Electrical Parameter Optimization for a Battery Electric Vehicle

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Abstract: Passenger vehicles are an essential part of everyone's life, yet their exhaust fumes are a major source of urban pollution that contributes to the greenhouse effect, which leads to climate change. The world's dependency on oil as the primary source of energy for passenger vehicles has economic and political ramifications, and the situation will undoubtedly worsen as the world's oil stocks deplete. The development of clean, efficient, and sustainable vehicles for urban transportation is being pushed by both environmental and economic concerns. Electric vehicles (EVs) driven by alternative energy sources and enabled by high-efficiency electric motors and controllers provide a clean, efficient, and environmentally friendly urban transportation system. Furthermore, renewable energy sources such as water, wind, and solar energy may be used to generate electricity for EV. EV and HEV provide lots of new increasingly complex design issues never seen in traditional automotive technologies and transportation systems. The automobile industry is devoting significant resources to the development of electric vehicles to fulfill increasingly stringent standards for fuel efficiency, economy, vehicle safety, performance, and environmental protection. This chapter helps to gain knowledge of electric and hybrid vehicles, including the advantages and design problems that come with them.

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1. Introduction

The world is facing the deficiency of the fossil fuel so every nation is moving towards the sustainable, reliable, efficient, economical and green resources of energy. One of the major fossil fuel consumptions is the transportation sector. Most of the public vehicles and personal vehicles are run by internal combustion engine (ICE) which could be considered the cause of the global warming due to which the glaciers are melting and rise in the temperature 2° C every year [1]. Interestingly an electric vehicle (EV) causes neither the carbon emission nor the contribution to the high oil price. The upcoming EV technology has social and economic benefits in both the transportation sector and energy sector. In spite of these benefits, enormous penetration of EVs on the national grid causes new challenges for the grid and the power engineers. Moreover, many automotive industries, organizations, and countries are investing for the research and development of the EV. For example, Google spent $10 million and the U.S government spent $2 billion for the development of the EV battery [2]. Considering the research and development in the EV industries, the Australian Energy Market Commission (AEMC) projected to increase the sales of the light EV from 15% to 40% by 2020 [3].

To overcome the global emission problem, the electric utility industries are moving towards the alternative resources such as renewable resources e.g. wind, solar and biofuels. The Chinese government sets the goal to install 150-180GW of wind power and 20 GW of Photovoltaics (PV) power generations by 2020. The enormous penetration of EVs into the national grid needs a large size of energy storage system (ESS) to overcome the demand and the supply of the electricity [4]. The contribution of PV base energy generation was less than 1% to U.S electricity production in 2015 [5] but due to the decrement in the cost and resources, the solar energy production will continue to grow. It is projected that the solar could contribute nearly 15% of U.S energy demand until 2030 and 30% by 2050 [6].

Therefore, the electrification of the medium-duty passenger vehicle is the important and right step towards the justifiable and reliable transportation [7-9]. This can be done by the efficient integration of EVs with the emerging green energy resources. Moreover, to make the environment clean and green, several incentives are given to the EV and renewable power generation owners. The integration of renewable energy resources and randomness of EVs imposes several challenges for widespread adoption of the smart grid, which need to be addressed. The renewable energy resources such as wind and solar based are very much irregular, and due to the integration of EVs to the smart grid, both demand and supply become more intermittent and may jeopardize the stability and reliability of the grid.

There are three main types of EVs: (i) a plug-in hybrid electric vehicle (PHEV), (ii) hybrid electric vehicle (HEV) and (iii) fully electric vehicles (EV). The PHEV uses the internal combustion engine to extend it cruising range and the battery to power up the electric motor [10]. The EVs have no internal combustion engine and the battery could be recharged by renewable energy resources and it has zero carbon emission [11]. The last type is the HEV and it is not considered as a fully EV. The HEV uses both the battery as well as the combustion engine to power up the vehicles.

