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Analysis of a Bi-Directional (V2G and G2V) Battery of Electric Vehicle Designed in Matlab Simulink

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***Abstract*— Electric Vehicles (EVs) have a lot of advantages over cars that run on gas or diesel. Also, making transportation systems run on electricity would make it possible to make more electricity from CO2 free and Renewable energy sources like wind energy, solar energy, and hydro energy because EVs are spread out and move around a lot and need a lot of power to charge and discharge, it is important to figure out how to control how they charge and discharge so that the future smart grid can make the most use of renewable resources. In this study, a new way to control two-way chargers for electric vehicles is shown. The charger is made up of two power converters that can work in both directions. Two types of converters are described here: one is an AC-DC converter that provides a constant DC link voltage and the other is a buck-boost converter. The Buck-boost converter is responsible for both charging the vehicle from the grid (known as G2V charging) and discharging the vehicle back into the grid (known as V2G charging). The charging station's bidirectional DC-DC converter modules handle battery charging and discharging. A model designed in MATLAB Simulink and analyzed the battery output it's proved that the bidirectional controller prototype works well with this control method. Dynamic charging and discharging are components of the control strategy.**

Keywords— Wall Charger Box(WCB), Vehicle to Grid (V2G), Grid to Vehicle (G2V) , Converter, Battery Switching Control.

I. Introduction

As an alternative to traditional internal combustion engine (ICE) vehicles also known as Electric vehicles (EVs). EVs and smart grids are considered essential to the fight against climate change. It has been implemented in the transportation sector to reduce the industry's environmental effect [1,2].Increasing the use of EVs has been proposed as a potential alternative for reducing fuel energy consumption and greenhouse gas emissions (GHG) as part of a broad effort to address environmental destruction and global warming [3,4]. Several nations, including the United States of America (USA), Canada, China, and India as well as some nations within the European Union (EU), have already implemented government incentive policies to encourage the production of electric vehicles [5]. For example, both the U.S. and Canada have recently announced a policy called Zero Emission Vehicle (ZEV).This policy offers financial incentives to encourage the purchase of ultralow emission and Zero-emission vehicles as well as the improvement of the electric vehicle charging infrastructure in public places. China provides financial subsidies for energy-efficient EVs. In addition, India has the objective of producing only electric vehicles by the year 2030. Germany, which has the largest automotive market in the EU, is currently offering a price subsidy and a tax exemption on electric vehicles for a period of ten years. As a result, the production of chargers and the preparation of the comprehensive power infrastructure for the massive increase in incoming power demand are of the utmost importance in order to meet the rising demand for electric vehicles. In this scenario, the process of charging the batteries of electric vehicles (also known as Grid-to-Vehicle, or G2V) needs to be regulated in order to maintain the power quality in the power grids. The charging topologies are broadly categorized as either unidirectional or bidirectional. Researchers have developed Bidirectional Batteries for charging and discharging, The author P. S. Tomar suggested A bidirectional, isolating dc/dc battery charger with a converter that delivers low losses, high power density, smooth switching, and zero voltage transition from no load to full load and vice versa. Each side's output voltage is nearly constant. One mode has superior voltage ripple or control than another. [6]. Power converter from Vehicle to Grid designed by N. Ameen incorporates a bidirectional alternating current and direct current connection [7]. In the publications by A. Kaiser and A. Nguyen[8], four intelligent functions (Soft-Start Reconnection, Auto Charge-Discharge, Volt-Watt, and Ramp Rate functions) were designed, implemented, and confirmed for Electric Vehicles. An 800V voltage-type PWM converter and a management strategy that does not require a DC current sensor are proposed by S. Yang for use in a single-stage, quick electric vehicle (EV) charger [9]. EVs provide frequency response service to the electrical grid as demand response resources. W. Wei and X. Guo's study [10] proposes a method for managing the charging frequency of electric vehicles that evaluates three charging schemes (dumb charging, constant charging, smart charging). Research in the field of EV is developing considerably. The electric vehicle is powered by the battery pack. Consequently, the accuracy of the battery model must be enhanced [11].That’s why in this paper, we design a Bi-directional Grid connected battery for EVs.

In our research paper, a new strategy for controlling the current between the electric vehicle battery charger and the power grid is proposed for the vehicle-to-grid(V2G) battery charger. The charging system is not impacted by unexpected shifts in load, which is a significant benefit of the control strategy, especially when compared to how things would normally be.

