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Engineering

PI CONTROL BASED ENERGY MANAGEMENT STRATEGY OF BATTERY/ULTRACAPACITOR HYBRID ELECTRIC VEHICLES

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ABSTRACT Hybrid electric vehicles have gained attention throughout due to its advantage of green technology and reduced greenhouse gases emission. More over, hybrid vehicles being powered by battery would be the best option of replacing current petrol or gas dependent vehicles. There are drawbacks also; battery has limited lifetime and is very costly. Hence, it is hybridized with other energy storage systems such as ultracapacitor. This work focuses on the energy management system for the energy storage system consisting battery and ultracapacitor of a hybrid electric vehicle using adaptive fuzzy logic based controller. This energy management system manages energy feed between battery and ultracapacitor. Simulation environment chosen is Matlab/Simulink.

KEYWORDS : Ultracapacitor-PI Controller-Energy Management system-Bidirectional Converter-Battery

INTRODUCTION

In recent years, global warming and water-related issues have warned that in many developed countries. It is important to reduce fuel consumption. Particularly focusing on automotive technology (that is fuel-efficient) in order to reduce the threat of global warming and energy issues. Few well-known technologies are hybrid electric vehicles (HEV) and full electric vehicle (FEV). Other researchers are working to improve the fuel efficient transport technology which provides internal combustion engines with power supply, power recovery systems, super capacitors, and efficient management of energy management.

All of them use a battery pack to supplement conventional ICEs. It is believed that such HEVs are only the intermediate products between conventional ICE vehicles and battery electric vehicles (BEVs, which use batteries as the primary energy source without ICEs). With the rapid development of battery technologies, lithium-ion batteries today have reasonable energy density compared with other types of batteries but become much cheaper. It is possible to utilize them as the primary energy storage component for automotive applications. On the other hand, a possible solution may be to select another energy storage component, ultracapacitor (UC), to assist batteries, forming a hybrid energy storage system (HESS) for EVs. UCs have high power density, long cycle life, quick dynamic response but low energy density, which are opposite towards batteries[3]. So the combination of them is anticipated to Complement one another.

LITERATURE RIVEW

Parallel Hybrid Electric Vehicle Configuration

The parallel HEV allows both ICE and electric motor (EM) to deliver power to drive the wheels. Since both the ICE and EM are coupled to the drive shaft of the wheels via two clutches, the propulsion power may be supplied by ICE alone, by EM only or by both ICE and EM. The EM can be used as a generator to charge the battery by regenerative braking or absorbing power from the ICE when its output is greater than that required to drive the wheels.

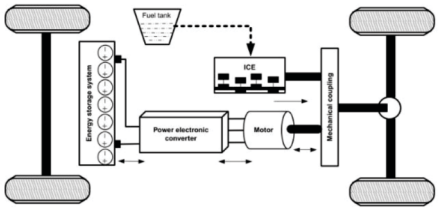

Figure 1: Parallel Hybrid Electric Vehicle Configuration

Battery/Ultracapacitor Energy Storage System

The efficiency of electric vehicles (EV) and hybrid electric vehicles (HEV) depends on their capability to store large amounts of energy, and also to quickly extract power from that energy. Currently, HEV rely on large battery systems to store their on-board electrical energy In order to meet the peak power demands, battery storage systems tend to be oversized and heavy.

This hybrid energy storage system (HESS) can be either passively or actively connected and both topologies will be considered in this work. The simplest of the configurations is the passively connected system. This is comprised of the ultracapacitor directly connected, in parallel to the battery. This configuration limits the control over the charge and discharge of the components. The voltage and state of charge (SOC) of each

SYSTEM MODELING

Figure 2 shows complete block diagram representation of Hybrid Energy Storage System of HEV. Each and every components are modelled separately by means of mathematical equations. The simulation environment is chosen here as Matlab/Simulink.

