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Modelling and Simulation of Electric Vehicle Coupled with Battery and Ultracapacitor

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ABSTRACT

Electric vehicles boom in the market started after the improvement in the battery technology but the improvement needs to be enhanced further. An Electric Vehicle has zero greenhouse gas emissions compared to conventional ICE vehicles or Hybrid Electric Vehicles and hence is a better alternative. An Electric Vehicle has a longer charging time which is a drawback. Hence using Ultracapacitor for fast charging purposes can be coupled with a battery to overcome the drawback. Therefore, improving the transient power capabilities of the battery to satisfy the road load demand is critical. This research studies integration of Ultra-Capacitor (UC) to Battery. The objective is to analyze the effect of integrating UCs on the transient response of the BEV powertrain. UCs have higher power density which can overcome the slow dynamics of batteries. An energy management strategy utilizing a peak power-sharing strategy is implemented. The goal is to decrease the power load on batteries and operate Ultracapacitor in its most efficient region. A complete model to simulate the physical behavior of UC-Integrated BEV is developed using MATLAB/SIMULINK. This increases the life of the battery since its protected from overcurrent. which increases the health of the battery based on the number of charge/discharge cycles.

Keywords: *Ultracapacitor, SOC, OCV, Powertrain and Regen Power etc.*

1. INTRODUCTION

In the recent years, there are various advances and development in the Energy storage system for an electric vehicle. The electric motors efficiency and capacity of high voltage energy storage devices has opened new frontiers. This has motivated the Car makers and OEMs to do research and development in all type of green vehicles as they are seen as potential solutions to reduce greenhouse gases and depleting oil reserves.

1.1 Motivation For Developing a Power Management Strategy with Integrated UC.

Adding a second power source will improve performance and reliability. This will increase commercial viability bringing down the cost of battery production in future. Adding a second power source not only added more degree of freedom, but also gives the flexibility to find and operate battery in its most efficient region as Ultracapacitor can satisfy power demand at other time. This research investigates designing a transformational power management strategy that distributes requested power among battery and UC. power sources used in the powertrain have different characteristics. There has to be an algorithm on how the propulsion power required is distributed or coordinated between both the energy sources. The effect of using Ultracapacitor for transient and high-power demands on the behalf of the battery and how it can affect the life of the battery is a part of this research. This Power Management System also ensures that the battery operates in the most efficient region. Apart from the prospect of efficiently managing positive power, the regenerative power can also be harvested in a much better way. Since there are two power sources that can use regenerative power, a very less amount goes waste. The Ultracapacitor can handle transient currents and can be used to absorb higher proportion of power compared to battery.

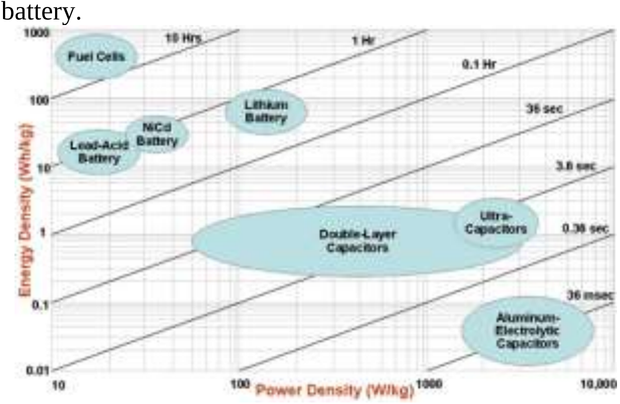

Figure-1 Ragone plot of electrochemical devices

Hence the battery need not absorb high current or high-power demand which enhances the battery life. Thus, by adding UC into the ESS, reduces surge currents from battery which extend their life as expected. Both batteries and Ultracapacitor have their pros and cons. A powertrain configuration having both in their ESS so that they can be used to the best of their capabilities would make a system quite efficient. But having two power sources in a powertrain and creating a power management strategy can be quite complicated. Thus, creating the Energy management strategy for this kind of powertrain is the aim of this research. From the figure-1 we can conclude the comparisons between different energy sources, hence using battery we can achieve high energy density and using ultracapacitor we can achieve higher power density so there is necessity of coupling both energy devices.

2. POWER MANAGEMENT STRATAGIES

Control Strategy regulates the energy in such a way that power demand is satisfied consistently.

- Plug-in charge mode - The Battery is charged
- Discharge mode - Both Ultracapacitor and battery discharges depending on the load.
- Regenerative mode – Ultracapacitor charged.

The control strategies can be based on different techniques.

