Abstract

The transition towards sustainable transportation has accelerated the development and adoption of electric vehicles (EVs) globally. Lithium-ion battery-based electric vehicles (EVs) offer numerous advantages over petroleum-fuelled internal combustion engine (ICE) vehicles, making them a more environmentally friendly and consumer-friendly option. In EVs, the fuel and maintenance costs are lower compared to those of an ICE-based vehicle. Therefore, in the long term, the cost of an EV is less than that of an ICE-based vehicle.

The basic functions required in EVs are charging, driving, and power support to the EV cabin for the air conditioner, electric heater, music system, etc. Along with these basic functions, some advanced functions are also required according to comfort. Those functions are vehicle-to-grid power supply and vehicle-to-vehicle charging. These two functions also create a dimension of energy trading. There are two types of available charging systems: 1) off-board, and 2) on-board. The off-board charger is a high-power DC fast charger, and its installation cost is higher. Therefore, its availability is less in rural areas. On the other hand, the on-board charger is a part of EVs, and its cost is included in the price of the EV.

The basic converter required in the two-stage on-board charger is AC/DC and DC/DC. The AC/DC converter takes the power from the AC supply into DC, and another DC/DC converter charges the battery with a constant-current constant-voltage (CC-CV) charging technique. In motoring mode, a DC/AC converter is used to drive the motor from the stored energy in the battery. Along with that, an additional auxiliary battery (generally 12V) and the main battery are used to support the EV cabin. The 12 V battery powers the low-power auxiliaries like the music system, light, wiper, and more, and the main battery powers the high-power auxiliaries, like the air conditioner, heated windshield, electric heater, and more. In advanced functions such as vehicle-to-grid power supply and vehicle-to-vehicle charging, an additional DC/AC converter is needed to supply power from the main battery to the grid or home, while a bidirectional DC/DC converter is required for vehicle-to-vehicle charging. All operations are mutually exclusive; for example, when charging is in progress, the motor remains stationary. Therefore, there is a scope for integrating one or more functions into a single converter.

This thesis presents the systematic improvement of the design of the on-board power processor for grid-to-vehicle (G2V) charging, vehicle-to-grid power (V2G) supply, vehicle-to-vehicle (V2V) charging, and motoring operation, with an optimum number of switch counts.

Along with that, the regulated auxiliary power supplies are available in all the modes of operation to cater to the demand of the EV cabin. During G2V charging, the proposed power processor maintains the unity power factor at the 120 V, 50 Hz single-phase supply and charges the 48 V, 36 Ah battery with a constant-current constant-voltage charging technique for the long life of the battery. The bidirectional property of the proposed power processor feeds 400 W of power to the 120 V, 50 Hz grid from the 48 V battery. Further, for the V2V charging, the proposed power processor from both vehicles is directly connected. In motoring mode, the proposed power processor restructured itself and drives either a 48 V, 4-pole 1 kW brushless DC motor (BLDC) or an induction motor (IM) according to the selected algorithm. In addition to these operations, the proposed power processor also gives two regulated DC outputs, i.e., 12 V and 72 V simultaneously, in all the operating modes. These regulated DC outputs help to provide a power supply to the auxiliaries of the EV cabin. The 12 V DC output of the proposed processor eliminates the need for an additional 12 V battery to supply the EV cabin's low-power auxiliaries. Further, the 72 V regulated output reduces the current requirement to feed the high-power auxiliaries. The control techniques for each operating mode are discussed, and the distinctions of the proposed processor are highlighted through comparisons with similar prior work. The comparison is presented in tabular form, highlighting the operating functions and the number of switches required to perform each operation. Additionally, a cost and comparison analysis are conducted with similar prior works, and it is found that the proposed power processor involves a smaller number of switches with respect to the number of functions compared with similar prior converters. Furthermore, a thermal analysis of the proposed power processor is conducted to evaluate its thermal stability.