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Performance of Modular Multilevel Converter in Electric Vehicles Charging Station

Journal of Electrical Systems

Abstract: - The awareness of air pollution is the main reason for the development of Electric Vehicles. Hence, the many number of Electric vehicle connected to grid produce power quality problem in conversion of AC-DC. In this paper, to avoid this drawback, the MATLAB/SIMULINK model of Modular Multi Level Converter is implemented in charging station. MMC not only provide bidirectional flow but also improve power quality. The converter works on boost mode and buck mode. In G2V, the boost mode is for charging the battery of electric vehicle and buck mode is discharging the battery. For, the G2V, the buck mode reduces the voltage to charge the battery with current or voltage constant which is about the state of the charge of the battery. The out of the battery is pure dc with mmc which replace the filter also. It increases the life of the battery. The model of the MMC-based charger for electric vehicle was created in MATLAB/Simulink, and simulation results shows the output power of the MMC and circulation current is controlled.

Keywords: Electric vehicle, Modular Multilevel Converter (MMC), Grid to Vehicle (G2V), Vehicle to Grid (V2G), MATLAB.

I. INTRODUCTION

Now a days, to reduce the transport pollution, fuel based vehicles are reduced by electric vehicle. Electric drive vehicles are appealing because they emit less pollutants on the road, can possibly reinforce the power grid by offering ancillary services, and have lower running costs than fossil fuels. They are also more energy efficient. Electric motors are used to propel a vehicle which uses electrical energy to operate is electric vehicle Charging the electric vehicle is challenging part for the researchers. Because it does not emit emissions like an internal combustion engine, it has a higher fuel economy than gasoline. However, the automobile industry is not yet fully committed to pure electric vehicles due to an issue with current battery technology. The battery is the most popular storage device used in electric vehicles for storing electric energy. It can store a lot of energy in a tiny amount of space and weight [1]. EV batteries can be powered by a single phase or three phase power supply. EV chargers are connected to this system due to the widespread availability of single supply ports. A three-phase supply system, on the other hand, provides more power and faster charging. The Fig. 1 Shows the block diagram of charging electric vehicle from grid. The power source for the Electric vehicle is supplied by the grid. The transformer is used to reduce the high voltage from the grid to medium voltage or low level voltage.

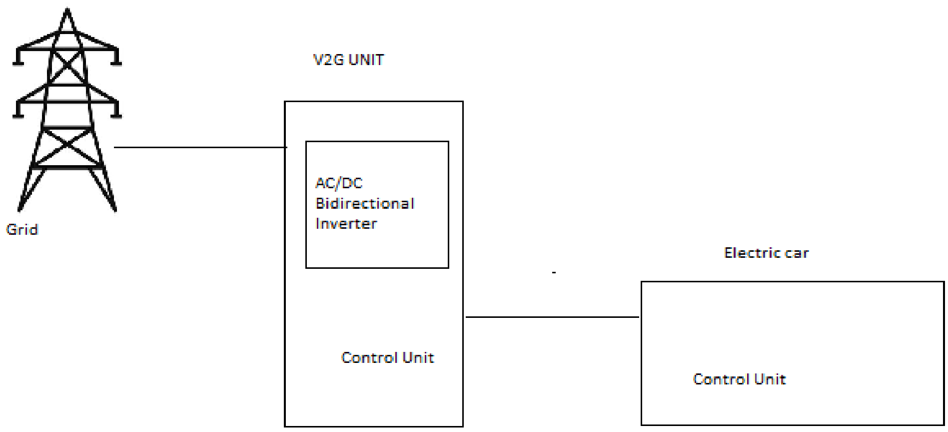

Figure 1. Block Diagram of Electric Vehicle Charger

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The main part in the charging station is converter which helps to convert desired voltage to electric vehicle. Traditionally, voltage source converters are used to convert the DC-DC. Due to many switching loss and bulk connection with filter, modular multi-level inverter are used. Modular Multilevel Converter (MMC) offers modular structure, expandable capacity, low cost for redundancy and fault tolerant operation, and minimal THD [3]. Taking into account the foregoing, this work provides a control technique with Modular Multi-level inverter for decreasing the current THD induced by a specific grid to vehicle and vehicle to grid voltage harmonic.

