

Chapter 7

General Conclusion and Scope of Future Work

7.1 Introduction

Design of an integrated on-board power processor with multifunctionality and auxiliary outputs is an essential need for EVs. All these functions in a single power processor provide more comfort at an affordable price, which attracts consumers towards its adoption. Further, it minimizes the impact on the environment due to the transportation system. Traditionally, different converters are used for different functions, such as a AC/DC and DC/DC two stage power converter are used for charging the main battery, unidirectional DC/DC converter is used to charging the 12 V auxiliary battery, and a bi-directional DC/DC converter is used to charge the 12 V auxiliary battery, a bi-directional DC/DC converter for vehicle-to-vehicle charging, an inverter is used for driving the motor, and a DC/AC converter is used for vehicle-to-grid power supply. For all these functions with different converters occupy more space in EV, which decreases the power density and efficiency. Further, it increases the weight and cost of the power processor. All these operations are mutually exclusive; therefore, the integration of these operations is possible. In the integrated on-board power processor, additional changeover switches are required to transfer one function to another. These changeover switches decrease the efficiency and durability of the power processor.

In this thesis, a step-by-step design of a power processor that performs grid-to-vehicle charging, vehicle-to-grid power supply, vehicle-to-vehicle charging, and motoring operation. Furthermore, during all these operations, the multioutputs are available to cater to the power demand of the EV cabin.

This chapter summarizes the conclusions of the work carried out in this thesis. Also, a brief note about the future scope of the work is included in this chapter.

7.2 Conclusion

The multifunction quasi-z source-based multimode power processor is designed to charge the EV from a 120 V, 50 Hz single-phase AC supply, drive the low-power 3-phase AC motor, provide V2V charging, and supply to the cabin's auxiliaries. During single-phase charging, the unit power factor at the source terminal is maintained, and the 48 V battery is

charged with a constant-current and constant-voltage charging technique. Along with the battery charging, it generates two more related outputs of 12 V and 72 V, powering the EV chain. In motoring mode, a modified sinusoidal pulse width modulation technique is proposed, which generates three outputs from the 48 V battery. First, the output drives the low-power 3-phase AC motor by generating buck-boost AC voltage; second, the third output voltages of 12 V and 72 V cater to the power demand of the EV cabin. One mode to the other modes is transferred with the help of seven changeover switches. Furthermore, the proposed power processor is restructured for V2V charging by four changeover switches. A total of 18 switches are required for all these operations, with seven dedicated to mode transformation. Further, a laboratory-scale prototype for the proposed concept is developed and tested at 550 W. In motoring mode, the designed power processor supports only the low-power three-phase AC motor drives, such as those typically used in golf carts.

Further, a BLDC motor drive with an adaptable multifunction power processor has multimode operations. A single converter architecture is integrated for charging, motoring, and auxiliary power supply functionalities within an electric vehicle (EV). The converter efficiently charged a 48 V, 36 Ah battery from a standard single-phase 120 V, 50 Hz AC supply, while simultaneously providing regulated 12 V and 72 V outputs to meet various EV cabin power requirements. A unified control strategy is employed to manage the charging mode at 500 W, demonstrating reliable battery charging and auxiliary system support. In motoring mode, the system was successfully reconfigured to drive a 1000 W, 4-pole BLDC motor using a high-PWM low-ON switching technique, ensuring efficient propulsion and continued support for cabin auxiliaries. Additionally, the converter supported vehicle-to-vehicle (V2V) energy transfer at 480 W by restructuring into energy supplier and acceptor configurations through three changeover switches. Comprehensive and cost analyses confirmed the proposed processor's advantages over existing systems, particularly in terms of integration and functionality. The calculated power density further substantiates its suitability for compact and efficient EV power management. Overall, the proposed multifunction power processor offers a promising, cost-effective solution for next-generation electric vehicle power systems with enhanced flexibility and performance.

Next, an on-board power processor having inherent V2V operation with reduced components is designed. The power processor serves as single-phase charging, multioutput for the auxiliaries, motoring operation, and vehicle-to-vehicle charging operation. A total of 14

switches have been used for all these operations, of which only three switches are used for the function selection. Only six active switches from both vehicles are used for vehicle-to-vehicle charging. The converter's efficiency in single-phase on-board charging, motoring operation, and V2V charging modes is 91.88 %, 92.3 %, and 93%, respectively, nearly 90 % of its rated load. Further, the thermal stability of the proposed converter is added in the experimental section. A laboratory-scale prototype is developed, which tests 780 W in charging mode, 1000 W in motoring mode, and 480 W during V2V changing operation.

In the next version, a reversible multifunction multimode on-board power processor with inherent V2G operation is designed. The power processor provides grid-to-vehicle (G2V) charging, motoring operation, vehicle-to-grid power (V2G) supply, vehicle-to-vehicle (V2V) charging, and auxiliary power supply for the EVs. During G2V operation, it charges the 48V battery from the 120V, 50Hz power supply and generates two more outputs of 12V and 72V to supply the low-power and high-power auxiliaries of the EV cabin. In V2G operation, the 3.5 A current is injected into a 120 V, 50 Hz AC grid system. In motoring mode, it drives the BLDC motor with a high-PWM low-ON switching scheme and generates regulated output voltages (12 V and 72 V) from the 48 V battery. The 12 V regulated output eliminates the demand for an additional low-voltage battery (12 V), and its charger and 72 V output reduce the current demand for the high-power auxiliaries in low-power EVs. Comparative analysis, cost analysis, and component utilization factors have been expressed in similar prior works to convey the novelty. The multifunction operation, control algorithm, and experimental results with load dynamics are presented to justify the proposed idea. A laboratory-scale prototype is tested at 780 W in G2V changing operation, 1 kW during V2G operation, 1 kW in motoring operation, and 480 W in V2V charging.

In the improved version, a multifunction multimode power processor enables induction motor drive with auxiliary power supplies for high-power EVs. The designed on-board power processor effectively integrates multiple functionalities G2V, V2G, V2V, induction motor drive, and auxiliary power supply within a compact and efficient architecture suitable for electric vehicles. All operational modes are achieved without the use of relays, except for motoring mode, which requires a single connector (S) for motor interfacing. The system accomplishes these functions using only 14 switches, demonstrating a reduction in component count compared to similar prior works. Experimental validation through a laboratory prototype confirms stable operation under load transients and across various modes. The processor achieves peak efficiencies of 97% (G2V), 95.3% (V2G), 97.2% (V2V), and 93.5% (motoring),

with consistent performance from 10% to 100% load variations. These results affirm the processor's suitability for practical EV applications, offering a reliable, space-efficient, high-performance solution for comprehensive energy management.

7.3 Scope of the Future Work

- The proposed laboratory-scale prototype will be commercialized as an industrial product.
- Further, the durability will be improved by adding the safety measures.
- Artificial intelligence (AI) will be integrated to monitor the performance and pre-fault detection.
- Active power decoupling will be added to reduce the bulky DC-link capacitor.
- Peak current control loop implemented in single-phase charging to operate the power processor in discontinuous conduction mode.