# PV &Grid Integrated EV Charging WithV2GOperation Using Level 3 Charging Station

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**Abstract—**
This paper makes use of electric vehicles (EVs) that are simultaneously connected to the Photovoltaic Cells (PV) and the power grid. In micro-grids, batteries of the electric vehicles (EVs) used as a source of power to feed the power grid in the peak demands of electricity. EVs can help regulation of the power grid by storing excess solar energy and returning it to the grid during high demand hours. This paper proposes a new architecture of micro-grids by using a rooftop solar system, Battery Electric Vehicles (BEVs), grid connected inverters, a boost converter, a bidirectional half-bridge converter, output filter, including L, LC, or LCL, and transformers. The main parts of this micro-grid are illustrated and modelled, as well as a simulation of their operation. In addition, simulation results explore the charging and discharging scenarios of the BEVs. 370

Keywords— PV to vehicle, PV to grid, Grid to vehicle, Vehicle to grid, Micro-grid, Demand Side Management.
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## I. INTRODUCTION

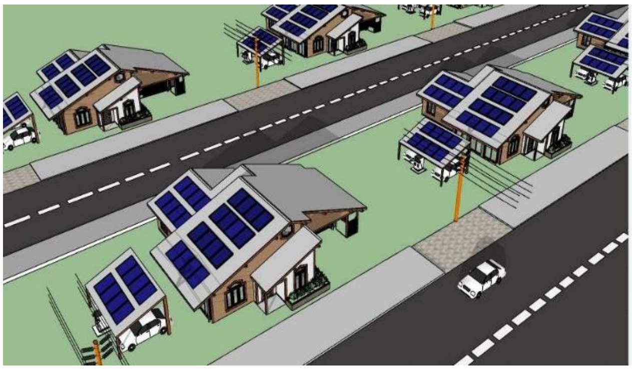
As the global population steadily increases, so does the number of vehicles on the road. However, traditional fuel sources like oil and gas won't be able to meet this rising demand. Thus, the shift towards electric vehicles (EVs) becomes imperative. EVs offer environmental benefits by reducing air pollution levels, contributing to cleaner air and a healthier environment. The market for electric vehicles (EVs) consists of three main types: Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs), and Hybrid Electric Vehicles (HEVs). Both Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) rely on power from the grid for charging. Over time, the battery capacities of these vehicles have increased, with BEVs typically ranging from 40 to 80 kWh and some models now offering batteries as large as 200 kWh.

Using renewable energy sources to charge electric vehicles (EVs) not only reduces vehicle emissions but also ensures a clean electricity supply.

Additionally, EVs can serve as dispersed energy storage units, potentially becoming integral components of smart grids by utilizing idle EVFig.1. DC fast charging station using PV toVehiclesbatteries to supply power to the grid when needed.Fig. 1. DC fast charging station using PV to Vehicles

Lithium-ion battery storage systems are commonly used as the primary storage batteries in electric vehicles (EVs).Electric vehicles (EVs) typically have three levels of charging options. Level 1 charging involves plugging into a standard 120-volt outlet, which is slow and best suited for short-distance travel. Level 2 charging uses a specialized 240-volt outlet, providing faster charging at up to 30 amps. Finally, Level 3, or DC fast charging, delivers rapid charging at up to 90 kW, allowing EV batteries to be charged in less than an hour.

While electric cars offer environmental and economic advantages globally, they also pose challenges for the power grid. The high charging loads from fast Level 3 charging stations can lead to electricity shortages, peak demand surges, voltage instability, and reliability issues for the power grid. To mitigate the strain on the power grid caused by electric vehicles, countries should prioritize the adoption of renewable energy sources such as solar and wind power.Fig. 1. DC fast charging station using PV to Vehicles The paper proposes a microgrid system that employs photovoltaic cells to charge Battery Electric Vehicles (BEVs) through a Level 3 charging station. Figure 1 illustrates the setup, showcasing a DC fast charging station powered by solar energy for charging electric car



batteries. This system enables high-power bi-directional charging for EVs, facilitating power flow from photovoltaic cells to BEVs, from photovoltaic cells to the power grid, from BEVs to the power grid, and from the power grid to vehicles.Finally, Thepaper's structure is outlined as follows: Section 2 provides an illustration of the proposed microgrid system's structure. Section 3 explains the DC fast charging method. Section 4 demonstrates the half bridge DC-DC converter and describes the charging/discharging modes of the batteries. Sections 5 and 6 cover the boost converter and LCL filter, respectively. Section 7 presents the simulation and results of the proposed system.

