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Design of soft switched boost converter in hybrid electric vehicle by Using MATLAB-Simulink

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Abstract

In recent years, electric vehicles (EVs) are a significant technology for mitigating greenhouse gas emissions and the utilization of fossil fuels. However, an effective energy management strategy is required to be improved the performance of the EVs. In this work, the battery system is integrated into the EV system. Further, the components of the BEV and HEVs systems were discussed. The model of HEV is simulated by using MATLAB-Simulink software. The soft switched boost converter improves the power quality of converter output and also reduces the switching losses.

Keywords Electric vehicles, Battery system, Hybrid system, Power supply, Fossil fuels, Soft Switching Boost converter, simulation.

1.0 Introduction

Nowadays one of the biggest problems that we are facing is environmental pollution. The causes of environmental pollution are industrial, vehicles. We can filter the industrial wastes in the industry itself but we are not able to filter the vehicle pollution. That is the reason we need to focus on vehicle pollution because transportation will play a significant role in the future [1][2]. Instead of normal vehicles, we need to use battery vehicles and hybrid electric vehicles.

Today, Electrical vehicles (HEV, BEV) are the latest technology [12]. This technology makes the world pollution-free and puts the world in a better position. Electrical vehicles are useful for the consumption and transportation of electrical energy. Electric vehicles are more economical and eco-friendly when compared with normal vehicles that use only diesel or petrol. The hybrid electric vehicle improves fuel efficiency [5][10][11].

In This paper, we discuss the dynamic model of Hybrid electric vehicles. This is one of the models of TOYOTA Prius. It describes the components of the Energy management system, Electrical subsystem, vehicle dynamics, ICE, planetary gear subsystem. In addition to that, it examines all simulation results.

This model is presented based on MATLAB/Simulink software and we compare the converters of a normal boost converter with PI controller and soft switched boost converter with PI controller duty cycle. Soft switched boost converter improves the Quality of dc output from the battery. Due to some losses at the switching device, the efficiency is reduced and the temperature of the junction increased. This converter minimizes the switching losses and improves efficiency by using a resonant soft-switching method. To obtain the required current or voltage, the soft switched boost converter employs an LC circuit, that leads to zero- current or zero- voltage. Zero–current switching (ZCS) is used to reduce the turn–off switching losses. Zero-voltage switching (ZVS) is used to reduce turn-on switching losses [6-8].

2.0 Hybrid EV components

A. Energy management system

The energy management system is useful to compare the powers of battery, generator, motor. According to the load requirement, hybrid energy management turn on/off automatically. In tough roads the hybrid on, for smooth and low friction roads hybrid off. If the battery is not capable of supplying power then hybrid on. The output of the energy management system is the reference torque of both generator and motor. The hybrid management system is based upon car speed, generator speed, motor speed, battery components like state of charge, current, voltage.

1. Battery management

The battery management system is based upon battery parameters. The output of battery management is battery power and battery limit. The battery management system operates the rate of charge and rate of discharge.it limits the battery SOC 30%-80% and notifies the power of sending and receiving.

2. Hybrid management system

A hybrid management system defined the torque of the generator, motor, battery.it also operates hybridization [3]. The hybrid management system decides to weather the hybrid on/off.it produces the reference torque of both motor and generator from the acceleration, speed of both generator and motor.

B. Electrical subsystem

The electrical subsystem is the main part of the hybrid electric vehicle.

1. Battery model

This tool is supervised for battery performance. It improves the battery management system (BMS) in the hybrid electric vehicle system (HEV) design. The battery management system is useful to measure the voltage, current, state of discharge. The state of charge (SOC) is obtained using the following equation [4][12][13].

a. State of charge

Battery consist of X blocks that are connected in parallel and each block consists of Y cells that are connected in series. The total combined cells are called the battery. The battery state of the discharge depends on time(t), temperature(T), and current(i)

$$SOD = \frac{1}{q_t}\int_0^t F(i(t)) * G(T(t))\ dt \qquad [1]$$

b. State of charge

In simple words, it is the remaining capacity of the battery. The state of charge depends on the rate of discharge, battery life, and temperature. As the equation given below, the State of charge is defined as a ratio of residual charge Q(t) and nominal capacity Qnm.

$$SOC = Q(t)/Qnm(t) \qquad [2]$$

2. dc/dc converter

Generally, a DC-DC converter is used to raise the voltage in an electric vehicle application. For better performance, the soft switched boost converter is used and compare the results. The converter duty cycle is controlled by the PI controller.