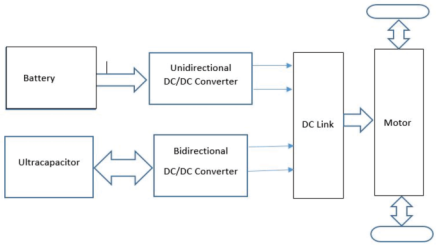

Figure 2: System configuration

Battery Model

The battery model is given by set of equations. The proposed model represents a non-linear voltage which depends uniquely on the actual battery charge [6]. The battery is modelled using a simple controlled voltage source in series with a constant resistance, as shown in Fig bellow.

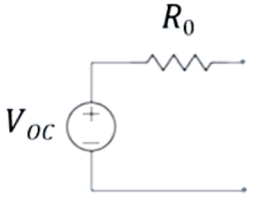

Figure 3: Battery Model

Ultracapacitor Model

Ultracapacitor should assist the battery by handling the momentary peaks in power. Due to relatively low internal resistance, it can

efficiently handle large power surges. Ultracapacitors can be used as secondary energy storage systems in Electric vehicles since it can instantly provide and consume large transient load requirements during sudden acceleration and regenerative breaking [7].

High current requirements during heavy acceleration can be met by ultracapacitor. This reduces battery size and hence increase the vehicle performance. Since, battery can be operated within safe limits battery life can be enhanced. UCs have high power density, long cycle life, and quick dynamic response but low energy density. Modelling can be done by the basis of parameters obtained from the data sheet.

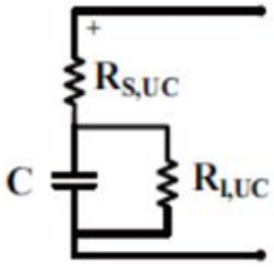

Figure 4: Ultracapacitor Model

DC/DC Converter

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 supercapacitor 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.

The boost converter is step up converter and produces a higher average output voltage than the dc input voltage. For Buck-Boost converter the output [9] voltage can be either higher or lower than the input voltage.

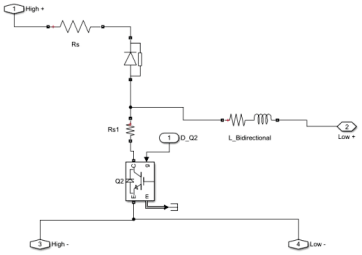

Figure 5: DC/DC Boost Converter

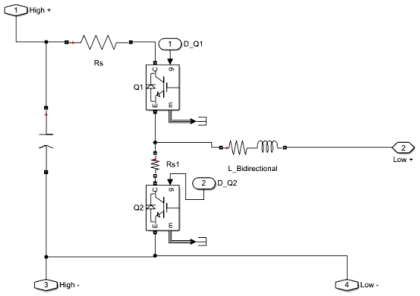

Figure 6: DC/DC Buck-Boost Converter

BLDC Motor

The BLDC motor has a permanent-magnet rotor surrounded by a wound stator. The winding in the stator get commutated electronically, instead of with brushes. This makes the BLDC motor. The composition of the BLDC motor also keeps the machinery inside a vehicle cooler and thermally resistant. Plus, because the motor is brushless, there is no dangerous brush sparking.

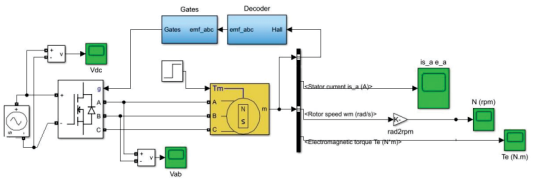

Figure 7: Matlab model of BLDC motor

Modelling of BLDC Motor

BLDC motor also known as Permanent Magnet DC Synchronous motor is one of the motor types which have gained more popularity, mainly due to their better characteristics and performance. The stator windings are star connected to an internal neutral point. The rotor is non salient pole type with trapezoidal flux pattern in the air gap. The Hall signals and the actual rotor speed are obtained as output from the motor. Terminal voltage with respect to the star point of the stator is given as follows [9].

$$V_a = I_a R_a + L\frac{dI_a}{dt} + e_a \ldots\ldots\ldots(1)$$

$$V_b = I_b R_b + L\frac{dI_b}{dt} + e_b \ldots\ldots\ldots(2)$$

$$V_c = I_c R_c + L\frac{dI_a}{dt} + e_c \ldots\ldots\ldots(3)$$

Where,
I_a, I_b I_c= Phase currents
L = Inductance
e_a, e_b e_c= Back EMFs

SIMULATION AND RESULTS

The simulation of PI controller based control of system performed using MATLAB/Simulink model. Fig.7 shows complete Simulink block diagram. Here BLDC motor is used with a seperate fuzzy based speed control mechanism to know about the charging and discharging characteristics of battery and supercapacitor. The results shows that there is a power split between UC and battery based on the speed of vehicle.