In the designed model, we use a two-stage bi-directional power converter with an AC-DC converter on the first stage and a buck-boost converter on the second stage. Where an AC-DC converter keeps the DC link voltage constant, a buck-boost converter charges and discharges the grid and the vehicle. The DC-DC converter [12] figures out when the power goes out on the grid and makes the reference current for charging and discharging the battery, which is also called "buck and boost" operation.

In addition, to keep the battery from getting worse during V2G operation, think about the minimum state of charge (SOC) for charging and the minimum SOC for discharging[13]. This will limit the impact on the grid. When the EV is connected to the power grid then energy can flow from Grid to Vehicle or Vehicle to Grid (G2V and V2G). If there is no power grid or if the power goes out, the EV can be used as a voltage source to the power loads. The system is not meant to be a actual energy backup, but it does have a system for storing extra energy. So, the changes from one mode to another can be smooth.

II. Methodology

The term "bidirectional power flow" is used to describe a technology in which Electric Vehicles (EVs) and the power grid can exchange energy in both directions. Through the two-way communication channel, EVs adopt various Energy Management Strategies.

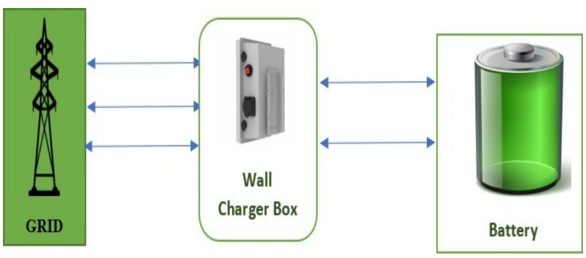


Fig. 01: Basic Design of Bi-directional Battery

In Fig. 1 depicts basic design of Bi-directional EV battery and Fig. 2 illustrates the Bi-Directional Battery Designed in Matlab Simulink. For the Bi-directional flow, a wall charger box is designed for our model. The wall charger box contains five parts, which has Connection control block (charging and discharging control), Converter (AC/DC and DC/AC), a Buck-Boost Converter, a DC-DC battery controller and a Battery switching control block. Fig. 3 depicts a Bi-directional battery design with parts of wall charger box and Fig.04 shows the Wall charger box subsystem design in Matlab Simulink. Fig. 05 is the connection control block connection with power grid. The connection control block is which connected with the power grid for charging and discharging the battery. It's a different way of thinking about how electric vehicles (EVs) can be wired into the electrical grid, as it involves the use of energy-storage technologies that enable two-way power flow between the power grid and the EV's battery.

