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Simulation of V2G and G2V, Mobile Application on Charging Cost and Energy Analysis

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ABSTRACT

Batteries from electric vehicles (EVs) can be used as potential energy storage systems in micro-grids. By storing energy when there is an excess (Grid-To-Vehicle, G2V) and supplying energy back to the grid (Vehicle-To-Grid, V2G), they can aid in micro-grid energy management. It is necessary to establish appropriate infrastructure and control mechanisms in order to implement this idea. This project presents an architecture for level-3 EV rapid charging in a V2G-G2V system on a micro-grid. A dc rapid charging station is modelled as part of a test micro-grid system for connecting EVs. V2G-G2V power transfer is demonstrated through simulation research. According to test results, EV batteries actively regulate power in the microgrid using G2V-V2G operating modes. The controller provides good dynamic performance in terms of dc bus voltage stability, and the charging station design ensures minimal harmonic distortion of grid-injected current. And also, a mobile application was designed for the energy consumption and generation analysis based on the sample data collected from a 24-hour MATLAB Simulation and gave the results of time at which the charging cost of an Electric vehicle is minimum or minimum on that particular day based on the obtained data.

Keywords: *Vehicle to Grid, Grid to Vehicle, State of charge, charging and discharging, Charging cost.*

1. Introduction

Vehicle-to-grid (V2G) is a system that enables electric vehicles (EVs) to interact with the power grid by allowing them to both draw electricity from and return excess electricity to the grid. In other words, V2G technology enables EVs to become mobile energy storage units that can provide power back to the grid during periods of peak demand or when renewable energy generation is low. The basic concept of V2G involves using the battery in an EV as a form of distributed energy storage that can be tapped into when needed. By connecting EVs to the grid and managing their charging and discharging, V2G technology can help to reduce the demand on the grid during peak hours, increase the use of renewable energy, and ultimately provide a more efficient and resilient energy system.

V2G technology is still in its early stages of development and there are many challenges to overcome, including the development of appropriate standards and regulations, the establishment of secure and reliable communication systems between EVs and the grid, and the development of efficient charging and discharging protocols. However, the potential benefits of V2G are significant, and the technology has the potential to play an important role in the transition to a more sustainable and resilient energy system.

Automobiles using conventional combustion engines, such as those powered by gasoline or diesel, are referred to as conventional vehicles. For many years, these vehicles served as the main form of transportation, and they are still commonly utilised today. They have an internal combustion engine, a gasoline tank, a transmission system, and an exhaust system, among other things. Fuel is used in the engine to produce power, which is then sent to the wheels through the transmission system. The exhaust system releases combustion by-products into the environment, including carbon dioxide and nitrogen oxide. For many people worldwide, conventional vehicles like automobiles, trucks, and buses with gasoline or diesel engines continue to be the main form of mobility. The disadvantages of conventional vehicles as a mode of transportation include air pollution, which releases harmful pollutants like carbon dioxide, as well as climate change, where they are a significant source of greenhouse gas emissions that contribute to the phenomenon and its effects, such as rising sea levels, and dependence on fossil fuels, where they rely on limited resources like oil and are subject to price fluctuations. Due to their reduced emissions and higher fuel economy, alternative fuel vehicles like electric cars are gaining popularity. On the other hand, electric vehicles (EVs) employ an electric motor that is powered by a battery pack. Hence, EVs aren't thought of as regular cars, but rather as a substitute for traditional cars. Compared to conventional cars, EVs have a number of benefits, including reduced emissions, low running costs, quieter operation, and a more comfortable driving experience. Already, the switch to electric vehicles (EVs) from conventional cars is still being made, but it is increasing the speed. Concerns regarding global warming, environmental damage, and energy security, together with improvements in battery technology and government initiatives to encourage EV use, are some of the factors influencing this transformation. Despite these encouraging developments, the switch from conventional to electric vehicles is still in its infancy. A number of issues still need to be resolved, including the limited range of EVs, the requirement for more charging stations, and the higher initial costs of EVs compared to conventional vehicles. However, and, we may expect to see a continuous movement towards electrification in the transportation industry as technology advances and more people become aware of the advantages of EV

2. Literature review

For usage in plug-in electric and hybrid electric cars, this paper compares and analyses the performance of two different types of bidirectional DC-DC converters: cascaded buck-boost capacitor in the middle (CBB-CIM) and cascaded buck-boost inductor in the middle (CBB-IIM). Based on device requirements, switch and component ratings, control scheme, and performance, the two converters are compared. Each converter topology offers some benefits over the others in particular areas. Efficiency study has been done for particular vehicle application situations. For both converter types, simulation and experimental results are given [1].

