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Performance Investigations on Multifunctional Onboard Charger

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Abstract

This project proposes a multifunctional onboard charger (OBC) for electric vehicles that operates in two main modes: Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G). In G2V mode, the charger converts AC power from the grid into DC power to charge the vehicle’s high-voltage battery efficiently. In V2G mode, the charger enables power to flow from the vehicle’s battery back to the grid, supporting energy balancing and load management. The system is designed with a bidirectional power flow capability and uses control strategies to ensure reliable and safe operation in both modes. The onboard charger is optimized for high efficiency and power density. Simulation and analysis of the system are carried out using MATLAB/Simulink to validate its performance in both G2V and V2G operations.

Keywords: Three-phase AC controller, Closed Control, Artificial Intelligence, Thyristor switching, Voltage regulation, Power electronics.

1. Introduction

An onboard charger is a critical component of electric and plug-in hybrid vehicles, responsible for converting alternating current (AC) from an external power source into direct current (DC) to charge the vehicle's traction battery. This integration allows for convenient and flexible charging, eliminating the need for external charging stations in many cases. Modern OBCs incorporate advanced power electronics, control systems, and safety features to optimize charging efficiency and ensure battery health.

Functionality of Onboard Chargers:
1. AC to DC Conversion: The primary function of an onboard charger is to convert AC power (typically from a charging station or grid) into DC power suitable for charging the vehicle's battery pack. This conversion involves rectifying AC power into DC using diodes or other semiconductor devices.

2. Power Factor Correction (PFC): Many modern OBCs incorporate power factor correction to improve the efficiency of AC to DC conversion. PFC circuits help to align the current waveform drawn from the AC supply with the voltage waveform, reducing harmonics and improving power efficiency.

3. Voltage Regulation: The OBC regulates the output voltage to match the charging requirements of the vehicle's battery pack. This includes adjusting the charging voltage based on the state of charge (SOC) of the battery and temperature considerations to optimize charging efficiency and battery health.

4. Charging Control and Monitoring: Onboard chargers include control logic and monitoring systems to manage the charging process. This involves monitoring battery parameters such as voltage, current, temperature, and SOC to ensure safe and efficient charging.

5. Safety Features: OBCs incorporate various safety features to protect against overcharging, overheating, short circuits, and other potential hazards. Safety mechanisms include insulation monitoring, fault detection, and shutdown systems to prevent damage to the charger or battery

Advantages:
1. Integration: Integration of the charger into the vehicle eliminates the need for external charging infrastructure in many cases, providing convenience and flexibility for charging at home.

2. Efficiency: Onboard chargers can be optimized for efficiency, reducing energy losses during the charging process and improving overall system efficiency.

3. Space Saving: Integration of the charger into the vehicle's powertrain saves space compared to external charging units, contributing to overall vehicle design and packaging.

4. Flexibility: OBCs can support various charging protocols and power levels, enabling compatibility with different charging stations and grid configurations.

Types of Onboard Chargers:
1. Single-Phase Chargers: Commonly used for residential charging applications, these chargers operate with a single-phase AC supply (e.g., 120V or 240V) and are suitable for lower power levels.

2. Three-Phase Chargers: Used for commercial or industrial applications, three phase chargers can handle higher power levels and are compatible with three phase AC supplies, enabling faster charging.

2. Simulation and Analysis of Isolated and Non Isolated DC- DC Converetrs

In modern electronics, power conversion is essential to provide the correct voltage and current levels required by various devices. DC-DC converters and Switched-Mode Power Supplies (SMPS) play a crucial role in efficiently converting electrical energy for different applications. A DC-DC converter is an electronic circuit that converts one DC voltage level into another. These converters are widely used in battery-powered devices, electric vehicles, renewable energy systems, and industrial power supplies. They improve efficiency, reduce power losses, and ensure stable voltage regulation. The converter is as shown in Fig.1.