It derives all their power from the combustion engine and cannot be recharged by the plug in. However, the battery is recharged by the regenerative braking system.

We proposed a novel simulation model for the full electric vehicle from the pre-existing HEV model. To validate the proposed EV model we compared the SOC of EV with HEV by using 76 representative vehicles weekday data for 3500 second from the city of Winnipeg, Canada [19]. We observed that EV expectedly consumes more current from the battery as compared to the HEV due to which the SOC of the battery of the EV decays earlier than the HEV that can be seen in the simulation results.

The paper is organized as follows: different vehicle technology such as HEV and its mode of operation and the fully EV is presented in section II. Section III presents the simulation results of both HEV and EV. The conclusion is drawn in section IV.

State of Charge (SOC) Battery Management System (BMS) is needed to avoid battery damage and failure. Battery State of Charge (SOC) and State of Health (SOH) are part of the information provided by BMS. Lithium-polymer battery is one of the batteries that used in numerous applications from the radio controlled equipment to commonly used transports and electric vehicle, in order to provide energy storage to these systems [5]. In paper, the prediction is used at Lithium-Polyner battery. SOC is a percentage of battery capacity while SOH is a measure of battery health. SOC is defined as the ratio of total energy capacity can be used from a battery with a full battery capacity. SOC describes the available energy and is written in percentage according to several references, sometimes considered the value of the capacity of the battery. The method to measure SOC from a battery can be done in 3 ways, namely Direct Measurement, Measurement Specific Grafity (SG) and Estimated SOC based on voltage. Direct measurement can be done if the battery can be discharged at a constant value and measurement. Measurement Specific Grafity, this method depends on changes in measurement of the weight of active chemicals. Whereas, Estimated SOC based on voltage, by measuring battery cell voltage as a basis for calculation of SOC or remaining capacity. The results can change depending on the real voltage level, temperature, discharge value, and cell age. In this study, lithium ion batteries were taken as the experimental object to carry out the same discharge experiment at different SOC values,. First, the values of the battery's SOC are shown to decrease gradually, which means that the battery has the highest SOC, and the one in has the lowest. It can be seen that the voltage drop curves of batteries with different SOC demonstrate a clear distinction under the same discharge current; that is, SOH has a remarkable effect on the instantaneous output power of the battery. However, thanks to the strong correlation between the SOC and internal resistance, studying the influence of battery internal resistance on SOC was not necessary .

2. Vehicle Technology

2.1 Hybrid Electric Vehicle

The HEV is known as a dual-power-source vehicle. These vehicles have the engine and the battery that is used to propel the vehicle. The source of energy can be the battery or the internal combustion engine. To minimize the pollution the HEV use the ICE engine and the electric motor in a most desirable way and save the energy. Three types of HEV are series hybrid, parallel hybrid and series-parallel hybrid vehicle [12].

The advantages of HEVs are:

1. Fuel efficiency and performance;
2. Lower fuelling cost;
3. Reduce the CO_2 emission;
4. Recover some of the energy by regenerative braking,
5. Use the existing fuel station.

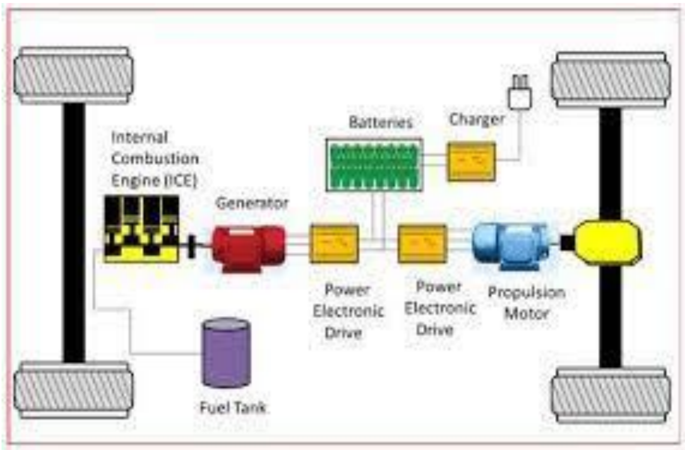


Fig. 1. Hybrid electric vehicle, Series-Parallel [8]

