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Utilizing a Bidirectional 3 - Phase Electric Vehicle Charger with Buck and Boost Converter (V2G and G2V Application)

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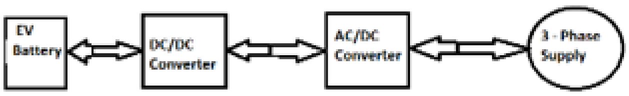
Abstract: ***This paper studies performance of a bidirectional three phase electric vehicle charger for Grid to Vehicle (G2V) and Vehicle to Grid (V2G) application. A bidirectional charger is made up of semiconductor based buck converter and boost converter. Electric vehicle charger stations will be opened all over India in the future, just as petrol and diesel stations are open. Buck and boost topology has been used in this paper. From which the battery is charged (G2V) and discharged (V2G). Buck and Boost Converter is a power electronics device. The ink bidirectional charger accomplishes the task in two different ways: (a) By using a rectifier to convert AC to DC (process G2V). (b) Use an inverter to convert DC to AC (V2G process). The charger is set up to work with a three - phase, 415 V, 50 Hz power source. In various operating conditions, the three - phase bidirectional charger's performance has been examined in the Matlab system. Even with an unbalanced load and grid, this bidirectional charger will function properly.***

Keywords: Bidirectional Charger, G2V and V2G, PLL, EV

1. Introduction

Electric vehicles will be used more in the coming time so that the whole world eliminates the pollution of the problem (Co2 emission). In the UNSC meeting, it was decided that in 2050, it was decided to discontinue petrol and diesel vehicles and use electric vehicles. Charging stations will be required to charge the battery of the electric vehicle The battery of the electric car will be charged in this topology, and the stored electric energy can be sent back to the power system (Electric Grid). The transportation industry, which depends on combustion engines, contributes significantly to the atmospheric concentration of CO2 [2]. Because of growing environmental concerns, the use of electric vehicles (EV) is increasing quickly in the transportation industry. Recently, the electrification of the transportation sector has attracted interest on a global scale as a potentially effective remedy for the aforementioned issues. EV A two - stage bidirectional battery charger has two steps. An AC/DC converter makes up the first stage (Buck converter), which makes it possible for electricity to flow in both directions from the grid to the internal DC link. Additionally, it is kept at unity power factor if necessary. A DC/DC converter makes up the second stage (the "Boost Converter"), which controls the voltage and current of the battery. Flow active electricity from the EV battery to the grid is referred to as V2GAdditionally, this mode allows for the adjustment of reactive power. The battery has the potential to be used as energy storage. Since an electric vehicle's battery can store a lot of energy and is parked for more than 85% of the time it is on the road.



Topology of bidirectional EV battery charger

Block diagram of a three - phase bidirectional charger is shown in Figure 1.

The bidirectional dc - dc converter is part of the three - phase bidirectional charger system that is needed for the AC grid, as illustrated in the block diagram of Fig.1.

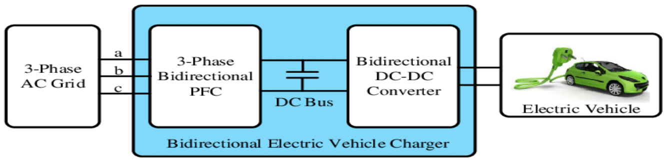


Fig.2 shows a block diagram of a three - phase bidirectional charger in use.

For the three - phase bidirectional charger system is shown in block diagram fig 2. This is high power energy system. In this system, converted ac power to dc power (G2V System) & dc power to ac power (V2G System). This is control block diagram of three phase V2G & G2V operation.