Recent years have seen extensive research on electric cars due to the possible shortage of fossil fuels and growing environmental issues (EV). Electric vehicles (EVs) that are plugged in charge their batteries using power from the distribution grid. This demonstrates the inevitable nature of the charging component and highlights the need for an effective rapid charging station network. However, the expanding EV charging infrastructure presents a number of difficulties for the current distribution system. This article models a three-phase rapid charging station with an integrated photovoltaic (PV) generator that also enables vehicle-to-grid (V2G) power exchange. By altering the reactive power flow, the battery charging station seeks to regulate the grid voltage level. Integration of renewable energy sources may prove to be an effective way to lower grid demand for electricity. A microgrid system is connected to the PV generating integrated EV charging station, and the system's performance and operation are examined by modelling various operational scenarios [2].

Modern electric car on-board charging systems are difficult to make bidirectional and effective. The power converter system described in this study, which provides bidirectional flow between the grid and an electric car battery and which benefits from a dual active bridge, is innovative. Many of the primary grid restrictions, including power quality, harmonic rejection, active and reactive power regulation, and others, may be readily met with a bidirectional architecture and correct control. The power converter's hardware prototype has been constructed. The basic functionality and claims of the V2G power interface are verified by experimental data from this hardware prototype [3].

Bidirectional power electronic converters are used to connect the grid and the EV battery and enable power exchange in both directions. Nevertheless, V2G and grid-to-vehicle (G2V) active power transfers can also be facilitated by a single bidirectional ac-dc conversion step. The different bidirectional ac-dc and dc-dc converter topologies that enable V2G and G2V active power flows are reviewed and compared in this research. This paper also covers the different charger/discharger system classes described for V2G applications, such as on-board/off-board, integrated/non-integrated, and conductive/inductive, and makes a comparison based on a set of suggested criteria. Also, the integration of renewable energy sources into EV charging/discharging infrastructures and the current developments in the use of wide band-gap semiconductors in high power-dense V2G capable converters have been examined [4].

A switching bi-directional buck-boost converter (SBBBC) for a vehicle-to-grid (V2G) system is presented in this work. The architecture can offer a bi-directional flow conduit for energy exchange between the grid and the electric vehicle's Li-battery/supercapacitor (SC) hybrid energy storage system (HESS). In addition to buck-boost functionality, this architecture also does energy management. In this study, the stability of the topology in boost and buck modes is examined using the state-space averaging approach. To guarantee that the output voltage and current are steady, the control strategy is provided in accordance with the state of charge (SOC) of the energy storage system. And constant current (CC) and constant voltage (CV) modes are both used to charge the Li-battery. Based on bode plots, the voltage and current controllers are constructed in the frequency domain. Ultimately, modelling and experimentation are used to validate the electrical viability of the topology, applicability of the design controller, and control approach [5].

With a fleet of electric vehicles (EVs) connected to a distributed power system via a network of charging stations, this study describes an optimized bidirectional Vehicle-to-Grid (V2G) operation. The system may schedule EV charging and discharging a day in advance to lower the cost of EV ownership charging by taking use of frequency and voltage control services. In order to better optimize the use of EVs to support both voltage and frequency regulation, the proposed system is able to respond to real-time EV consumption data and identify the necessary modifications that must be made to the day-ahead energy projection. The initial battery State Of Charge (SOC), EV plug-in time, regulation pricing, intended EV departure time, battery degradation cost, and vehicle charging needs are all taken into account in an optimization technique for V2G scheduling. Five EV charging stations are integrated into a typical IEEE 33-node distribution network to show the efficacy of the proposed system. To confirm the contribution of this advanced energy supervision technique, two case studies have been conducted. The incorporation of V2G technology offers a clear potential to provide frequency and voltage support while also lowering EV charging costs, particularly during on-peak times when the demand for active and reactive power is high [6].

The bidirectional DC-DC converter is necessary for the electric car. To link a low input battery voltage to a high input DC voltage and vice versa, a high conversion ratio is preferred. In this paper, a novel-high gain DC to DC bidirectional switched converter is suggested. In order to decrease input current stress and ripple, the suggested converter employs the interleaved approach on the input side. The suggested bidirectional converter offers broad voltage conversion and has a common ground, making it appropriate for use in electric and hybrid vehicles. Discussions include steady-state functioning, analysis, and simulation verification. The experimental results are reported after the experimental verification is completed [7].

Electric vehicles (EVs) are thought to be one of the best methods for lowering gas emissions and oil consumption. In the near future, they will be welcomed for use in regular road traffic. EVs become grid able EVs when they are linked to the power grid for charging and/or discharging (GEVs). These GEVs will have a significant influence on society and, ultimately, human existence. The potential and difficulties associated with GEVs interconnecting with the grid, namely the vehicle-to-home (V2H), vehicle-to-vehicle (V2V), and vehicle-to-grid (V2G) technologies, are examined and discussed in this study. The aim is to offer techniques, approaches, and foresights for the V2H, V2V, and V2G developing technologies [8].

