IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

ANALYSIS AND SIMULATION OF V2G AND G2V ON MATLAB SIMULINK

[1]Dhruv Jaiswal, [2]Kajal Singh Gaharwar, [3]Divyansh Taose, [4]Dr. Sanjiv Kumar Jain

[1]Student,[2]Student,[3]Student, [4]Assistant Professor

[1]Department of Electrical Engineering,

[1]Medi-Caps University, Indore, India

Abstract: Electric vehicle (EV) batteries serve as promising energy storage solutions within microgrids, facilitating energy management by absorbing excess power during surplus periods (Grid-To-Vehicle, G2V) and supplying energy back to the grid during peak demand (Vehicle-To-Grid, V2G). However, the successful integration of this concept necessitates the development of appropriate infrastructure and control systems. This paper proposes an architectural framework for deploying a V2G-G2V system within a microgrid context. A microgrid test system is modeled, featuring an Outlet V2G/G2V Terminal for interfacing with EVs. Simulation studies are underway to illustrate V2G/G2V power transfer dynamics. Initial test outcomes demonstrate active power regulation within the EV battery microgrid across G2V-V2G operational modes. Notably, the charging station design prioritizes minimizing harmonic distortion in the injected grid current, while the controller exhibits robust dynamic performance, particularly concerning DC bus voltage stability

Index Terms - Electric Vehicle, Microgrids, Grid-To-Vehicle, Vehicle-To-Grid, State of Charge, Charging and Discharging

I. Introduction

The G2V process can occur in different modes. For an EV with no specific charging time requirement, the vehicle can be charged at a convenient time when electricity prices are low. Timer control can be used to start and stop charging at specific times. In a controlled manner, the vehicle can be adjusted to begin charging only when an abundance of renewable energy is available from sources such as wind or solar. This can help to reduce dependency on carbon-based energy sources. In future scenarios, the EV may be parked for the majority of the day, unused for transportation. Energy may be abstracted from the grid during off-peak periods when electricity prices are low and stored in the EV for use at a later time. Load leveling can be performed where the stored energy is returned to the grid during periods of high demand or emergencies. Utilities may offer incentives to EV owners to provide power to the grid and many EVs may be used as a mobile storage device for renewable energy. Electric vehicles (EVs) are becoming increasingly popular as a result of rising fuel costs and growing concern over the environmental impact of fossil fuels. Various research and development activities have been taking place to facilitate the integration of electric vehicles with the electrical power system, one of which is Vehicle to Grid (V2G) which allows the EVs to provide power in both directions, to and from the grid, using intelligent control methods and bidirectional power electronics. The use of EVs for V2G purposes can provide potential economic and environmental benefits for the vehicle owner and the grid as a whole. In recent years, power systems have faced a difficult challenge to meet the ever-increasing demand for electrical energy. The main reason is due to an increase in population and also an increase in the use of automated appliances. The results are overloading of the transformers, high voltage drops, and also an increase in the system losses. Also, during peak hours, utilities are not able to meet the load demand and the generating costs are high. Hence, there is a necessity to implement a smart grid which is an intelligent power distribution system. The smart grid uses two-way communications between the consumer and the supplier to control the power from the source to the destination efficiently and economically. Nowadays, plug-in electric vehicles (PEVs) are increasing in popularity due to their environmental benefits and economical maintenance.

This increase in PEVs will affect the power system and hence it can be used as an energy storage unit for the grid. Bidirectional power transfer between the vehicle and the grid is called Vehicle-to-Grid integration (V2G) and Grid-to-Vehicle integration (G2V). This technology can be a part of a distributed energy storage system which helps the grid in providing additional load power at the peak hours and also helps in taking excess power during off-peak hours of the day. If the vehicle battery is fully charged and the PEV is currently not in use, the battery can be considered as spare energy storage available for the grid. By discharging the vehicle batteries during peak hours, the power quality and reliability of the grid can be improved. During off-peak hours, the vehicle batteries can be charged taking advantage of lower-cost electricity. This will help to reduce the load on the distribution system and the transmission losses of the power consumed by the PEV. This concept leads us to do an analysis and simulation of V2G and G2V on MATLAB Simulink.

