



## Bidirectional Transformer-less Electric Vehicle Charging with V2G Application

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**Abstract:-** There are moments of peak load, which is excess demand, and other times of off-peak load, which is less demand than the power generated, depending on the quantity of power generated in the grid by its sources and the demand. This is where V2G (Vehicle-to-Grid) technology for electric vehicles comes into play. Smart technologies that enable communication between EVs and the grids are in place to ensure the smooth operation of V2G. Around six ranges of the battery SOC are considered for this purpose. If the battery is completely degraded or completely discharged, the Soc is 0 to 10% and the extraction of current from grid case is high in this scenario. The power is 2.5 kW as shown. Similarly, another case of SOC between 10% to 30%, power is taken as 2.4 kW and further reduces as SOC goes high. This complete operation is done in BMS. In BMS the SOC is sensed typically and power reference is given accordingly and current is calculated. Three sensors are being used, the SOC, battery voltage and mode. The mode is 1 for charging and 0 for the discharging mode. The output is the battery reference which is the current reference given as the reference to the bidirectional DC-DC converter controller. For the battery charging operation, the battery current is positive and in the discharging operation battery current is negative. In both cases the DC output voltage, which is regulated by the rectifier is balanced to the 200V. Also, the battery voltage changes as the discharging mode operate. A grid current and grid voltage are stable in the fraction of time and improving the performance of the operation.

**Keywords:-** Transform-less, Electric Vehicle, Vehicle to Grid, Bidirectional, DC-DC Converter

### I. INTRODUCTION

Over the past decade, developments in technology related to EVs have seen a rapid growth in reaction to the anticipated market demand for such vehicles. The high-density rechargeable battery packs of EVs are one of the most important components that directly impact the acceptance of electric mobility [1–3]. EVs are typically charged from the utility power grid through battery charging systems however other charging methods like charging directly from solar PV plants or wireless inductive charging also exist. Battery swapping is also a method for charging EVs wherein depleted vehicle batteries are replaced by pre-charged ones. These conductive battery charging systems are further classified as on-board and off-board chargers as shown in Fig. 1.1 [4], according to the standards defined by the SAE, USA as shown in Fig 1.2 [5]. In general, on-board chargers are mounted on the vehicle chassis whereas off-board chargers are kept external to the vehicle. Each power unit type has its own merits and demerits. Among all these power units, the DC-DC converter stage is more popular since it plays the important role of matching the charger rating with the required battery power requirement [6–8]. The internal architecture comprises of two power conversion stages: AC-DC and DC-DC. The AC stage is responsible for improving the input power factor while the DC stage provides the suitable voltage and current in accordance with the battery profile [9]. Nowadays, the development of highly efficient and economic EV battery chargers is of high interest. Many EV charger configurations have been developed in the past decade in which the development of DC-DC converter stands out as a prominent development. This power conversion stage has made the converter capable to deliver power according to battery rating [10, 11].

In practice, EVs use rechargeable battery packs for powering the electric traction system. The batteries are recharged by using battery chargers that take power from the utility grid. It is an arduous task to work on a particular FBDC configuration inside an EV charger since these have a diverse nature. Among the available topological configurations, no specific configuration stands out for EV battery charging applications. Many aspects are considered for designing a particular topology, and some crucial aspects that are considered while justifying the merits of a FBDC are as follows:

1. Power regulation of the converter according to battery charging characteristics.
2. Ability to operate converter switches with soft-switching.
3. Lesser voltage spikes across the isolation transformer poles and secondary rectifier diodes.
4. Minimal losses during converter operation.

On these lines, this thesis work aims to investigate the topological structures and hence, the topological refinements of DC-DC converters for improving the configuration and performance of the emerging converter configurations. As a specific contribution of this work, an auxiliary circuit based snubber-less configuration has been developed for a reliable operation of the converter.

