Research Article
Volume 10:7, 2021

International Journal of Electrical &s Electronic Systems

ISSN: 2332-0796 Open Access

A comparative study of various convert Topologies of Electric vehicles consider V2G Applications

Hamid Rahim*

Department of Science & Technology (NUST), National University, Islamabad, Pakistan.

Abstract

The motive of Vehicle to Grid (V2G) is to optimize the way we produce, transport, and use electricity by turning electric cars into virtual power plants. According to this concept, we can maintain the stability of our power system by using Vehicle to Grid implementation. V2G offers many advantages like real power and reactive power compensation, load control, filter current harmonics, etc. Wind, grid, and PV system also need batteries for storage purposes. Grid uses batteries power during peak hours and transients. Electric vehicles have a battery bank that can be used for this purpose. For V2G applications battery of the electric vehicle should be highly efficient, must be having deep cycling capability, high energy density and a longer life. A set of challenges, benefits, power-flow methods, and charging-discharging techniques are discussed in this paper. This review article briefly explains and compares the control of different topologies adopted for V2G and G2V scheme. Additionally, our research shows that Vehicle to Grid application is advantageous only if efficient battery charging-discharging techniques are used.

Index Terms—Vehicle-to-Grid(V2G); Bi-directional converter; Single-Stage Converter; Electric vehicle; DC-DC converter ;DC-AC converters; Unidirectional & Bidirectional power flow; Battery storage systems.

Keywords: Participatory Management • Employees Commitment • Employees' Performance

Literature Review

Air pollution, carbon emissions, water pollution, depend on limited resources i-e fossil fuels. Fluctuating prices of electricity is the most catastrophic dilemma that world is facing these days. Diesel power plants, factories and vehicles mainly consume fossil fuels. To reduce dependency on these non-renewable energy sources, a study has been con-ducted to discover new energy production techniques. Idea of electrification of transportation sector is briefly described EVs (electrical vehicles) are emerging technology to solve these problems that are discussed. In the upcoming years, elec-tricity consumption would be less than electricity utilization because the consumers will share the surplus electrical power, generated by the renewable energy sources, to the distribution network and thus creating a business opportunity. The rate of research on renewable energy resources is increasing day by day. The rate of research on renewable energy resources and electrical vehicle is increasing day by day shown in (Figure 1).

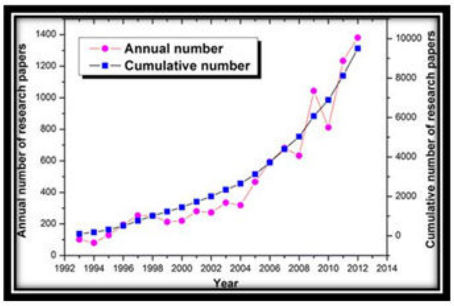

Figure1: Research on electric vehicle

EVs (Electric Vehicles) offer many advantages like real power and reactive power compensation, load control, filter current harmonics, etc. Wind, grid, and PV systems also need batteries for storage purposes grid uses batteries power during peak hours and transients. The main advantages of using EVs (Electric Vehicles) are that they do not contribute in carbon emissions due to the replacement of IC (internal combustion) engines with motors and batteries. Trending of electric vehicle in market is shown in (Figure 2).

***Address to correspondence:** Hamid Rahim, Department of Science & Technology (NUST), National University, Islamabad, Pakistan; E-mail: hraheemeep20.ces@student.nust.edu.pk*

Received: 12 October, 2021; **Accepted:** 26 October, 2021**; Published:** 02 November, 2021

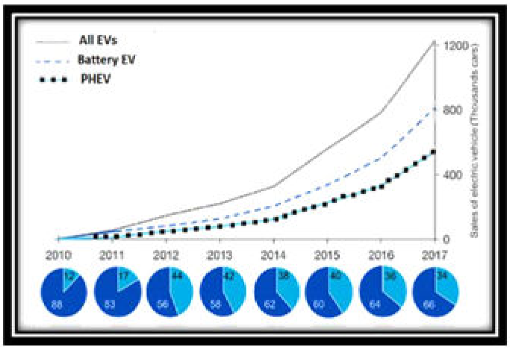

Figure 2: Trend of Electric Vehicle sale

By either sending power or taking power from the grid by establishing a communication link

