SIMULATION OF INTEGRATED MULTIFUNCTIONAL POWER ELECTRONIC INTERFACE FOR HYBRID ELECTRIC VEHICLES

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***Abstract*—** The necessity for a better fuel economy and further reduction in greenhouse gas emissions is pushing automotive industry to go through a comprehensive restructuring to electrify the vehicles and introduce plug-in hybrid electric vehicles (PHEVs) and electric vehicles, cumulatively called plug-in electric vehicle (PEVs). The electrical powertrain of current and upcoming PEVs is composed of an energy storage system connected to propulsion machine through an inverter. In addition, an add-on battery charger is inevitable part of vehicle powertrain. In majority of PEVs, a bidirectional dc/dc converter is deployed between the battery and propulsion machine inverter. This converter is responsible to boost the battery voltage and efficiently control the delivered or absorbed power during cruising and acceleration or regenerative braking, respectively. In this conventional structure, the bidirectional dc/dc converter is only operated during propulsion and an individual ac/dc converter is utilized to charge the battery.

I. INTRODUCTION

The basic power electronic interfaces rendering volume and weight of electric and plug-in hybrid electric vehicles are an inverter, an on-board charger, and a bidirectional dc/dc converter. This paper proposes an innovative integrated bidirectional converter with a single-stage on-board charger to reduce the number of switches, size, and weight of the power electronic interfaces. The analyses show that 266 cm^3 and 1.1 kg can be saved due to the elimination of the inductor core used for power factor correction in charging mode, in addition to the reduction achieved through removal of inductor winding, power switches, diodes, and additional heat sink of the conventional structures. A proof-of-concept prototype with power limits of 8.4 kW in charging and 20 kW in propulsion modes has been designed and validated at various power levels. The peak efficiencies for propulsion and regenerative braking operations are measured as 96.6% and 94.1%, respectively. The power factor is 0.995 at 1.8 kW charging power, where crest factor and peak efficiency are recorded as 1.49 and 91.6%, respectively. The overall electric powertrain with a single integrated power electronic converter is illustrated in Fig. 1. In this structure, the charger and the bidirectional dc/dc converter share the same power stage as charging and propelling do not happen at the same time. As a result, overall cost, weight, and volume of the power electronic converter can be reduced effectively through reducing the number of switches, sensors, and large volume energy storage elements such as inductors.

In this regard, this paper proposes a new integrated single-stage charger topology for PEVs, which can also be used in retrofit conversion of an HEV to a PHEV. The proposed converter uses minimum circuit components offering a further cost-effective solution in comparison to the other integrated charger topologies presented in the literature review. With the boost charging capability, it enables operating with wide single-phase charging voltage ranges including 120/220/240 VAC, considering the battery voltage is between 300–400 V, which is the case in Chevy Volt. In addition, it is capable of stepping up and stepping down the voltage in both power flow directions during cruising and acceleration, as well as regenerative braking.

This paper is organized as follows:-

- The advantages and motivation of using an integrated charger and a bidirectional dc/dc converter in the powertrain.
- The proposed integrated topology is introduced and operation modes are explained in detail.
- The proposed converter is compared with other possible basic single-stage charger topologies.
- In addition, detailed analyses on size reduction, loss, and reliability are presented in this section.
- The overall control scheme developed for controlling each essential operation mode is explained in detail.

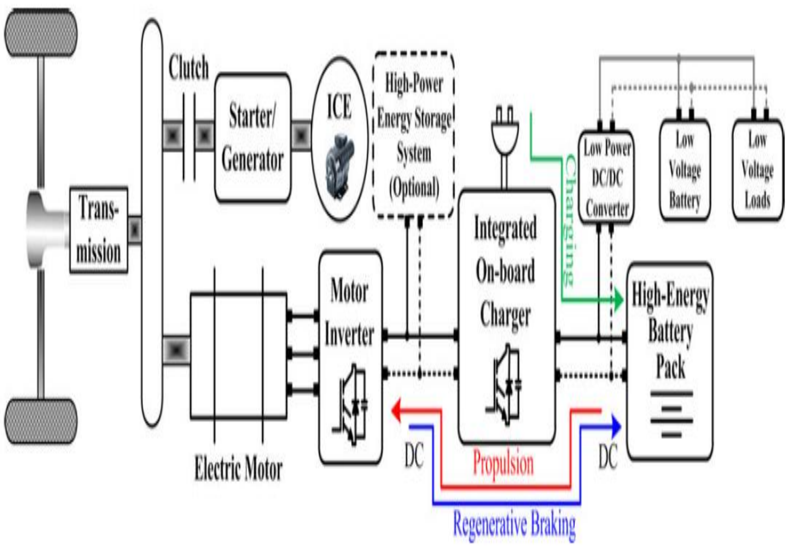

Fig. 1. System level structure of a parallel powertrain PHEV with on-board integrated battery charger

II. OVERVIEW OF A HYBRID ELECTRIC VEHICLE

A hybrid electric vehicle (HEV) uses both an internal combustion (IC) engine and an electric motor in the powertrain, and also uses a bank of batteries to recapture and store energy from braking. This combination of an electric motor and an IC engine is more efficient from a system viewpoint than a conventional powertrain. There are many different configurations of hybrid electric systems, including series, parallel, and power-split platforms. All PHEVs in this study have a parallel hybrid configuration with a pre-transmission motor location and a continuously variable transmission (CVT). This configuration is shown in Figure 2.

