CONTROLLING THE POWER FLOW FROM GRID TO VEHICLE USING A DC-DC CONVERTER

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Abstract: Vehicle-to-Grid (V2G) is a promising technology that allows the batteries of idle or parked electric vehicles (EVs) to operate as distributed resources, which can store or release energy at appropriate times, resulting in a bidirectional exchange of power between the ac grid and the dc EV batteries. In recent years, bidirectional DC to DC converters have attracted a lot of interest in electric vehicle applications. A smart grid (SG) as a whole face the greatest challenge from interactions between electric cars and the grid (V2G) or between vehicles (G2V). Electric vehicles (EVs) of the future will be developed with the incorporation of renewable energies, allowing for a larger positive impact on the environment and reduced CO2 emissions. The goal of this research is to create a DC-to-DC converter that can be implemented for both grid-to-vehicle and vehicle-to-grid connections in EVs. Traditional bidirectional converters use Pulse Width Modulation (PWM) to create the switch-triggering pulse.

Keywords- Electric Vehicle, Bi-directional DC-DC Converters, V2G, G2V, Smart Grid.

1.0 INTRODUCTION

Electric vehicles (EVs) carry a reliable, high-power and high-energy battery pack that powers their propulsion. Conventional EVs are considered only as a load on the power system since they consume grid power to recharge their batteries. The concept of Vehicle-to-Grid (V2G) introduces a second power flow mode, where power can flow from the EV battery to the grid [1]. Thus, rather than considering EVs as just loads on the grid, the state-of-the-art V2G technology targets to use the batteries of EVs as grid-connected energy storage systems. This makes an idle or parked EV perform a secondary function of a distributed resource, where the EV battery can be charged to store power temporarily so that it can be fed back to the grid as and when required [2]. This increases the total power generation capacity as well as improves the stability, reliability and efficiency of the grid [3]. EV batteries can also be utilized to store the intermittent power generated from renewable sources like solar and wind. A typical V2G infrastructure is presented in Fig. The grid receives power from renewable as well as non-renewable sources. The idle or parked EVs are connected to the grid to operate in one of the following modes – G2V, V2G or standby [4]. EVs that support V2G functionality help utility operators answer serious problems related to voltage regulation, reactive power compensation, active power regulation, load balancing, reserve capacity requirements, peak load shaving and current harmonic filtering and in return, the EV owners enjoy significant economic benefits The state-of-the-art Vehicle-to-Grid network connects the ac grid to the batteries of EVs and allows a bidirectional flow of power between them. Accordingly, a bidirectional interface, having the potential to match different voltage levels, is required between the grid and the EVs to charge the EV battery while generating minimal current harmonics, and to feed battery power back to the grid in accordance with regulations [5]. Here, power electronics play a crucial role in converting the ac grid voltage to chargeable dc voltage and vice versa.

2.0 RELATED WORKS

H. Tao, A. Kotsopoulos **[6],** conducted a study on bidirectional DC-DC converter in a HEV. This DC-DC converter is a high-power converter that links the high voltage battery (HV) at a lower voltage with the high voltage DC bus. The typical voltage of a battery pack is designed at 300 to 400V. The best operating voltage for a motor and inverter is around 600V. Therefore, this converter can be used to match the voltages of the battery system and the motor system. H. Tao, J. L. Duarte et al **[7]** formulated a zero-voltage switching (ZVS) bidirectional isolated DCDC converter. This is used in high power application especially for power supply in fuel cell vehicles electric vehicle driving system and power generation where a high-power density is required. H.-J. Chiu, H.-M al. **[8]** formulated a novel integrated bidirectional ac/dc charger and dc/dc converter (henceforth, the integrated converter) for PHEVs and hybrid/plug-in-hybrid conversions is proposed. The integrated converter is able to function as an ac/dc battery charger and to transfer electrical energy between the battery pack and the high-voltage bus of the electric traction system. G.-J. Su, J. P et al. **[9],** presented the basic requirements and specifications for PHEV bidirectional ac dc converter designs. Generally, there are two types of topologies used for PHEVs: an independent topology and a combination topology that utilizes the drive motor's inverter. Evaluations of the two converter topologies are analysed in detail. T. Mishima, E. Hiraki et al **[10]**, proposed a multipower-port topology which is capable of handling multiple power sources and still maintains simplicity and features like obtaining high gain, wide load variations, lower output-current ripple, and capability of parallel battery energy due to the modular structure. The scheme incorporates a transformer winding technique which drastically reduces the leakage inductance of the coupled inductor.