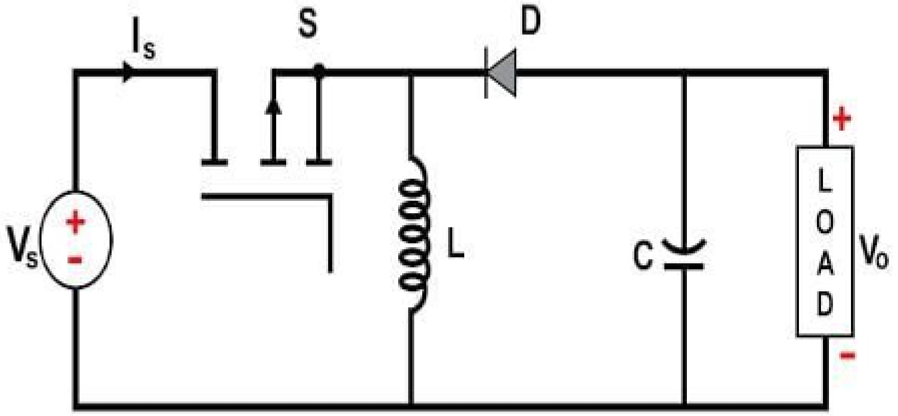

Fig.1 Three Phase AC Voltage Controller

The simulation waveforms include input voltage, input current, output voltage, and inductor current plotted over time for Buck Boost Converter. The simulation waveforms of the circuit is as shown in Fig.2.

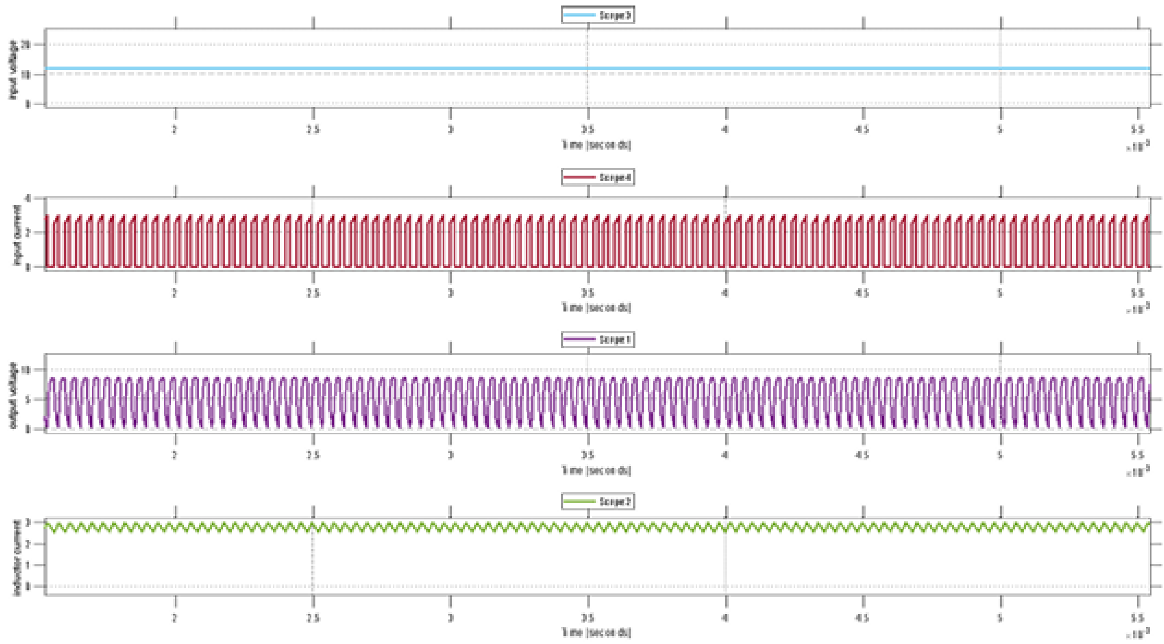

Fig.2 Simulation results

The simulation waveforms include input voltage, voltage across primary, rectified output voltage, inductor current and output voltage plotted over time for Half Bridge SMPS is as shown in Fig.3