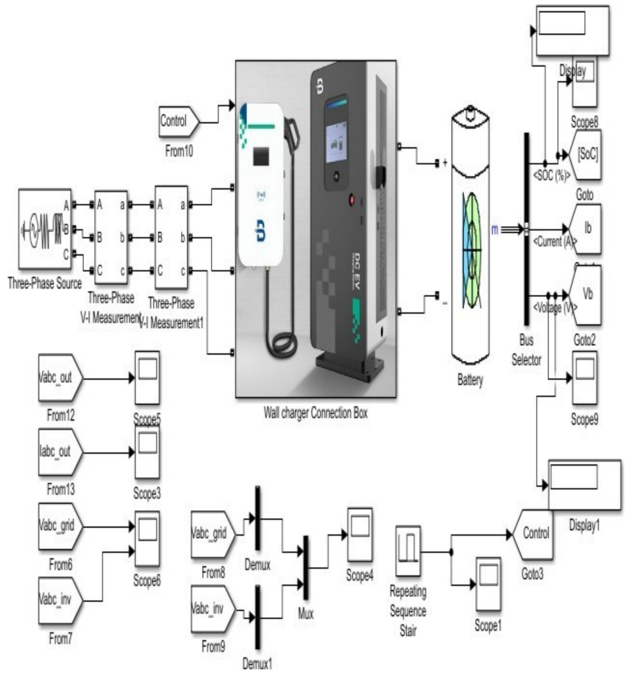


Fig. 02 : Bi-directional Battery Design in Matlab Simulink

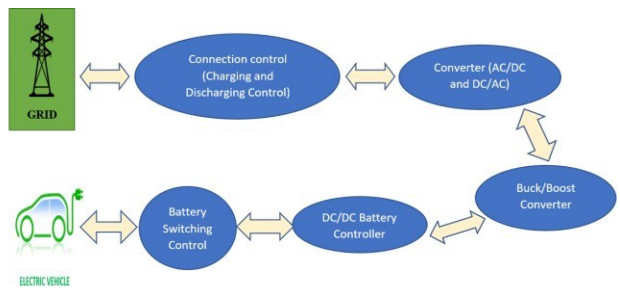


Fig. 03 : Bi-directional Battery Design with parts of wall charger box

Bidirectional converters, (AC to DC and DC to DC) are the building blocks of a standard electric vehicle charger. In the charging mode, rectifier circuits invert the incoming alternating current (AC) from the power grid into direct current (DC), and in the discharging mode, rectifier circuits invert the resulting direct current (DC) back into alternating current (AC) for injection. Fig. 06 is the subsystem of Buck-Boost converter, this converter is used for voltage step-up and step-down and the Buck-Boost converter is controlled by PID. The PID controller controls the buck-boost converter's duty cycle to maintain a constant output voltage relative to a set reference value. Overshoot, oscillation, and error steady state in the output system are all things that can be corrected for by using these controllers. Our model for managing the battery makes use of a PID controller and DC/DC converter.

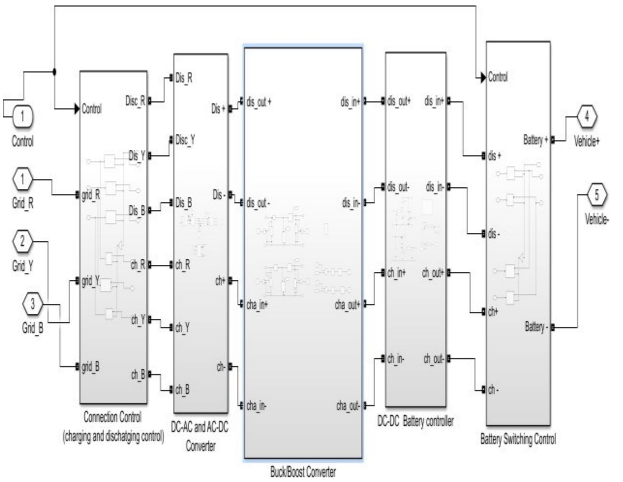


Fig. 04 : Wall charger box subsystem design in Matlab Simulink

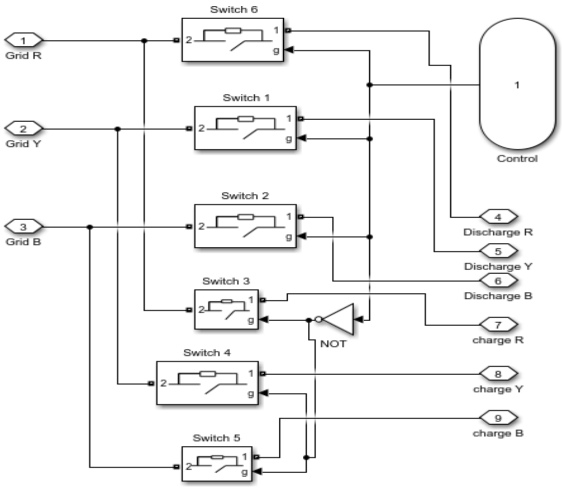


Fig. 05 : Connection Control block connection with power grid.

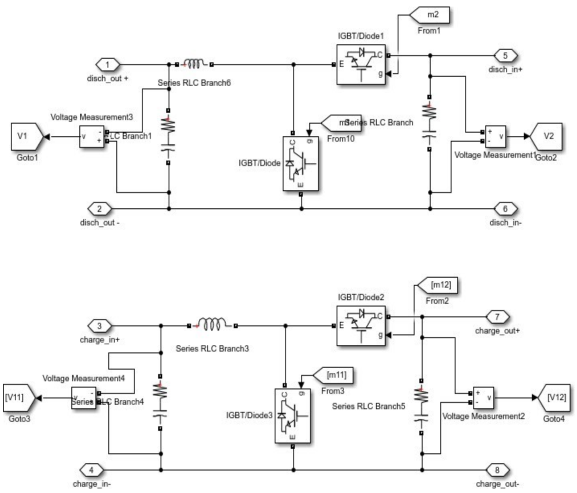


Fig. 06: Subsystem of Buck-Boost Converter

DC/DC converters that are also bidirectional converters are useful in regenerative braking systems because they can transfer power in both directions. The duty cycle refers to the proportion of time a switch is "on" relative to the total time it is "off," and it is used to regulate the amount of power flowing from the input to the output. This is typically done to regulate the power output, the power input, or the power output.

