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Bidirectional Power Flow Grid-to-Vehicle & Vehicle-to-Grid (G2V&V2G) in Electric Vehicle

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***Abstract*—The growing number of electric vehicles (EVs) imposes greater stress on the power grid. One prospective remedy for this issue is the installation of a bidirectional charger that is also adept at aiding the power grid. The charging and discharging of the battery in an EV are both accomplished by bidirectional converters, one of which is an AC-DC and the other is a DC-DC. Changing the operating mode of a DC-DC converter can lead to it behaving differently. The plug-in hybrid electric car (PHEV) might work as an automobile that transmits power from "vehicle to grid." (V2G). Electric car batteries can engage in bidirectional electricity exchange with the grid. The objective of the paperwork is to design a control approach for efficient power flow for V2G and G2V in EV. Peak load reduction, load balancing, voltage control, and enhanced electrical system stability can be achieved as a consequence. The utility grid can absorb the distributed stored power provided by V2G equipment in the manner of rotatory reserve power. The ability to transfer battery energy back to the power grid through V2G technology contributes to the enhancement of electrical system stability. If there is a bidirectional discharging circuit available, there is also an opportunity to supply power from the grid. In the framework of G2V and V2G in EVs, the research effort focuses on the battery parameter, the voltage of the inverter, and the grid. We will be designing and building bidirectional charges for the battery in EV using MATLAB Simulink for this present work. The simulation focuses on two primary modes of operation: - V2G and G2V. Both of these modes are depicted.**

Keywords— Bidirectional AC/DC converter, Bidirectional DC/DC converter, Vehicle-to-Grid (V2G), Grid-to-Vehicle (G2V), Proportional Integral Controller (PI), State of Charge (SOC).

I. INTRODUCTION

Electric vehicle usage is increasing day by day due to the replenishment of fossil fuels. The grid is primarily responsible for powering the battery of an EV, which frequently puts additional strain on the grid. Therefore, the concept of V2G is used to reduce the strain on the grid and support the grid by discharging the power stored in the battery during peak load demand. Electric vehicle owners can earn a certain amount of revenue by discharging the power stored in the battery. The V2G concept offers a wide range of benefits. A global need for the carbon reduction of energy systems to provide an efficient and environmentally friendly power source, while simultaneously reducing the emission of greenhouse gas. This initiative aims to mitigate the risks associated with global warming. The widespread adoption of battery energy storage has witnessed an enormous surge. G2V and V2G can be achieved via the use of a bi-directional converter, which enables the charging and discharging of batteries in EVs. EV chargers require rapid charging capability and, within the framework of smart grids, can offer reliable and stable services to the grid, thereby permitting bidirectional power flow. The paper presents a proposal for a compact charging system that allows G2V and V2G operations. There will not be an additional strain on the grid until the bidirectional chargers are installed, and they will have enormous utility for the grid. It can be done to design the charger so that it is suitable for both hybrid and completely electric vehicles. This concept of the charger, an explanation of the many operating events that are carried out by the charger, and a simulation of both stages of the charger and discharge operation. While electrifying transport is vital for global decarbonization, power grid integration of electric vehicles poses obstacles, such as high demand peaks requiring expensive transport modifications. Sustainable transportation is predicted to hinge on technologies like bidirectional battery chargers for electric vehicles, which show great promise for improving grid integration between EVs. No cost-effective electric transport integration is feasible without smart charging. [1].

There is knowledge on the personal and societal benefits of EVs which hinder their widespread adoption. This study proposes a concept for energy users to become EV consumers through V2G technology. Increased energy user understanding and risk tolerance for EV adoption empower them to become grid-independent during peak hours. The smart grid provides substantial optimism since it is a crucial function in the decision-making process and assists in the mitigation of grid-related instabilities. Vehicle-to-grid (V2G) is the concept in discussion [2].