II. LITERATURE REVIEW

M. A. George [1] In recent years, there has been a surge in research focused on electric vehicles (EVs) due to concerns over the potential depletion of fossil fuels and escalating environmental challenges. Electric vehicles, commonly referred to as EVs, rely on charging stations connected to the power grid to replenish their batteries, underscoring the critical need for a robust network of rapid charging stations. However, the proliferation of EV charging infrastructure poses several challenges to the existing distribution systems. This article proposes a model for a three-phase rapid charging station equipped with an integrated photovoltaic (PV) generator, facilitating vehicle-to-grid (V2G) power exchange. By manipulating reactive power flow, the charging station aims to stabilize grid voltage levels. The incorporation of renewable energy sources such as PV may offer a viable strategy for reducing electricity demand on the grid. The system includes a microgrid connected to the PV-integrated EV charging station, allowing for the evaluation of its performance and operational effectiveness across various scenarios

Sharma and S. Sharma [2] Power electronic converters play a crucial role in connecting the grid to electric vehicle (EV) batteries, facilitating bidirectional power exchange. However, a single bidirectional AC-DC conversion step can also enable both vehicle-to-grid (V2G) and grid-to-vehicle (G2V) active power transfers. This study delves into various bidirectional AC-DC and DC-DC converter topologies that support V2G and G2V power flows, offering a comprehensive review and comparison.

Furthermore, the research explores different classes of charger/discharger systems tailored for V2G applications, includingdistinctions like on-board/off-board, integrated/non-integrated, and conductive/inductive setups. A comparative analysis based on predefined criteria is conducted to assess the effectiveness of these systems.

Moreover, the paper investigates the integration of renewable energy sources into EV charging/discharging infrastructures and examines recent advancements in utilizing wide band-gap semiconductors in high-power, dense V2G-capable converters

S. Liu, X. Xie, and L. Yang [3] This study introduces a novel switching bi-directional buck-boost converter (SBBBC) designed specifically for a vehicle-to-grid (V2G) system. The architecture of this converter facilitates bidirectional energy exchange between the grid and the electric vehicle's hybrid energy storage system (HESS), which comprises a Libattery/supercapacitor (SC) setup. Beyond its buck-boost capabilities, this architecture also incorporates energy management functionalities.

The stability of the converter's topology in both boost and buck modes is thoroughly investigated using the state-space averaging approach in this research. To ensure steady output voltage and current, a control strategy is devised based on the state of charge (SOC) of the energy storage system. The charging of the Li-battery employs both constant current (CC) and constant voltage (CV) modes. Voltage and current controllers are developed in the frequency domain utilizing bode plots.

Validation of the electrical viability of the topology, the effectiveness of the design controller, and the control approach is carried out through a combination of modeling and experimentation techniques

S. A. Amamra and J.Marco [4]This study presents an optimized bidirectional Vehicle-to-Grid (V2G) framework within a distributed power system, wherein a fleet of electric vehicles (EVs) interfaces with charging stations. The primary focus lies on scheduling EV charging and discharging activities a day ahead to mitigate the cost associated with EV ownership charging, while concurrently leveraging frequency and voltage control services. To enhance the optimization of EVs for voltage and frequency regulation, the proposed system integrates real-time EV consumption data, enabling dynamic adjustments to day-ahead energy projections as necessary. Various factors including initial battery State Of Charge (SOC), EV plug-in time, regulation pricing, intended EV departure time, battery degradation cost, and vehicle charging requirements are factored into the optimization process for V2G scheduling. To validate the efficacy of the proposed system, five EV charging stations are integrated into a standard IEEE 33-node distribution network. Two case studies are conducted to substantiate the efficacy of this sophisticated energy management technique. The incorporation of V2G technology exhibits promising potential in providing frequency and voltage support, while concurrently mitigating EV charging costs, particularly during peak periods characterized by heightened demand for both active and reactive power

Ahmad, A. R. Beig, J. Alsawalhi, and K. al Jaafari [5] This paper proposes a novel high-gain bidirectional DC-DC converter essential for electric vehicles. It efficiently converts low-input battery voltage to high-input DC voltage and vice versa. Employing an interleaved approach on the input side reduces input current stress and ripple. With broad voltage conversion capabilities and common ground, it's suitable for electric and hybrid vehicles. Discussions cover steady-state operation, analysis, and simulation verification, followed by reported experimental results