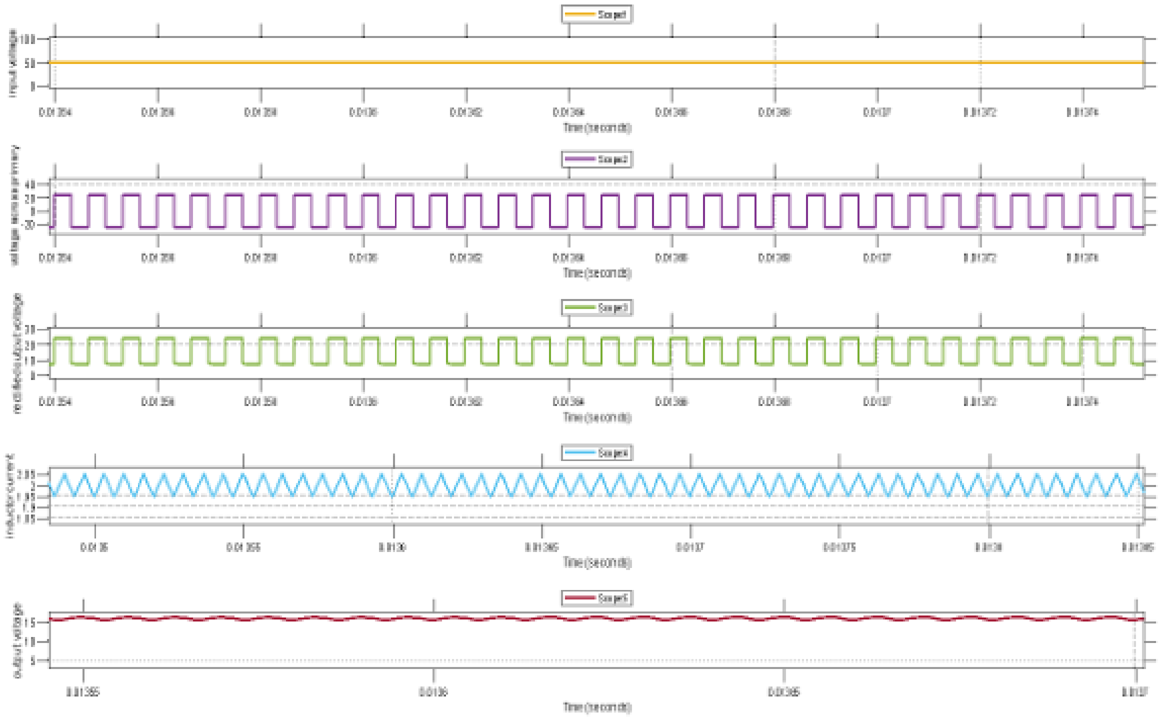

Fig.3 Simulation results of Half Bridge SMPS

The simulation waveforms include input voltage,input current, voltage across primary, rectified voltage , inductor current and output voltage plotted over time for Full Bridge SMPS is as shown in Fig.4.

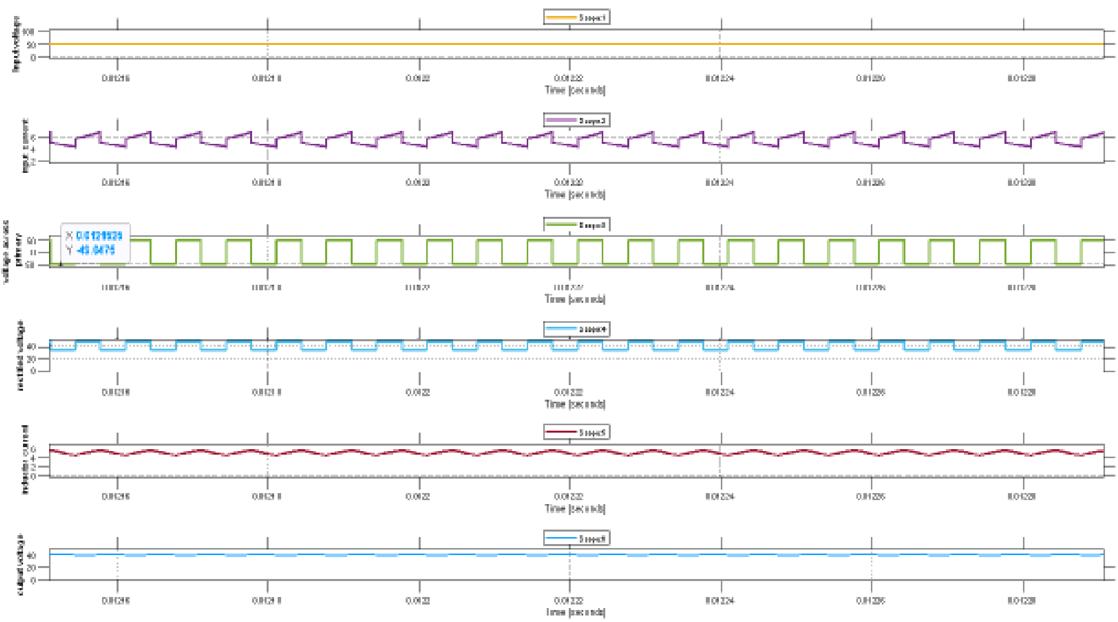

Fig.4. Sumulation results of Full Bridge SMPS

The simulation waveforms include input voltage, voltage across primary,Volatge across secondary rectified voltage and output voltage plotted over time for Dual active bridge is as shown in Fig.5.