II. LITERATURE SURVEY

The development of battery charger systems for electric cars (EVs) has gotten a lot more attention from researchers, automakers, and government agencies [6]. An electric vehicle charger is a type of power converter that converts electric energy from the grid to a storage device. It serves as a vital link between the grid and the battery pack of electric vehicles [7]. The traditional converters like two level voltage source converters convert the input DC to the desired voltage with some harmonics. To reduce the harmonics the LC filters are used which makes the circuit more difficult. To reduce these harmonics without filter and switching loss many developed converters are used. Hamed Nademi [5] developed a two layer control framework in modular multi-level converter which is used to reduce the dc ripples and decrease the harmonic current in the grid. Erdem Gümrükcü [9] proposed an optimal management method for horizontal and vertical load unbalancing with MMC arms. In this power flow management algorithm is implemented which helps to control the circulating current and regulate the module voltages to provide sufficient energy with pure desired DC. D. Selvabharathi [8] discussed about the power quality issues like harmonics, switching losses and also proposed a design in MATLAB with inductor and capacitor to reduce harmonics and also increase the life span of the battery. Gowthamraj Rajendran [10] compared different level of Vienna rectifier to provide the better efficiency and also fact DC charging the vehicle. Michail Vasiladiotis [11] focuses on power converter for interfacing medium voltage AC grid to Electric Vehicle Batteries. In this transformer less conversion process takes place help of Cascaded H-bridge converter to achieve the high currents. This survey concludes about converter is important in charging the battery of EV and also improves the power quality.

III. PROPOSED METHODOLOGY

The growing number of electric cars (EVs) concentrating in congested metropolitan areas necessitates the construction of large-scale EV charging stations [4]. While charging the electric vehicle in the charger box, the supply from the grid side sent to the EV battery through the converter. The converter which helps to convert varying DC level to desired DC output. The conventional converter has filter to reduce the harmonics this makes the circuit so complex. To reduce this complex circuit, modular multilevel converter is used which has no filter. This MMC has five level switching to reduce the harmonics and while using minimum level, it will reduce the switching loss. The modular multi-level inverter is mainly used for providing power quality and sufficient energy to the Electric Vehicle Battery. This increases the battery life of the Electric Vehicle. This paper presents a system configuration for a large-scale EV charging system that uses a modular multilevel converter (MMC) topology for the grid-side interface.

A. Modular Multi Level Converter

Modular multi-level converter have been used over conventional converter for medium level voltage and high level voltage. This converter applications are depend on capability of transformer-less conversion, produce less harmonics and yield high efficiency [12]. MMC is classified into two types depends on the phase, they are single-phase MMC, Three Phase MMC [13]. In this for Medium Level voltage Electric Vehicle, three phase MMC is used. The Basic Structure of Three Phase Modular Multi-level Converter is shown in Fig.2.