M. M. Faruk, N. T. Khan and M. A. Razzak, [6]The imperative to transition towards clean and sustainable economies has become increasingly evident due to escalating environmental risks. To explore and integrate superior energy sources, such as electric vehicles for intelligent grids, numerous groundbreaking technological advancements have been developed. This study proposes a simulation framework representing a **microgrid** comprising a fleet of electric vehicles, along with a limited vehicle-to-grid application. In practice, discharging mode is only engaged during peak demand situations with exceptionally rapid response times. The components constituting this **microgrid**are delineated, modeled, and subjected to simulation to illustrate their functionality. The research further scrutinizes charging and discharging scenarios, delving into the management techniques employed for power control within this simulation

H. Chtioui and G. Boukettaya [7] The imperative to transition to cleaner, sustainable economies in light of escalating environmental risks is increasingly evident. Pioneering technical advancements, such as integrating electric cars into smart grids, are underway to seek better energy sources. This study proposes a simulation environment simulating a **microgrid**with electric car fleets and a limited vehicle-to-grid application. Discharging mode is primarily activated during peak demand with high reaction times. The **microgrid** components are detailed, modeled, and simulated to illustrate their functionality. Further analysis delves into charging and discharging scenarios, along with management techniques employed to regulate power in the simulation.

Sagar Navinchandran, Mini Sujith [8]A single-phase on-board charger is proposed for electric vehicles, designed to operate bi-directionally for Vehicle-to-Grid (V2G) and Grid-to-Vehicle (G2V) functions. The charger includes a buck converter and a high-gain boost converter. Charging and discharging are regulated based on the State of Charge (SOC). MATLAB Simulink models are employed to validate the bidirectional onboard charger, particularly the high-gain boost converter

Saleh Dinkhah et al. [9] The proposal outlines a fixed grid system enabling a house with a Photo-voltaic system and Vehicle-to-Grid (V2G) capability to operate in grid-tied, tie line connection, and island modes. This model facilitates the study of access, energy distribution, and error investigation. To manage challenging conditions like transients, power control of the battery and PV, as well as voltage and frequency control in island mode, are employed. Adjusting Maximum Power Point Tracking (MPPT) enables power limitation and full EV battery charging. The integrated control system utilizes droop control and virtual inertia. MATLAB/Simulink simulation, possibly verified with OPAL-RT, validates the feasibility of the proposed model.

III. OBJECTIVE

The objective of this research paper is to develop a technical overview of Vehicle-to-Grid and Grid-to-Vehicle Bi-directional Electric Vehicle Charger and perform a simulation of the same to demonstrate the working and understanding of the two technologies.

IV. METHODOLOGY

Vehicle-to-grid (V2G) technology revolutionizes the role of electric vehicles (EVs) by allowing them to serve as flexible energy storage units, capable of both drawing power from and supplying electricity back to the grid. In essence, V2G transforms EVs into mobile battery storage systems, enhancing grid stability and resilience. Mathematically, the power flow in V2G systems can be represented by the equation:

PV2G = − Pev

Where PV2G denotes the power sent from the EV to the grid, and Pev represents the power demand of the EV. This equation encapsulates the essence of V2G technology, illustrating the capability of EVs to discharge electricity back to the grid when needed. Now, the negative sign in front of − Pev indicates that the power flow is directed from the EV to the grid. In other words, when the EV is providing electricity to the grid (discharging), the power flow is considered negative. This is a convention used to indicate the direction of power flow.

OUTLET V2G/G2V TERMINAL

Upon connecting the charger to the vehicle's battery, it becomes possible to establish the initial State of Charge (SOC) to a desired level, allowing the battery to be charged up to the predetermined value. The charger is supplied with inputs from the grid for power supply and controls for regulating operations (V2G or G2V). The Outlet Charging Terminal consists of the following components:

1. Grid Connection Control
2. AC-DC Bi-directional converter
3. Buck-Boost converter
4. DC-DC converter with battery controller
5. Battery Switching control.

1. **Grid Connection Control:** Effective management of connections in an electric vehicle (EV) charger is crucial for enabling Vehicle-to-Grid (V2G) and Grid-to-Vehicle (G2V) operations. This bidirectional flow allows EVs to both draw and supply power to the grid. Chargers need to support bidirectional charging, allowing power to be drawn from the grid for charging and discharged from the EV battery back to the grid. Thus, the charger's connection control mechanism must be well-designed to facilitate this bidirectional power flow.We receive the control signal from the Repeating Sequence Stair signal, which outputs and repeats a stair sequence specified by the Vector of output values parameter. For instance, we might specify the vector as [3 1 2 4 1]'. Each value in the vector is output at a time interval, and then the sequence repeats. In our case, we specified the vector as [1 0 1 0 0] to enable V2G for 'zero' output and G2V for 'one' output, or vice versa using a 'not' gate.