The need to shift to clean and sustainable economies has become more apparent as a result of growing environmental risks. To find and incorporate better energy sources, such as electric cars for smart grids, several ground-breaking technical advancements have been produced. In this research, a simulation environment that represents a micro-grid with a fleet of electric cars and a restricted vehicle-to-grid application is suggested. In actuality, the discharging mode is only utilized in the situation of peak demand with a very high reaction time. The components that make up this micro-grid are described, modelled, and given a simulation of how they function. The research analyses the charging and discharging scenarios further and digs into the management techniques utilized to control the power in this simulation [9].

3. Methodology

V2G stands for Vehicle-to-Grid, which is a technology that enables electric vehicles (EVs) to provide electricity back to the grid. Typically, EVs are charged from the grid, but with V2G, they can also discharge electricity back to the grid, allowing them to function as a mobile battery storage system. This technology can be used to balance the grid during peak demand periods or when there is a shortfall in the electricity supply. It can also help to integrate renewable energy sources into the grid, such as solar and wind power, by storing excess electricity generated during low demand periods and returning it to the grid when needed.V2G technology works through a two-way charging system that enables the EV battery to be charged or discharged as needed. When the EV is connected to the charger, it can communicate with the grid to determine when to draw power or supply power back to the grid.

4. Working and operation

V2G stands for Vehicle-to-Grid, which is a technology that enables electric vehicles (EVs) to provide electricity back to the grid. Typically, EVs are charged from the grid, but with V2G, they can also discharge electricity back to the grid, allowing them to function as a mobile battery storage system. This technology can be used to balance the grid during peak demand periods or when there is a shortfall in the electricity supply. It can also help to integrate renewable energy sources into the grid, such as solar and wind power, by storing excess electricity generated during low demand periods and returning it to the grid when needed.V2G technology works through a two-way charging system that enables the EV battery to be charged or discharged as needed. When the EV is connected to the charger, it can communicate with the grid to determine when to draw power or supply power back to the grid.

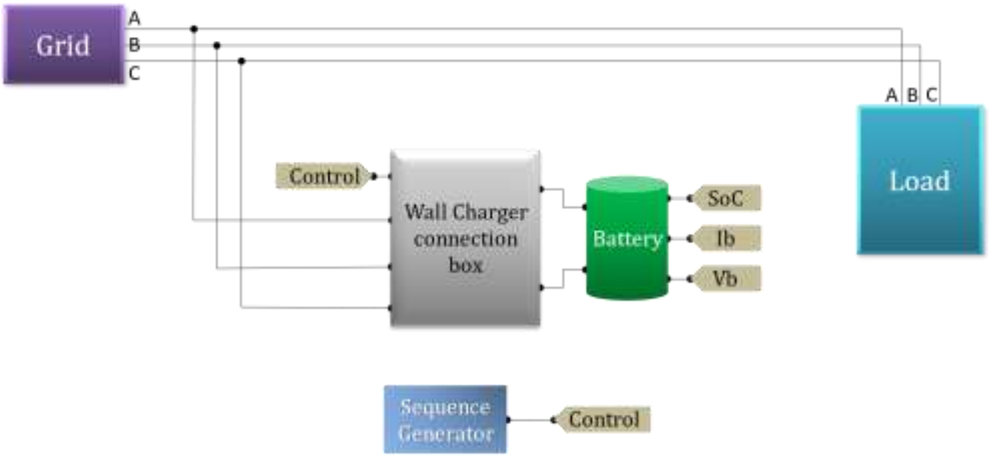


Fig. 1. Vehicle to grid architecture.

4.1 WALL CHARGER CONNECTION BOX

When the charger is connected to the vehicle's battery, we can set the initial SOC of the battery of a desired value so that the battery can be charged up to the pre-set value.

The inputs given to the charger are the grid for the power supply and the control for controlling operation (V2G or G2V). Inside the charger connection box, we have the following blocks.

1. Connection control
2. DC-AC/AC-DC converter
3. Buck-Boost converter
4. DC-DC converter with battery controller
5. Battery Switching control.

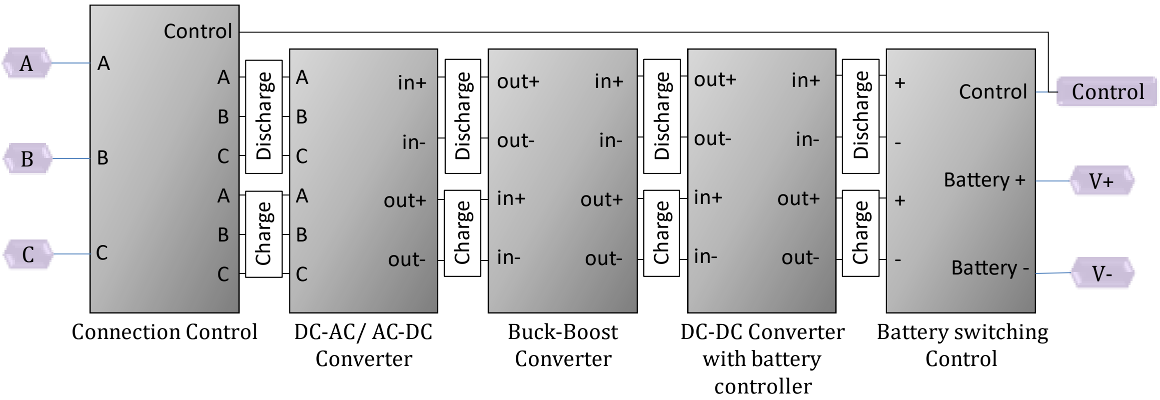


Fig-2 Inside the wall charger connection box.