The concept under consideration is a prospective technological advancement that is anticipated to be

comprehended in the future, ultimately coinciding with environmentally friendly practices [3]. Minimizing the number of pollutants and carbon dioxide emissions to make transportation easier in EV battery's charging and discharging operations are handled by a PI controller, and the system's response to such operations has been analyzed in particular [4]. As global temperatures rise, fossil fuel consumption for electricity generation and transportation exerts an adverse impact on the environment. Further fossil fuel use may cause catastrophic pollution and should be avoided to maintain life. Bidirectional converter for modernized electric vehicle (EV) battery charge and discharge control [5]. Bidirectional DC-DC converters are beneficial due to their high step-down and high step-up voltage gains, extendibility, high efficiency, and low-rated switches. Also, they're equipped with the ability to convert in both directions [6],[7]. For efficient EVs, it is possible to improve the voltage profile and frequency stability of the grid while the power quality of the grid [8].
Revenue is generated for supplying energy back to the grid in V2G mode using a time-based -tariff using IOT technology [9]. EVs should be active distributed assets that could offer energy to the grid and charge other EVs in the context of the establishment of a smart grid [10]. This paper compares the effectiveness of the proposed concept to benchmark solutions that refrain from employing smart routing or real-time charge control[11]. EVs integrate many energy sources into a single platform[12]. They reviewed the merits and policy for V2G concepts.[13].The impact of EV cooperation on resilience revealed that, as compared to individual-prioritized EVs, system-prioritized EVs might substantially minimize vital load curtailment[14]. The switches are bidirectional, enabling power to flow in dual directions, as well as G2V and V2G charging. For rapid recharging of the battery utilizing a DC source, for instance, acquiring DC grids and EV batteries [15].

The paper research proposes a model intended for a three-phase grid with a bidirectional electric vehicle battery charger, incorporating G2V and V2G modes. The system has a three-phase grid with a voltage of 380V and a frequency of 50 Hz, along with a bidirectional charger and discharge. To validate the control approach used to perform grid integration. The buck-boost DC-DC converter is used to charge the battery in the buck mode, and it is used to drain the battery in the boost mode. A proportional-integral (PI) controller controls the current and voltage used to charge the battery. It provides an analysis of the operation of EVs in terms of their charging and discharging. G2V and V2G can be achieved via the use of a bi-directional converter, which enables the charging and discharging of batteries in EVs. The measurements encompass the SOC, battery current, and battery voltage in both G2V and V2G modes. The analysis focuses on the voltage of the inverter and the grid in the framework of V2G and G2V in EVs.

II. Proposed Work

A. Configuration

In the paper, the design of a control approach for efficient power flow for e in EV. The bidirectional charge for the G2V and V2G EV charger includes various components. Fig.1 exhibits the basic design of the system. The charger obtains the power it needs from the power grid, where it performs a conversion procedure to transform the three-phase alternating current (AC) voltage into direct current (DC). The system itself can be switched to either charging or discharging the battery by a simple switching algorithm. If the battery requires recharging, the converter will switch to a buck DC/DC converter. This operational mode is generally referred to as G2V. If the user desires to deplete the battery to supply electricity to the grid, the system will switch to a boost converter. The operational phase in question is commonly referred to as "vehicle-to-grid” (V2G). Fig.1 shows the block diagram.

B. Methodology

A bi-directional converter is when power flows in both methods that range so that both V2G and G2V can get the greatest benefit out of it. An EV charger encompasses AC/DC and DC/DC converters, which may operate in both directions. Rectification is used to turn AC power from the grid into DC power so that EVs can be charged, and it is also used to turn DC into AC before it passes back to the power grid when the EV is discharged. The DC/DC converter works as a Buck converter, a boost converter, according to the way it is being charged or discharged. The two-way power flow gives the power system operators more benefits.

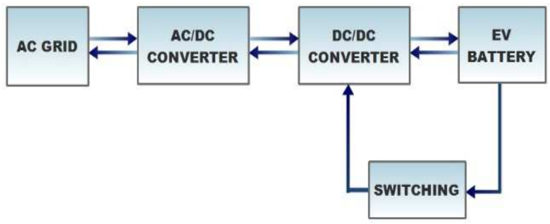

Fig. 1. Block diagram

1) Model of the Battery: The parameters of the electric vehicle (EV) battery used in the simulation model are presented in Table I. Electric vehicles (EVs) incorporate lithium batteries as an outcome of their distinctive properties, sustainable nature, and ability for efficient charging and discharging. A lithium battery is an instance of a rechargeable battery with stores energy by the reversible suppression of lithium ions. Lithium battery is the most popular rechargeable battery used in EVs.