2. **AC-DC Bi-Directional converter:** A DC-AC converter, or inverter, transforms DC voltage into AC voltage, customizable for different applications. It uses an oscillator to convert DC to high-frequency AC, then steps up the voltage with a transformer. Output waveform can be adjusted with filters, amplifiers, and PWM. Conversely, an AC-DC converter, or rectifier, changes AC voltage to DC. It rectifies AC using a diode bridge, resulting in pulsating DC, which is then smoothed with capacitors and inductors to provide stable DC voltage. Additional circuitry like voltage regulators can enhance stability and performance. AC-DC converters are adaptable to various AC power sources, such as single-phase or three-phase AC, and can produce DC output voltages with different levels of regulation and ripple. To generate pulses for switches in the universal bridge, the PWM Generator (2-level) block is employed. This block generates pulses for carrier-based pulse width modulation (PWM) converters using a two-level topology. It can control switching devices (FETs, GTOs, or IGBTs) for three different converter types: single-phase half-bridge (1 arm), single-phase full-bridge (2 arms), or three-phase bridge (3 arms). The reference signal, or modulating signal, is compared with a symmetrical triangle carrier. If the reference signal surpasses the carrier, the pulse for the upper switching device is set to high (1), while the pulse for the lower device is set to low (0).

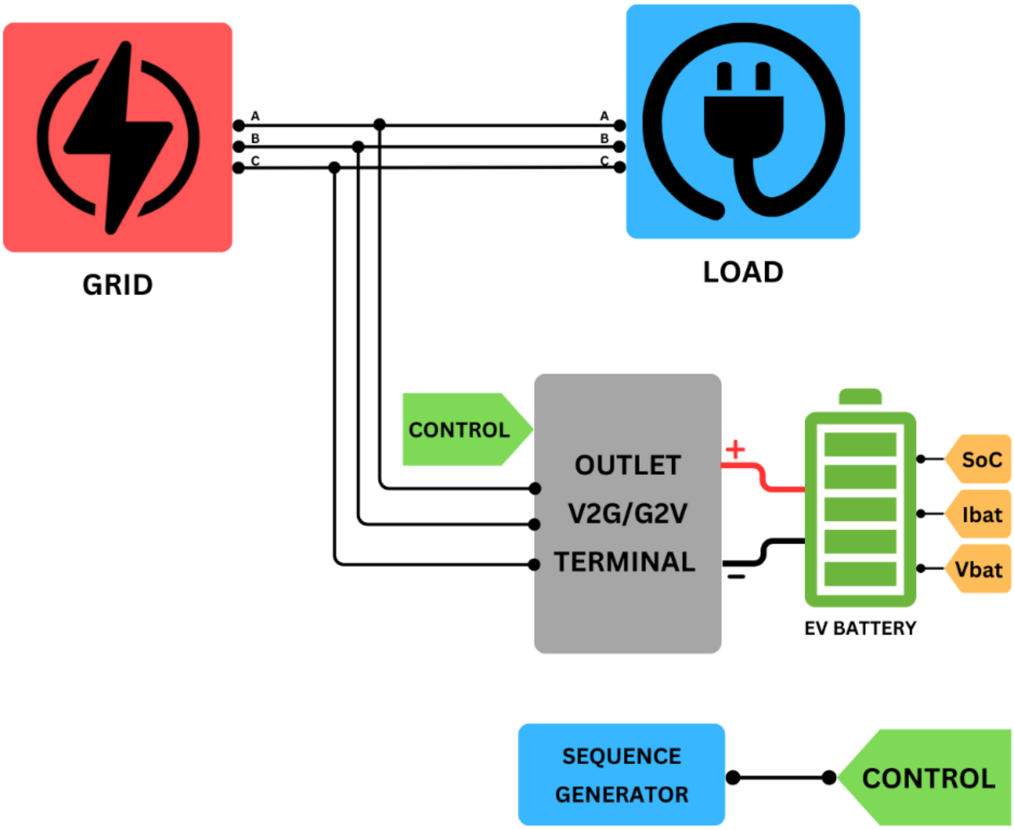

Figure 1 - EV Terminal Connection Scheme

To manage a single-phase full-bridge device, you have two options: unipolar or bipolar PWM modulation. With unipolar modulation, each part of the device works independently. Another reference signal is created internally by shifting the original one by 180 degrees. On the other hand, bipolar modulation synchronizes certain parts of the device. While unipolar modulation results in better AC waveform quality, bipolar modulation reduces common-mode voltage fluctuations.

