Grid Interfaced Off-Board Charger for Electric Vehicles with V2G and G2V Capabilities

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***Abstract*—This paper develops an off-board charging system with a bi-directional converter integrated with a voltage source converter (VSC). The grid-tied off-board charger's control stemsfrom a bi-directional converter comprising two stages: a front end and a second end. The front end functions as a three- phase AC-DC converter during charging mode, transitioning into a DC-AC converter for energy recovery. The second stage operates as a bi-directional DC-DC converter, mimicking battery charge and discharge behavior. The bi-directional properties of the system enable various functions, including grid-to-vehicle (G2V), vehicle-to-grid (V2G), and PV source-to-vehicle (PV2V) operations. To validate the effectiveness of the proposed system, we conducted tests under dynamic conditions by disconnecting and reconnecting household loads.**

***Index Terms*—bidirectional converter, secondary battery, V2G, G2V,**

I. INTRODUCTION

The increasing recognition of greenhouse gas impacts and limited fuel reservoirs is driving a transition towards Electric Vehicles (EVs) within the transportation industry. EVs provide advantages such as emission-free operation and reliable electric-powered mechanics. To promote the adoption of EVs, it is essential to develop a strong charging infrastructure, incorporating both on-board chargers (OBCs) and off-board chargers.

The concept of off-board chargers extends beyond mere replenishment of energy; it encompasses a spectrum of functionalities that are pivotal in realizing the full potential of electric mobility. Among these functionalities are Vehicle-to-Grid (V2G) and Grid-to-Vehicle (G2V) capabilities, which represent groundbreaking innovations in the realm of energy management and utilization.

Charging electric vehicles (EVs) from the grid might leadto power quality challenges arising from power electronic devices. This has driven the incorporation of renewable energy sources (RES) such as solar photovoltaic (PV) or wind energy into charging systems. Strategies like Maximum PowerPoint Tracking (MPPT) are employed to enhance the utilization of RES.

The proposed system consists of a front-end converter also known as an active rectifier which convertes AC grid voltage toDC and maintain a constant voltage across the DC bus. Then we have a bi-directional buck-boost converter used to control the battery current during charging and discharging operation. The controller used in the front-end converter regulates 400V (voltage) across the DC bus. In the bi-directional buck-boost controller, it is used to regulate the battery charging and discharging current.

II. THE PROPOSED SYSTEM

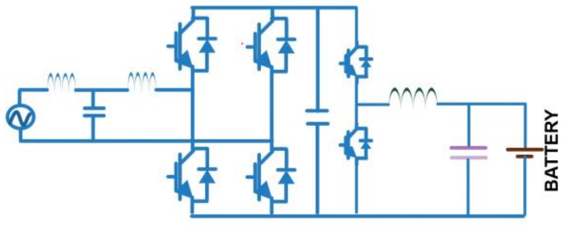

Fig. 1. Structure of the Proposed System

The proposed system structure is shown in Fig.1. As can be seen, six power switches, three inductors, three capacitors are used. In the proposed structure, there is a front-end converter Fig.2, that includes two inductors, two capacitors and four power switches. It is also known as active rectifier which convertes AC grid voltage to DC and maintain a constant voltage across the DC bus.

And there is a bi-directional buck-boost converter Fig.3, which includes two power switches, one capacitor, and an inductor, used to control the battery current during charging and discharging operation.