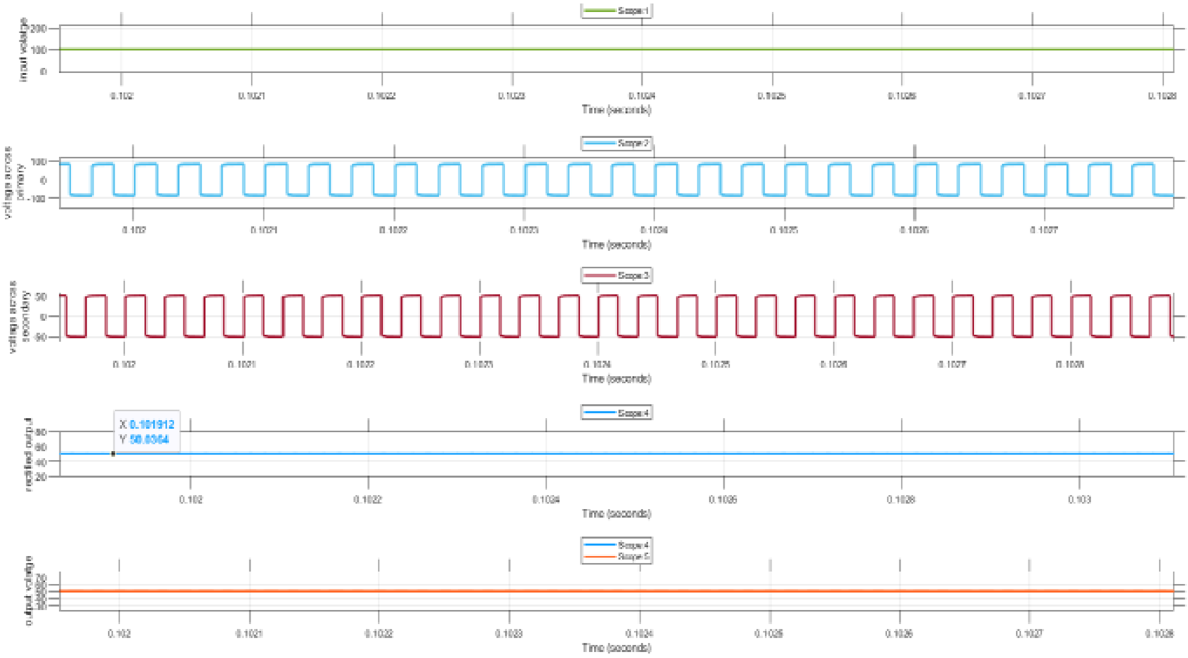

Fig.5 Simulation Results of Dual Active Bridge

3. Multifunctional Onboard Charger

Fig.6 shows the operations of Modes 1 and 2. Mode 1 uses the ac grid to charge the HVB. The active switch in the tertiary stage is turned off to prevent power being delivered to the LVB. The APD circuit conducts a buck or boost operation to minimize voltage ripples on the dc-link by using a magnetizing inductor included in the HF transformer (TR2). The secondary stage is operated as an LLC resonant converter for more efficient charging of the HVB during the relatively long period of a constant current.

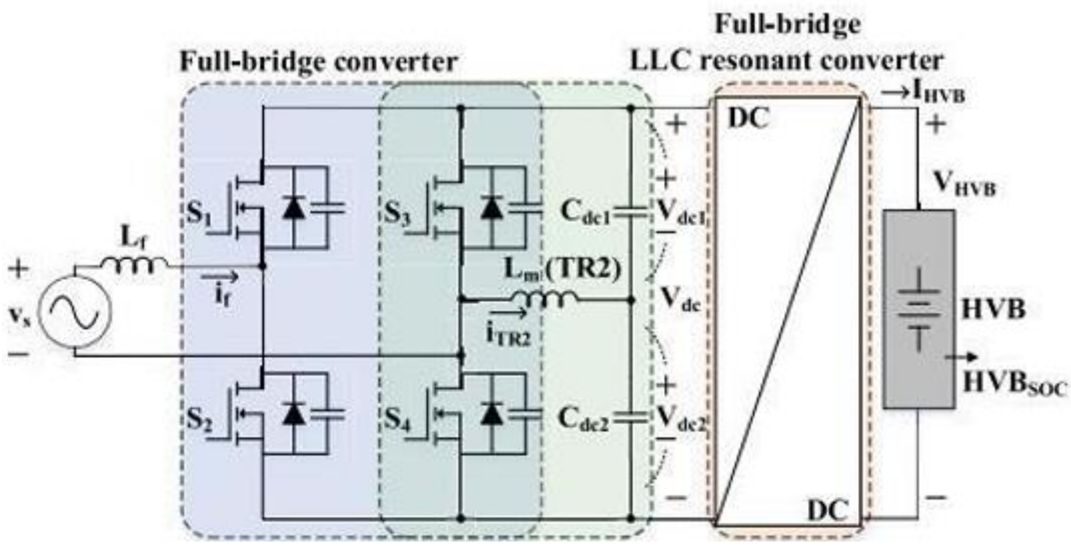

Fig.6 Multifunction onboard charger

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The simulation results are as shown in Fig.7.

