Bidirectional charger for A Single-Phase Electric Vehicle using Buck Boost Converter (G2V & V2G Application)

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ABSTRACT: This paper studies performance of a bidirectional on-board single phase EV charger for Grid- to -Vehicle (G2V) and Vehicle- to -Grid (V2G) application. A bidirectional charger is made up of semiconductor based buck converter and a boost converter. For charging the vehicle battery a DC-DC converter work on buck mode whereas boost mode is used for discharging the battery i.e power feedback to the grid, here the converter works on inversion mode. Battery state of charge affects both charging and draining. The MATLAB simulation is performed to investigate capability of a bidirectional onboard charger with buck boost converter.

Keywords: - Vehicle-to-Grid (V2G), Grid-to-Vehicle (G2V), Buck Boost Converter, Bi-directional power

I. INTRODUCTION

Now a days the carbon emission due to burning of fossil fuel has some severe environmental issue. The continuous carbon emission is responsible for global warming. These adverse envirment changes affects human health. The conventional fuel are limited and they will drain out after few decades, so there is a need to adopt a substitute of these conventional resourse of energy.
An advanced technology bidirectional charger provides alternative use of vehicle battery. An Electric vehicle (EV) bidirectional charging capabilities could be used to power at home, industrial Area, feed energy back in to the connected grid and even provide a backup power source during emergency and blackout. EVs are pollution free (Eco friendally) and also good from noise pollution. Since EVs has numerous benefits, no. of automobile company has invested significant amount of money in this sector for research and development. Power transfer technology from the grid and from the vehicle to the grid is a crucial component of the infrastructure for EVs. A bidirectional charger, as opposed to a conventional on-board charger, transforms grid AC voltage into DC output voltage for charging electric vehicles (EVs) and transforms DC battery voltage into grid AC voltage for grid feeding. The use of a bidirectional on-board charger allows for the regulation of power quality.

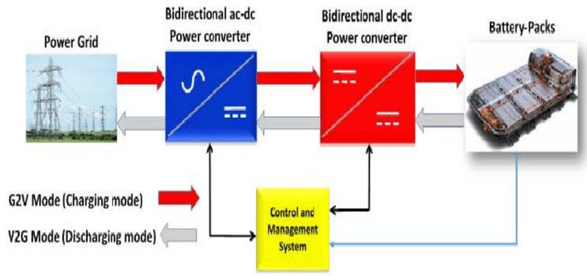

Fig.1 Block diagram of a single-phase bidirectional charger system.

According to Fig. 1's power flow diagram, a single-phase bidirectional charging system, which is a component of DC to DC, is needed for the AC grid
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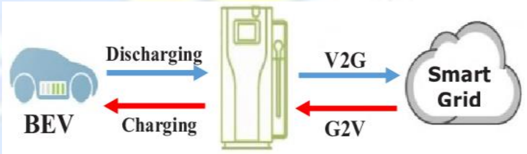

Figure 2 illustrates the power flow of a single-phase bidirectional charger operating V2G and G2V.

II. Bidirectional Charger Topology

Bidirectional battery charger operates between Electric grid and Electric Vehicle. There are two systems.

1 - AC to DC converter and DC to DC Buck converter for battery charging.
2 - DC to DC Boost converter and DC to AC converter (Inverter) for Vehicle to Grid power transfer.

A bidirectional charger is smart technology for electric vehicles (EVs) and it is capable of charging and discharging of Electric vehicle battery. A bidirectional charger uses high frequency switching for AC to DC converter. The input supply for an On board bidirectional charger 230V, 50 Hz and the current limited is 16 Amp rated. The charging power of the On board charger is set at 2KW. Since the operating frequency of DC converet is high the On board charger uses IGBT and MOSFET. For charging the battery AC to DC converter will convert AC input voltage into corresponding DC voltage and this DC voltage is further step down to a suitable DC voltage level for battery charging. PWM controlled is used for AC to DC rectification a simple diagram of single phase bidirectional charger is shown fig 3. The dc-dc boost converter, which uses two switches similar to S7, will operate alternately to reduce ripple while converting the battery's 160 V to 325 V for charging the dc-400 link's V.