2. Mathematical Representation of 3 phase Network

Considering, 3 - phase balanced network of phase - to - phase voltage at 415V, phase to neutral voltages is represented as:

$$va(t) = Vmsin\omega t \quad (1)$$

$$vb(t) = Vmsin\,(\omega t - 2\pi\ 3) \quad (2)$$

$$vsc(t) = Vmsin\,(\omega t + 2\pi\ 3) \quad (3)$$

Operating in balanced network conditions, three active powers (Pa, Pb and Pc), reactive powers (Qa, Qb and Qc) and corresponding apparent powers (Sa, Sb and Sc) components are considered.

$$Iaeff = Sa/\,Veff \quad (4)$$

$$Ibeff = Sb\,/Veff \quad (5)$$

$$Iceff = Sc\,/Veff \quad (6)$$

Three line and neutral currents can be written as:

Three line and neutral currents can be written as:

$$isa(t) = \sqrt{2}Iaeffsin\,(\omega t - \varphi a) \quad (7)$$

$$isb(t) = \sqrt{2}Ibeffsin\,(\omega t - 2\pi\ 3 - \varphi b) \quad (8)$$

$$isc(t) = \sqrt{2}Iceffsin\,(\omega t + 2\pi\ 3 - \varphi c) \quad (9)$$

Total Current value:

$$isn(t) = -[isa(t) + isb(t) + isc(t)] \quad (10)$$

The Inductor Value

L= $\{(VDC/(2*fSW*\Delta ipp|max)\}$ H

The Capacitor Value

C = $\{(8m/5\pi\Delta vC*3\omega)*Im\}$ F

3. Mythology of Battery Charger Configuration

There are two MOSFET/IGBT switches in it, and they are both always turned on by complementary control signals.

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 V batt. 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

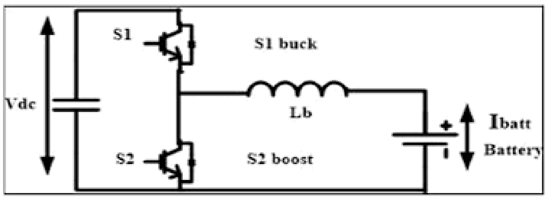
$$Vbatt = Vdc*D$$

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

$$Vdc = Vbat/(1 - D)$$

where D is the lower switch's duty cycle.



c) LCL FILTER

The primary purpose of the LCL filter, which is linked at the grid side, is to supply the grid with output that is entirely sinusoidal. The DC to AC converter's harmonics and the wave shape from which the AC output is initiated are present during V2G operation. This harmonic is eliminated by the LCL filter, which produces pure AC.

4. Bidirectional Charger Topology

3phase Bidirectional battery charger operates between Electric grid and Electric Vehicle. It comprises of two systems

1) DC to DC Buck converter for charging batteries and an AC to DC converter.
2) A DC - to - DC boost converter and a DC to AC converter (inverter) are used to transfer power from a vehicle to the grid.

For electric vehicles (EVs), a three - phase bidirectional charger is clever technology that may be used for both charging and discharging batteries. 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 10KW. Since the operating frequency of DC converter 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 avoid ripple while converting the battery's 360 V to 415 V for charging, which will result in 800 V of dc power.

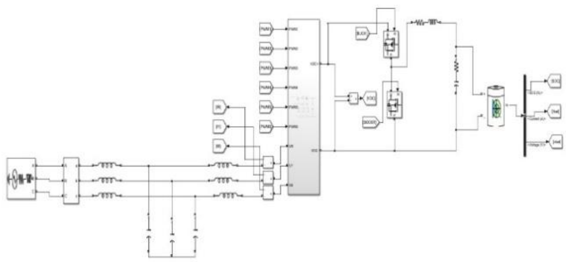


Figure 3: Three - phase Bidirectional Charger G2V and V2G Topology

The suggested topology's three phase, bidirectional G2V and V2G charger is depicted in Figure 3. Based on this thesis paper, electric vehicle battery can be charged by a high - power energy charging station and this charging station can be supplied to the grid.