2.2 Hybrid Vehicle Mode of Operation

The HEV combines the both ICE engine and the electric propulsion system to achieve the better fuel economy than the conventional vehicles. The latest HEV use the modern technology such as regenerative braking system to recapture the vehicles kinetic energy in to electrical energy that stored in the battery. The HEV is better for the urban driving, because in urban driving vehicle often does start and stop, at that time the vehicle recapture the kinetic energy into the battery. The typical hybrid vehicle has four modes of operation as shown in Fig.2. The modes of operations are as follows [15-18]: I. Start and low to mid-range speeds. During the low to mid-range speeds or in the starting of the vehicle, the engine totally stops and the motor alone propels the vehicle.

2.3 C. Electric Vehicle

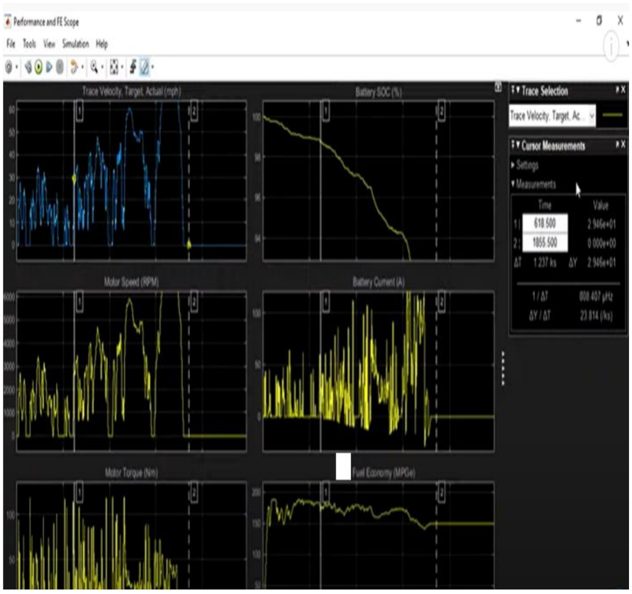
In order to validate the proposed EV model we did the comparison of the proposed EV model with the pre-existing HEV model. As we all know that traditional vehicles use the gasoline to drive the vehicle whereas, the fully EVs use the electric motor which is run by the battery or fuel cell. The benefits are as follows:

1. Smooth and quiet drive
2. Fuel cost saving
3. Rechargeable
4. Higher total energy efficiency
5. Emission-free vehicle
6. Low maintenance cost and 7. No gasoline requires propelling the vehicle.

3. Simulation Results

3.1 Hybrid Electric Vehicle

The pre-existing HEV model (Fig.1) taken from Ref. [18] is utilised in Simulink built using Simscape, Simscape electronics, Simscape Driveline, and Simscape Power Systems. The digital simulation studies were conducted using the practical data of 76 representative vehicles from the city of Winnipeg, Canada [19, 20]. The simulation study results show that the state of charge (SOC) of the HEV decays slowly than the EV due to the presence of the internal combustion engine as shown in Fig. 5 and Fig. 9 respectively. The Series-Parallel HEV is utilized for the comparison of the speed, acceleration and SOC with the EV. The speed of the vehicle depends upon factors such as vehicle body, road inclination, wind velocity and tyre slip. The speed (Kph) is shown in the Fig.3 for the time interval of 3500 seconds.