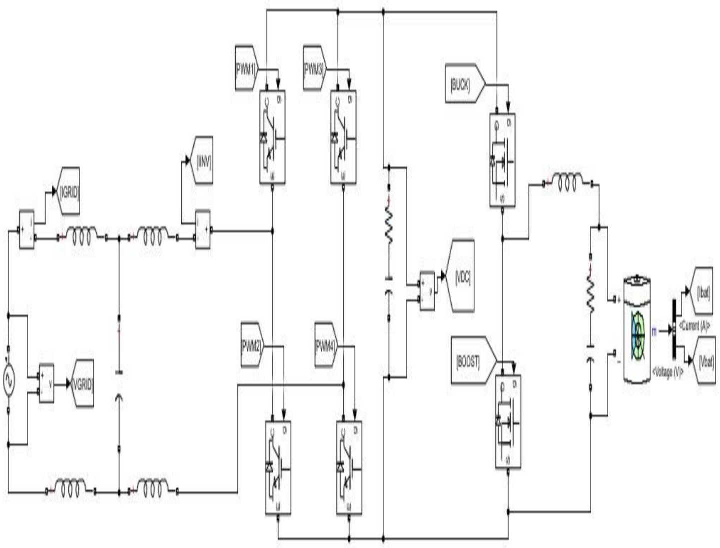

Fig. 3 Single-phase Bidirectional Charger (G2V & V2G) topology.

III. Proposed G2V and V2G For A Single-Phase On-Board Bidirectional Charger Using A Buck Boost Converter

Parameters	Value
Grid Voltage	230Vrms
Frequency	50 Hz
Power	2kW
DC link Voltage	400V
Switching Frequency	10kHz
Battery Nominal Voltage	160V
Output Capacitor	100uF
Filter Inductor 1	4.36mH
Filter Inductor 2	4.06mH
Filter Capacitor	6.23uF
Buck Filter Inductor	20mH
Buck Filter Capacitor	5600uF

Table 1: Model parameter

This is shown in above Table the charging voltage of buck-boost converter for a single-phase Onboard charger system needs input 230Vrms of grid voltage and the output voltage 160V of the battery.
V2G & G2V technology ensures the bidirectional flow of energy from the grid and vehicle. This will help in peak load shaving, load levelling, voltage regulation and power system stability improvement. The battery charger is required for the bidirectional energy flow.
The built-in bi-directional chargers are designed for res idential use and it offers slow charging [2].
Buck mode, for design inductor and a capacitor value can be calculated as:

$$L\ buck\_m = \left(\frac{Vo}{\Delta IL.fsw.Io} D^2 buck(1 - Dbuck)\right)$$

$$Cbuck\ min = \left(\frac{IoDbuck}{\Delta Vo.fsw}\right)$$

Where Dbuck = Duty cycle ratio of buck mode.

fsw = Switching Frequency

Boost mode, for design inductor and a capacitor value can be calculated as:

$$Lboost\_min = \left(\frac{Vo}{\Delta IL.fsw.Io} Dboost(1 - Dboost)^2\right)$$

$$Cboost\_min = \left(\frac{(1-Dboost}{8.Lboost.Vbat.f^2sw}\right)$$

Where Dboost = Duty cycle ratio of boost mode.

IV. Mythology of Battery Charger Configuration

It consists of two MOSFET based switches which are controlled by suitable signal.
(A)Buck Mode of Operation (Charging Mode)

Buck mode is used for charging of battery. When the upper switch the converter work as the buck converter. Buck converter step down a DC voltage. The input voltage to the buck converter Vdc which is converted to battery charging voltage Vbatt. The current flow from switch indicator to the battery when the switch off the path following by the current is through the indicator and lower switch diode. In This duty cycle of buck converter then battery voltage given by

$$Vbatt = Vdc * D$$

(B)Boost Mode of Operation (Discharging Mode)

Boost mode of operation is used for discharging the battery i.e power feed to Grid. Boost operation take place when lower switch ON. Boost converter is used to UP DC Voltage. The lower switch is on the current flow through the indicator and completes it circuit through antiparallel diode (Upper switch and capacitor). If this is the DC circuit boost converter then

$$Vdc = Vbat/(1\text{-}D)$$

Where D is duty cycle of lower switch.