## II.Structure of the proposed micro-grid system

The proposed microgrid system comprises a rooftop photovoltaic system, a transformer, Battery Electric

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Vehicles (BEVs), a DC fast charging station, and necessary power converters, asdepicted in Figure 2

Fig.2.Structure of the presented microgridsystem

This microgrid system operates in four modes: PV to Vehicle, PV to Grid, Vehicle to Grid, and Grid to Vehicle. Firstly, when sufficient solar power is available, the PV system charges the BEV batteries. Secondly, when the batteries reach full capacity, surplus solar energy can be diverted to support the national power grid. During cloudy days and at night when solar radiation is unavailable, the power grid can charge BEVs rapidly via a DC fast charging station within one or two hours. In times of peak electricity demand to prevent shortages and avoid power cuts, power utility companies can utilize the stored energy in BEVs to supply the power grid through a demand-sidemanagementsystem.

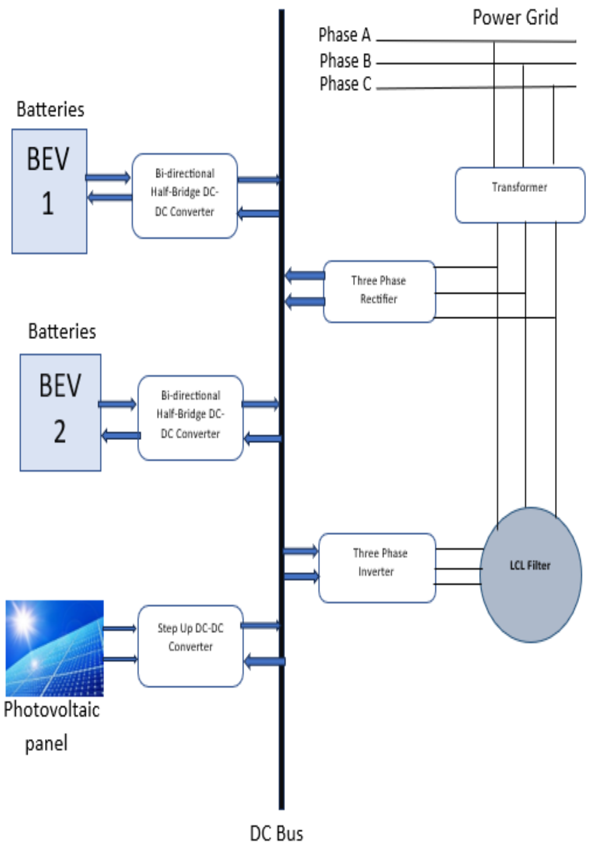


Fig. 3. PV to Vehicle; PV to Grid; Vehicle to Grid; Grid to Vehicle, using a DC fast charging station

Figure 3 illustrates the presented microgrid system operating in all four modes: PV to Vehicle, PV to Grid, Vehicle to Grid, and Grid to Vehicle, facilitated by a DC fast charging station. Each component of the system is connected to the DC bus of the charging station, enabling rapid power generation for the grid and swift charging of BEVs, all within a short timeframe of less than one hour.