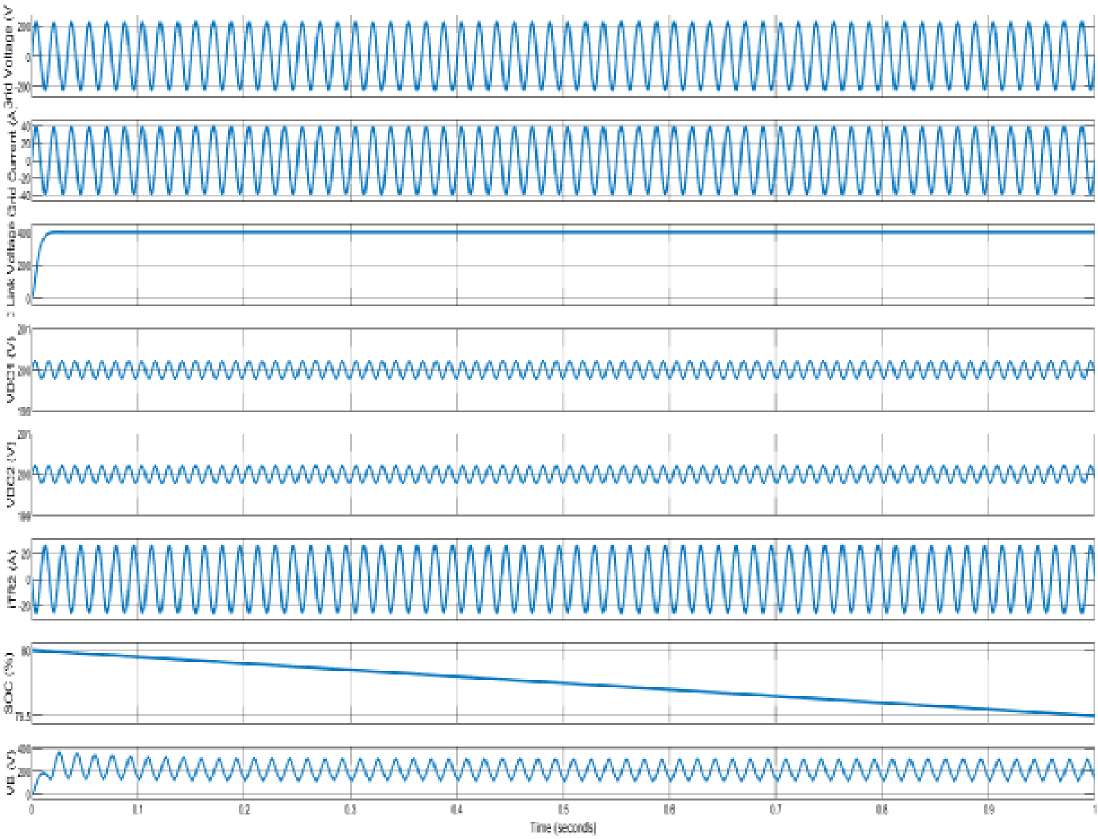

Fig.7 Simulation results of Multifunction onboard charger

Conclusion

Before implementing the multifunctional On-Board Charger (OBC), various isolated and non-isolated DC-DC topologies were analyzed—namely Buck, Boost, Half-Bridge SMPS, Full-Bridge SMPS, and the Dual Active Bridge (DAB) converter. The Dual Active Bridge (DAB) converter, operating at 100 V input voltage and 30 kHz switching frequency, outperforms the Buck-Boost and Half-Bridge SMPS converters in high-power applications. The DAB offers high efficiency with 0.0102 mH inductance and 660 µF capacitance, providing lower ripple compared to the higher inductances and lower frequencies of the other converters. Its 200 VA transformer rating allows for high power density and soft-switching, reducing losses. Unlike the Buck-Boost and Half-Bridge, the DAB supports bidirectional power flow, ideal for G2V and V2G applications. With a robust PI controller (Kp = 0.0000085, Ki = 0.05), the DAB adapts efficiently to varying load conditions. Overall, it offers superior performance, making it the best choice for a reconfigurable OBC system

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