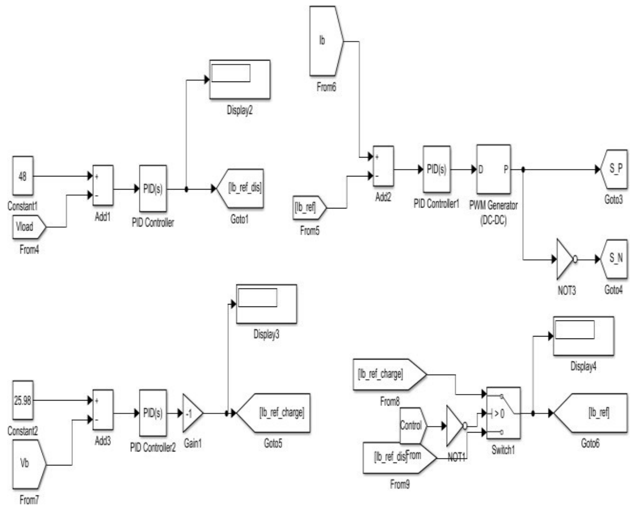


Fig. 07: Battery controller of DC/DC converter

III. Result and Analysis

The technologies known as Vehicle to Grid (V2G) and Grid to Vehicle (G2V) allow for the transfer of energy in both directions.

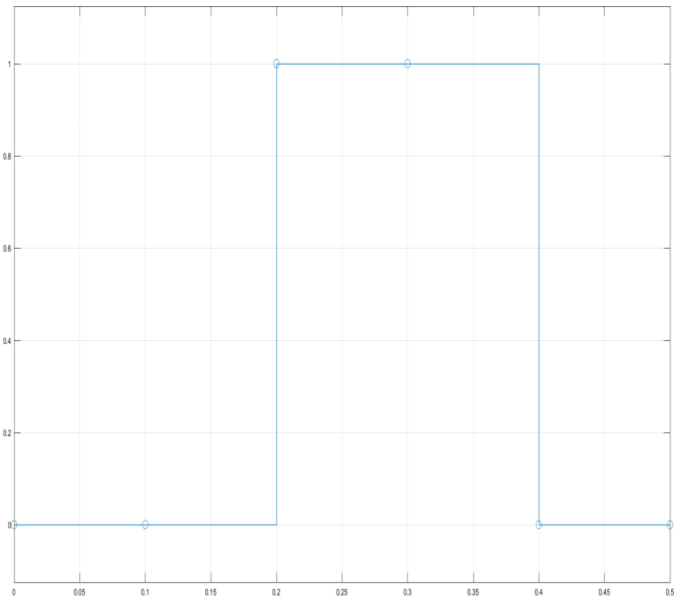


Fig. 08 : Output curve of Battery switching

The energy can be transferred from the vehicle to the grid when the amount of energy that is stored in the battery (battery high mode) or it can be transferred from the grid to the vehicle when the amount of energy is needed for battery it (battery low mode). In our model, a Simulation is conducted to test the activity of the proposed bidirectional battery under charging and discharging mode. In control value block 1(one) means the battery is giving supply to the grid and 0 (zero) means the battery is taken charge from grid. Fig.08 is the output curve of battery switching, from this curve we observe the battery charging and discharging. The SOC of the battery is set to 25 percent and it’s chosen to ensure that the battery is able to receive or supply power when necessary so that the Battery is recharged from the grid when the SOC reaches to 25%. SOC is the most important characteristic for controlling an electric vehicle and securing the power responses in response to varying operating conditions, Fig. 09 represents the output SOC of battery and Fig. 10 shows the battery voltage.