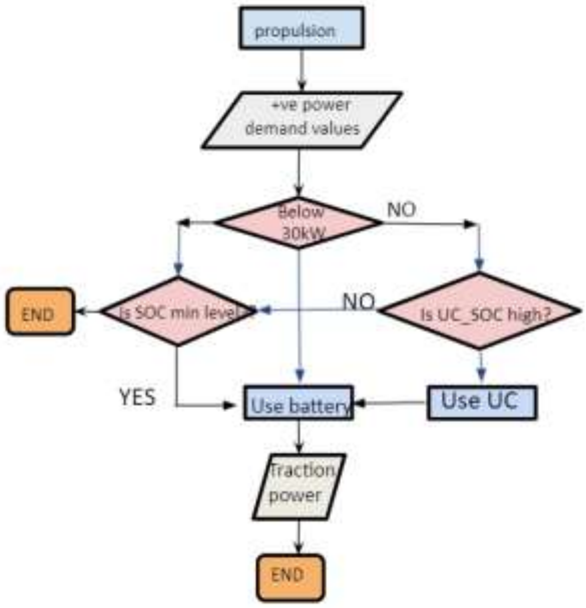

Chart-1 Flow chart showing coordination between battery and ultracapacitor.

From the above chart algorithm, I have developed mathematical model of the battery and ultracapacitor coordination using MATLAB and Simulink.

The chart-1 shown above is for propulsion duration i.e., when the power is positive the algorithm checks whether the power required is below 30KW if yes it gives signal to the battery to work if the power is above 30KW ultracapacitor will supply the required energy, if in case Ultracapacitor is shortage of charge then there will be backup from the battery i.e., the battery will supply the required power if in case the battery SOC is also low then vehicle stops.

3. UC VERSUS BATTERY DYNAMICS

In modern urban driving conditions, there are many start/stop scenarios like stopping at a traffic light or at stop signs along with rapid accelerations and braking on urban and highway driving condition. A drive cycle like FTP75 which is a very aggressive drive cycle incorporates all these conditions. While driving with conditions like this, the Ultracapacitor becomes an ideal power source to be used to provide quick energy and capture regenerative energy while braking. Ultracapacitors have very high-power density compared to all other energy sources and hence fast charge and discharge can be achieved, typically in the range of microseconds as shown Figure-2. Batteries on the other hand have a slow charge/discharge profile. So, the Ultracapacitor is capable of harvesting a lot of regenerative energy quickly and efficiently.

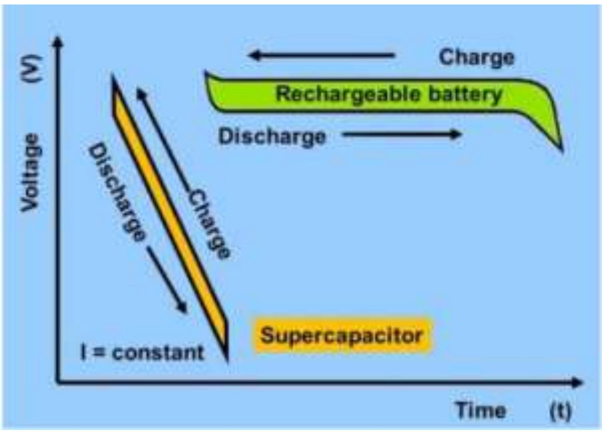

Figure-2 Charge/Discharge Profile Comparison

The figure-3 shows the drive cycle for which the simulation results were obtained.

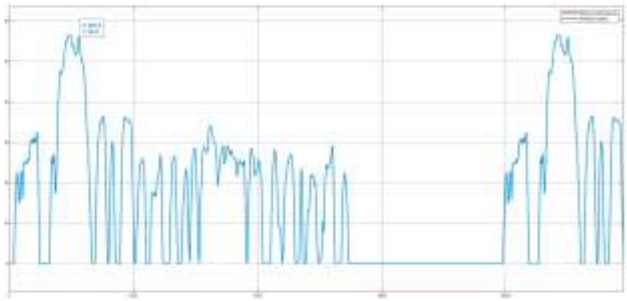

Figure-3 FTP 75 Drive Cycle

4. MODELLING IN SIMULINK

The model was completely made up of a mathematical equation. Using characteristics of battery and ultracapacitor the model of each was developed as shown in figure-4 and similarly the ultracapacitor model was developed. The battery model works on the SOC vs OCV, SOC vs Charge resistance and SOC vs Discharge resistance characteristics which is achieved here using the lookup tables. And since the characteristics is for a single cell, we have multiplied it depending the number of cells required in series and parallel.