3.0 DESIGN OF PROPOSED CONVERTER

To design a Bidirectional converter for renewable energy systems, the complete prototype is carried in the following sequences, they are given in steps. Finalizing the total circuit diagram, listing out their components and their sources of procurement. Procuring the components, testing the components and securing the components. Making the model as per the circuit diagram on the breadboard and testing the results. Making layout, preparing the inter connection diagram as per the circuit diagram, preparing the drilling details, cutting the laminate to the required size. Drilling the holes on the board as per the component layout, painting the tracks on the board as per the inter connection diagram. Etching the board to remove the unwanted copper older than track portion. Then cleaning the board with water and solder coating the copper tracks to protect the tracks from rusting or oxidation due to moisture. Integrating the total unit, inter wiring the unit and finally testing the unit. Keeping the unit ready for demonstration.

Design Of Circuit Parameters

Three phase filter on the grid side and inductor and capacitor of the battery side can be calculated as follows:

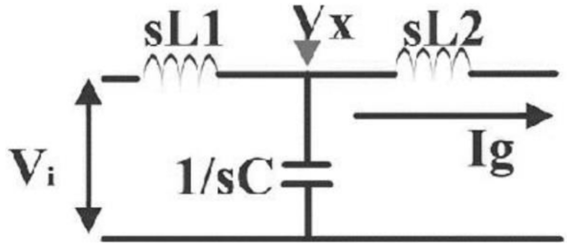

Figure 1: Basic LCL filter

Consider basic L-C-L filter,

Fig. depicts the suggested converter's configuration. Eight MOSFET switches, seven inductors, and four capacitors make up the converter. Both the grid and the battery are connected to the converter's ports A and B, respectively. The suggested converter functions as a boost converter while operating forward and as a buck converter when operating backward. Based on the converter's duty cycle for a specific output voltage, the Gating signals are delivered.

For the analysis of the suggested converter design, some

assumptions were made,

- Initial charging of all capacitors and inductors
- All capacitors and inductors are the same.
- MOSFETS' ON state resistance is disregarded.

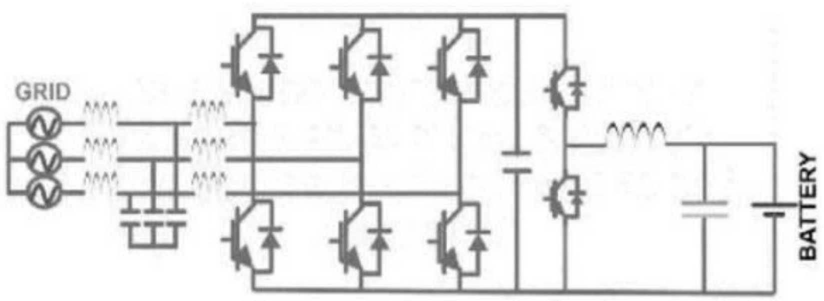

Figure 2: Proposed Bidirectional DC-DC Converter

Backward Operation:

A buck-boost converter pair that is anti-parallel. Q1 will not operate in stepdown mode whereas Q2 will operate in accordance with the duty cycle. Between each operation, there is a brief dead period to prevent cross-conduction. The topology in question is a non-isolated half-bridge BDC topology that was created by connecting a buck converter in parallel with a boost converter. This topology is more effective and straightforward.