I. Connection Control:

Connection control in an electric vehicle (EV) charger is critical for enabling Vehicle-to-Grid (V2G) and Grid-to-Vehicle (G2V) capabilities. V2G and G2V are two-way power flows that allow EVs to not only draw power from the grid but also supply power back to the grid, depending on the need.To enable V2G and G2V, the EV charger must have bidirectional charging capabilities. This means that the charger should be able to not only draw power from the grid and charge the EV battery but also discharge power from the EV battery back to the grid. The connection control mechanism in the charger should be designed to enable this bidirectional flow of power.

Here we have control signal from the Repeating Sequence Stair signal. The Repeating Sequence Stair block outputs and repeats a stair sequence that we specify with the Vector of output values parameter. For example, we can specify the vector as [3 1 2 4 1]'. A value in Vector of output values is output at each time interval, and then the sequence repeats. We specified the vector as [0 0 1 1 0] as we can be able to provide v2g for 'zero' output and g2v for 'one' output or vice versa by using 'not' gate.

II. DC-AC/AC-DC converter:

A DC-AC converter, also known as an inverter, is an electronic device that converts a DC (direct current) voltage into an AC (alternating current) voltage. The AC voltage produced by the inverter can be of different frequencies, amplitudes, and waveforms depending on the application. The DC voltage is first converted into a high-frequency AC voltage using an oscillator, which is then stepped up to the required output voltage level using a transformer. The output waveform can be modified using additional circuitry such as filters, amplifiers, and pulse-width modulation (PWM) techniques. An AC-DC converter, also known as a rectifier, is an electronic device that converts an AC voltage into a DC voltage. AC-DC converters are used in a wide range of applications, including power supplies for electronic devices, battery charging systems, and motor control circuits. The AC voltage is first rectified using a diode bridge or other rectifying circuitry, which produces a pulsating DC voltage. The pulsating DC voltage is then filtered and smoothed using capacitors and inductors to produce a stable DC voltage. Additional circuitry such as voltage regulators and feedback control loops can be used to further improve the stability and performance of the converter.

AC-DC converters can be designed to operate from different types of AC power sources, including single-phase or three-phase AC, and can produce DC output voltages with different levels of regulation and ripple.

For the generation of pulses for the switches in the universal bridge, PWM generator was used as shown in Figure 2. The PWM Generator (2-Level) block generates pulses for carrier-based pulse width modulation (PWM) converters using two-level topology. The block can control switching devices (FETs, GTOs, or IGBTs) of 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, also called modulating signal, is compared with a symmetrical triangle carrier. When the reference signal is greater than the carrier, the pulse for the upper switching device is high (1), and the pulse for the lower device is low (0).

To control a single-phase full-bridge device, you can select unipolar or bipolar PWM modulation. Using the unipolar modulation, each arm is controlled independently. A second reference signal is internally generated by phase-shifting the original reference signal by 180 degrees. Using the bipolar modulation, the state of the lower switching device of the second arm is the same as the state of the upper switch of the first arm, and the state of the upper switch of the second arm is the same as the state of the lower switch of the first arm. The unipolar modulation produces better quality AC waveform, but the bipolar modulation produces very low-varying common-mode voltage.

For generating the reference value, the grid voltage value will be given as the input to the PLL(3ph) block. The PLL (3ph) block models a Phase Lock Loop (PLL) closed-loop control system, which tracks the frequency and phase of a sinusoidal three-phase signal by using an internal frequency oscillator. The control system adjusts the internal oscillator frequency to keep the phases difference to 0. The three-phase input signal is converted to a dq0 rotating frame (Park transform) using the angular speed of an internal oscillator. The quadrature axis of the signal, proportional to the phase difference between the abc signal and the internal oscillator rotating frame, is filtered with a Mean (Variable Frequency) block. A Proportional-Integral-Derivative (PID) controller, with an optional automatic gain control (AGC), keeps the phase difference to 0 by acting on a controlled oscillator. The PID output, corresponding to the angular velocity, is filtered and converted to the frequency, in hertz, which is used by the mean value. For generating the reference signal from the given inputs, a simple code will be given to the MATLAB function (Ref_generation)

```
function [a, b, c] = ref_generation (x, ma, shift)

shift_k=shift*pi/180;

a=(ma*(sin((x)+shift_k)));

b=(ma*(sin((x)+shift_k-(2*pi/3))));

c=(ma*(sin((x)+shift_k+(2*pi/3))));
```

The generated reference value will be given to the PWM generator and hence pulses will be given to the switches of the Universal bridge and thereby we can control the output AC voltage while performing V2G.