The addition of HEV technology to a vehicle design improves efficiency primarily by four ways. First, the addition of the electric system allows the IC engine to operate in a more efficient range a greater amount of time. Typically, IC engines are more efficient at a higher load near wide open throttle. In a conventional vehicle, power requirements at cruising and idling are so low that the engine is forced to run at a lower than optimum loading. However, with a hybrid configuration, the IC engine can run at the most efficient load most of the time, using the excess power to charge the batteries. If the batteries are charged, the electric motor can provide the small amount of power required to propel the vehicle while the engine remains off.

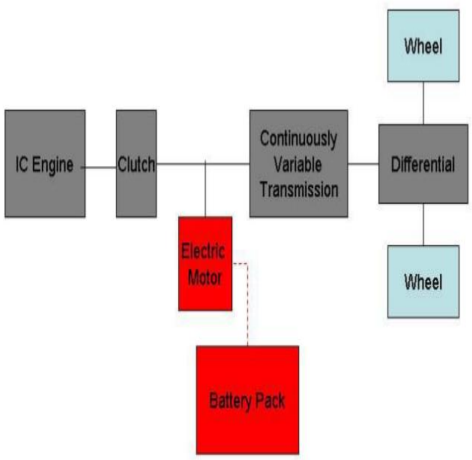

Fig.2. PHEV Parallel Pre-Transmission Configuration with CVT

Second, having the power of an electric motor at hand, it makes it possible to downsize the engine. Electric motors have higher torque at low rpm range while IC engines typically have high torque at high rpm range. This makes using an electric motor combined with an engine during acceleration, a time when the highest torque is needed, more efficient that using a larger equivalent torque IC engine. Also, having a smaller engine reduces the engine braking load, leaving more energy available to be recovered by regenerative braking. Thirdly, having an electric motor allows the IC engine to completely shutoff instead of idling. The electric motor can simultaneously start the car moving and start the engine. Not having the engine idling while sitting at a traffic light significantly increases fuel economy in city driving.

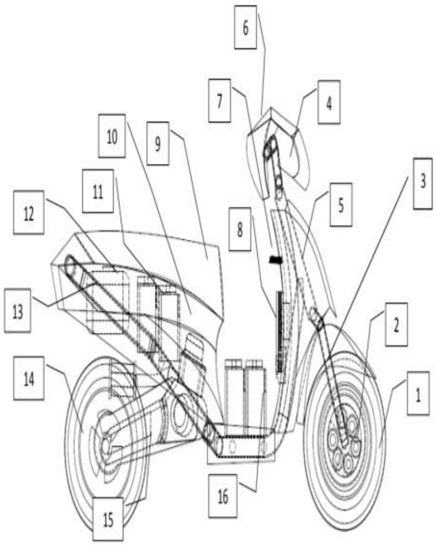

Fig 3. Wire Frame Model Side View

Components: -

1) Tyre

2) Hub Motor

3) Suspension

4) Headlamp

5) Body Cover

6) Display

7) Microcontroller

8) Hub Motor Controller

9) Seat

10) Engine

11) Front Battery

12) Fuel Tank

13) Chassis

14) Rear Tyre

15) Transmission

16) Rear Battery

Battery Pack

The battery pack is the main electrical energy storage device. It is typically made up of a number of modules, connected in series with an open circuit voltage in the range of 100 to 300 volts, with the best designs at the higher end of this range. Each module is made of a number of cells. Battery packs can be come in much different chemistry, but the most common are Nickel Metal Hydride (NiMH), Lead Acid (Pb Acid), and Lithium Ion (Li Ion). These are the chemistries considered in this study. Each chemical battery type has its own power, energy, and voltage characteristics.

The battery pack's energy capacity is given in amp-hours and its state of charge (SOC) is defined as:

$$SOC = \frac{(C_{max} - C_{used})}{C_{max}}$$

…………. (3.1)

Where C_{max} is the nominal rated C/3 capacity of the pack in A-h and Cused is the capacity of the pack in A-h that has been used since the pack was fully charged. C/3 is the capacity rating where the entire charge of the pack is discharged in 3 hours. The safe operating SOC range varies with different battery chemistries but is forced to stay over the constant range of 0.2 to 1 for this study. For most battery chemistries, the battery pack starts to be damaged at a SOC less than 0.2.

Electric Motor

The electric motor often referred to as simply the motor, converts electrical energy from the battery pack to mechanical power into the CVT. The electric motor can also be used in reverse as a generator, converting mechanical energy from braking into electrical energy to be used to charge the battery pack. There are two main types of electric motors used in HEVs. The first is permanent magnet motors, using a permanent magnet to create the magnetic field needed to produce power. The second is an induction motor, which uses current to create the magnetic field. This study investigates only permanent magnet motors, the more common of the two in HEV applications.

Power Electronics

Since the battery pack is basically a constant voltage device, a motor controller is needed to vary the current so that the motor produces the necessary torque. The power electronics are typically designed to the specific characteristics of the electric motor and are typically comprised of a microprocessor, power switching semiconductors, and a thermal management system.

CONCLUSION

In this paper HEV is a vehicle that uses two sources of power- gasoline and battery. For low power application battery drive is used whereas for high power application where power requirement is very high gasoline engine is used. Gasoline drive is most efficient at high speed drive. Thus HEV's both mode of operation occurs at their maximum efficiency. But in gasoline engine low speed operation is not efficient. Its high speed mode is only efficient. Therefore, it gives twice the mileage given by a normal vehicle. As this hybrid vehicle emits 50% less emission than normal vehicle it plays an important role for reducing pollution to certain extent without compromising with efficiency. Thus it is most efficient in urban areas mainly in high traffic where gasoline engines are least efficient as the energy from gasoline is being wasted away and creates pollution.

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