3. Inverter

The Inverter helps to convert battery DC to AC. The inverter is controlled by the PWM technique and vector control method.

4. Transmission model

Transmission can be defined as transferring the power from sources to the wheels. There are two types of transmission models. Single-speed transmission and multi-speed transmission. In single-speed, transmission model consists fixed gear ratio and it occupies less space. The cost of the single-speed transmission model is less. In multi-speed, transmission model generally treated as the two-speed transmission model. In this model, two different gear ratios are used. These transmissions are too heavy and costly and vehicles achieved top speed [3][10].

C. vehicle dynamics

In-vehicle dynamics, we observe all mechanical components of a hybrid electrical vehicle. car, tires, friction, simple gear, differential Vehicle dynamics are observed in the model of longitudinal vehicle dynamics. There are three variables for the states of the dynamic model of the hybrid electric car. They are wheel slip in the longitudinal direction, speed vehicle center of gravity, and wheel circumferential speed. These are the variables to control the moment of the vehicle.

Table1

Specifications	Value
Mass(kg)	1360
Frontal Area(m^2)	2.57
Drag coefficient	0.26
CG height from the ground (m)	0.5

3.0 DC/DC Converter

In Electric vehicles like battery electric vehicles (BEV), hybrid electric vehicles (HEV) have one DC/DC power converter. This converter raises the voltage at the required level. The source is DC. This converter stores DC energy in the form of both electric and magnet fields like inductor and capacitor [9][14][15]. In the electric vehicle application boost converter is suitable. If the Boost converter is used in the electric vehicle, it reduces the size and cost of the battery. Other than boost converter we face a problem at manufacture state not in simulation state.

Generally, DC/DC c converters are designed to transfer the power in one-directional from source to load. However, in this scenario, we are using a bi-directional DC/DC converter. A bi-directional converter can transmit the power in both directions. Which is a useful application in electric vehicles. Even though the boost converter gives the best results we used a soft switched boost converter to improve the output voltage of the converter and also reduce the switching losses. The soft switched boost converter reduces the switching losses and improves efficiency [6-8].

The amount of power flow between the input and the output can be controlled by adjusting the duty cycle (ratio of on/off time of the switch). Usually, this is done to control the output voltage, the input current, the output current, or to maintain constant power. Transformer-based converters may provide isolation between the input and the output. The main drawbacks of switching converters include complexity, electronic noise, and high cost for some topologies.

4.0 Technical specifications

In this study, the vehicle specifications of the hybrid electric vehicle are the TOYOTA Prius U.S-based car model. We can collect data from DOE in the USA [11].

Table 2

Subassembly	Specifications	
	Description	Value
Vehicle	Weight	1360kg
Engine	Max power	57kw@5000rpm
gear	Ratio	2.6 (78/23/30)
Electrical motor	Max power	50 kW
	Max speed	6000 rpm
	Max torque	400 Nm
Electrical generator	Max power	30 kW
	Max speed	10000 rpm
	Max torque	160 Nm
battery	Li-Ion	28
	Energy	1.3 kWh
	voltage	201.6 V

5.0

simulation of hybrid electric vehicle

All the block diagrams are connected in a sequential manner and simulate each component in the hybrid electric vehicle (HEV). The simulation model consists of five components. They are energy management system, electrical subsystem, vehicle dynamics, ICE, planetary gear system. The electrical subsystem involves the battery model, transmission model.