2) Converter topology: When an EV connects to the grid, the V2G paradigm lets it receive a two-way flow of energy. The power source permits the G2V and G2V to send and receive power. To ensure that electricity can flow in bidirectional, three-phase converters equipped with insulated gate bipolar transistors and antiparallel diodes are needed. These converters can either be used as rectifiers or inverters. The following are the main aspects of the proposed system. G2V and V2G using MATLAB SIMULINK in Fig. 2.

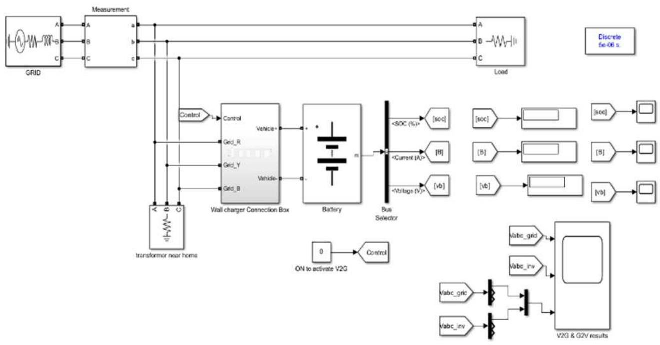

Fig. 2. *MATLAB Simulink Simulation*

Modeling the controller with a PI controller generates phase shift angles for charge and discharge control. As a result of the integration of the proportionate action, PI control affords a quicker response time when compared to I-only control. Fig. 3 PI controllers compare reference values to measured values, generating error signals for the PI controller to generate phase shift angles [4],[5] with appropriate Kp and Ki gains.

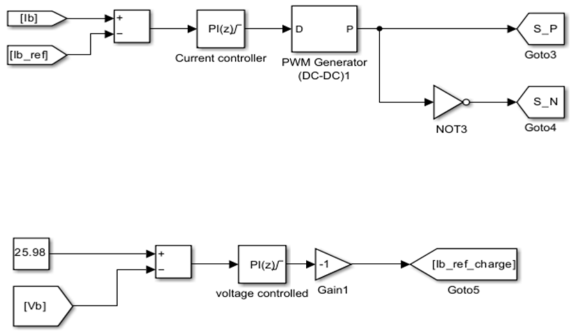

Fig. 3. PI Controller

Compensators of the proportional-integral (PI) form are employed with the sole exception of the battery current controller, which makes use of an integral compensator voltage on the grid maintained at 380 V_{rms}, and the frequency is set at 50 Hz. In the simulations, it is expected that there will be two modes, G2V and V2G. The first simulation, which will occur while the system is in G2V mode, will be one in which it charges the battery. The second one will be in V2G mode, which is when the battery will start to discharge.

TABLE I. SYSTEM PARAMETERS

Parameter	Values
Grid Voltage (Vs)	380 V_{rms}
Grid frequency (f)	50 Hz
Nominal Battery Voltage (V_{bat})	230V
Initial State of Charge (SOC) %	70%
Rated capacity (Ah)	100Ah
Voltage Controller (PI)	Kp-40 Ki-2000
Current Controller (PI)	Kp-0.005 Ki-10

III. RESULTS AND DISCUSSION

The simulation will assess the performance of the system throughout its operation in G2V and V2G modes. The system, performance evaluation, waveforms, and results are depicted as follows:

A. Simulation results for G2V Mode :

The measurements of the battery are displayed in the Grid-to-Vehicle (G2V). The increase in State of Charge seen in the Fig. 4 from the battery relative to the battery's initial value of SOC provides evidence for this assertion Because the current is flowing through the battery in the opposite direction from which it came, this indicates that the battery is being charged. This signifies that the battery is being charged because the current is passing through the battery in the opposite direction in Fig.5. A battery's nominal voltage is the average voltage it produces when completely charged. The actual voltage can be higher or lower than the nominal voltage depending on the battery's state of charge and load. The chemical reaction that powers a battery determines its nominal voltage and is also based on Cell Configuration in Fig.6. Both the voltage grid and the inverter have an out-of-phase relationship in G2V in Fig. 7.