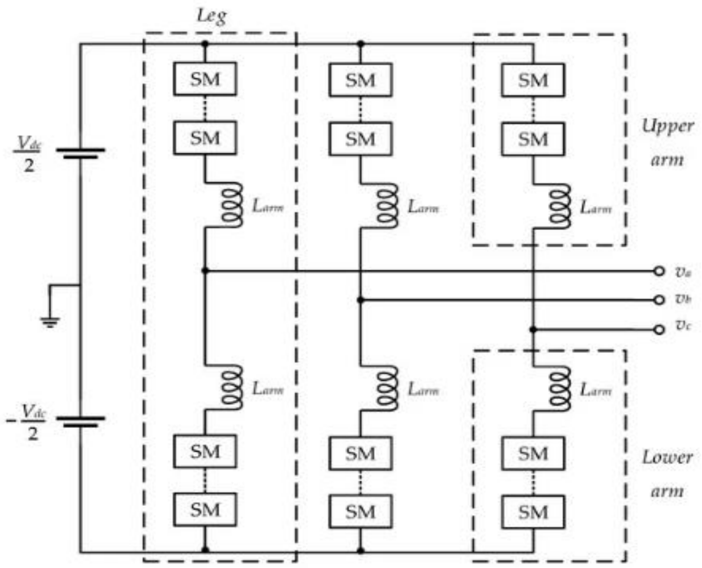

Figure 2. Basic Structure of Three Phase Modular Multi-Level Converter

The MMC is mainly used for conversion of varying input to DC/AC voltage to desired DC/AC voltage without transformer or Filters. It has N level Submodules and separate into Upper arm and Lower arm. The submodules connected in the arms are operating separately. This submodules connected in series to increase the voltage Level.in the output side. Each Submodules are having IGBT devices and capacitance[14]. Capacitor Average values in every submodules are U_b/N in both upper and lower arm. The N number of submodules gives output voltage in N+1 Level. The advantages on the specific applications are suppression of circulating current [14], energy storing in EV batteries [15], balancing the capacitor Voltage [16], and controlling the current in Upper arm and Lower arm [17], Hybrid Renewable Energy System [18], Motor Drives [19].

IV. SIMULATION ANALYSIS

The below MATLAB/SIMULINK shows the Vehicle to grid and Grid to vehicle bidirectional Electric Vehicle charger with Modular Multi Level Converter is used to provide low harmonics in the output side voltage.

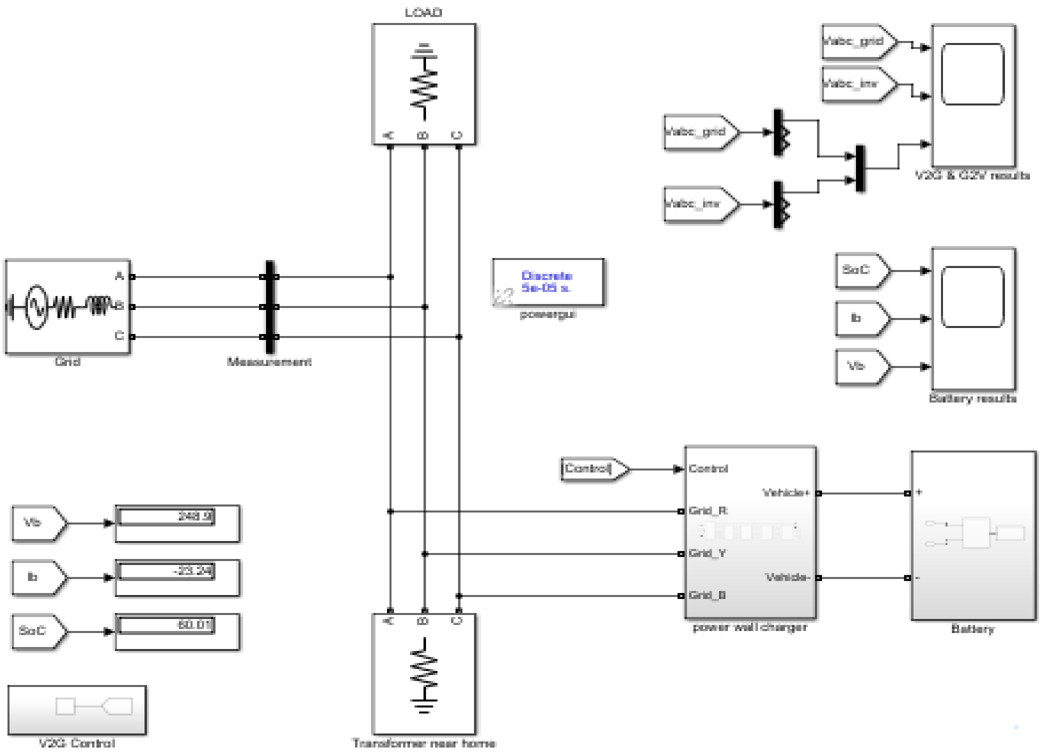

Figure 3. SIMULINK model of V2G – G2V

The three phase Grid source with V_{rms} 480 is given to the Load. The source for the transformer is taken in between the Grid and load. The transformer placed for stepdown the voltage for Electric Vehicle Battery. The step down voltage send to the Wall Charger. The wall charger consists of battery controller, switching controller, Modular multi-level converter, Buck-Boost converter, where the DC varying input voltage is convert to the Desired constant output DC voltage. This output is given to the Electric Vehicle to charge the Battery with constant pure DC voltage.