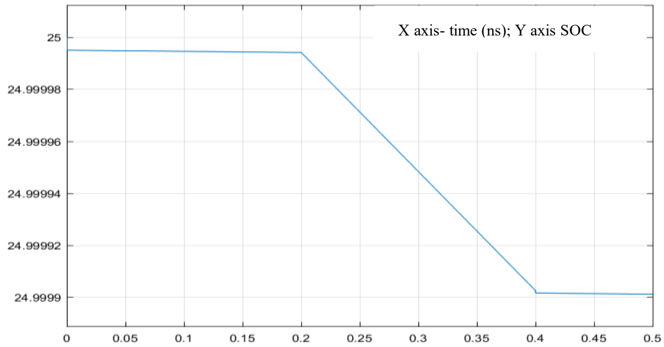


Fig. 09 : SOC of battery

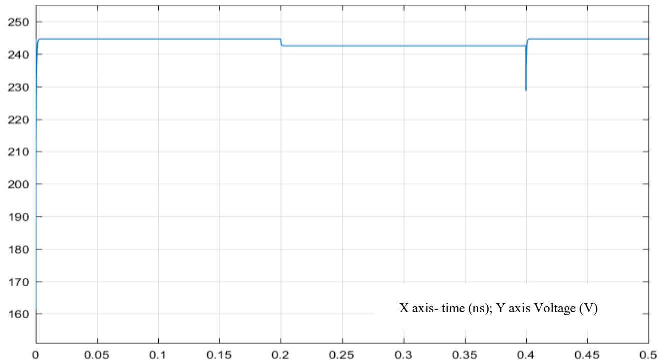
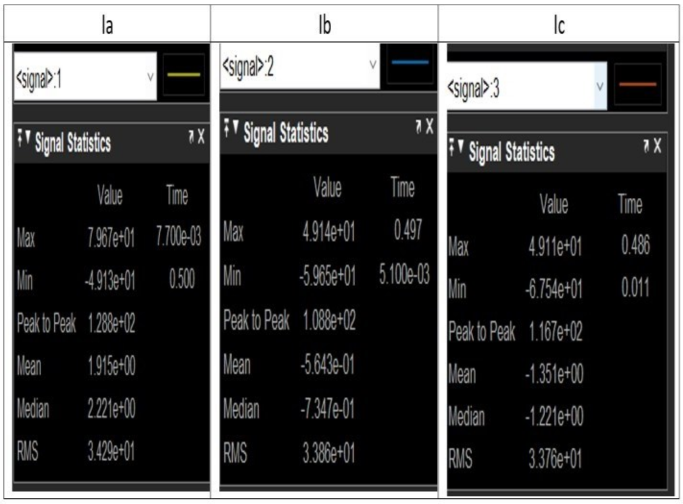


Fig. 10 : Battery Voltage.

In Fig.11 and Fig.12 shows the total grid voltage (Vabc_grid) and total grid current (Iabc_grid) signal statistics. From where we can observe maximum value, minimum value, peak-to-peak value RMS value of every phase of voltage(Va,Vb,Vc) and Current (Ia,Ib,Ic) and from the statistics we can observe there is little bit of fluctuations in beginning and ending of the signal. In Fig.13 depicts the Current of V2G Current(Iabc_grid) and voltage of V2G Voltage(Vabc_grid). Fig.14 is the output curve of G2V voltage(Vabc_inv) and G2V current (Iabc_inv).

	Va Value	Va Time	Vb Value	Vb Time	Vc Value	Vc Time
	<signal>:1		<signal>:2		<signal>:3	
Max	1.110e+02	0.202	4.146e+01	0.200	2.681e+02	0.000e+00
Min	-1.512e+02	0.200	-2.681e+02	0.000e+00	-5.574e+01	0.204
Peak to Peak	2.622e+02		3.096e+02		3.239e+02	
Mean	-1.000e-01		-1.136e-01		2.137e-01	
Median	4.149e-03		-1.120e-03		-2.807e-03	
RMS	1.286e+01		1.141e+01		1.226e+01	

Fig.11 : Vabc_grid signal statistics (from matlab)



	Ia Value	Ia Time	Ib Value	Ib Time	Ic Value	Ic Time
	<signal>:1		<signal>:2		<signal>:3	
Max	7.967e+01	7.700e-03	4.914e+01	0.497	4.911e+01	0.486
Min	-4.913e+01	0.500	-5.965e+01	5.100e-03	-6.754e+01	0.011
Peak to Peak	1.288e+02		1.088e+02		1.167e+02	
Mean	1.915e+00		-5.643e-01		-1.351e+00	
Median	2.221e+00		-7.347e-01		-1.221e+00	
RMS	3.429e+01		3.386e+01		3.376e+01	

Fig.12 : Iabc_grid Signal statistics (from matlab)

From Fig. 15 we observe the Vabc_grid (G2V) and Vabc_inv (G2V) in one scope, where we see the vehicle to grid and grid-to-vehicle in same phase, but some fluctuations,ripple and noise are shown in starting and ending point. These fluctuations, noise and ripple is caused by the imperfect suppression of the ac waveform following rectification.