III. 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 switches of the upper branch will be turned on by the pulses m2 and m12, the inductor will be charged until the switches are in ON position. Then the switches will be turned off and the diodes which are parallel to the other branch of the converters will be turned ON due to the reversal of inductor polarity.

Hence the inductor delivers the output power. During the boost mode, the switches of the lower branch will be turned on by the pulses m1 and m11, the inductor will be charged until the switches are in ON position. Then the switches will be turned off and the diodes which are parallel to the other branch of the converters will be turned ON due to the reversal of inductor polarity. Hence the inductor and the source together deliver the output power.

The bi-directional DC-DC converter consists of two power switches, two diodes, and an inductor. The switches are controlled by a pulse width modulation (PWM) signal that determines the duty cycle and frequency of the output voltage. The diodes are used to prevent reverse current flow, and the inductor stores energy during the switching cycle.

Using two PID controllers, one of which compares a reference value with the input voltage and the other which compares a reference value with the output voltage, the firing pulses to the two switches of the converters will be provided. The PWM generator will receive the output from the controllers and use it to generate pulses that will be delivered to the switches to enable discharging and charging.

IV. DC-DC converter with battery controller

A DC-DC converter with a battery controller is a system that can convert the voltage of a DC power source (such as a battery) to a different level that is required for a load, while also monitoring and controlling the battery's charging and discharging behaviour. The basic working of a DC-DC converter with a battery controller can be explained as follows:

Input voltage regulation: The DC-DC converter takes in a DC voltage from the battery, which may not always be at the desired voltage level. The battery controller monitors the battery voltage and sends a signal to the DC-DC converter to adjust the output voltage as needed.

Conversion: The DC-DC converter then converts the input voltage to the required output voltage level for the load. This conversion is achieved using a switching circuit that can change the input voltage waveform to the desired output waveform.

Output voltage regulation: The output voltage is monitored by the battery controller, which can adjust the DC-DC converter's output voltage if necessary to maintain a stable voltage level for the load.

Battery management: The battery controller also monitors the battery's charging and discharging behaviour to ensure that it is operating within safe limits. This may include monitoring the battery's temperature, current, and voltage levels to prevent overcharging, undercharging, or overheating.

V. Battery Switching Control

Battery switching control is a mechanism that enables the transfer of electric vehicle (EV) batteries between the vehicle and a charging station. This technology can be used to support both Vehicle-to-Grid (V2G) and Grid-to-Vehicle (G2V) applications. To enable V2G and G2V, the EV charger must have bidirectional charging capabilities. This means that the charger should be able to not only draw power from the grid and charge the EV battery but also discharge power from the EV battery back to the grid. The connection control mechanism in the charger should be designed to enable this bidirectional flow of power. Here we have control signal from the Repeating Sequence Stair signal. The Repeating Sequence Stair block outputs and repeats a stair sequence that we specify with the Vector of output values parameter we can be able to provide v2g for 'zero' output and g2v for 'one' output or vice versa by using 'not' gate.

4.2 MOBILE APPLICATION ON ENERGY ANALYSIS AND CHARGING COST OF EV

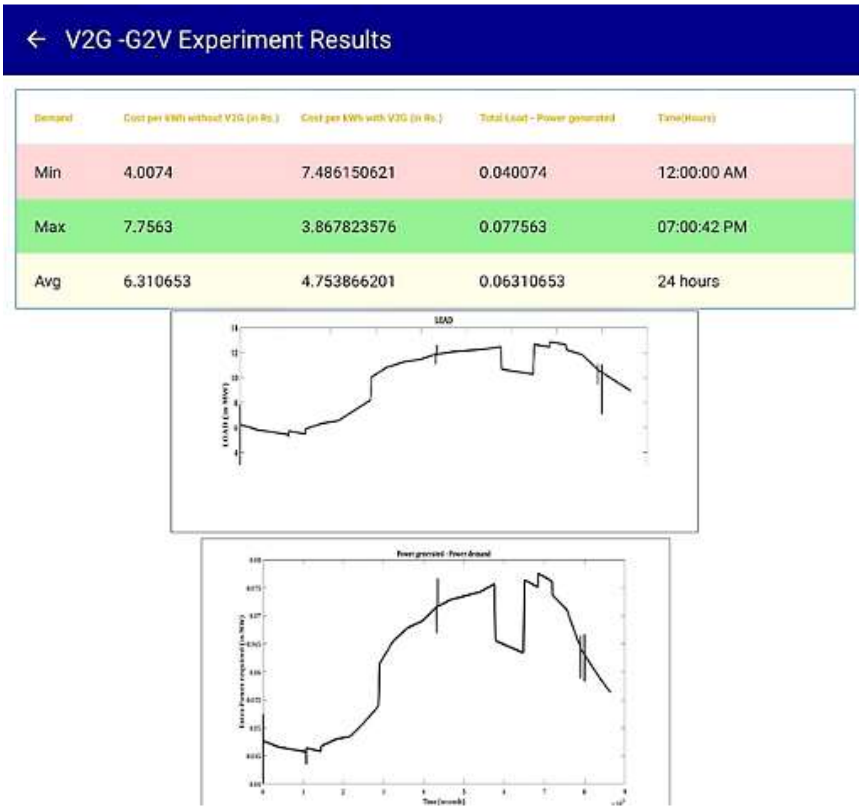
We designed a mobile application for the monitoring of charging cost of an electric vehicle on a day based on the load demand and will find a particular time of the day at which the charging cost is minimum and maximum as well as the app gives the average charging cost. For getting the sample data of power generation and power demand of a particular day, we used a simulation which is available in the MATLAB tool and collected the data.