4.0 RESULTS AND DISCUSSION

The simulation presented us the bi-direction power flow of Grid and EV. From the results, we summarized that EV can be operated in both mode i.e. V2G or G2V. Moreover, voltage profile in both mode is same while current and apparent are different.

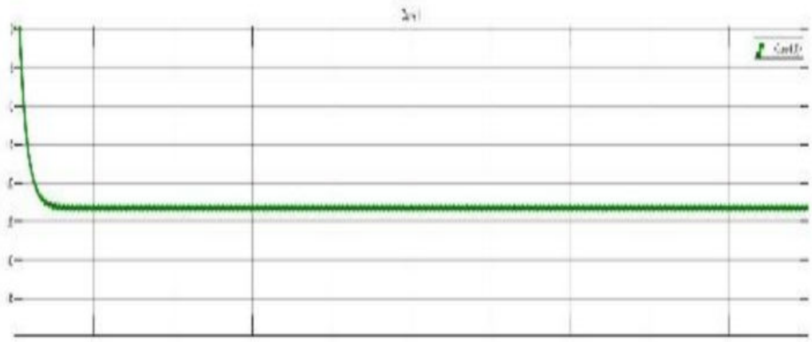

Figure 3: Battery Current in G2V mode

Figure: shows the graph of battery current in grid to vehicle mode that time current flows from grid to battery and from battery to vehicle current that time current is leaving from battery terminal therefore battery current will be negative in grid to vehicle mode.

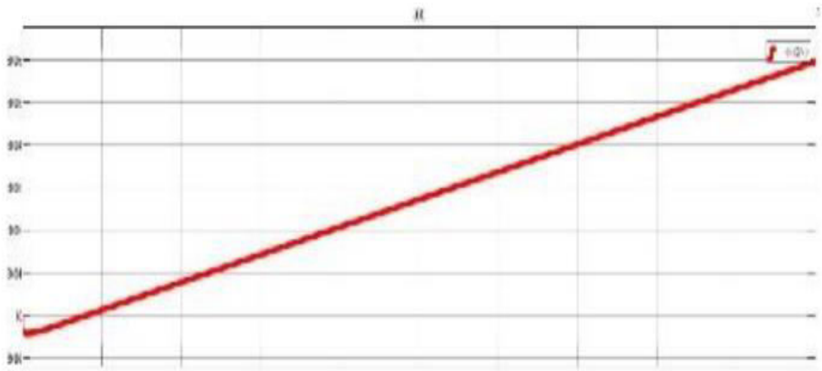

Figure 4: Battery SoC in G2V mode

Figure shows the graph of battery state of charging (SoC) in grid to vehicle power flow battery will charge.

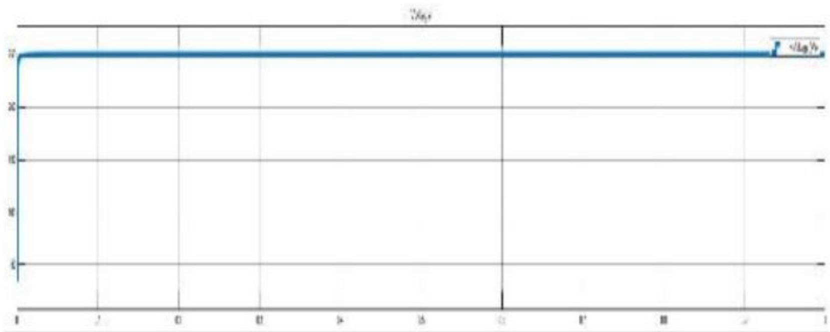

Figure 5: Battery Voltage in G2V mode

Figure: shows the graph of battery voltage this is DC voltage it will be maintained in grid to vehicle or vehicle to grid power flow.