5. Specification of V2G & G2V Three Phase Bidirectional Charger Operation

Table 1

Parameter	Value
Grid Voltage	415 V_{rms} (L - L)
Filter (Inductor & Capacitor)	5mH & 30uf
Buck Capacitor	5600uf
Buck Inductor	20mH
Output Capacitance	0.625uf
Battery Nominal Voltage	360V
Switching Frequency both Converter	10KHz
Total Rated Power	10 KW
DC Bus Voltage	800V

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6. Control System

3phase bidirectional chareger is control power electric vehicle battery charger, there are used difference componet of semiconductor devices. A bidirectional charger has two modes of operation, rectification (G2V) and inversion mode (V2G). A single PI based control model is shown in fig 5. A reference voltage is set in the controller is controlled Vdc ref. Vdc is battery DC voltage. In comparator Vdc is compared with Vdc ref. Battery is charged by giving suitable gate signal to the converter. 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 control diagram of Buck Boost converter, this controller is regulated battery charging & discharging controller. It provides a smooth start up and avoids transient in frequency and singularities issues.

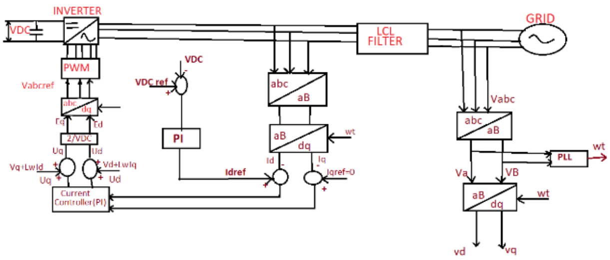


Figure 4: Control Block diagram System of 3 Phase Bidirectional Battery Charger

(A) Phase - locked loop (PLL)

A semiconductor device, that is. It is an electronic circuit that continuously modifies its voltage or voltage - driven oscillator to match the frequency of an input signal system. Synchronizing the output oscillator signal with a reference signal is the principal goal of a PLL.

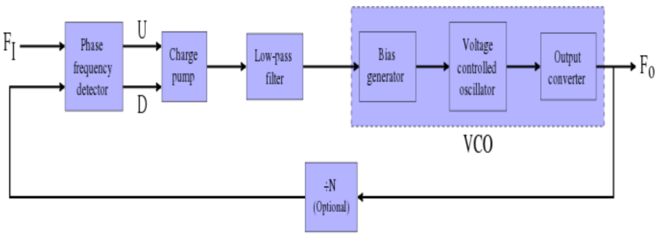
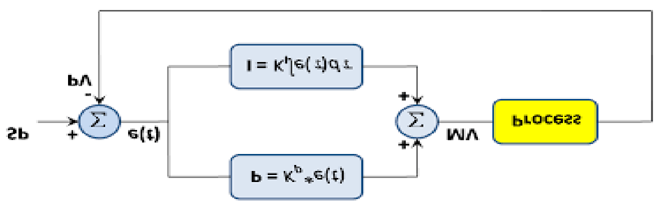


Figure 5: Block diagram of PLL

(B) PI Controller

The proportional - integral controller (PID) combines the control actions of two independent controllers—proportional and integral—to create a more effective controller that does away with the drawbacks of each. The proportional plus integral controller is represented mathematically as follows:

$$m(t) = K_p\, e(t) + K_i \int e(t)$$



7. MATLAB Simulation

The suggested three - phase bidirectional Buck Boost converter and its control approach are validated in this model; the simulation setup is depicted in Fig.6 and the simulation has been validated using PSIM. 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 DC bus voltage, which is regulated to 800 V during V2G operation.

The system is in G2V mode because when electricity is transmitted from the grid to the batteries, the wave form (voltage & current) are not in phase. The simulation results are shown in Fig.6–10. The simulation waveforms of the converter in buck mode under open loop control are shown in Fig.7. To scale down the voltage from 415V to 360V, the duty cycle was set at 23 percent. The output's nominal discharge current is 131A, and its maximum power is 10kW. 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. Under these circumstances, the converter is operating in boost mode to boost the battery voltage from 360V to 415V using an 85% duty cycle.