4.2.1 Charging cost of an EV

The cost of charging electric vehicles in India can vary depending on a number of factors, including the type of charging station, the electric vehicle's battery capacity, the distance travelled, and the time of day. In general, there are two types of charging stations for electric vehicles in India: slow chargers and fast chargers. Slow chargers typically take 6-8 hours to fully charge an electric vehicle, while fast chargers can charge the same vehicle in 1-2 hours. The cost of charging an electric vehicle at a slow charging station is generally lower than at a fast-charging station. Some charging stations may offer free charging for a limited time, while others may charge a fee based on the amount of electricity consumed or the time spent charging.

The cost of electricity in India also varies depending on the state and the time of day. Some states may offer subsidies or incentives to encourage the adoption of electric vehicles, while others may impose additional taxes or fees. Overall, the cost of charging an electric vehicle in India is generally lower than the cost of fuelling a petrol or diesel vehicle. However, the knowledge of minimum charging cost and maximum charging cost and average charging cost of a particular day helps the customer financially as well as it is beneficial to compare the charging cost with and without V2G since charging costs will be reduced when we use V2G.

By using vehicle to grid power conversion, we can reduce the overall average cost and standard charging during peak time in public charging stations because of V2G power conversion we can save some amount of energy we meat over energy demand. It's also worth noting that some public charging stations may have different pricing structures, and the cost of charging at these stations may depend on the time of day or the location. Based on the value of "power generated – power demand" at a particular instant we found the minimum, maximum and charging cost in a particular day and compared the costs of with V2G charging and without V2G charging as shown in fig.3.



Demand	Cost per kWh without V2G (in Rs.)	Cost per kWh with V2G (in Rs.)	Total Load - Power generated	Time(Hours)
Min	4.0074	7.486150621	0.040074	12:00:00 AM
Max	7.7563	3.867823576	0.077563	07:00:42 PM
Avg	6.310653	4.753866201	0.06310653	24 hours

Fig-3 Charging cost of an EV in a day

The minimum charging cost of an electric vehicle (EV) depends on several factors such as the size of the battery, the charging speed, and the cost of electricity in your area. However, in general, the best time to charge your EV is during off-peak hours when electricity demand is lower and rates are typically cheaper. Off-peak hours are usually in the early morning hours or late at night. Some utility companies offer time-of-use (TOU) plans that incentivize customers to charge their EVs during off-peak hours by offering lower rates. Additionally, some EVs have built-in scheduling features that allow you to set the charging time for when rates are lowest. But due to V2G, the scenario changes to minimum charging cost at maximum demand.