To generate the reference signal, the grid voltage serves as input for the PLL (Phase Lock Loop) block. This block mimics a control system that monitors and adjusts the frequency and phase of a three-phase signal. It uses an internal frequency oscillator to maintain phase consistency. The three-phase input signal is transformed into a rotating frame, and its phase difference is filtered. A PID controller, possibly with automatic gain control, ensures phase consistency by adjusting an oscillator. The PID output, representing angular velocity, is converted to frequency and used for control.

For generating the reference signal, a simple MATLAB function func_RefGen is -

```
function [a, b, c] = func_RefGen (x, ma, Shift)
Shift_th = Shift *pi/180;
a=(ma*(sin((x)+ Shift_th)));
b=(ma*(sin((x)+Shift_th-(2*pi/3))));
c=(ma*(sin((x)+Shift_th+(2*pi/3))));
```

The reference value generated will be passed to the PWM generator. This will trigger pulses to operate the switches in the Universal bridge, allowing us to regulate the output AC voltage while engaging in V2G operations.

3. **Bi-directional DC-DC converter:** A bi-directional DC-DC converter is an electronic device that can convert a DC voltage from one level to another in both directions. It can step-up (boost) or step-down (buck) a DC voltage depending on the application requirements. During the buck mode, the upper branch switches are activated by pulses m2 and m12, allowing the inductor to charge until the switches are on. Then, the switches are turned off, triggering the parallel diodes in the other branch to switch on due to the inductor's polarity reversal. This process enables the inductor to release output power. In the boost mode, the lower branch switches are activated by pulses m1 and m11, charging the inductor until the switches are on. Afterward, the switches are turned off, causing the parallel diodes to switch on due to the inductor's polarity reversal. Here, both the inductor and the source work together to deliver output power. The bi-directional DC-DC converter is constructed with two power switches, two diodes, and an inductor. Control over the switches is achieved through pulse width modulation (PWM) signals, which determine both the duty cycle and frequency of the output voltage. Diodes serve the function of preventing reverse current flow, while the inductor functions to store energy throughout the switching cycle. Employing two PID controllers, the system compares a reference value with both the input and output voltages. Based on these comparisons, firing pulses are generated for the switches. These pulses are then utilized by the PWM generator to produce signals for the switches, thereby facilitating the processes of charging and discharging.

4. **DC-DC converter with battery controller: In** applications where input voltage levels can fluctuate due to factors such as battery discharging over time or changes in load conditions, DC-DC converters maintain a constant output voltage, providing reliable power to the system's components