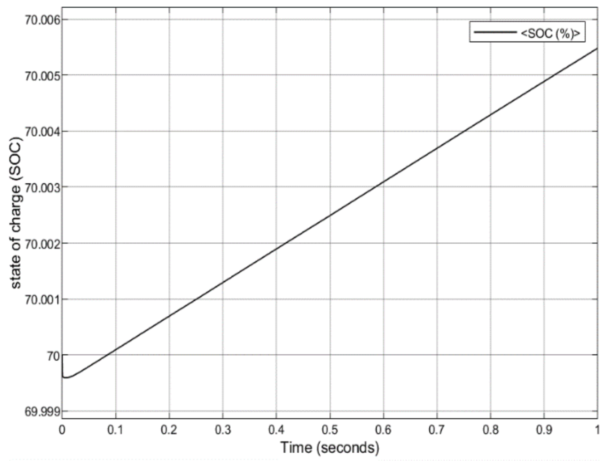

Fig. 4. State of charge

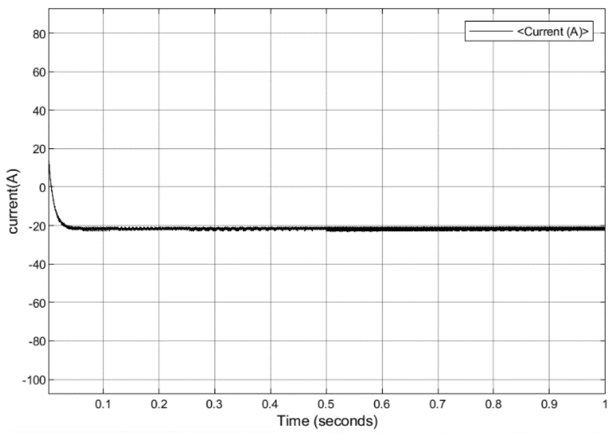

Fig. 5. Battery Current

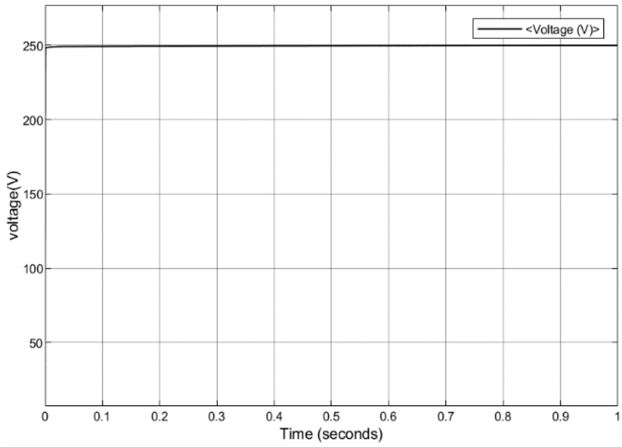

Fig. 6. Battery Voltage

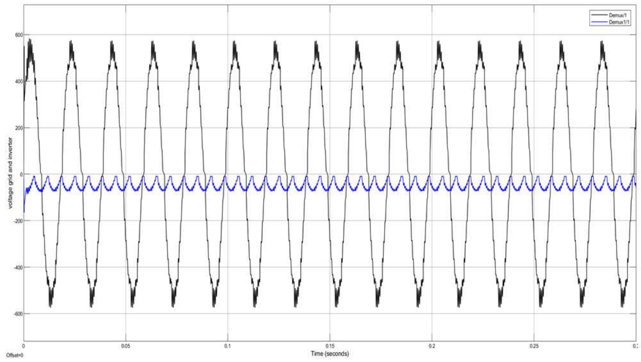

Fig. 7. Voltage grid and inverter

B. Simulation results for V2G Mode

The measurements of the battery are shown in the V2G (vehicle-to-grid) modes. A decline in the State of Charge is observed relative to the original SOC from Fig. 8. In the V2G system, the battery starts the discharging process. In Fig. 9, the direction of current flow is regarded as positive throughout the battery discharge process.

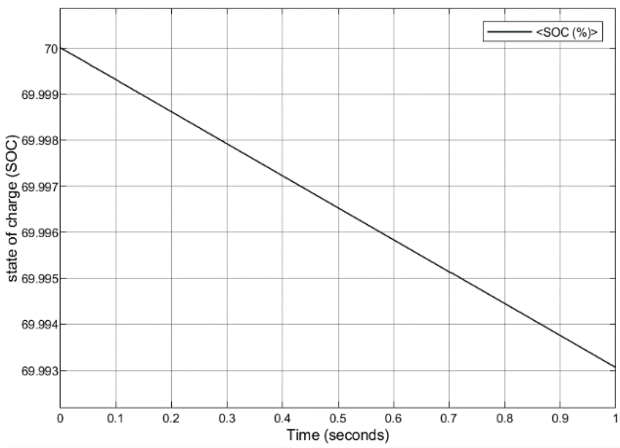

Fig. 8. State of Charge

The battery voltage in Fig. 10 remains constant at voltage. When operating in V2G mode, a vehicle may perform similarly to a distributed energy source and provide the grid with power to serve peak load demands. As the vehicle transmits electricity to the grid, the Fig. 11 voltage grid and the inverter exhibit phase synchronization, easing the burden on the grid.