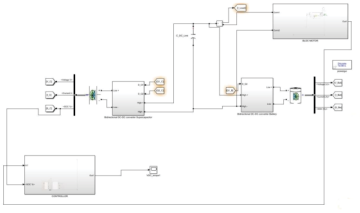

Figure 8: Simulink Model for energy management system

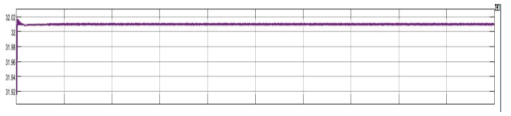

Figure 9: Ultracapacitor Voltage versus time



Figure 9: Ultracapacitor Current versus time

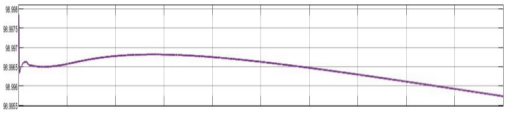

Figure 10: Ultracapacitor Soc versus time

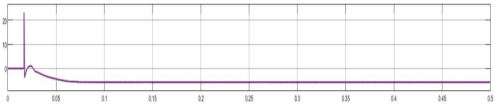

Figure 11: Ultracapacitor Power versus time

It can be seen that even for variations in load, the battery voltage flucuations are reduced and the high frequency load requirements are met by the ultracapacitor; and the the DC bus voltage is maintained constant at 400V.

During motoring, the high frequency components are taken by UC and the remaining is met by battery; and hence power split mechanism is achieved. During regenerative breaking, the UC gets charged, and after it is completely charged reaching the specified working voltage of UC, battery gets charged. From the graphs, it can be seen that, high frequency transients are handled by ultracapacitor and current in the battery is raised gradually. Since high transients are handled by ultracapacitor, only safe current flows from the battery. Hence, battery terminal voltage can be kept within safe limits...

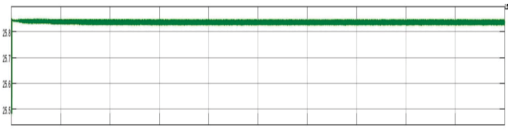

Figure 12: Battery Voltage versus time

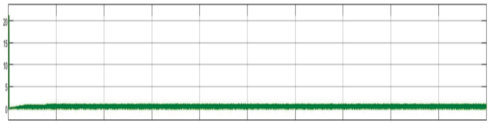

Figure 13: Battery Current versus time

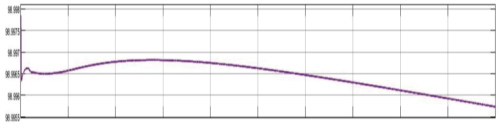

Figure 14: Battery Soc versus time

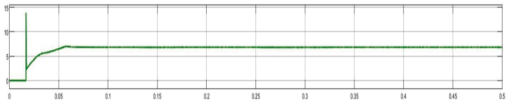

Figure 15: Battery Power versus time

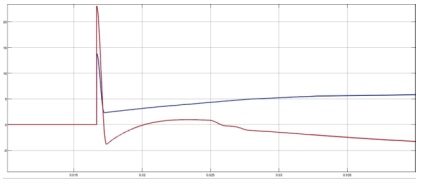

Figure 15: Battery Power and UC Power

CONCLUSION

By adding an ultracapacitor in Hybrid Electric vehicles to assist batteries, regenerated currents can be effectively stored and reused. Also, high current requirements during heavy acceleration can be met by ultracapacitor. This reduces battery size and hence increase the vehicle performance. Since, battery can be operated within safe limits battery life can be enhanced.

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