V2G technology uses energy present in electric vehicle batteries and delivers this energy by discharging batteries, back to the grid during peak hours. Batteries present inside the electric vehicles act as a storage unit of power. Thus, with the help of the Vehicle to Grid (V2G) application, stress on distribution networks and their composition can be reduced. This is done by discharging EV batteries during peak hours of the day. Vehicle to Grid (V2G) application is attractive and relatively new in power systems. For purposes of the research, "Vehicle to Grid (V2G)" is used for both Vehicle to Grid and Grid to Vehicle power flow. Batteries present in the electric vehicle are connected to the grid with the help of a bidirectional charger. Grids also use batteries power during peak hours and transients. The battery banks of EVs can be used for this purpose and can also be used for electricity storage when load demand is low and energy cost is also low. In addition to that, these battery banks act as virtual power plants by discharging the batteries especially during peak hours. Charging of electric vehicle batteries can be done at home or at a dedicated port. Because of these extra EV loads on the grid, which is the main cause of frequency and voltage fluctuations, conditions of instability might arise between the generation and the load side. With the help of EVs (Electric Vehicles) we can control voltage and frequency of the grid by drawing and injecting active and reactive power. Hence, to create a balance between supply and demand, this bidirectional flow of energy between the Electric Vehicles and the distribution system needs to be properly controlled. By using Electric Vehicles we can improve efficiency, reliability, generation dispatch, and stability of the grid. However, to perform these tasks, vehicles should have intelligent and efficient control and a bidirectional dedicated charger, which will allow them to charge and discharge. This designed bidirectional battery charger must have following abilities: High speed Charging and Discharging of Batteries. Filtering of Current Harmonics Active and Reactive Power Support Load control by Valley filling Peak Shaving Grid Conditioning Ability In the strategies of management for Vehicle to Grid and all involved key issues such as battery fatigued, dual-purpose charger, intelligent and independent control of bidirectional charger, and BMS (battery management system) are discussed in detail. In the researchers tried to pursue the practical implementation of Vehicle to Grid application that will decrease emissions of carbon gasses due to the replaced internal combustion engines. It also increases the dependency on renewable energy sources. In an overview of V2G (Vehicle to Grid) technology has been given. Management of Battery for longer life and high efficiency is explained in

In utilization of Electric vehicles has been dis-cussed for frequency control. Related research is seen where integration of the electrical vehicle with the grid has been discussed; nevertheless, more research is ongoing on battery management and energy storage rather than the Vehicle to grid implementation concept. The influence of EVs on the grid system and its interpretation using the load flow method has been explained the concept of gaining and delivering power to the grid by idly parked EVs is discussed this concept needs three elements: link with the grid, bidirectional communication between EV and the grid, and intelligent metering.

In Figure 3, all requirements and components needed for Vehicle to Grid system are represented. There are six major subsystems of the V2G system:

1) Energy Sources
2) ISO
3) Charging Foundation
4) Bi-Directional Flow of Power
5) Intelligent Metering and Control
6) Battery Charger and Management System for Charging. A summary of the specifications and requirements of bidirectional AC to DC converters and all topologies of the power c0onverters and their performance are discussed Moreover, all topologies for conversion of AC to DC and DC to DC by using the AC to DC and DC to DC converter connected by a DC link capacitor that helps to regulate voltage is present In grid-tied inverters, used for the vehicle to grid mode, there are many ways in which we can synchronize an inverter to the grid. For synchronization of the inverter, voltage, frequency, phase of the inverter, etc. must be the same as that of the grid. Many methods for grid synchronization like Delayed Signal Cancellation, Zero Crossing Detection, Artificial Intelligence, Adaptive Notch Filter, etc. are explained (Figure- 3).

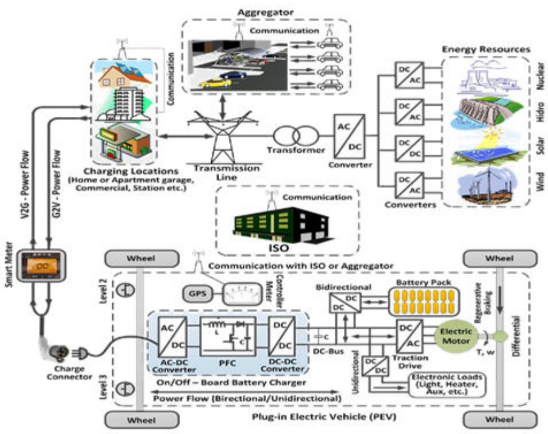

Figure3: Vehicle to Grid System

The synchronization of inverter with the grid, by hysteresis current control is discussed In a major constraint for the vehicle to grid implementation i-e battery degradation is discussed. In requirements for intelligent communication and reduced energy losses are discussed. High-speed charging and discharging of Electric vehicles affect battery cycle life and storage ability of batteries present in EV. These problems listed above can be resolved by proper communication between the operator of the grid and owners of EV. Topologies and advantages of V2G implementation are reviewed.