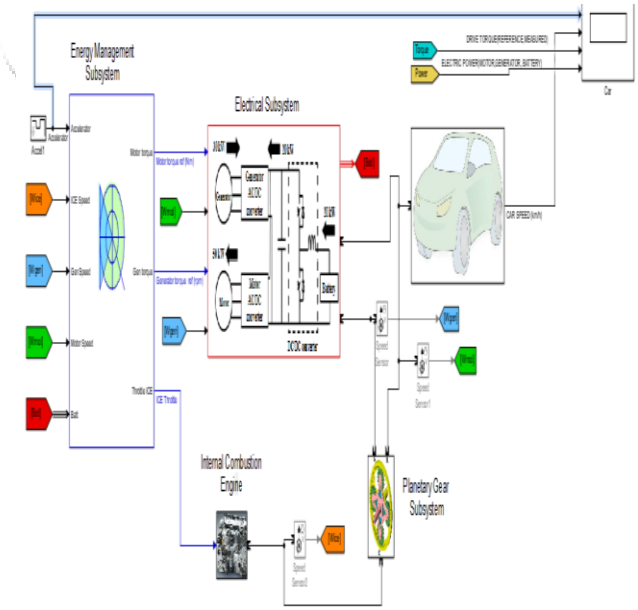

Fig1 simulation of hybrid electric vehicle

6.0 Results and Discussions

The Simulink/ MATLAB software is used to design the hybrid electric vehicle. it is designed to solve all programming, computing and visualization in one software.it is also useful to solve scientific and engineering problems. In the MATLAB/Simulink software we designed hybrid electric vehicle as show in Fig1. This design contain different subsystem blocks. furthermore, the results shown in fig2 to fig6 represent simulation results of hybrid electric vehicle. In these figures we observed voltage, current, power, torque of battery, motor and generator. We also observe state of charge of battery.

In this project, we are comparing the results of normal boost converter to soft switched boost converter. In Fig2 to Fig6 the waveforms are normal boost converter. In Fig7 to Fig11 the waveforms are soft switched boost converter results. Soft switched boost converter results improve the car speed and reach the stable and safe operating point. Soft switched boost converter reduce the error between reference torque to measured torque. Battery power transferred to vehicle. In this simulation, all the waveforms are in good condition. In addition to that, New European Driving Cycle (NEDC) was selected to measure the performance and observe the phenomena of fuel economy and engine emission [10][11].

BOOST CONVERTER

Normally, boost converter is used in the electric vehicle. boost converter gives good results according to the power, torque, state of charge, car speed waveforms observed as shown below.