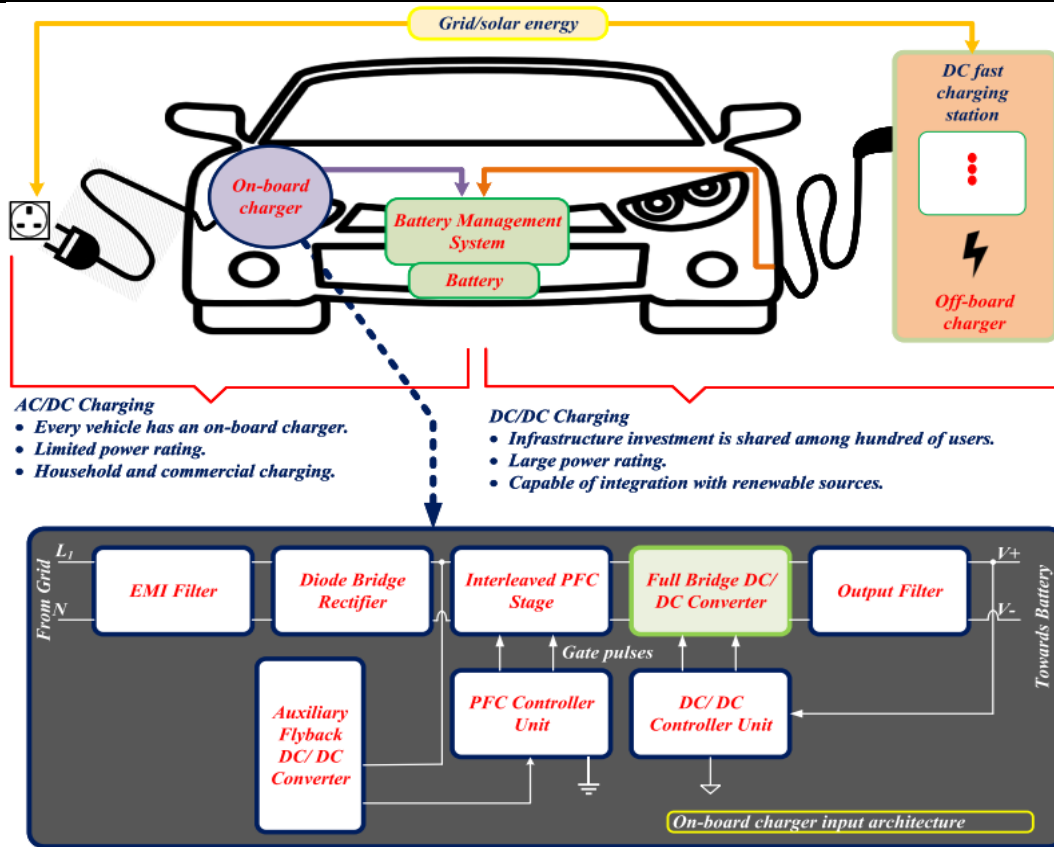


Figure 1: On-board vehicle charger and its single-phase input architecture

## II. PROPOSED METHODOLOGY

The disadvantage of electric cars being expensive sometimes because of comparatively lesser production commercially can be overcome by Vehicle to Grid Technology as the owner could earn back the money over a period of time.