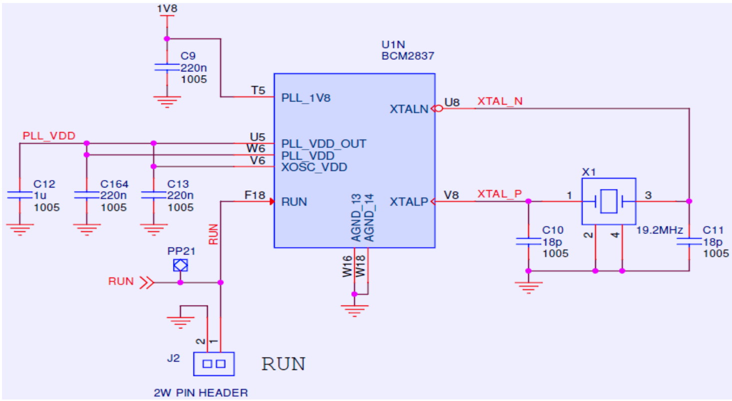


Fig. 3. Raspberry Pi HEV Speed at different time

The vertical axis shows the acceleration of the vehicle in m/s² and horizontal axis shows the time in second. The simulation is carried out for the time interval of 3500 second and the acceleration vs time graph is shown in the Fig.4.

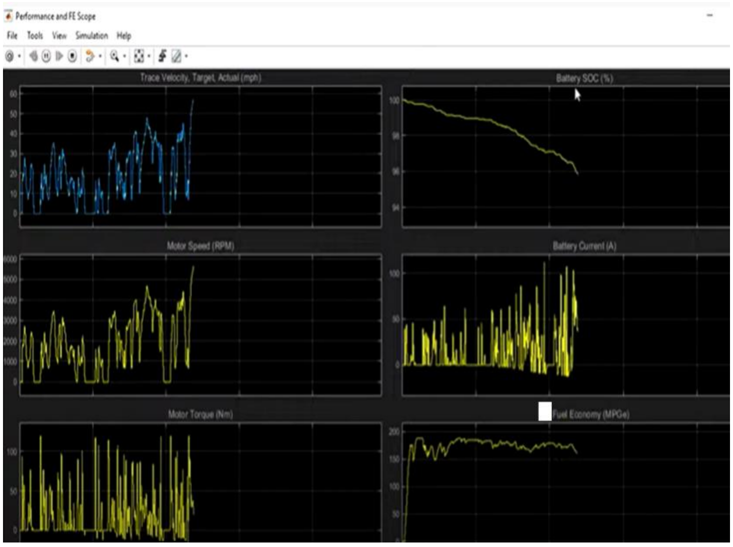


Fig. 4. HEV Acceleration at different time

The SOC of the battery is use to describe its remaining charge which is one of the most important parameter of the HEV. It also determine that how long can the vehicle go within a single charge. Fig.5 shows the SOC vs time graph for the time interval of 3500 second. It can be observed that with the passage of time the SOC of the battery is decaying.

of both HEV and EV is conducted. For the simulation studies, the 76 representative vehicles weekday data for 3500 second from the city of Winnipeg, Canada are utilised. At 3500 second, the SOC of HEV decayed to 97.3 % while at the same time the EV decayed to 89 %. Both HEV and EV are assumed to have the same speed and acceleration. In summary, the SOC of EV decays more quickly than the HEV as expected because the EV does not have the internal combustion engine. SOC testing of batteries is carried out in two stages. That is, when the battery is in a condition of not getting electricity supply and then burdened until the battery reaches a minimum point and when the battery is in a condition of getting electricity supply. The graph can be seen on the SOC graph at Fig 5 when charging has a linear upward pattern in accordance with the condition of the battery being charged to the full state. There is a difference that is not too far from the test curve when compared with the SOC curve during prediction. The graph can be seen in the SOC graph when the discharge has a linear descending pattern in accordance with the condition of the battery being discharged until it is full. The difference that is not too far from the test graph when compared with the SOC curve during prediction. The power of hybrid electric vehicles is provided by engine and dynamic batter, it is very important that the judgement of the battery situation to the vehicle work .So we need to understand the real-time battery state of charge (SOC), timely maintenance and charge-discharge to it.

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