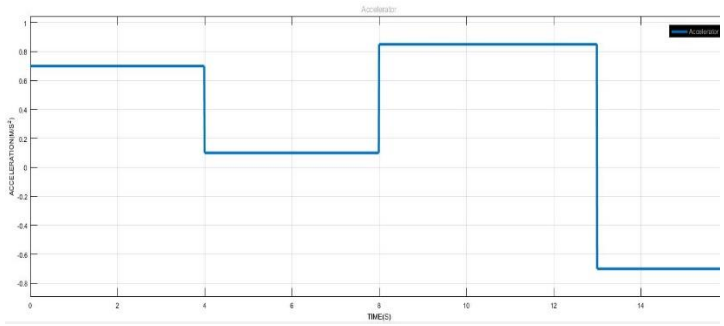

Fig2 acceleration

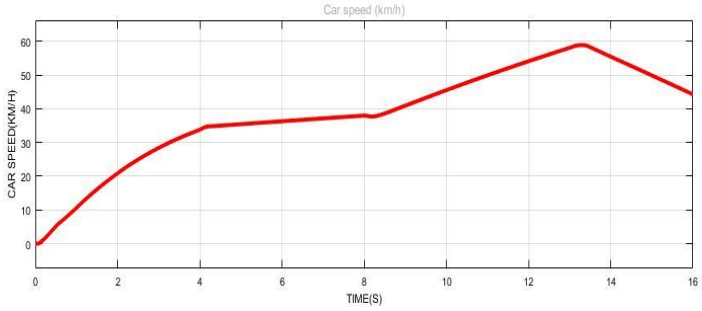

Fig3 car speed

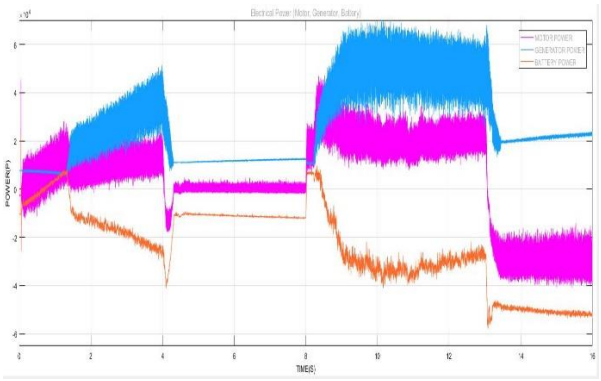

Fig 4 power of motor, generator, battery.

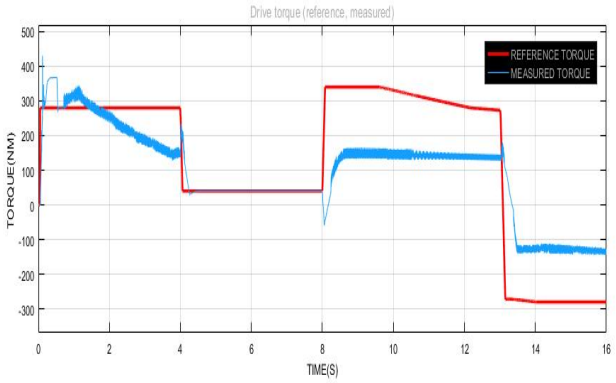

Fig 5 Torque of measured, reference

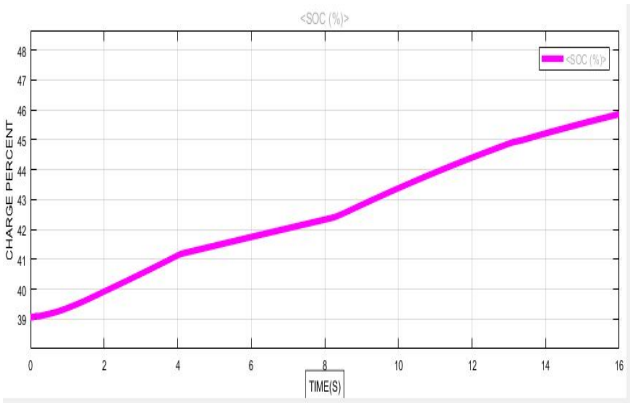

Fig 6 state of charge

Soft switched boost converter Soft switched boost converter improves the results. This converter applicable to hybrid electric vehicle application. Car speed, power, torque, state of charge, voltage of battery waveforms are observed as shown below. The switching losses decreases in soft switched boost converter.

