. Bidirectional DC-DC converter

Bidirectional converters allow energy flow from source to load and load to source by means of switches operated in aspecific configration.A bidirectional converter that can work in boost mode while motoring action and in buck mode while in regeneration action is given in Fig.3.Battery Vb and Supercapacitor Vsc acta as a voltage source. Resistor Ra in series with the inductance La acts as a DC motor load.

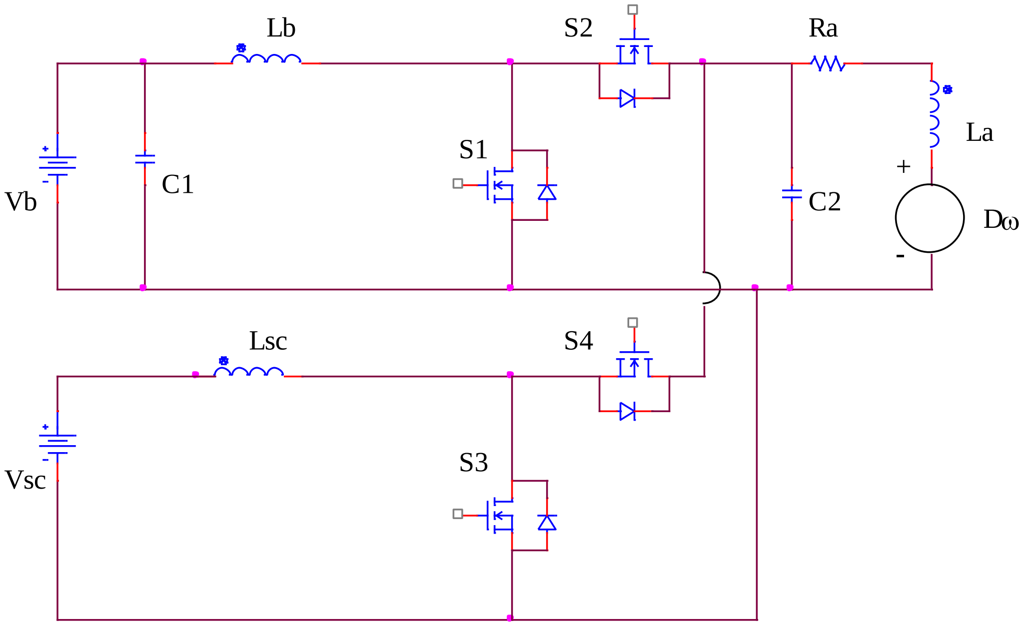

Fig.3. Bidirectional Converter

The switch pairs S1 and S2 are operated in complimentary to each other. In the first mode, switch S1 is turned ON, and the inductor, Lb charges through the battery.In the second mode,S1 is turned OFF and S2 is turned ON. If the sum of battery voltage plus voltage across the inductor, Lb is greater than VDC through out the period when S2 is ON, net current will flow from battery side to motor. This is known as boost mode ie. motoring action.If the inductor does not charges sufficienty through the battery current when S1 is ON, and sum of battery voltage plus voltage across the inductor, Lb is less than VDC. If this condition is true for all the time when S2 is ON, then net current will flow from motor to battery. This is known as buck mode ie. regeneration action. For those values of duty cycle of boost switch S1, at which the current crosses the zero values, the average value of the current will determine the mode in which the circuit is operating.

IV Hardware model of battery and Supercapacitor fed electic dirve system for EVs

A hardware model is developed to demonstrate the motor drive system for EV application.The DC source is provided from a 12V battery and a bank of supercapacitors formed by 6 supercapacitors each of 5.5V, 1F connected in parallel. The MOSFET switches (IRF840) are controlled by a microcontroller (Audino UNO) by providingproper gate signals. Optocoupler MCT2E is used to isolate the power circuit from the microcontroller.DC motor is used as load. High wattage resistive load is used to discharge the supercapacitor. Theprotype model which is developed and tested is given in Fig.4.Motoring action is verified through hardware model. Regenerative action needs fine tune for the expected results.

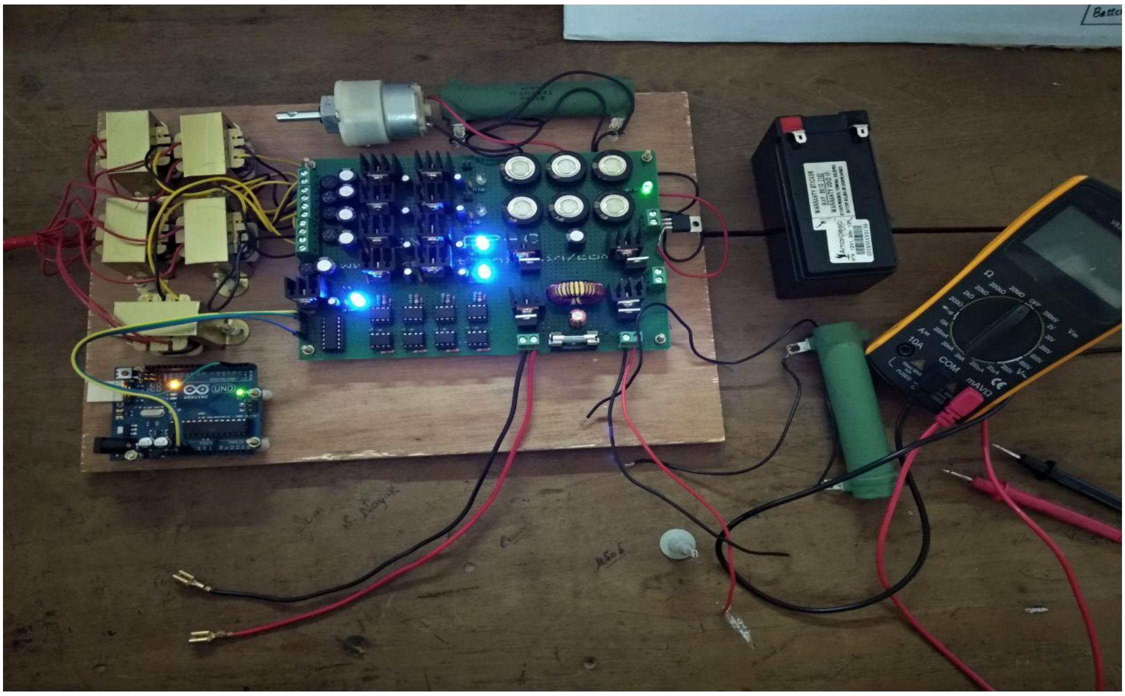

Fig.4. Prototype Model of Electric Drive System

CONCLUSION

Combination of Battery and Supercapacitor has been used as an energy storage system for the electric vehicle. Bidirectional DC-DC converter has been used for the coordinating power flow between Battery and Supercapacitor and regulating the DC-Link voltage.Simulation results provethat the bidirectional power flow and fast charging and dischargingcharacteristic of supercapacitors.Paralleling of supercapacitors along with the batteries satisfies the required performance of EV in terms of efficiency of the motor by energy saving and life of battery.

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