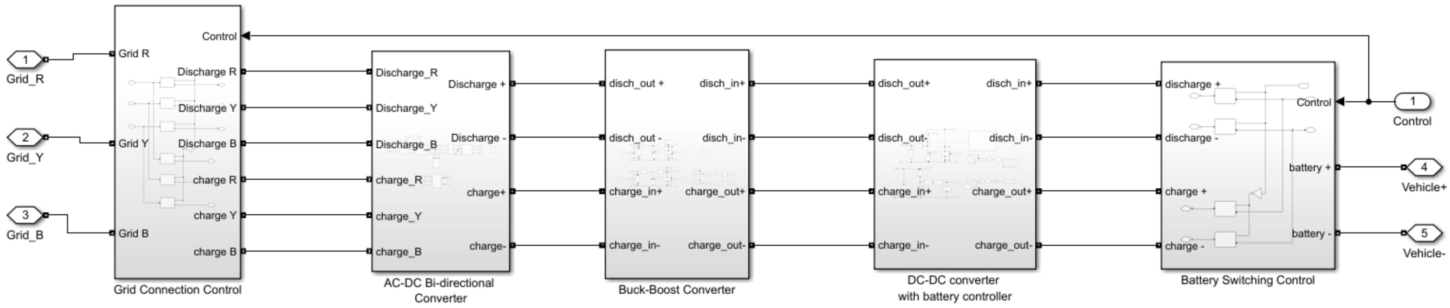

Figure 2 - Simulink Model of Outlet V2G/G2V Terminal

5. **Battery Switching Control:** Battery switching control is a pivotal component in managing the transfer of electric vehicle (EV) batteries between the vehicle itself and the charging station. This technology plays a crucial role in supporting both Vehicle-to-Grid (V2G) and Grid-to-Vehicle (G2V) applications. For these functionalities to be enabled, an EV charger needs to be equipped for bi-directional charging, which entails its ability to draw power from the grid to charge the EV battery and to discharge power from the EV battery back to the grid. The charger's connection control mechanism must be intricately designed to facilitate this two-way power flow. Within this framework, we employ a control signal generated by the Repeating Sequence Stair signal block. This block is responsible for producing and repeating a stair sequence based on the specified vector of output values. By adjusting this vector accordingly, we can activate V2G for a 'zero' output and G2V for a 'one' output, or vice versa by employing a 'not' gate.

V. RESULT

The simulation thus performed can be practically installed at car parking areas to allow the electric vehicles to get connected to the grid as supplementary energy sources to meet high load demands and reduce instantaneous loading over the electric grid. The above simulated outlet terminal will take initial SOC as input and based on the sequence or changes in load conditions, DC-DC converters maintain a constant output voltage, providing reliable stair signal the V2G and G2V operation can be performed based on the stair signal