METHODS OF POWER FLOW FOR V2G

Communication and control are the most important parts of the V2G system for services such as frequency regulation, voltage regulation, power balance, and tracking of power prices and spinning reserves. Com-medication between the battery of the vehicle and the grid is essential for managing both V2G and G2V operations.

In general, to report the status of the battery and receive other commands, communications must be bidirectional. Measuring and control of power capacity and SOC (state of charge) are a problem for V2G implementation. Maximization of profit, reduction of carbon emissions in the atmosphere, and improvement in the stability of the grid are a main areas under consideration. Both on and off-board bi-directional chargers have been introduced to support EV Bidirectional power flow. With the help of smart metering, we can combine all renewable energy and Electric Vehicle controllable loads In advantages of using GPS and onboard meters are shown. With the help of smart meters and sensors on each charging location, we can measure and deliver collected data to the main control center for robust control over the entire system. Sharing of data is done through a field network explain Protocols of communication (Sigsbee, Z-Wave, Bluetooth, and Home Plug) have been discussed

Institute of Electrical and Electronics Engineers (IEEE) and Society of Automotive Engineers (SAE) give specifications and requirements for necessary communications shown without highly efficient power electronic devices, EV chargers generate a lot of harmonics that disturb the grid

Allowable limit of dc current and harmonic into the grid is discussed in Institute of Electrical and Electronics Engineers (IEEE) and Institute of Electrical and Electronics Engineers (IEEE)-1547 Society of Automotive Engineers (SAE) -2894 and International Electro technical Com-mission (IEC) -1000–3-6 Therefore In active power converter topologies for reduction of harmonic currents and power factor correction (PFC) are presented.

Unidirectional V2G

Unidirectional Vehicle to Grid is a technology in which power is flowing in only one direction between the electrical vehicle and grid. Electric Vehicles containing one-directional chargers can only charge the EV but cannot deliver power to the grid. It is more attractive because it needs only a dedicated port, hardware and software for the battery management system. This technique enhances the performance of the grid by increasing grid stability and acting as spinning reserve. To encourage V2G technology smart trading policy is adopted. For different methods of battery charging Table 1 gives the value of voltage, and current, and real power. Very low additional cost is required for the Implementation of this system only a bridge of diode for rectification with filtering mechanism and dc to dc conversion stage is needed for this purpose. To restrict weight, size, cost, and losses single-stage converters are used For isolation requirements, isolated HF transformers can be used By designing one-directional chargers, we can deliver or extract reactive power by controlling the phase angle of the current. For unidirectional V2G, extra transmission expenses would not be required in many regions

The simplicity of Control makes easy for grid operators to handle severely loaded transmission lines and feeders. Study shows that one-directional charging has established intelligent charging techniques that give more advantages to the utility and owner of the vehicle. researchers also search the influence of electric vehicles on-grid systems the one-directional charger can satisfy most utility goals with high performance as compared to the, expenses, charging current control, and other safety matters linked with two-directional chargers with a higher number of electric vehicles Authors in simulate the main advantages and influences by combining all efforts linked with control and working mechanism of one-directional V2G. Unidirectional techniques provide fewer advantages Comparisons with bidirectional Vehicle to Grid algorithms, yet it is less complex to implement.

Bidirectional V2G

Bidirectional V2G is a technique in which power is flowing in both directions among the electrical vehicle and utility grid shown in (Figure -4) below.

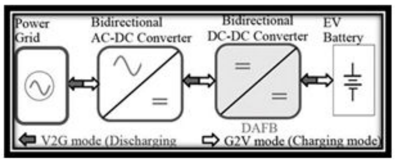

Figure4: Bidirectional power transfer

A comparison study has shown Bidirectional V2G has several benefits over unidirectional Vehicle to Grid. For the two-sided power flow, the bidirectional charger holds two stages:

1) Bi-directional AC to DC stage capable of P.F improve-mint which is done by reducing the harmonics.