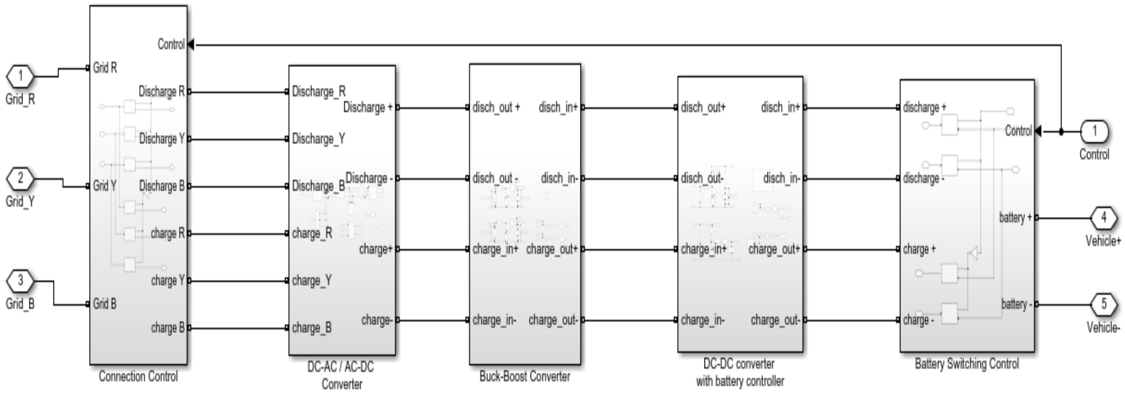

Figure 4 Blocks of Charger unit

The above fig.4 . Shows the components inside the charger for Charging the Electric Vehicle. The charger used for EV has connection box, DC-AC/AC-DC converter, Buck Boost Converter, DC-DC converter with battery controller and Battery Switching Control. The connection box used in the charger is the purpose for plugin the Electric vehicle where all the components are kept. While power through vehicle to grid, it is vice versa. The DC-AC/AC-DC converter is Bidirectional Modular Multilevel Converter. This can act as converter when charging from Grid to EV battery and convert grid AC source to Electric vehicle Battery desired DC output. This also act as inverter when charging from vehicle to grid, which inverts the DC voltage to AC voltage. The Buck-Boost converter can convert output side DC magnitude is greater than the input DC magnitude. The DC-DC converter with battery controller is for battery in Electric Vehicle, to provide constant DC the Battery. The Switching control is used for charging and discharging the voltages from vehicle to grid and grid to vehicle. When switch is activate, the charging is from Grid to Battery and switch is in off condition, the discharging from vehicle to grid. In this power Charger, main component is MMC which has five level and applicable for medium level voltage applications like charging the Electric Vehicle Battery.

The Fig. 5 . Shows the Modular Multi-level converter with five level switching. In this three phase MMC, upper arm having 4 SM (Submodules) and lower arm having 4 SM. Each SM consists of half bridge with capacitor. Generally voltage and power of the converter increased by connecting the number of Submodules in series. In this, 24 Submodules are used to convert grid side voltage to desired voltage in charger for Electric Vehicle. In each arm the circulating current in the upper arm and lower arm is equal to addition of the half current in a phase (i_{a}), third or fifth of the DC current (i_{dc}), and circulating current (i_{c}), the equation is formed by

$$i_{upa} = \frac{i_a}{2} + \frac{i_{dc}}{3} + i_{za}$$

$$i_{lowa} = -\frac{i_a}{2} + \frac{i_{dc}}{3} + i_{za}$$ [1] & [2]

The sum of all the current which is circulating in the arms or phases is Zero, because the upper arm indicates positive sign and the lower arm indicates negative sign. The Each phase output voltage is N+1levels. If the number of arms is 4 means, the output voltage has five levels. This MMC is five level voltage which is applicable medium voltage applications.