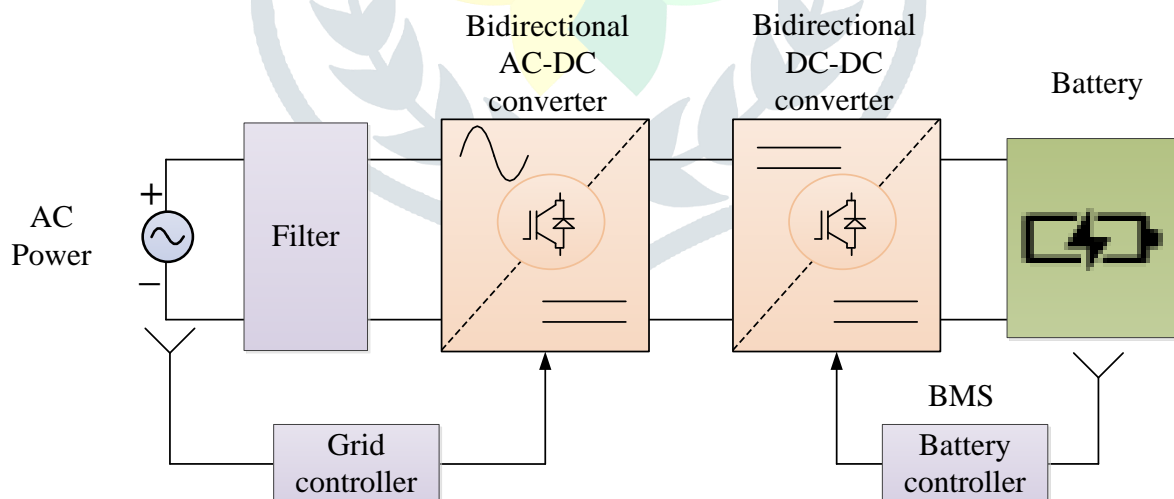


Figure 2: Basic block diagram of transformer less EV battery charging

The Electric Vehicles are idle and just sit in the parking almost 95% of the time. Hence, they are known to be energy assets. V2G allows electric vehicle (EV) batteries to store energy and discharge it back to the power network when it's most needed, such as during peak hours when demand of the power supply across the country is highest. This is also an advantage to the EV car owners as they could possibly sell the charge they are not using and earn back money. The Vehicle to Grid technology is a boon for the electric vehicle users as they can earn whilst they are saving the environment as it reduces the climate change impact. V2G helps reduce the use of the fossil fuels. It can help stabilize the grid. The charge stored is provided back to the grid using group of power converters thus helping the grid sustain peak demand.

Battery management system (BMS) is the important aspect to control the charge of the battery in the charging mode as well as discharging mode. Proposed model of this work basically depends upon the charge control of battery as shown in figure 2.

### Bidirectional Power converters:

The bi-directional converters are generally feasible for Vehicle to grid and Grid to Vehicle operations. The two mandatory types of bi-directional converters that are essential for operation of electric vehicle to grid technology are bidirectional AC-DC converters (BADC) and Bidirectional DC-DC converters (BDC). These help power transfers between the grid and the electric vehicle. The following three converters are used in the Vehicle to Grid Technology:

#### DC-AC Inverter

DC power source (from batteries, solar panels, or fuel cells, for example) is converted to AC using inverters. AC does not necessarily refer to a perfect sinusoidal waveform block diagram representation of inverter shown in figure 4.2. The size and frequency of sinusoidal AC outputs are Both frequency and phase ought to be controllable. Inverters can have one of the two fundamental topologies depending on the type of AC power waveform: voltage source inverters and current source inverters. The output of the inverter might be single-, three-, or multi-phase.

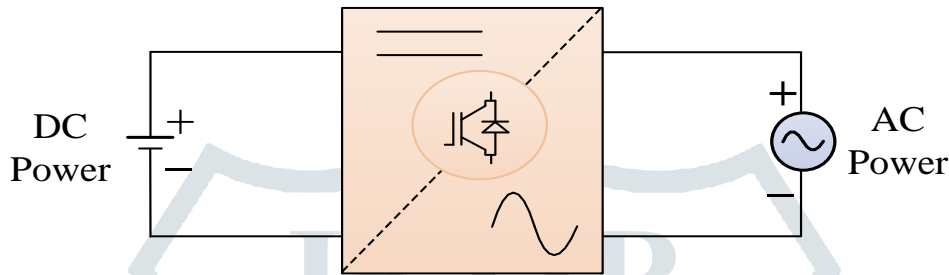


Figure 3: Basic diagram of DC-AC Inverter

#### AC-DC Rectifier

Direct current (DC) output power is produced by a rectifier using alternating current (AC) input power as input. Rectifiers can be classified into half wave and full wave rectifiers to deliver ripple-free DC voltage or DC current to the load, rectifiers are necessary. Block diagram representation of AC-DC rectifier shown in figure 4.3. Low power applications up to 15kW are appropriate for single-phase diode rectifiers. Three-phase, six-pulse rectifiers are used in applications requiring medium and high-power electronics.