(C) LCL FILTER

LCL filter is connected at the grid side the main function of the LCL filter is provide pure sinusoidal AC output for the grid. During V2G operation the DC to AC converter have harmonics and the wave form the AC output is started from. The LCL filter removes this harmonic and provide pure AC output.

V. CONTROL SYSTEM

V2G and G2V power control modes are the two primary modes of operation, and the control figure is given in Fig. 5. The G2V mode uses the utility grid to provide electricity while charging an electric vehicle's battery. Constant Voltage (CV) mode and Constant Current (CC) mode are the two states in which the control algorithm operates in this mode. When the SoC is less than 80% of its capacity, the battery will be charged in CC mode. When the SoC is 80% or more, the charging method will change.
The system's power in V2G mode will be supplied by the battery and injected into the utility grid. There are two control loops: the Vdc-link loop and the ib feedback loop. Both the ib feedback loop and the Vdc-link loop are voltage loops. This is a control diagram for a buck boost converter. It is a regulated controller for battery charging and discharging.
To determine position and speed, a redesigned control function and an enhanced phase locked loop (PLL) are used. It offers a smooth start-up and prevents frequency transients and singularity problems.
80%

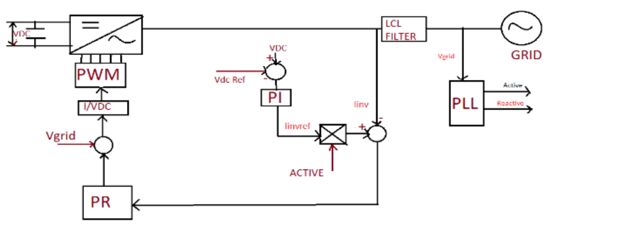

Fig. 4 Control Block diagram of Bidirectional charger using Buck Boost converter

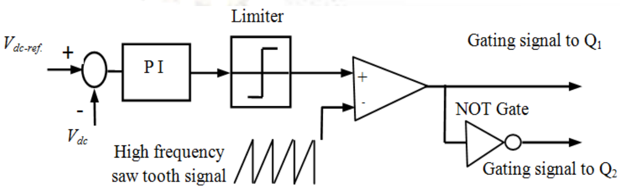

Fig 5 Controller & Operation of System

VI. MATLAB SIMULATION

The simulation in this model has been validated using PSIM, and the simulation configuration is illustrated in Fig. 6. This model has to validate the bidirectional Buck and Boost converter and its control concept. The system is in V2G mode because the voltage and current are in the same phase, transferring power from the battery to the grid. This is the battery's 400 V-regulated Dc bus voltage during V2G operation.
Voltage & current are not in the same phase when electricity is transferred from the grid to the batteries, resulting in the G2V mode. The results of the simulation model are displayed in Fig. 6-10.
The simulation waveforms of the converter in buck mode under open loop control are shown in Fig. 7. To step down the voltage from 325V to 160V, the duty cycle was set at 23 percent. The output power is 2kW, and the output current is 16A.
In order to send power to the dc-link and then transmit that power to the utility grid, simulation waveforms in the discharging mode of operation are shown in Fig. 8. In this

situation, the converter is operating in boost mode to increase the battery voltage from 160V to 325V by employing a 80% duty cycle.