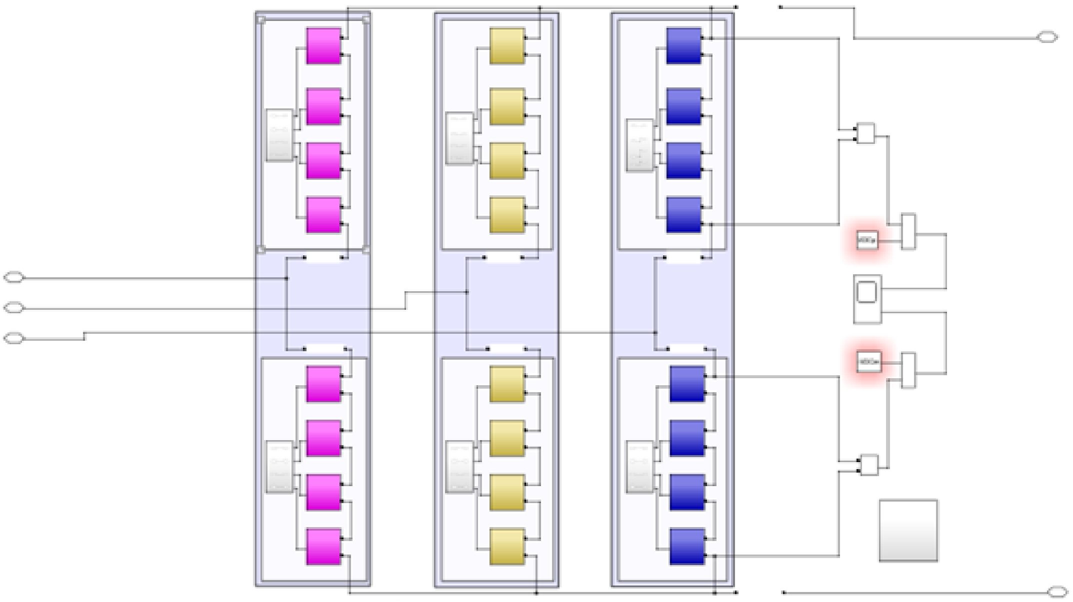

Figure 5 . Circuit Model of Three Phase MMC

The formula for calculating Arm Voltage of the MMC is given,

$$v_{arm} = \sum_{i=0}^{n} v_{SM} + L_{arm} \frac{di_{arm}}{dt} + R_{arm} i_{arm}$$ [3]

Where, L arm is Lower arm,
SM is voltage in Submodules,
di arm is change in current
The output Voltage of the MMC is,

$$u_k - u_0 = v_{arm}$$ [4]

Where, u_k is the phase and k is the number of phase.

Generally, the harmonics present in the output side is reduced by the LC filter. In this MMC the filter is not required, the submodules present in the converter consists of IGBT which circulating current is controlled by the each arm in the phase. By controlling the circulating current, the harmonics reduced. This makes the circuit simple. This bidirectional converter act as inverter as well as converter depends upon the charging and discharging of the battery in Electric Vehicle.

V. SIMULATION RESULTS

The below fig.6 . shows the output waveform of Modular Multilevel Converter with upper arm and lower arm waveform in top and bottom respectively. Both waveform has Five level depends on the number submodules. Here only 4 Submodules are used for medium voltage Electric Vehicle application with no LC filter. Here, by controlling the circulating current in the arm by the arm capacitor , harmonics are reduced when compared to conventional Voltage Source Converter.