2) DC to DC converter used to control the Electric Vehicle charging and discharging.

When working in G2V operation, the EV charger must draw a zero harmonic current with a defined constant phase angle to control apparent power. During Vehicle to Grid operation, the charger must transfer pure sinusoidal current to the grid.

Most research has been conducted unidirectional Vehicle to Grid because there are severe hurdles for the Implementation of bidirectional V2G. These challenges involve battery degradation due to fast charging and discharging. Synchronization, metering issues, and interface concern some extra challenges and require more cost than unidirectional V2G. Also there are synchronization and protection problems present in bidirectional V2G. Bidirectional power flow is cur-gently unavailable with existing Plug-in Electric Vehicles because EV customers want a power guarantee to ensure that the vehicle charging (SOC) is enough for their own use extensive safety measures are discussed which will be required for a successful and efficient bidirectional charger. A different battery Management System (BMS) is adopted for EVs for Bi-directional V2G.

POWER CONVERTERS FOR V2G A. Single Stage converter

For a battery charger, a single-stage converter is the most uncomplicated structure with the minimum components re-quire for implementation. Single-stage topology is attractive for reducing the weight as well as the size of the charger, due to a reduction in switching losses and thus improved efficiency. The more useful single stage converters are

H-Bridge Converters.

Full Bridge Converters.

Multi-level converters.

Different types of every topology have been developed and are

briefly explained many topologies which match the pattern of single-stage converters have been studied and discussed. A single inductor is used as an AC filter. Afterward, a FB (full bridge) switch converter which consists of switches, and conducts bidirectional power flow, is used [?]. The power transfer component stage is the modeling of inductance called leakage inductance of the HF transformer. After the transformer, there is another Full bridge converter present on the DC-side and a capacitor is used on the output side for regulating output. This capacitor further performs the function of the DC filter and removes the ripple harmonics from the current. This topology is suggested for both three-phase power and single-phase power [?] for DC voltage of V=600V, rated power of S=40KVA, and operating frequency f=6 kHz.

Half Bridge AC-to-DC Converter: Simplest topology among all bidirectional AC-DC converters is Half-Bridge AC-DC Converter. To achieve boost operation at the dc side, it utilizes two controllable switches the main Drawback for this topology is when switches are in off state, all dc voltage appears across these switches, therefore there is a huge stress of voltage on these switches. Weight & size of the charger is increased due to pair of big capacitors present at the DC side. For dc-side voltage regulation controller is usually present in an external loop and for AC side current wave shaping and power factor controller is commonly present in an internal loop (Figure -5).

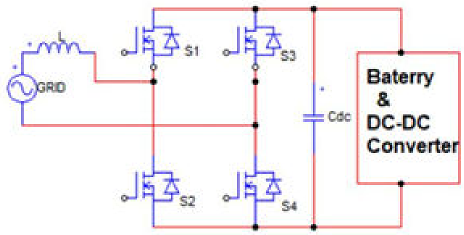

Figure5: Half Bridge AC-to-DC Converter

Full Bridge AC-to-DC Converter: Full bridge topology is consists of a total of 4 MOSFETs. It boosts power with the capability of power factor improvement. In full-bridge converter, voltage stresses on the switches is half of the battery voltage due to division of battery voltage between two switches and conduction losses are also reduced. Due to this, when voltages of battery appear on the AC side, the power loss in full-bridge is half relative to the half bridge topology, thus decreasing the switching loss make full bridge converter more efficient than half-bridge in applications of high power. While in the half bridge converter, the DC voltage holds harmonic components that are multiple of grid frequency. Due to these harmonics, waveform gets distorted and requires extra filtering circuits for harmonic reduction. This converter can also be controlled with a PWM controller. A PWM is applied to provide the control input and it also is used as a controlling factor for regulating the DC voltage, whereas to control the output voltage variable frequency control is used (Figure -6).

