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Comparative analysis of a supercapacitor and Li-ion battery based electric vehicle

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Abstract

This paper has simulated an Electric Vehicle (EV) in MATLAB/Simulink environment where Supercapacitors (SC) are compared with Li-ion batteries. Simulated EV is tested under both above discussed scenarios for evaluating its performance under certain speed and torque load conditions. The critical aim of the government or any manufacturing company is to reduce the carbon footprint and provide better living conditions for their

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people. The major step to achieve this aim is to maximize EV usage. Therefore, it can be attained through the implementation of battery energy storage system. This paper has paved the way towards the goal by showing supercapacitors or Li-ion as energy sorage interms of there performances and recharging time. The inhibition of supercapacitors instead of the currently used Li-ion can turn out to be a game changer as it can be reused which decreases the chances of E-wastage but it has certain limitation. Moreover, supercapacitors are known for having high speed of charge (1000 times faster than Li-ion) that increases the efficiency of the EV.

Subject Classification: *58-XX , 74A15.*

Keywords: *Vehicle batteries, Electric vehicles, Supercapacitors, Lithium-ion battery, MATLAB/ Simulink.*

1. Introduction

With the soaring prices of fossil fuels in the global market, EVs are adopted to compensate for the inflation by the governments in the world. Latest EVs run with Li-ion energy storage system show better performances over their predecessors with conventional batteries. The major issue for less EV uptake is the Li-Ion battery as the energy source. It has been found that defiance in thermal characteristics on run of Li-ion batteries has led to explosion and dreadful conditions. Another aspect is large number of used Li-Ion batteries thrown as e-wastage. All these gaps found in shifting electrical driving over EVs are enough to find an alternative to Li-ion battery in EVs. This paper is an attempt to find a solution by using supercapacitors (SCs) as an energy storage system in EVs. Lot of research is being carried over in this direction. Supercapacitors being the latest green and efficient technology has shown great potential in industries and field [1]. Despite many advancements in many technology current batteries do not fully meet the energy requirements of EV consumption and hence a viable solution to this are supercapacitors [2], [3]. The supercapacitor technology has lately become a viable option for replacement of batteries in different application such as transportation market [4]. A very crucial role in EV application is paid by the charging infrastructure technical challenges of infrastructure and organization of charring network are few of the challenges being faced currently [5], [6], [7],[8].With zero tail pipe emissions, EV's are mostly environment friendly which further states cleaner CO2 emissions and fewer particulates release[10]. Electrochemical supercapacitor are developing as a good energy storage devices [11],[12],[13]. The major drawback of EV's is its high prices. The lithium-ion battery used in EV's are very expensive and not reusable causing

people to dump their old batteries which is further leading to E-wastage. With all the drawbacks, EV's are still the best option in the coming future. One of the major technological advancements in the EV sector is the use of the supercapacitors instead of Lithium- ion batteries for designing an electric vehicle. Supercapacitor is like a battery which stores and releases electricity and it works by simply storing electricity in a static state rather than it being locked up in chemical reactions like in Li-ion battery. Supercapacitor do already exist in cars with regenerative braking systems because of their greater power density which allows them to quickly store and release electricity. But they're yet to take over Li-ion batteries as the primary source of EV.

This paper has simulated an Electric Vehicle in MATLAB/Simulink environment where the Lithium- ion batteries are compared with supercapacitors. Simulated Electric Vehicle is tested and discussed for evaluating its performance under certain speed and torque load conditions.

2. Methodology

2.1 *Dynamic Model of Electric Vehicle*

A vehicle can be considered as a mass having its weight. If we apply a perpendicular force on the vehicle, it will get some speed and it will travel some distance in some time interval. The mathematical modelling is done to represent the vehicle in the form of mathematical equations so that we can obtain a relation between the input and output [12].

Here input is the force and outputs are speed, velocity and displacement. Considering a vehicle, if a force is applied tangentially on the wheels in a certain direction, the opposing forces we get are "m*a" (where m is mass of vehicle and a is its acceleration) and the aerodynamic drag force (F_d) which depends on shape of the vehicle and certain environmental conditions such as air density[14,15]. This force formula will remain same for two-wheeler as well as for four-wheeler.

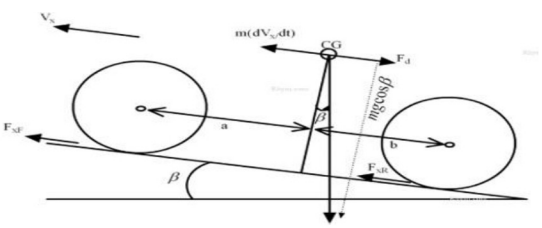


Figure 1

Dynamic Model of Vehicle

For simplicity we have considered rear wheel drive and accordingly, force F x R is produced. The incline angle with the horizontal surface is β as shown in Figure 1. Due to this angle β, we get two components of the CG (Center of Gravity) i.e. horizontal component (mg cosβ) and vertical component (mg sinβ).

2.2 *Motor Drive*

Motor drives are often also mentioned as "motor controllers", since controller circuits are usually combined with the drive circuits in order to produce a single unit as shown in Figure 2. Different kinds of Motor Drive commonly used are stepper, AC, DC and servo. All of these motor drives have input power types that are modified to the output functions for their implementation.

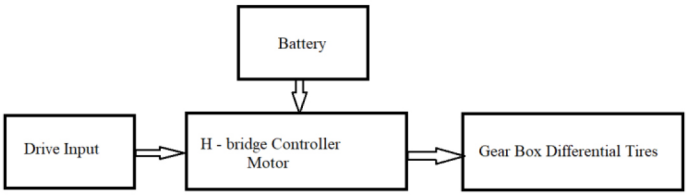


Figure 2

Block Diagram of Motor Drive.