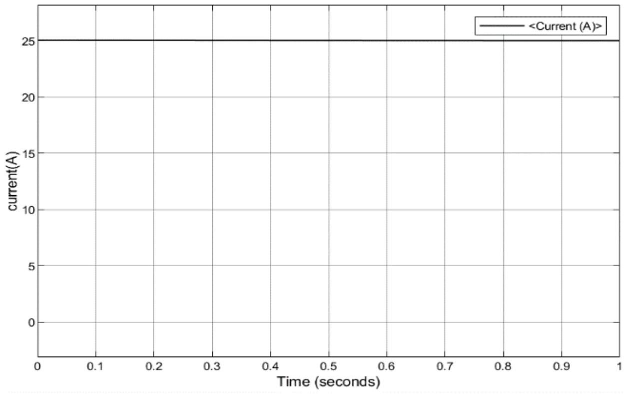

Fig. 9. Battery Current

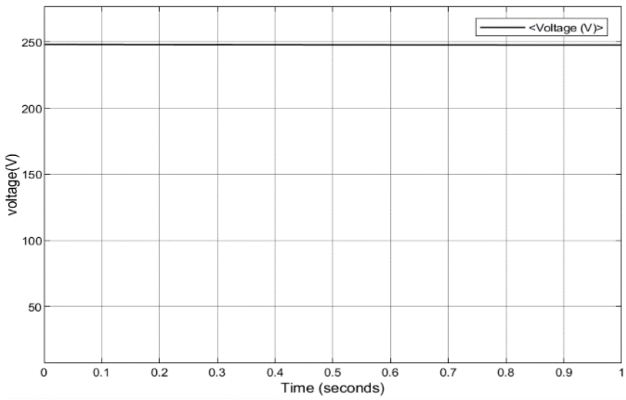

Fig. 10. Battery Voltage

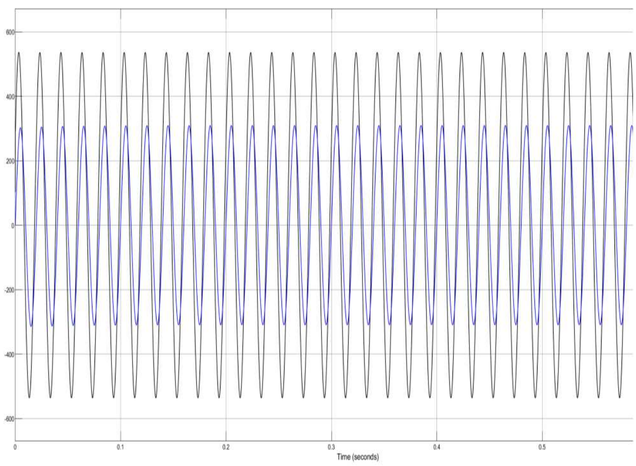

Fig.11. Voltage grid and inverter

IV. Conclusion

The primary intent of the paperwork is to develop an effective and bidirectional EV battery charger that is also able to supply power to the power grid to mitigate the amount of strain that is imposed on the power grid. The rapid growth of the electric vehicle market is putting extra stress on the power grid. The flow of power in a bidirectional system occurs in both directions, permitting the greatest benefit to be derived by both the V2G and G2V systems. Accordingly, the DC/DC converter serves the functions of a buck-boost converter. V2G can benefit from the energy that is produced by local EV owners and contribute that energy to the power grid. This is achieved by distributing oversight and control responsibilities to a local aggregator, who is eligible to receive a predetermined amount of revenue. Following the result of the simulation executed, the battery of the electric vehicle is charged utilizing the power that is supplied by the AC grid to achieve a higher level of charge when operating in G2V mode. We can simulate that the EV battery eases additional pressure on the grid by discharging the stored power and supplying the surplus power from the vehicle's battery to the grid in V2G mode.

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