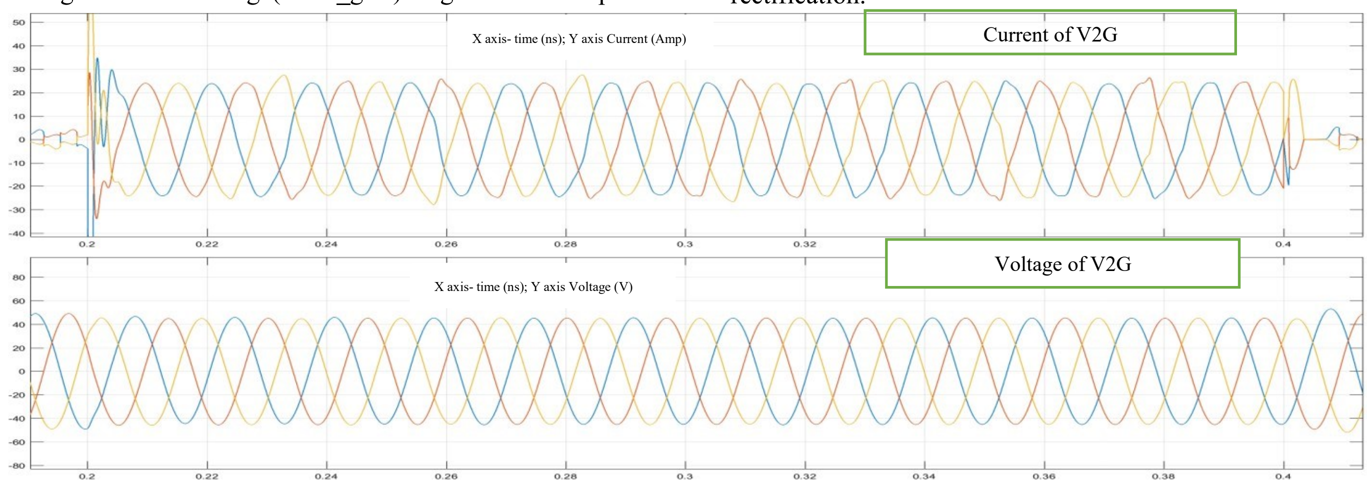


Fig. 13: Current and Voltage of V2G

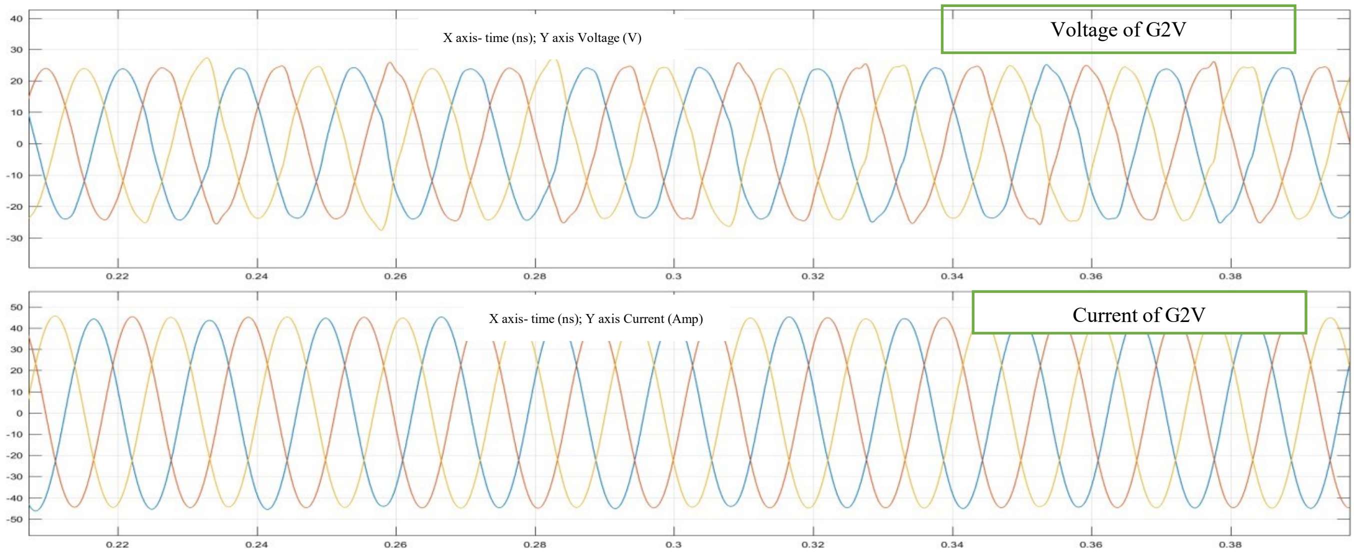


Fig. 14 : Voltage and Current of G2V

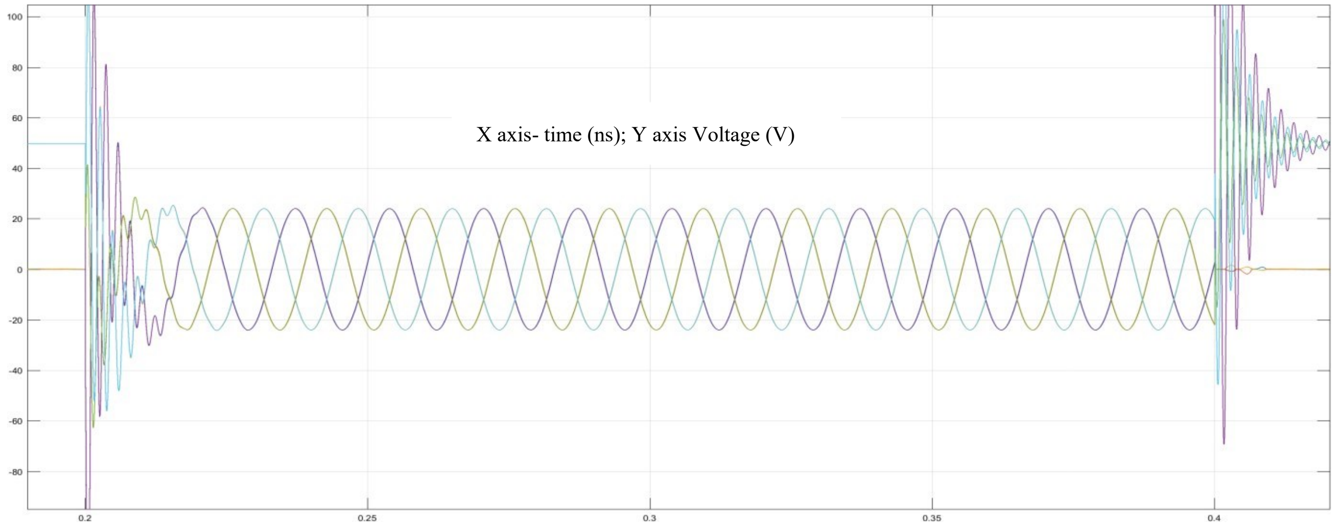


Fig. 15 : Vabc_grid (G2V) and Vabc_inv (G2V)

IV. Conclusion

The next decade will see a dramatic increase in the global adoption of electric vehicles. This growth pattern will significantly alter the operations of electric utilities and put a strain on the current system. For electric vehicles to function reliably within the Power Grid, the necessary charging infrastructure must be in place. In this work, we propose a new method of controlling the DC-DC converter found in EV charging stations. At its core, the charging station is an ac/dc converter used to interface with the grid and a number of dc/dc converters used to manage the batteries. By performing the charging and discharging operations, the proposed control technique allows the power system to operate with minimal losses. A comprehensive simulation study in MATLAB Simulink was performed to test the efficiency of the proposed control strategy. Extensive simulations reveal that the charging station's control architecture can achieve the goals of integrated electric vehicle and utility interface control while giving superior performance during constant and variable charging and discharging.

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