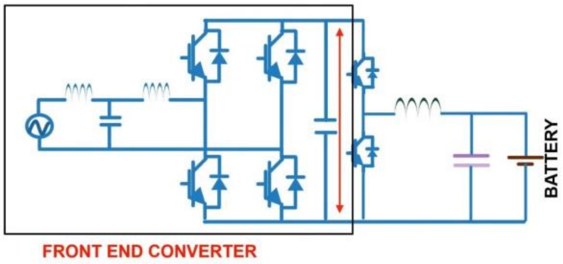

Fig. 2. Structure of the Front-End Converter

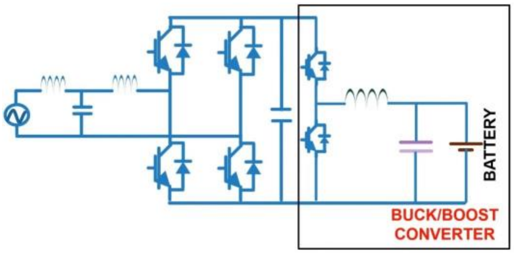

Fig. 3. Structure of the Buck-Boost Converter

III. BATTERY CHARGER CONFIGURATION

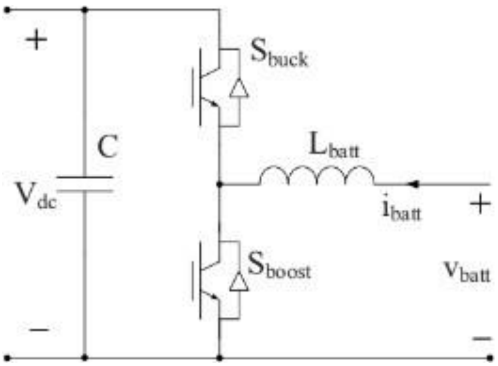

Fig. 4. Battery Charger Configuration

The battery charging configuration (Fig.**??**) is also the buck-boost converter which consists of two switches, one capacitor, one inductor, and one battery. During the V2G (Vehicle-to- Grid) operation, the battery voltage is lower than the gridvoltage (i.e., battery voltage is low and grid voltage is high) so the voltage is need to get higher compared to the battery for this to happen we need to turn on the boost switch (S_{Boost}).

Also, for the G2V (Grid-to-Vehicle) operation, the gridvoltage to the load is higher so it need to step down for thestep down process we turn on the buck switch (S_{Buck}).

To turn on the bi-directional switches nothing but the IGBT or MOSFET we need to give them pulses. For thepulses, PWM (pulse width modulation) method is used in the controller circuit. The controller circuit gives the switches the pulses and by getting the corresponding pulses the buck-boost switching operation is getting done.

IV. CONTROLLER BLOCK DIAGRAM

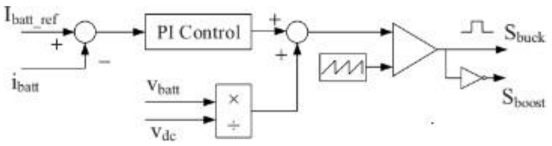

Fig. 5. Constant current control strategy for battery charger

A constant current control strategy using PI controllers is implemented for charge / discharge control of the battery charger circuit and is shown in Fig.5. The controller firstcompares the reference battery current with zero, in-order to determine the polarity of the current signal, to decide between charging and discharging modes of operations. Once the mode is selected, the reference current is compared with the measured current and the error is passed through a PI controller to generate the switching pulses for S_{Buck} / S_{Boost}. S_{Boost} will be turned off throughout the charging process and S_{Buck} will be turned off throughout the discharging process.

V. SIMULTION DIAGRAM OF THE PROPOSED SYSTEM

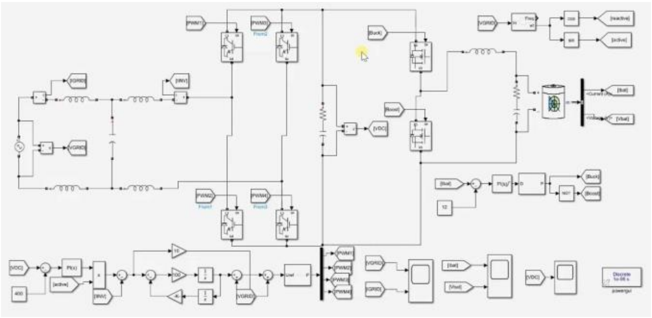

Fig. 6. Simulation Diagram

VI. EXPECTED SIMULATION RESULTS

- The Fig.7 shows the expected output of V2G (Vehicle-to-Grid) operation. Here the voltage and current are aligned out of phase which means power is transferred from the battery to the grid.
- The Fig.8 shows the battery voltage and current during V2G mode