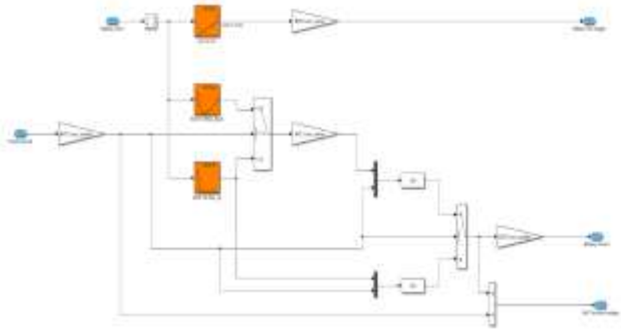

Figure-4 Battery Model

The battery SOC i.e., state of charge which tells us how much charge is available for the use is also calculated using Coulomb counting method for SOC estimation. The modelling equations are as shown in figure-5.

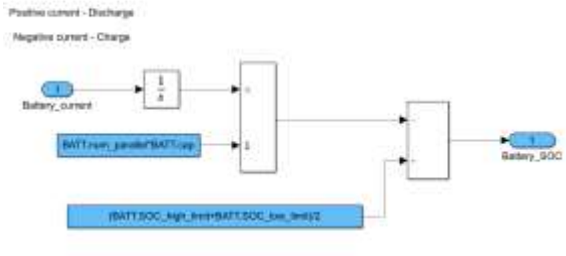

Figure-5 Battery SOC estimation using Coulomb counting method.

Using the algorithm flow chart-1 we developed the model where when the power required by the vehicle is more than 30KW ultracapacitor will come in to action if not battery will supply the energy and if in case the ultracapacitor as less SOC then battery will backup and supply power to the vehicle, as shown in figure-6.

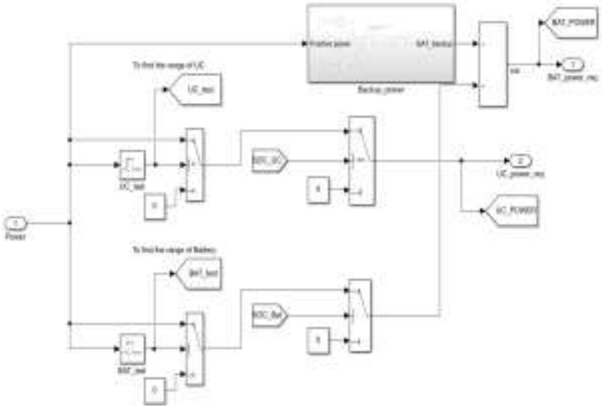

Figure-6 Battery SOC estimation using Coulomb counting method.

So, the above model is when the vehicle is in propulsion when the vehicle is braking the regenerative power generated is only given to the ultracapacitor.

5. RESULTS

The model is simulated for FTP75 drive cycle. How the power is coordinated is shown in figure-7.

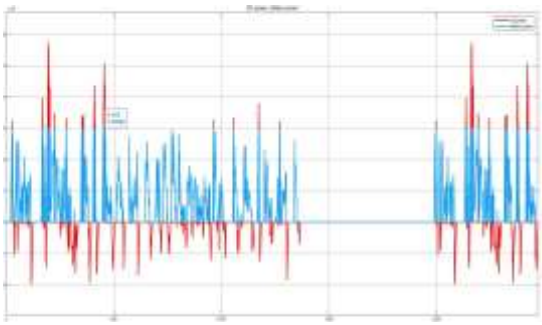

Figure-7 Power coordination

In figure-7 we can observe red lines indicate Ultracapacitor power and blue line indicates battery power, we can clearly observe how power is coordinated between both the energy sources according to the algorithm whenever the power required is above 30KW ultracapacitor comes into action and also, we can observe the negative power i.e., the regen power is only absorbed by ultracapacitor. Doing so the SOC plot for ultracapacitor and battery is as shown figure-7.

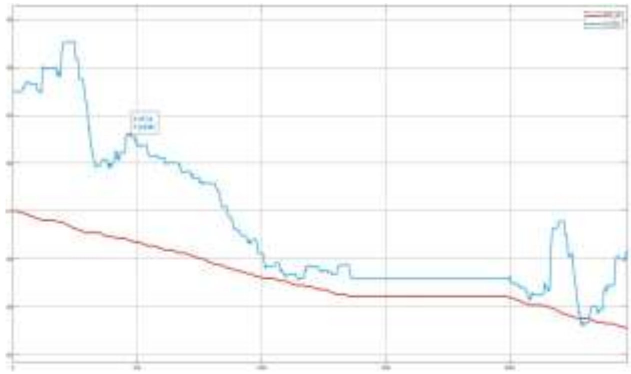

Figure-8 SOC plot

From the SOC plot we can observe State of charge increase is only seen in ultracapacitor, hence following the algorithm increases the battery life because when there is braking the current surge is high which is advisable to be given for ultracapacitor hence battery health can be increased and there won't be necessary for replacement of the battery frequently.

6. REFERENCES

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