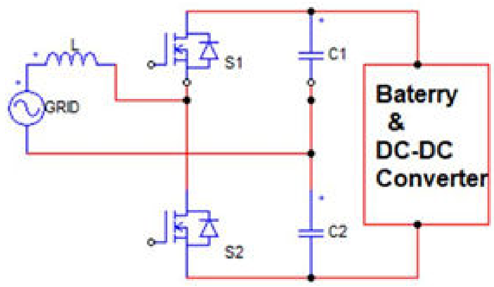

Figure6: Full Bridge AC-to-DC Converter

Multilevel Converter: Multilevel PWM Converter is a kind of AC to DC Boost converter. By using multilevel Pulse Width Modulation converters, voltage stress on the switches is reduced because of the division of battery voltage between switches and conduction losses also reduce, and this converter offer benefits in terms of less switch power loss due to less switching frequency, improved power factor, reduced harmonics on grid side and regulated voltage on Battery side. Multilevel PWM AC to DC converters is fit for high power and higher voltage purposes. The drawbacks include the cost of the power circuit, complex control which decreases its priority where only one charging level is desired. In various single phases 3 levels PWM AC to DC topologies are described (Figure -7).

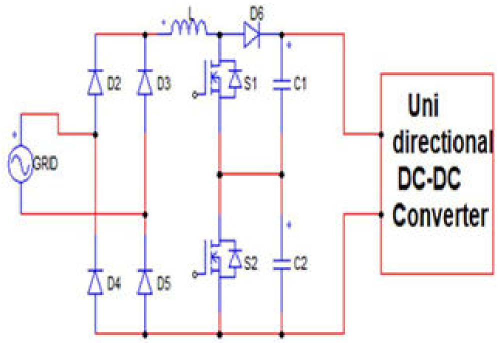

Figure7: Multilevel Converter

Diode Clamp Multilevel Converter: In diode clamp converter is briefly described. Each switch experiences voltage stress on the MOSFETs are half of the battery voltage (VDC /2). An outer loop is used for maintaining and regulating the battery voltage and an internal loop used for harmonic less sinusoidal and better quality current and it also improves PF at the grid side. A PF= 0.998 and efficiency =90% at the power=900W have been reported in with the help of a lab prototype.

Switched Clamp Multilevel Converter: In a multi-level switched clamp converter is presented, and this topology is also shown in Fig. 9. Voltage stress on 2 switches (MOSFET/IGBT) of SCM Converter is VDC (battery voltage) and voltage stress on other 2 switches (MOSFET/IGBT) of SCM Converter is VDC/2. In the control technique is described in this topology, for tracking the reference current, current control is designed in the internal loop. Topology in exhibits a PF=0.999 and an efficiency=89% (Figure -8).

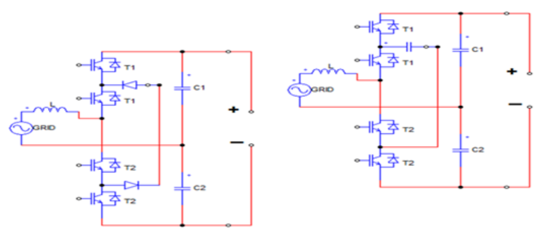

Figure8: Switched Clamp Multilevel Converter

Capacitor Clamped Multilevel Converter: In the capacitor Clamped Multilevel Converter topology has been described. A flying capacitor is utilized and is also shown in Fig.10. Voltage stress on 4 MOSFETs is half of the battery voltage (VDC/2). Control design for capacitor clamp converter is the same as that explained in which is also uses for the multilevel switched clamp converter. Laboratory results achieved in from the model, exhibits an efficiency = 86% with a power factor almost unity for power=1000W (Figure -9).

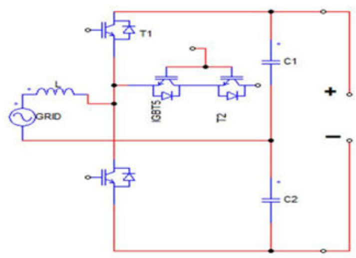

Figure9: Capacitor Clamped Multilevel Converter

Three-Level PWM Converter: 3-level PWM topology based on the concept of half-bridge converter presented in Same as the Switched Clamped Multilevel topology. Voltage stress on 2 switches of this converter is VDC (battery voltage), and voltage stress on other 2 switches of this converter is VDC/2. Concept of double boost operation is used in this converter because the voltage generated is twice the voltage of the grid. With the help of a lab prototype a power factor of almost 0.994 can be achieved through experimental results. In Other bidirectional 3-level and 5-level converters with bidirectional power flow and more number of switches are reviewed (Figure -10).