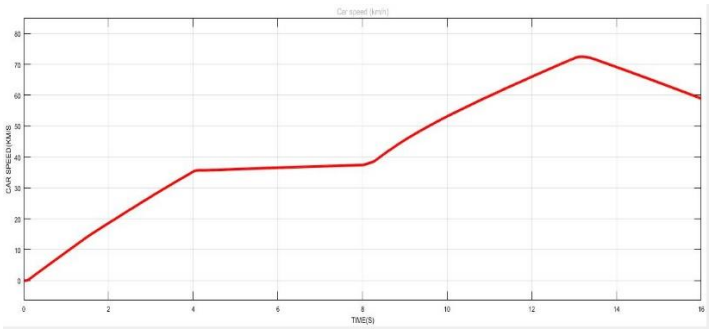

Fig7 speed of car

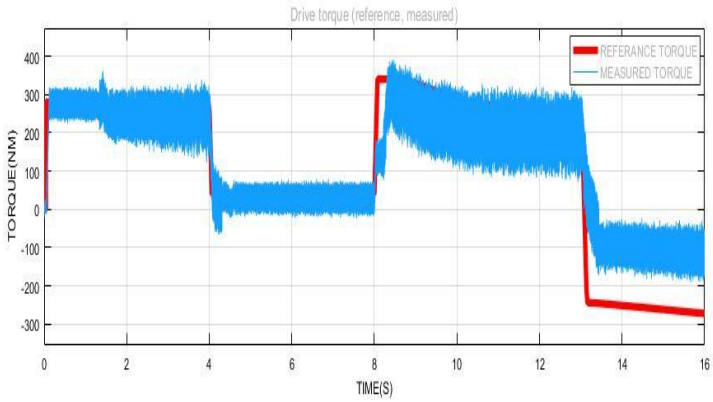

Fig 8 torque of reference, measured

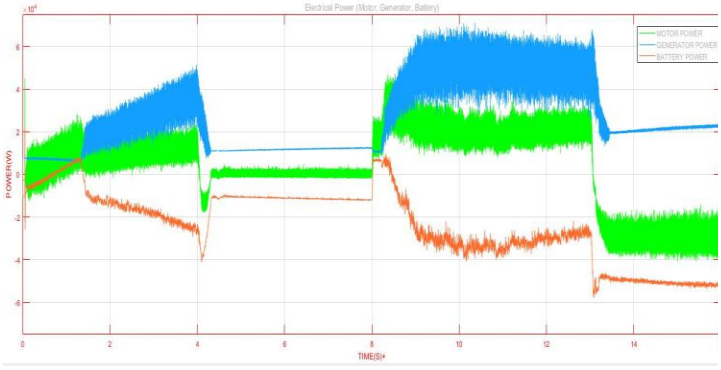

Fig9 Power of motor, battery, generator

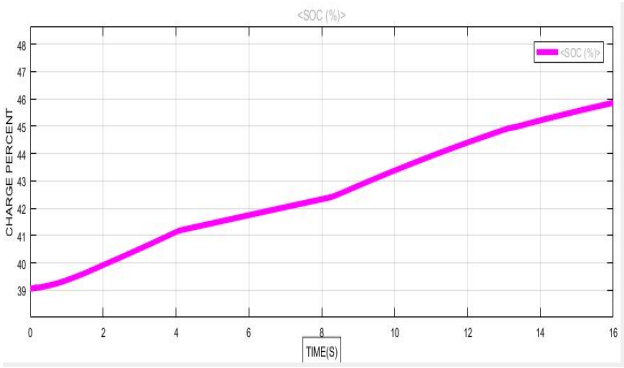

Fig10 state of charge of battery

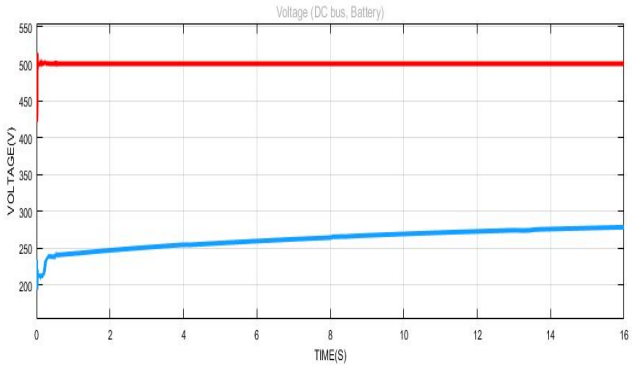

Fig 11 battery output and converter output.

7 .Conclusion

The demand for fossil fuels, increase in CO2 emission, and global warming leads a bright way for EVs. EVs with better battery technology is going to be more popular shortly. In this work, soft switching boost converter-based power electronic component is investigated with battery for enriching the energy flow, performance, accuracy, and efficiency. The system has been developed in the MATLAB/Simulink software. As per the simulation outcomes, the proposed battery integrated soft switching boost converter shows greater performance than other studied approaches concerning the speed of the EVs in uncertain circumstances.

A lot of opportunities are still there to establish the best results of hybrid electric vehicle and battery electric vehicle models. That will be the basis for future researchers. The purpose of find the power, torque, current, voltage of components. State of charge and state of discharge of the battery. With this, the component size is reduced and the losses are minimized, and improves efficiency. This type of modeling and simulations are useful for automotive designers.

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