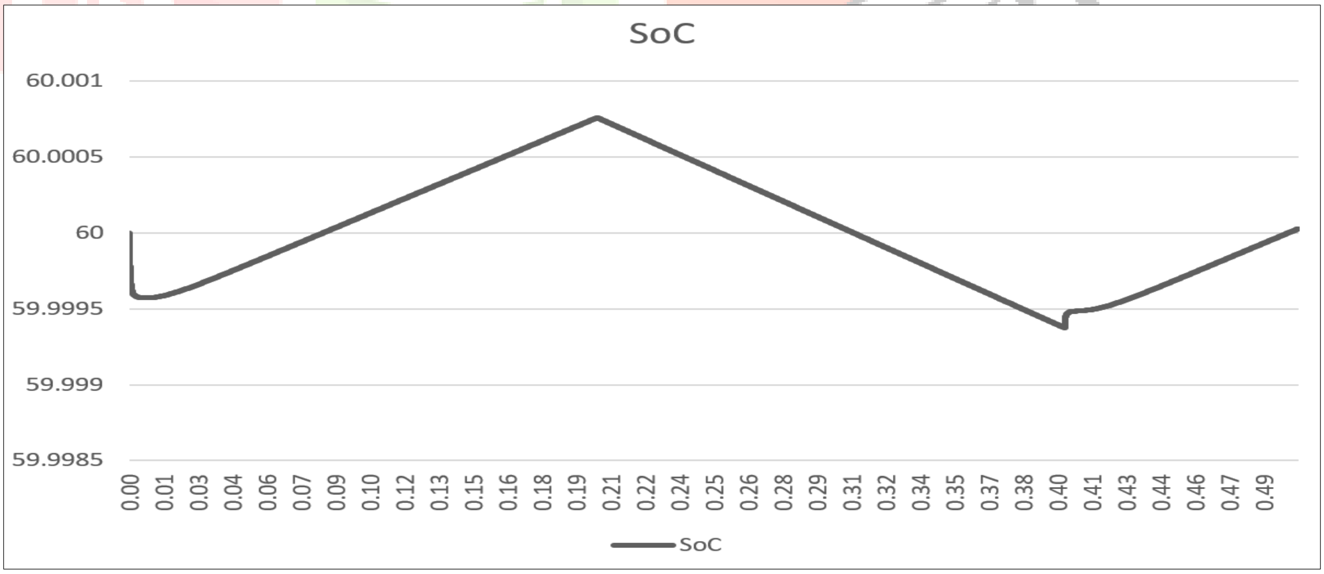

Figure 3 – Battery State of Charge (SoC) Simulation

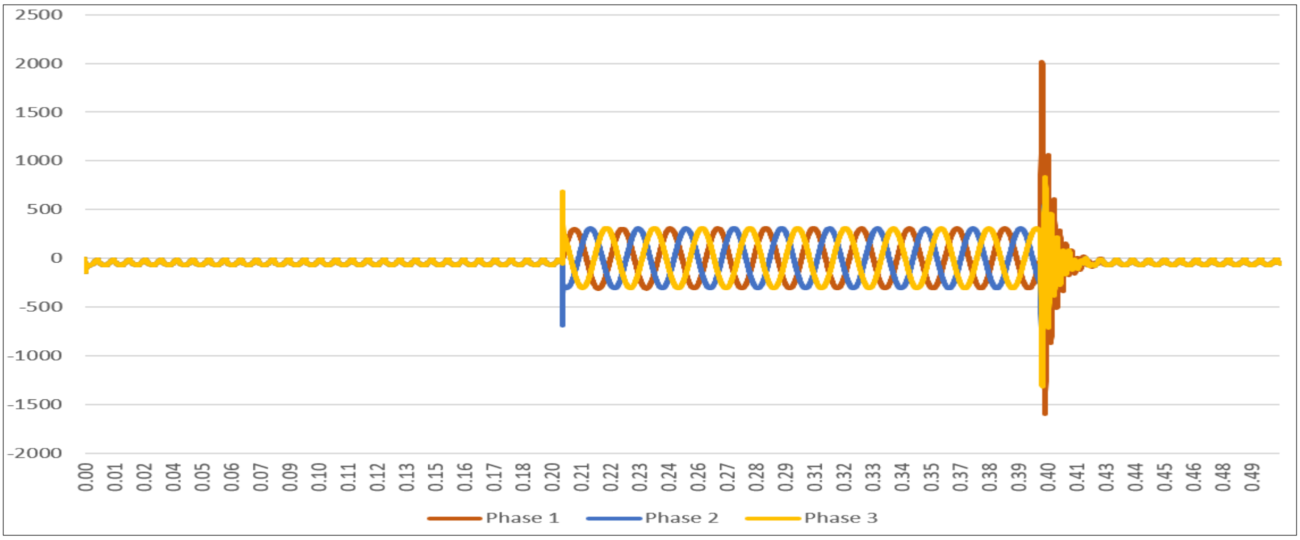

Figure 4 – Output Voltage of 3 – Phase Inverter

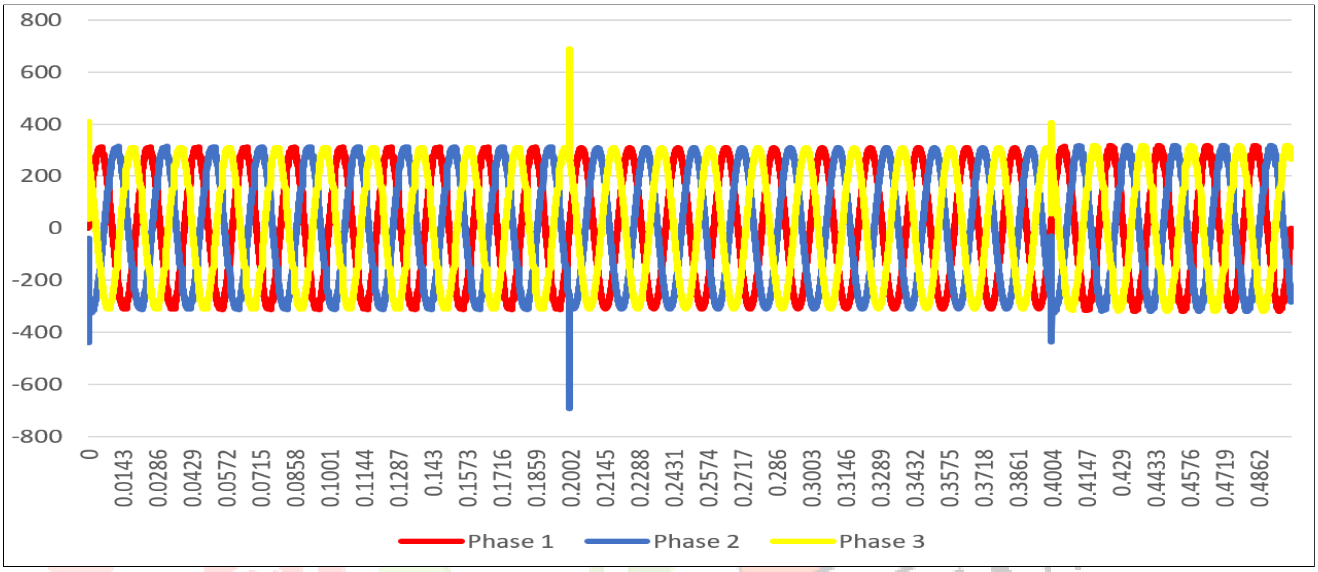

Figure 5 - Voltage Output of 3-Phase line

For instance, if we input [0 0 1 1 0] and set the simulation runtime to 0.5 seconds, the time will be divided into five equal intervals to match the sequence length. During intervals marked as 1, power flows from the vehicle to the grid, while during intervals marked as 0, power is drawn from the grid to the vehicle. Thus, the battery's State of Charge (SoC) throughout the simulation is depicted in fig.3.

During the initial 0.2 seconds, the charger functions in the grid-to-vehicle mode, resulting in a DC output voltage from the inverter. Subsequently, for the following 0.2 seconds, it switches to the vehicle-to-grid mode, causing the inverter's output to be AC. The three-phase grid voltage pattern is depicted in fig.5.

VI. REFERENCES

1. M. A. George, G. K. Rao, and P. Jena, "Performance analysis of fast charging stations for G2V and V2G microgrid systems," in 2020 21st National Power Systems Conference, NPSC 2020, Dec.2020. doi: 10.1109/NPSC49263.2020.9331885

2. Sharma, Sharma, and S. Sharma conducted a review of power electronics in vehicle-to-grid systems, published in the Journal of Energy Storage, volume 21 by Elsevier Ltd on February 01, 2019.

3. S. Liu, X. Xie, and L. Yang, in their paper titled "Evaluation, Modeling, and Implementation of a Switching Bi-Directional Dollar-Boost Converter Based on Electric Car Hybrid Energy Storage for V2G Device," published in IEEE Access, volume 8, pages 65868–65879 in 2020, discussed the evaluation, modeling, and implementation of a switching bi-directional dollar-boost converter. This converter is utilized for electric car hybrid energy storage for vehicle-to-grid (V2G) devices.