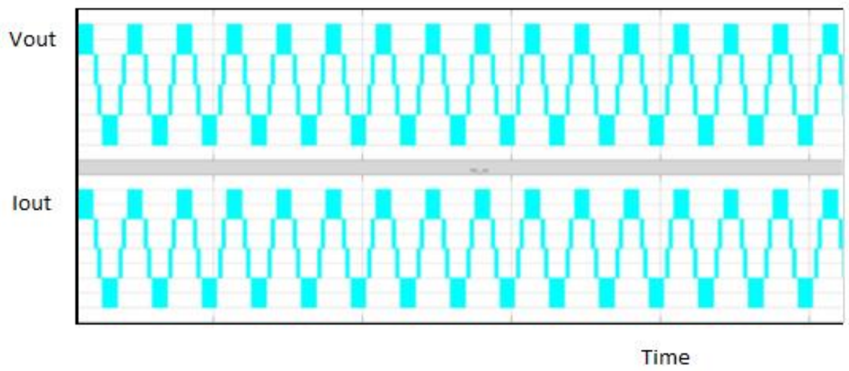

Figure 6 . Output waveform of upper Arm and Lower arm of MMC

The Fig.7 shows the output waveform of the MMC to Grid. The three phase voltage of Vrms of 480v with high frequency is given to the MMC. The waveform has high harmonics. Each phases are shows clearly. The R phase in red colour, Y phase in yellow colour, B phase in blue colour. This input three phase AC voltage given to the MMC where the AC voltage converted into DC voltage. This bidirectional MMC acts as both converter and inverter when charging and discharging respectively.

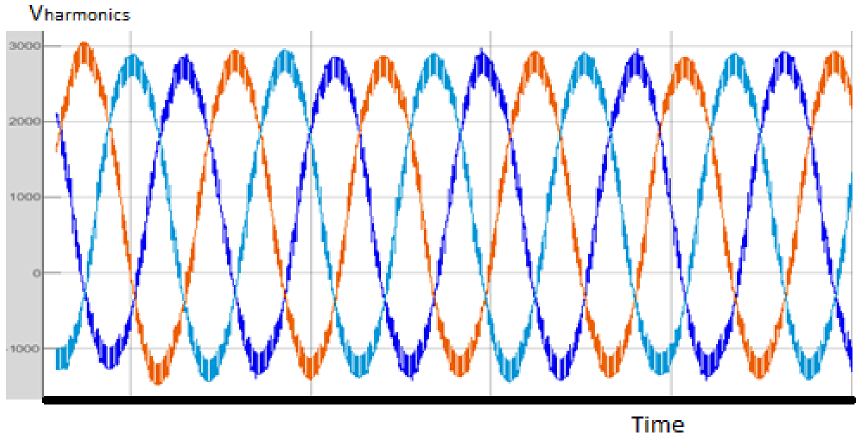

Figure 7. Output waveform of Grid to MMC

The Fig. 8. shows the output waveform of Battery Charging. The three outputs are State of Charge(SoC), Current(Ib), Voltage(Vc). The state of charge is charge level of the battery capacity. It expressed in %. In this 67% of level charged. In conventional method, SoC is 59%. By using this, level of charge is increased by 6% and achieved pure DC voltage. In the waveform, where red line shows the State of charge of the battery, yellow line is DC voltage charging in the battery and the blue is Current in Electric vehicle battery. When reducing the harmonics with reducing circulating current, life of the battery is increased.