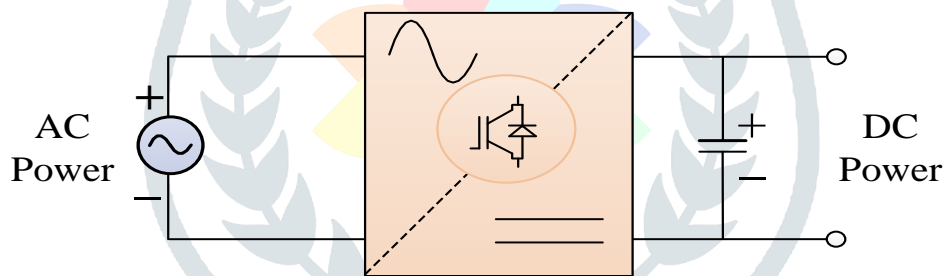


Figure 4: Basic diagram of AC-DC Rectifier

#### DC-DC Converter

DC voltage is changed from one level to another using DC-DC converters, often known as choppers. In addition to being able to produce a regulated DC output voltage from an unregulated DC input voltage, DC-DC converters can also be used to correct line voltage that is variable in magnitude. Switch Mode Power Supplies (SMPS) or Switching Regulators are DC-DC converters that use IGBTs and MOSFETs as switches. Different topologies can be used to create DC-DC converters to perform the following tasks:

To produce a lower regulated DC output voltage, step down an unregulated DC input voltage: The name of this DC-DC converter is buck or step-down converter. To get a greater regulated DC output voltage, step up an unregulated DC input voltage. Known as a booster step-up converter, this DC-DC converter shown in figure 4.4. To create a lower/higher regulated DC output voltage, step down then step up an unregulated DC input voltage. An example of this is a buck-boost converter. When compared to the input voltage, the buck-boost creates a negative output voltage.

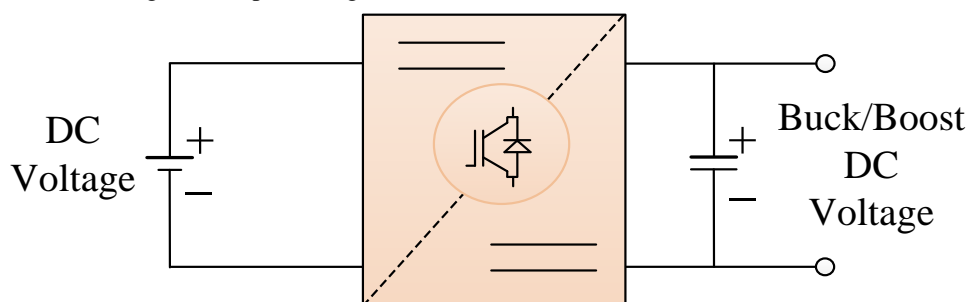


Figure 5: Basic diagram of DC-DC converter

### III. SIMULATION RESULTS

A simulation model is created on the MATLAB platform to confirm the viability of the novel topology as a bidirectional AC-DC converter. The MATLAB simulation is verified in three modes:

- DC-AC Inverter useful for the discharging mode
- AC-DC rectifier with resistive load useful to validate power factor correction and voltage regulation
- AC-DC rectifier with a bidirectional DC-DC buck-boost converter, useful to validate the charging i.e., G2V and discharge i.e., V2G modes of an electric vehicle.

The details for each parameter are shown in Table 1, and the AC input voltage is 230V RMS, or 325V peak. The switching frequency is 10 kHz, whereas the grid frequency is 50Hz. A filter inductor which is used with the grid as 4.5mH and the filter capacitor is 2200 uF. For vehicle charging performance use a lithium-ion battery where the nominal voltage of the battery is 72V.

Table 1: Parameters to validate the proposed work

| Parameters                       | Value             |
|----------------------------------|-------------------|
| Grid voltage ( $v_s$ )           | 230 VRMS          |
| Filter inductor ( $L_s$ )        | 4.5 mH            |
| Filter capacitor ( $C_o$ )       | 2200 uF           |
| Resistive load ( $R_o$ )         | 20 Ohm            |
| Switching frequency ( $F_{sw}$ ) | 10 kHz            |
| Grid frequency ( $f_g$ )         | 50 Hz             |
| EV battery load                  | Lithium ion (72V) |

A Vehicle to Grid that is a bidirectional flow of energy between the EVs and the grid. This work gives a detailed and thorough description of the V2G technology with a broad focus. For electric vehicle charging need to required AC-DC converter for the PFC and DC voltage regulation and DC-DC converter for state of charge (SOC) control. For AC-DC rectification proposed a converter that is operate as a buck mode for charging and boost mode for discharging. Figure xx shows the charging and discharging process. In the case of charging (before the time  $t < 1$ ) grid voltage is in phase with grid current that means angle between both is  $0^\circ$  i.e., the power factor is unity and current direction is from grid to vehicle. Furthermore, in the discharging mode the grid current direction is reversed so both are in  $180^\circ$  out of phase. That means the current direction is from vehicle to grid. Figure 6 and 7 show the phase angle between grid voltage and current for V2G and G2V operation.