4. S.A. Amamra and J. Marco's paper titled "Vehicle-to-Grid Aggregator to Support Power Grid and Reduce Electric Vehicle Charging Cost," published in IEEE Access, volume 7, pages 178528–178538 in 2019, discusses the role of vehicle-to-grid (V2G) aggregators in supporting the power grid and lowering electric vehicle charging costs.

5. Ahmad, A. R. Beig, J. Alsawalhi, and K. al Jaafari, “A Novel High Gain Bidirectional DC-DC Converter,” in 2020 IEEE Industry Applications Society Annual Meeting, IAS 2020, Oct. 2020. doi: 10.1109/IAS44978.2020.9334792

6. M. M. Faruk, N. T. Khan and M. A. Razzak, "Analysis of the Impact of EV Charging on THD, Power Factor and Power Quality of Distribution Grid," 2021 Innovations in Power and Advanced Computing Technologies (i-PACT), Kuala Lumpur, Malaysia, 2021, pp. 1-6, doi: 10.1109/i-PACT52855.2021.9697024

7. H. Chtioui and G. Boukettaya, “Vehicle-to-grid management strategy for smart grid power regulation,” in 6th IEEE International Energy Conference, ENERGYCon 2020, Sep. 2020, pp. 988–993.doi: 10.1109/ENERGYCon48941.2020.9236530.

8. S. Navinchandran and M. Sujith, "Bidirectional On-Board Single Phase Electric Vehicle Charger with High Gain Boost Converter for V2G Application," 2020 Fourth International Conference on Inventive Systems and Control (ICISC), Coimbatore, India, 2020, pp. 363-368, doi: 10.1109/ICISC47916.2020.9171133.

9. In their paper titled "V2G for Reliable Microgrid Operations: Voltage/Frequency Regulation with Virtual Inertia Emulation," S. Dinkhah, C. A. Negri, M. He, and S. B. Bayne presented their research at the 2019 IEEE Transportation Electrification Convention and Expo (ITEC) held in Detroit, MI, USA. The paper discusses the utilization of Vehicle-to-Grid (V2G) technology for ensuring reliable microgrid operations, particularly focusing on voltage/frequency regulation with virtual inertia emulation