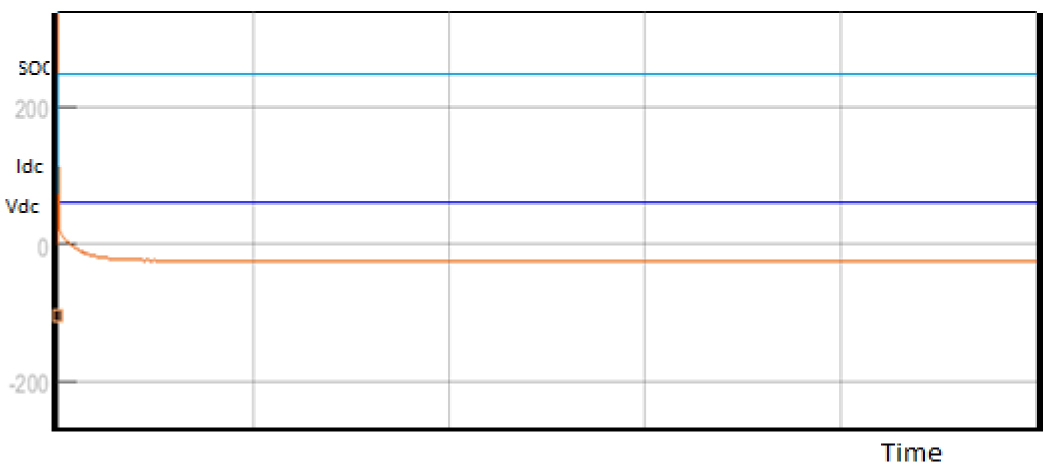

Figure 8 .Output waveform of Charging Battery from G2V

The Fig.9.shows the waveform of the Vehicle to grid and Grid to vehicle. The three phase high voltage waveform is output voltage from Grid to Vehicle. The three phase low voltage is the waveform for the output voltage from Electric vehicle Battery to Grid. The number of charging Electric Vehicle increased in the charger. The harmonics in the output of Grid which is in Fig.7. has high level of harmonics when compared to the output of the Modular multi-level converter based conversion in the charger.

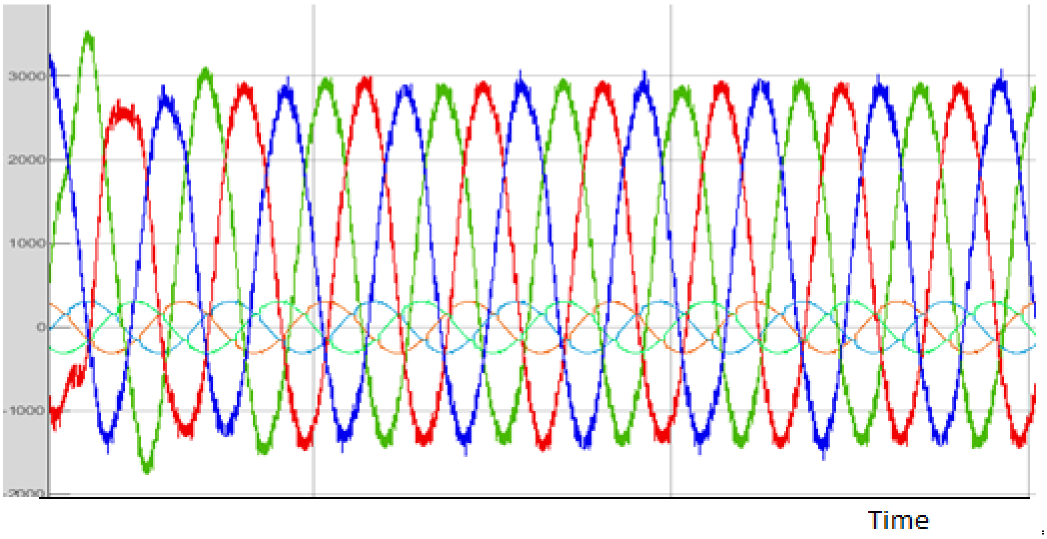

Figure 9 . shows the waveform of V2G and G2V

The conventional voltage source converter has separate IGBT which has capacitor and inductor which produce high harmonics and high switching loss. Converting this power charger into Electric Vehicle charging Station. In this each component are designed with path for converting the AC-DC and DC-AC voltage. By using separate submodule the capacitor in the each module educe the half the capacitor value Un/2. This reduce the current in the lower arm and upper arm. The waveform of the each component in the circuit is predicted in the MATLAB/SIMULINK software.

VI. CONCLUSION

In this Experiment, the proposed model of Modular Multi Level Converter is implemented in the large Electric Vehicle Charging Stations. This method is mainly used to reduce the power quality problem in Electric Vehicle Battery charging and Discharging. Also, reduce the switching losses in the conversion of Bi-directional converter from V2G and G2V. MMC having capability reduce fault during charging the battery and interfacing the Vehicle to Grid and Standard House Hold Equipment. By Using 24 Sub Module converter each having separate Capacitor path for current flow. These capacitor controls the circulating current in the Module. MMC does not need a filter, to reduce the harmonics. This improves the conversion efficiencies in the both directional flow. The SIMULINK results clearly shows that the output 5 level MMC converter reduce the switching loss and improves the power quality between the vehicle to grid and Grid to Vehicle. With this converter method the state of charge of the battery is also increased and life of the battery is also increased.

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