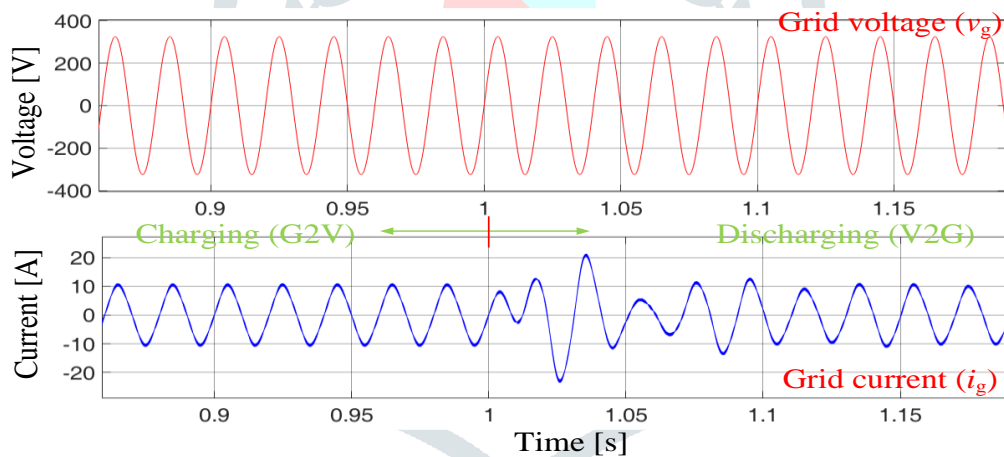


Figure 6: Grid voltage and grid current to verifying the charging and discharging mode

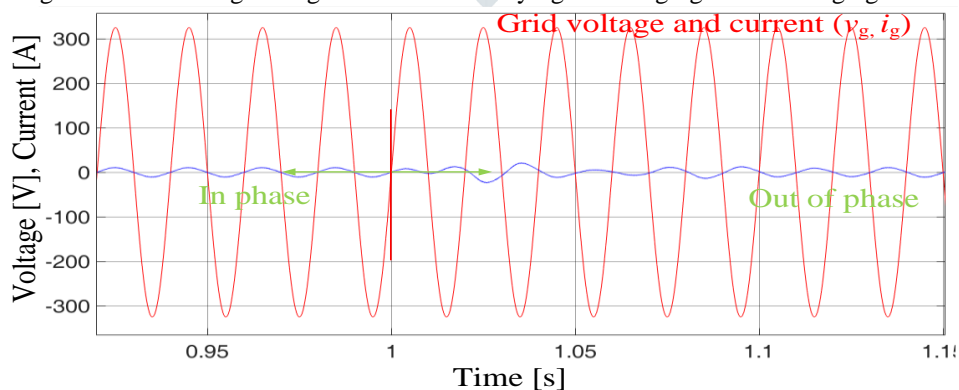


Figure 7: Grid voltage and grid current to validate PFC

For the battery charging operation, the battery current is positive and in the discharging operation battery current is negative. In both cases the DC output voltage, which is regulated by the rectifier is balanced to the 200V. Also, the battery voltage changes as the discharging mode operate. Voltages and currents are balanced in the fraction of time so it shows the controller tracking accuracy. Figure 8 shows the rectifier regulated voltage, battery voltage and battery current for charging and discharging mode of operation.