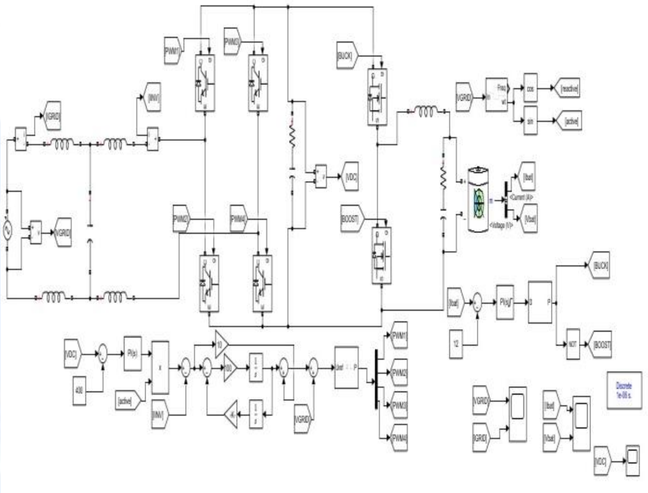

Figure 6 shows the simulation circuit for the PSIM-developed bidirectional Buck Boost converter for charging and discharging batteries.

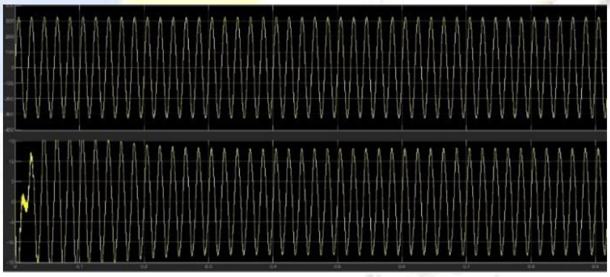

Fig 7 Simulate wave form of buck converter. (G2V mode)

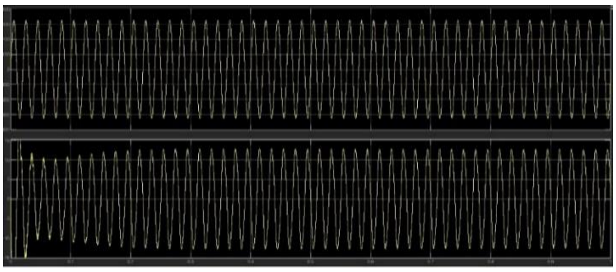

Fig 8 Simulate wave form of boost converter. (V2G mode)

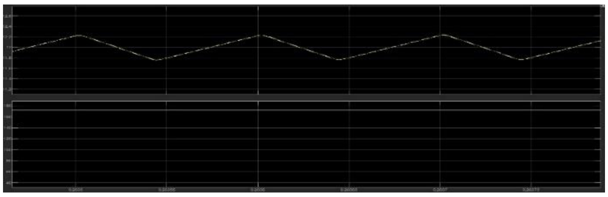

Fig 9 Simulate wave form of Vdc. (V2G mode)

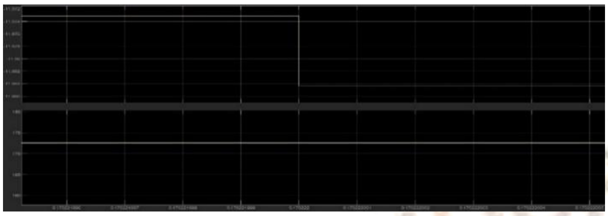

Fig 10 Simulate wave form of Vdc. (G2V mode

VII. CONCLUSIONS

The electrical car in this study can receive a very quick charge from the grid to the battery, and the remaining battery can provide electricity back to the grid. The proposed topology is verified by simulation using the buck boost mode converter PSIM results. This topology makes it possible to increase battery power capacity while also saving time. Houses and the roofing business can both benefit from this. Additionally, this may allow the power plant to conserve coal or other resources. When switching from CC mode to CV mode to charge a battery, the buck mode converts the 325V of the dc-link to 160V at a current of 12A and responds to the iref as well and boost mode, which uses a PWM duty of 80% to transfer the voltage from Vb 160V to Vdc 400V for control voltage constant. With a battery model of 160 volts and a DC link voltage of 400 volts, the bidirectional EV charger for V2G application is successfully simulated in Matlab. Electrical energy will never again be a problem, and it will also be possible to save traditional resources and solve the pollution issue.

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