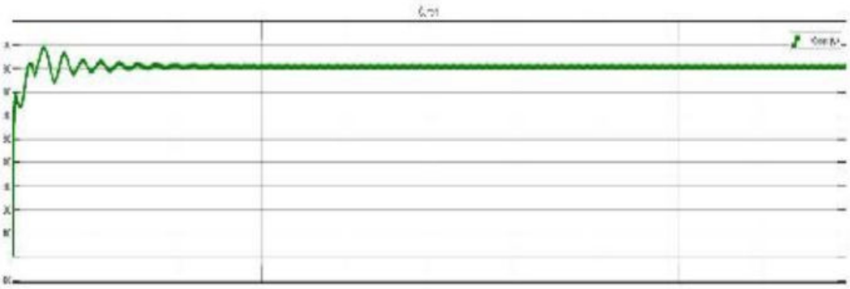

Figure 6: Battery Current in V2G mode

Figure shows the graph of battery current in vehicle to grid mode that time current flows from vehicle to battery and from battery to bidirectional converter that time current is entering in the battery terminal therefore battery current will be positive in grid to vehicle mode and at starting there is transient state because of change of mode from G2V to V2G.

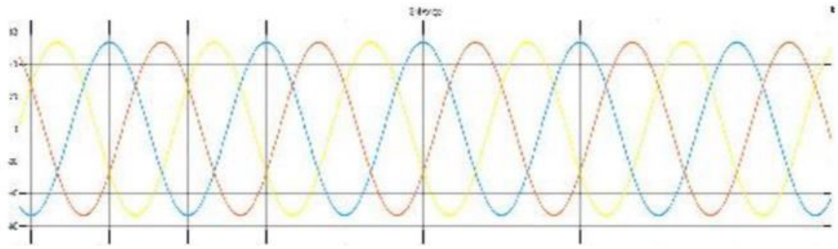

Figure 7: Grid Voltage in V2G mode

Figure shows the graph of grid voltage in vehicle to grid power flow it is the three phase AC voltage and it will remain same in grid to vehicle power flow.

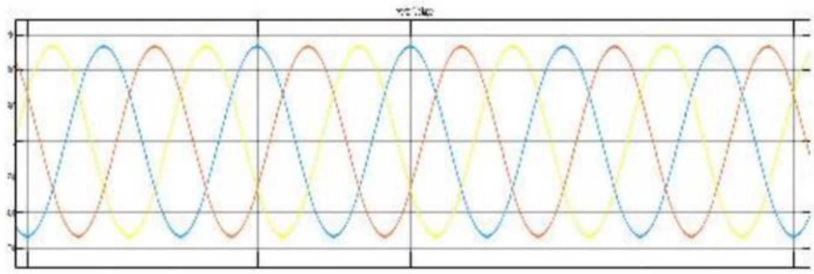

Figure 8: shows the graph of Inverter

Voltage in vehicle to grid power flow inverter will only require in vehicle to grid power flow to converter DC bidirectional converter voltage to AC voltage for grid.

Table 1: Grid to Vehicle results summary

Sr. No	Parameter	Value
1	Grid Voltage	380 V rms
2	Grid Current	450 A rms
3	Battery Voltage	250 V
4	Battery Current	-23.2 A (due to charging)
5	Battery SOC	0.01% increase / sec

Above results show that in G2V mode, the battery is getting charged through the grid. In this mode, our converter operates in buck mode for stepping down the voltage. SoC graph clearly shows that the battery SoC is increasing.

Table 2: Vehicle to Grid results summary

Sr. No	Parameter	Value
1	Grid Voltage	380 V rms
2	Grid Current	450 A rms
3	Battery Voltage	210 V
4	Battery Current	800 A (due to discharging)
5	Battery SOC	0.22% decrease / sec

CONCLUSION

Electric vehicles are expected to play the role of energy storage in the smart grid. Any surplus energy produced by the smart grid must be stored in the EV's battery. This energy reserve can be drawn upon in the future as needed. This work introduces a bidirectional dc-dc converter that can be used in an electric car to achieve this dual function. The proposed converter was tested, and it was found to function flawlessly in both G2V and V2G mode. It has been shown through digital simulations that a basic hysteresis current controller can produce a smooth transition between the step-up and step-down regimes, and that operation is stable in either operating mode.

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