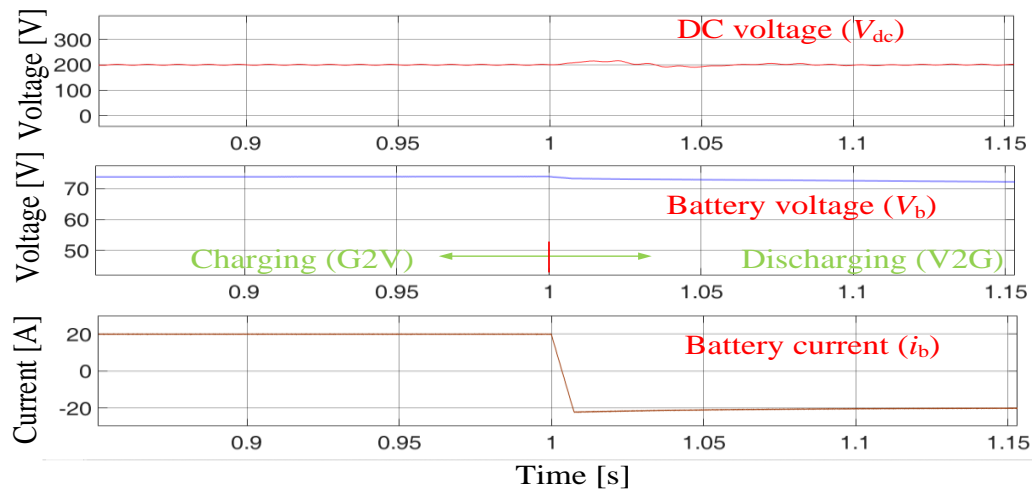


Figure 8: V2G operation with output voltage of rectifier, battery voltage and battery current for charging and discharging mode

For charging mode state of charge (SOC) is increases and for discharging process SOC is decreases. Figure 9 shows the SOC battery voltage and battery current where the slop of the SOC i.e., charging power and discharging power is same and it can be regulated by the controller. A grid current and grid voltage are stable in the fraction of time and improving the performance of the operation.

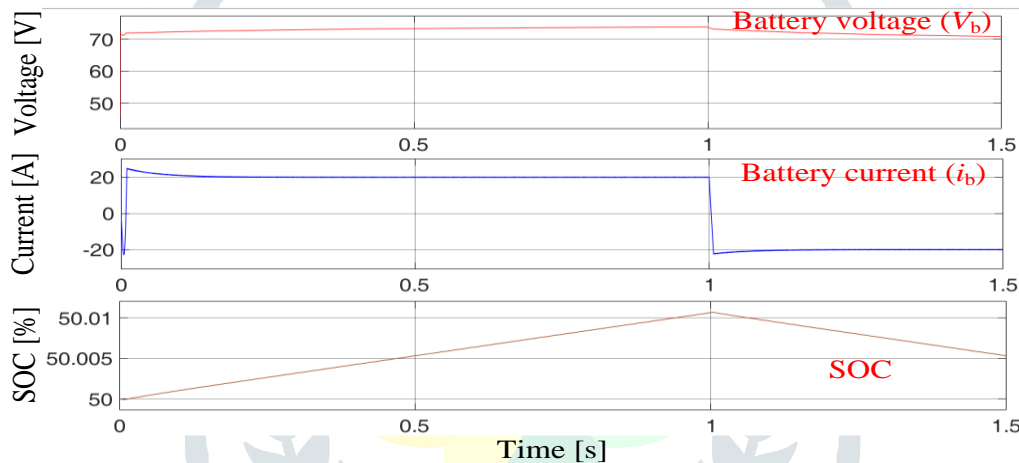


Figure 9: V2G operation with battery voltage, battery current and state of charge (SOC)

#### IV. CONCLUSION

The EV industry has plenty of advantages when compared to fuel-powered cars. But they also involve some disadvantages. The huge number of Electric vehicle sales will alter the electricity load curve especially during the evenings because of owners plugging in the chargers after returning home. Even the percentage is a slight increase, load problem will surely have its effect at a local demand level. There are also transformer losses and overloading of components which are incurred in EVs. Also, the main concern in using EVs is the grid stability issues.

The power achieved is minimum 2kW and maximum is 2.5kW and not higher than that. To increase the power, the specifications of the devices need to be changed accordingly. For calculating the constants of the controllers being used or the value of inductor in the L filter, it is mandatory to take a reference value of power. The following code is designed to successfully design a controller, which is user friendly and the user can control the charging and discharging mode based on the State of Charge of the Electric Vehicle Battery.

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