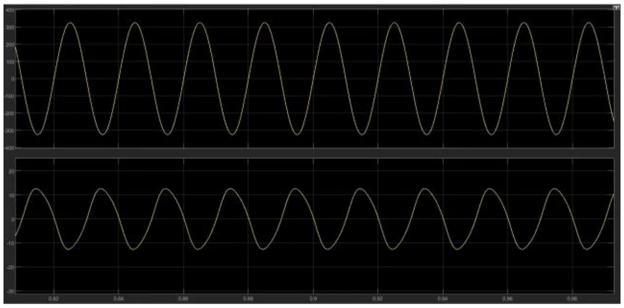

Fig. 7. Expected result of V2G mode

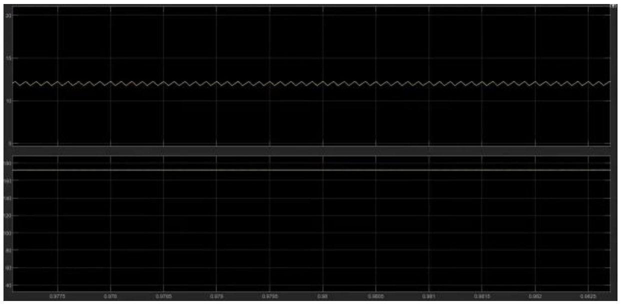

Fig. 8. Battery voltage and current during V2G mode

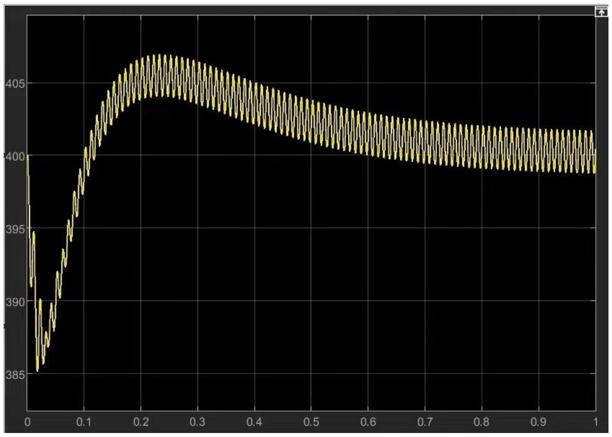

Fig. 9. DC bus voltage during V2G mode

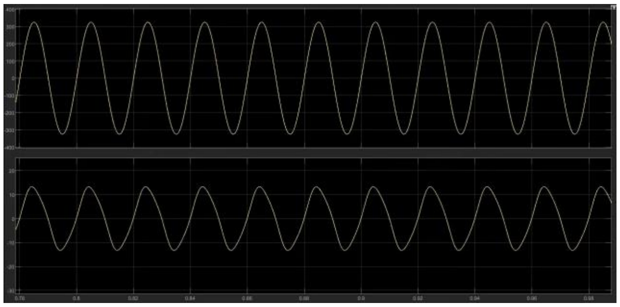

Fig. 10. Expected result of G2V mode

- The Fig.8 shows the DC bus voltage during V2G modewhich is regulated at 400V
- The Fig.10 shows both voltage and current are aligned in phase that is the power is transferrd from grid to the battery so the system works in G2V mode

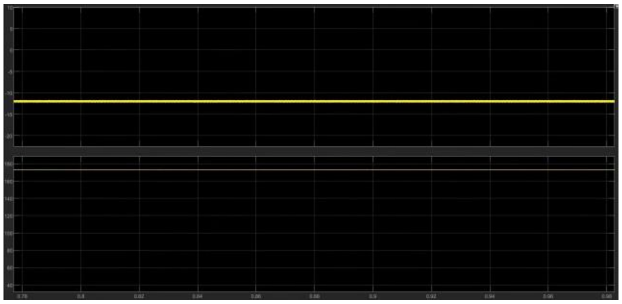

Fig. 11. Battery voltage and current during G2V mode

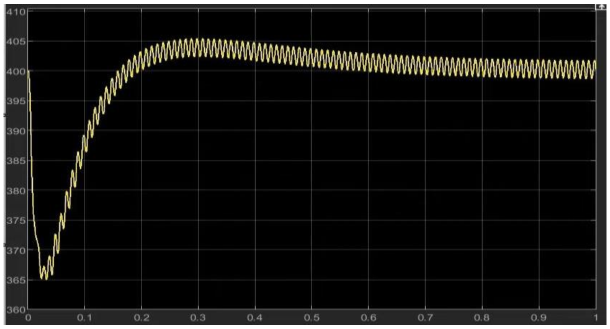

Fig. 12. DC bus voltage during G2V mode

- The Fig.11 shows the battery voltage and current during G2V mode, here we can see that polarity of battery current has reversed.
- The Fig.12 shows the DC bus voltage during G2V mode which is regulated at 400V

VII. CONCLUSION

Modeling and design of a V2G and G2V system in a micro-grid using bidirectional charging architecture is presented in this paper. In this system the circuit consists of a front-end converter, bi-directional buck-boost converter. The front-end converter is used to convert AC grid voltage to DC and maintain a constant voltage across the DC bus and the bi- directional buck-boost converter used to control the battery current during charging and discharging operation.The off- board charger system's bi-directional properties facilitate es- sential functions like bidirectional power flow, enabling both grid-to-vehicle battery charging and grid power supply. This capability enhances system flexibility and efficiency, support- ing features such as vehicle-to-grid (V2G) technology and energy management.Various testing conditions were employedto validate the proposed system's effectiveness, encompassing simulations of diverse charging scenarios, assessments of performance under varied loads and temperatures, and compat- ibility tests with various electric vehicle models. Real-world tests were also conducted to evaluate reliability, efficiency, and safety, collecting data on charging times, energy efficiency, and overall performance to ensure compliance with required standards and specifications.

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