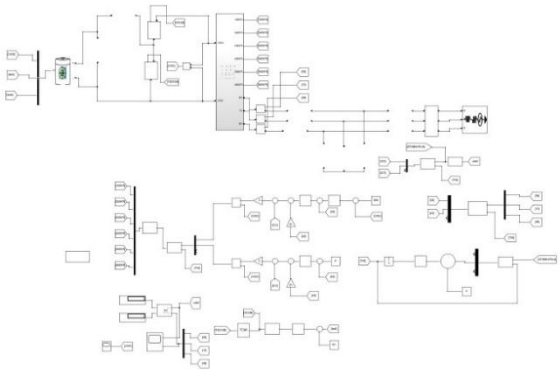


Figure 6: Simulation circuit of 3phase bidirectional Buck Boost converter for battery charging & discharging developed in PSIM.

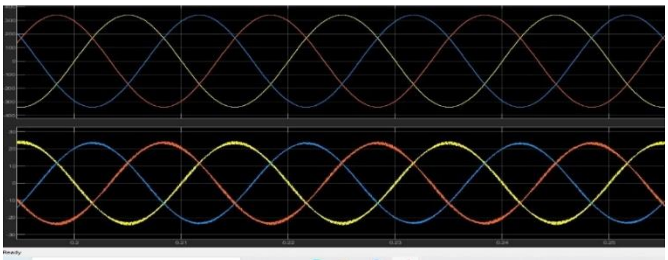


Figure 7: Three Phase Simulate wave form of buck converter. (G2V mode)

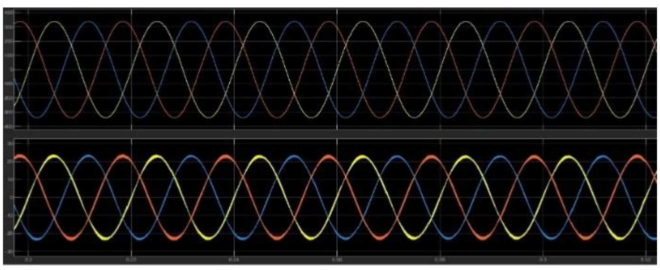


Figure 8: Three Phase Simulate wave form of boost converter. (V2G mode)

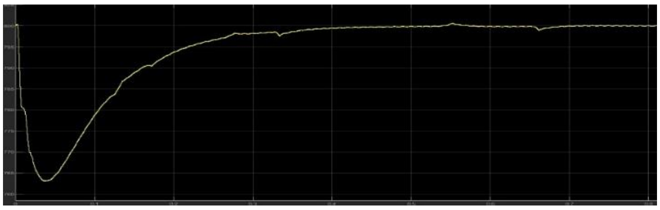


Figure 9: Three Phase Simulate wave form of Vdc. (G2V mode)

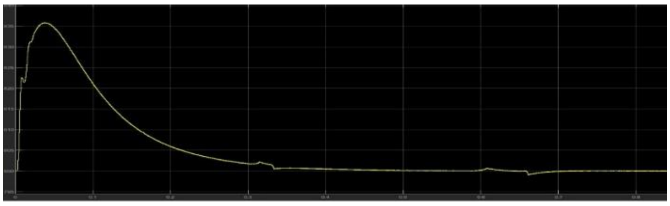


Figure 10: Three Phase Simulate wave form of Vdc. (V2G mode)

8. Conclusion

A 3phase bidirectional charger is proposed in this paper. The charger is providing proper DC output for G2V operation and smooth AC output to feed the Grid (V2G operation). The theory is verified with the help of MATLAB simulation from simulation result. It can be concluded that this topology is providing improved battery capacity and same the time.
In the future, there will never be a problem of electrical energy and can also save the conventional resource and the problem of pollution will also be removes.

Future Scope, setup of the bidirectional onboard EV battery charger that can minimize and correct for unbalanced active and reactive power exchange between three phase supply has been presented. Additionally, methodologies for controlling AC/DC and DC/DC converters are being developed.

Appendix
Three phase (L2L) voltage=415V (rms), frequency (f) =50Hz, interfacing inductor (Lc) = 5mH, ripple filter, ripple filter capacitance (Cf) = 30uF, battery voltage (Vb) = 800V.

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