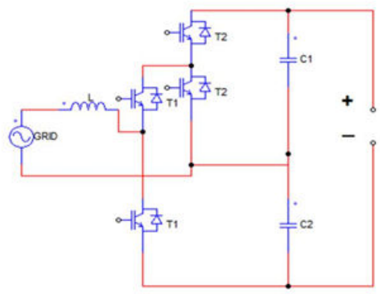

Figure10: Three-Level PWM Converter

Isolated AC-DC Converter: A single-stage isolated bidirectional charger is proposed in and is shown in fig 5. Due to safety reasons, isolation for electric vehicle chargers can be a desirable feature This proposed converter con-sists of 2 active bridges with an intermediate HF AC resonant circuit. The power density of this converter is increased due to the resonant circuit and the high-frequency AC and for the operation of the soft-switching, a resonant tank is used. Control scheme purposed in this converter uses square wave modulation to control switches of the bridge present in the grid side. For controlling active bridge present at battery side, control signal is generated by shifting phase between –90and 90by assuming the first modulating signal as a reference to allow bidirectional power flow. By using this control scheme, we can achieve a PF=1. Current contains harmonics multiple of the frequency of the grid on DC side, due to which the waveform gets distorted and requires an extra fitter for filtering the harmonics (Figure- 11).

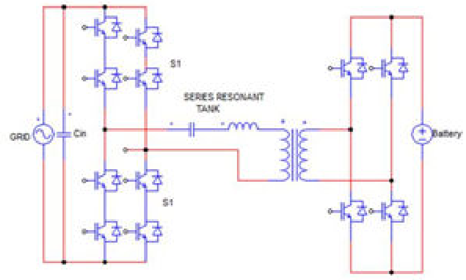

Figure11: Isolated AC-DC Converter

Swiss Front-End Charger Topology: The circuit of the Swiss front end topology is shown in basically, it contains front end active AC to DC converter that sets up parallel connections for DC to DC topology as given in the figure below. Main advantage of Swiss Front-End Charger Topology is negligible switching losses due to frequency commutation of switches. Therefore, with the help of this topology, we can make small size, low weight, and high efficient onboard charger.(Figure-12).

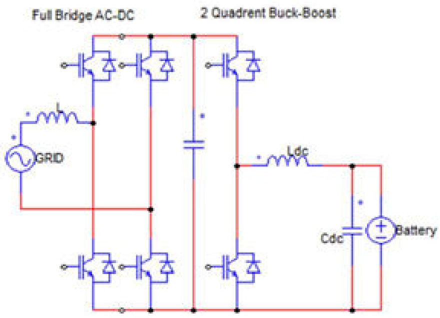

Figure12: Swiss Front-End Charger Topology

STAGE TOPOLOGIES

Most of the chargers for electric vehicles (EV) reported in the literature consist of two stages. In comparison to single-stage topologies, 2 stage topologies have more efficient and improved performance because these topologies aid multilevel charging. A study of the different two-stage topologies is as follows:

Full Bridge with 2 Quadrant Buck Boost: FB converter with 2 Quadrant Buck-Boost converter is shown in the figure

The cascaded combination of the buck-boost converter with a 1-phase full-bridge converter is the most common converter for the two-directional power flow explained For ac-side, power factor correction (PFC) current wave shaping and regulating the DC voltage Single-phase AC to DC topology is responsible, while the direction of the current of the battery for charging and discharging is controlled by a DC-to-DC converter. The control schemes use for this topology are the same as those discussed The external loop is used to control the battery voltage and to produce the amplitude of reference current on the AC side.(Figure-13).

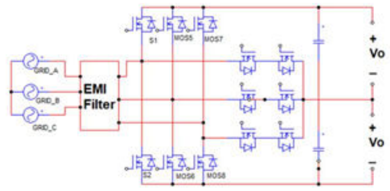

Figure13: Split Phase 3 Leg AC to DC with 2-Quadrant Buck Boost

Bidirectional 3-phase VSI Topology: This topology contains a battery group that is connected with a DC-DC stage & a 3-phase VSI. Moreover, to reduce harmonics present in the line current the LCL filter is employed between the grid and inverter. DC to DC converter will act like a buck converter or boost converter depending upon the direction of battery current.