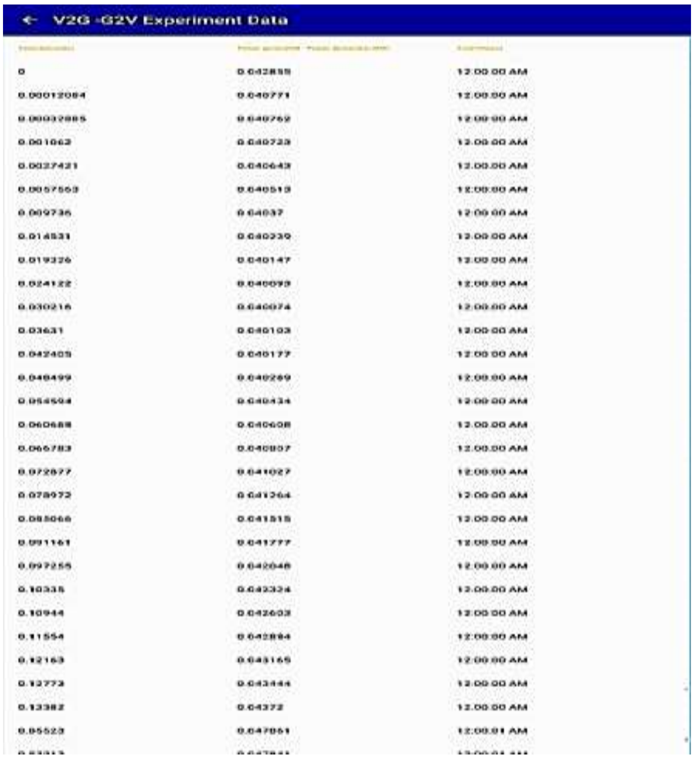
4.2.2 Energy analysis of a given day

As we know, the power demand is less in the night time rather than the morning as well as the power generated by the solar and wind will also be less at that time. Knowing the minimum consumption of a load can be useful in determining its energy efficiency and in calculating the cost of operating the load over time. It can also help in designing power supply systems, where it is important to ensure that the load always receives enough power to operate properly, even during periods of low demand. Also, understanding the maximum consumption of a load is essential for ensuring that electrical systems are designed and operated safely and efficiently. These things will be shown in the mobile application as well as the value of “power generated – power demand” at every instant of a particular day was shown in the application. The data was extracted from the simulation using the following code making it run on the MATLAB tool.

```
clear all;

close all;

clc;

h=openfig('Generated power - Power demand.fig');

h=findobj(gca,'Type','line');

x=get(h,'Xdata');

y=get(h,'Ydata');

A=[];

A(:,1)=x;

A(:,2)=y;

dlmwrite(‘data.txt',A,',');
```

In the code, we open the figure named ‘Generated power – power demand’ which was file saved in the MATLAB figure format which contains x-axis as time of 24 hours in seconds and why axis has the value of ‘Generated power – power demand’ in kW. We’ll get the x-axis and y-axis data of the figure using the “get ()” function. Thereafter, we’ll insert the data into matrix defined as “A” as shown in the code. The data in the matrix will be written into a file named “data”, a file in txt format.

Now, we got the data to be displayed on the application. So, we inserted the txt file into the application source code to display the data in the application as shown in figure.4.



[illegible]	[illegible]	[illegible]
0	0.042855	12:00:00 AM
0.00012084	0.040771	12:00:00 AM
0.00032885	0.040762	12:00:00 AM
0.001062	0.040723	12:00:00 AM
0.0027421	0.040643	12:00:00 AM
0.0057563	0.040513	12:00:00 AM
0.009736	0.04037	12:00:00 AM
0.014531	0.040230	12:00:00 AM
0.019326	0.040147	12:00:00 AM
0.024122	0.040093	12:00:00 AM
0.030216	0.040074	12:00:00 AM
0.03631	0.040103	12:00:00 AM
0.042405	0.040177	12:00:00 AM
0.048499	0.040269	12:00:00 AM
0.054594	0.040434	12:00:00 AM
0.060688	0.040608	12:00:00 AM
0.066783	0.040807	12:00:00 AM
0.072877	0.041027	12:00:00 AM
0.078972	0.041264	12:00:00 AM
0.085066	0.041515	12:00:00 AM
0.091161	0.041777	12:00:00 AM
0.097255	0.042048	12:00:00 AM
0.10335	0.042324	12:00:00 AM
0.10944	0.042603	12:00:00 AM
0.11554	0.042884	12:00:00 AM
0.12163	0.043165	12:00:00 AM
0.12773	0.043444	12:00:00 AM
0.13382	0.04372	12:00:00 AM
0.85523	0.047061	12:00:01 AM

Fig-4 AC-DC front-end topologies for dc fast chargers.

The graphical representation of the results will be shown in figure 5.

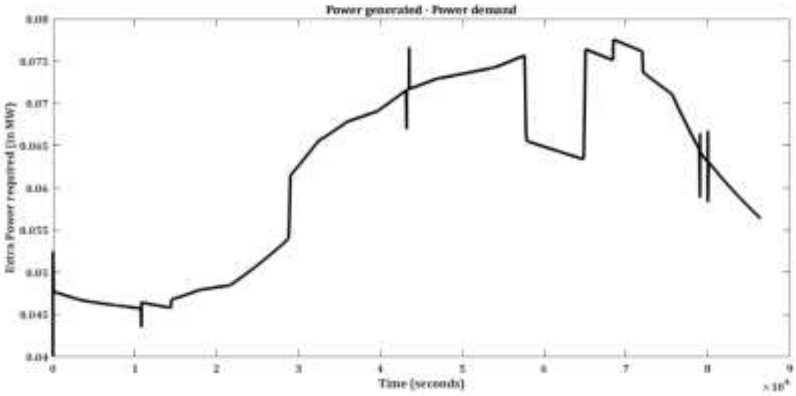


Fig. 5: Power generated – power demand

5. Results and Discussion:

In this simulation, the charger designed for designed for V2G and G2V is more suitable to install in the parking slots rather than the charging stations. The charger takes the initial soc of the battery as the input and based on the load demand we can set the values in the repeating sequence stair hence the charger keeps the SoC of the battery remains at the initial soc before unplugging the charger. In-between it supplies the power to the grid based on the input of sequence stair. For example, we have given the input as [0 0 1 1 0] and kept the run time of the simulation as 0.5 seconds. So, the 0.5 seconds will be split into 5 equal intervals as we have given 5 values in the sequence stair. And, the power will be supplied from vehicle to grid whenever the input is 1 and takes power from grid to vehicle when the input is 0. So, the SoC of the battery over the run time will be as shown in *figure 6.*