2.3 *Electric Traction System*

Traction system simply is a system which can cause the propulsion of vehicle in which further tractive or driving force is obtained from various other devices which include the electric motors, steam engine drives and diesel engine drives.

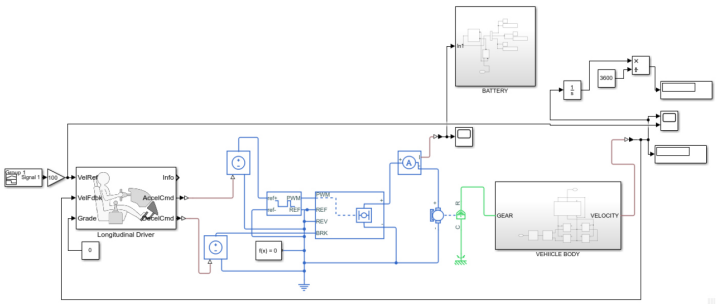


Figure 3

Block Diagram of considered Electric Vehicle

Electric Traction system is a system which uses electricity at any process or in all the process involved in the locomotive movement largely depends on type of battery [12,14]. Driver input, Motor of Controller, battery and vehicle body are considered in this simulated model as shown in Figure 3. Lithium- ion batteries and supercapacitors are used to check their feasibility in designing an Electric Vehicle.

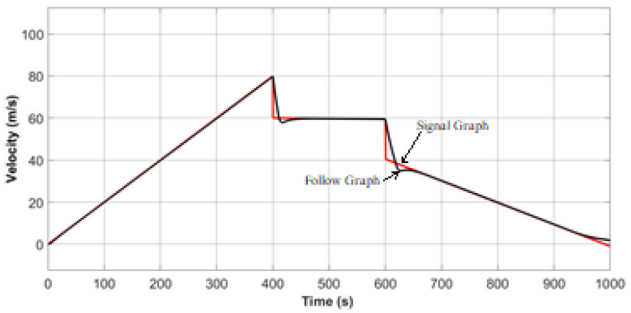
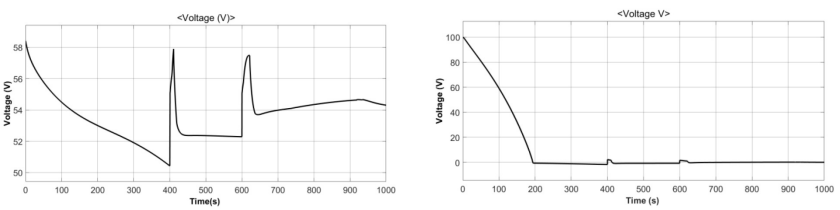


Figure 4

Comparison of Signal Graph and follow graph



(a) (b)

Figure 5

Voltage graph of running EV a) Li-ion b) supercapacitor

3. Results and Discussion

The comparison of Electric Vehicle with a Li-ion battery and supercapacitor is done in terms of voltage, current and state of charge (SOC). . Signal Graph is given as the input to the driver and follow graph is the output of Vehicle body. Figure 4 shows that the follow graph is similar to the signal graph except at breaking. For this, supercapacitors are replaced with Li-ion battery and the following results are obtained. Figure 5 shows voltage graph of running EV with Li-ion and supercapacitor. In this figure voltage in li-ion give value around 50 v where supercapacitor

discharges at 0. As the load is same during both batteries, EV with Li-ion and supercapacitor follows same current graphs as shown in Figure 6. Current keeps on increasing during the acceleration period and becomes negative during braking as it should happen due to regenerative braking.

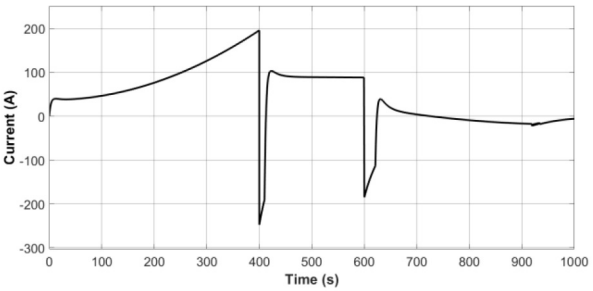
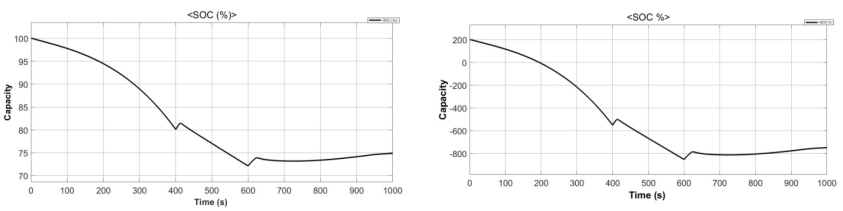


Figure 6

Current graph of running EV a) Li-ion b) supercapacitor



(a) (b)

Figure 7

State of charge of running EV a) Li-ion b) supercapacitor

Comparison graph of State of charge between Li-ion and supercapacitor running EV is shown in Figure 7. It can be clearly seen that the charge is going negative in case of supercapacitor which indicates that current is flowing opposite to the direction in which it ideally should be flowing, which shows that currently supercapacitors cannot be used currently in electric vehicles. In future, SCs it can be used with changes.

4. Conclusion

This paper has addressed the designing and simulation of an Electric Vehicle with supercapacitors and Li-ion as its energy source. The performance under certain speed and torque load conditions shows the superiority of Li-ion over supercapication in some areas. While

supercapacitors have lots to offer, they cannot yet compete with Li-ion batteries in the automotive market. There are newer developments on daily basis and with time their use will extend more from just ancillary devices to public transportation, power stabilization devices and in hybrid supercapacitor-battery.

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