Full-Bridge Rectifier with DAB DC Converter: For connecting the Full-Bridge with the Dual Active Bridge Con-verger a capacitor is used for this topology. This electrolytic High Voltage capacitor provides the necessary buffering and works as a filter on the DC side. Due to their large size and bulkiness, these types of capacitors are not used for portable chargers. The main goal here is to make small-size chargers by reducing the size of this large and heavy capacitor through intelligent control methods. The converter shown in (Figure-14).

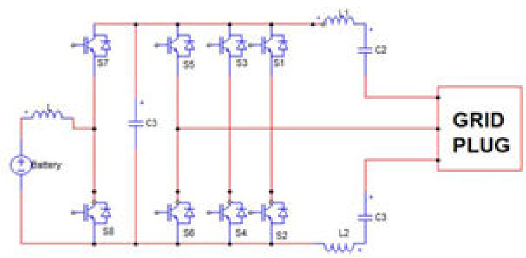

Figure14: Full-Bridge Rectifier with DAB DC Converter

INTEGRATED TOPOLOGIES

In classical EV arrangements, a circuit of the inverter is used for traction which is not present with in the battery charger. The basic purpose of this topology is to reduce the size, cost, components and weight. A review of the different converters is given below.

Integration of AC-to-DC with DC-to-DC Converter: The concept of integration of chargers with EVs was first introduced in 2009. A cascaded combination of a diode rectifier and buck-boost converter is the original topology but research has been done on modification of

DC-DC converter design, which operates in 3 different modes:

Charging in Plug-in Mode.

Discharging of battery by delivering power to HVD point.

Charging by taking power from the High Voltage point.

Due to the presence of a diode rectifier power flow fromV2G (vehicle to grid) is not possible. Therefore a topology to maintain V2G and G2V operation is presented in to achieve an improved power factor equal to unity and reduce harmonics in current. A 3-level Pulse Width Modulation AC to DC converter is used on the AC sides. Pulse Width Modulation control is used as a control signal for the charger. Control and other operation are described the designed charger circuit capable of multiple operations, does not utilize any external control device. Therefore, efficient and comprehensive control is needed for this charger to operate the battery in the safe zone.

Conclusion

Conclusively, each topology used, has its own pros and cons. The choice of the topology really depends on the preferences by the manufacturers for their battery chargers. If a low power, relatively slow, single phase design is required, the single stage convertor topologies can be used. Three phase topologies are usually used for high power and efficient design. Isolated converters provide isolation and thus should be an essential part of any design. 2 stage and 3 stage topologies offer high efficiency and robust control over the power flow and are also capable of bidirectional flow of power which allows both V2G and G2V applications simultaneously in a highly efficient manner. Thus the choice of topology is a question of preferences of a design. More sophisticated Topologies offer high power handling capability, efficiency and bi-directional power flow.

References

1. Thrimawithana D J. Madawala U K, Two-name R. and Vilathgamuwa D M. “A novel matrix converter based resonant dual active bridge for v2g applications.” IEEE 10(2012):503–508.
2. Ibrahim S, Taghavi M, Tanami F, and H Orate. “A single-phase integrated bidirectional plug-in hybrid electric vehicle battery charger.” in IECON 2014-40th Annual Conference of the IEEE Industrial Elect Sock 14(2014):1137–1142.
3. Tonic J, and Kempton W. “Using fleets of electric-drive vehicles for grid support.” J power sour 168(2007):459–468.
4. Wilma M, and Rein P T. “Review of benefits and challenges of vehicle-to-grid technology.” IEEE Energy Convert Cong Expo 19(2012):3082–3089.
5. Dharmakeerthi C, Mithulananthan N, and Sasha T K. “Overview of the impacts of plug-in electric vehicles on the power grid.” Innovate Smart Grid Techno 6(2011):1–8.
6. Ma Y, Houghton T, Crude A, and Infield D. “Modeling the benefits of vehicle-to-grid technology to a power system.” IEEE Trans power sys 27 (2012):1012–1020.
7. Resale S, Farah E, and. Khorramdel v. “Probabilistic analysis of plug-in electric vehicles impact on electrical grid through homes and parking lots.” IEEE Transact Sustain Energy. 4 (2013):1024–1033.
8. Kempton W, and Tonic J. “Vehicle-to-grid power fundamentals: Calculating capacity and net revenue.” J power sour 144 (2005):268–279.

How cite to this article: Hamid R. "A comparative study of various convert Topologies of Electric vehicles consider V2G Applications " *Int J Electr Electr Syst* 10 (2021) : 1000256.