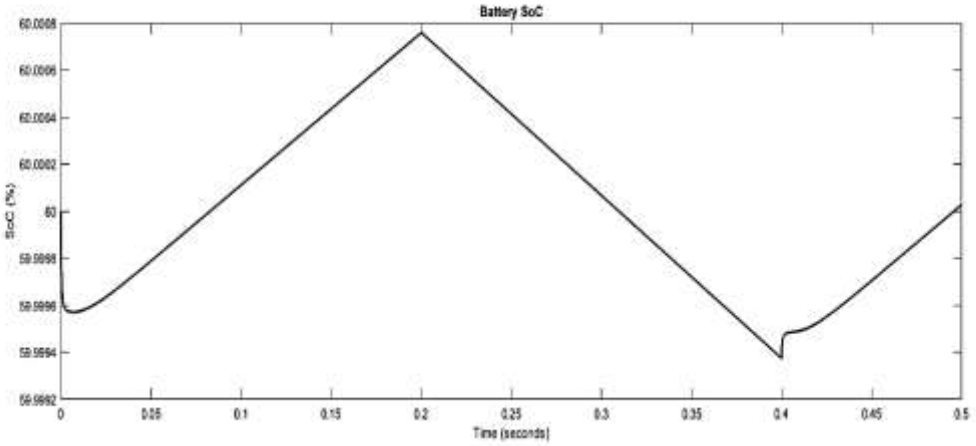


Figure 6: Battery SoC

The 3-phase grid voltage and the inverter voltages will be as shown in *figure 7* and *figure 8.*

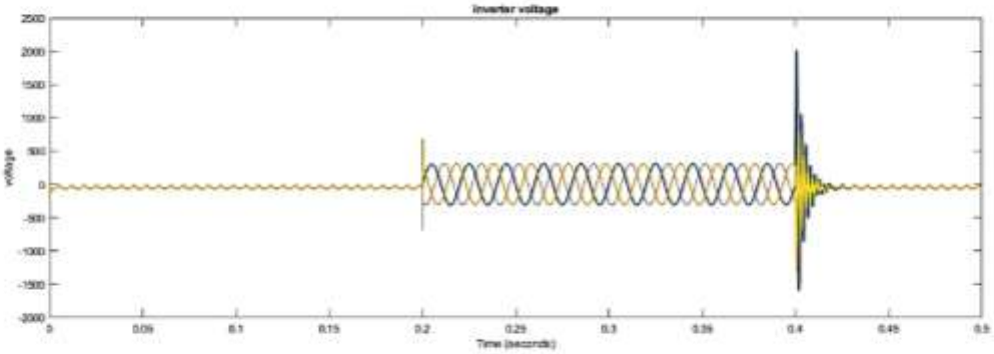


Figure 7. Output voltage of Inve3rter

For the first 0.2 seconds, the charger is operating for grid to vehicle hence the output voltage of the inverter is DC and the next 0.2 seconds, it is operating for vehicle to grid hence the output across the inverter is AC. The 3-phase grid voltage will be as shown in figure below.

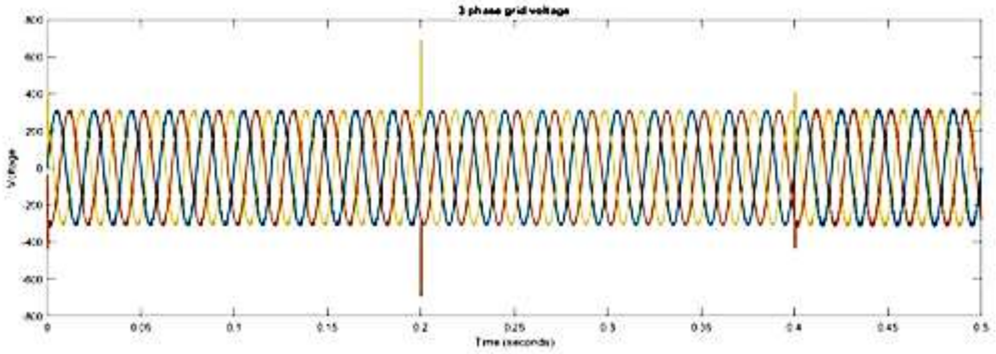


Figure 8. 3-phase grid voltage

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