## III.DC fast charging

In a DC fast charging system, there are four primary components: EV batteries, voltage converters, three-phase inverters, and an LCL filter. The voltage converter plays a crucial role in stepping up the output voltage of the batteries to match the voltage of the DC bus before feeding it into the inverter. While electric cars offer environmental and economic advantages globally, they also pose challenges for the power grid. The conversion process in a DC fast charging system involves steps like voltage conversion, inversion to AC, and filtering to achieve a pure sinusoidal waveform. Additionally, boosting the AC output voltage via a step-up transformer is necessary for injection into the power grid. These processes, while essential for charging EVs efficiently, can contribute to negative consequences such as electricity shortages, peak demand spikes, voltage instability, and reliability issues for the power grid. Fast Level 3 charging stations for electric vehicles pose challenges such as electricity shortages, peak demand spikes, voltage instability, and reliability issues for the power grid. To address this, power utility companies should strategically install these stations on stronger buses to prevent peak demands. Installing them on weaker buses could lead to severe voltage drops and increased power losses. Therefore, it's crucial for power companies to identify strong and weak buses in each area and prioritize the installation of Level 3 charging stations on the stronger buses.

**IV.Half-bridge dc to dc converter** In electric vehicles (EVs), a bi-directional half-bridge configuration is commonly employed. This configuration serves dual purposes: it can function as a step-down converter to charge the battstep-up converter to discharge the batteries and feed power back into the grid.

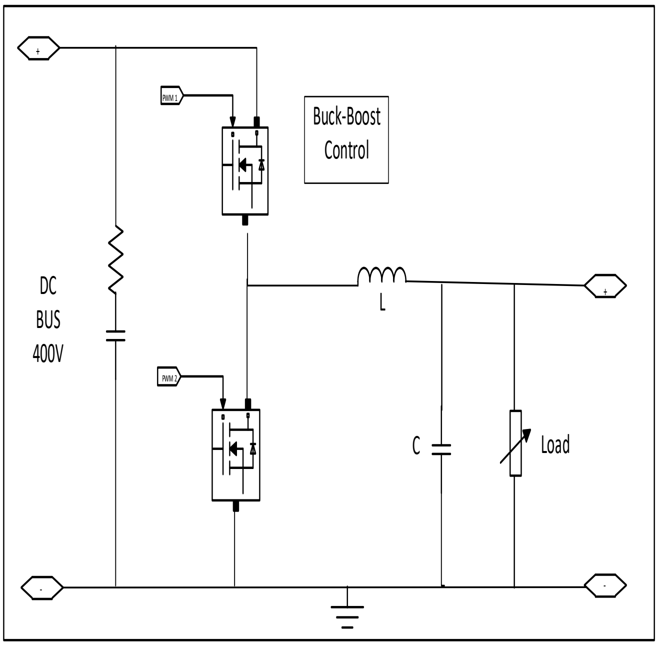


Fig 4. Bidirectional half-bridge dc-to dc converter

Figure 4 depicts a bidirectional half-bridge DC-to-DC converter, featuring two switches (Q upper and Q lower). This configuration allows the converter to function as either a step-down or step-up converter. Additionally, two freewheeling diodes are positioned in parallel with the switches, facilitating the transfer of current across them. There are two modes of operation for this converter.

A. *Step-down mode: charging the batteries*

During the step-down mode, only switch 2 is active, allowing the batteries to be charged either by the solar system or the inductor. This process results in the output voltage of the solar system being reduced to charge the batteries.

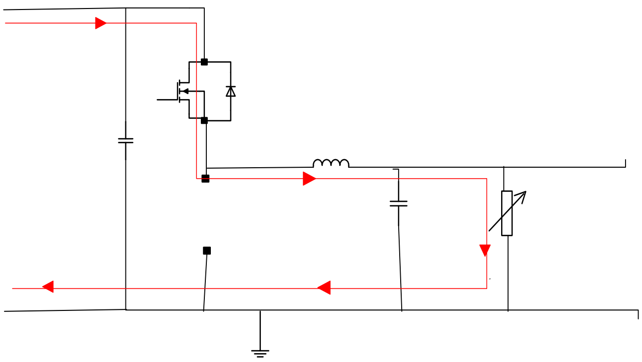

Fig. 5. Mode 1: charging the batteries by solar modules

In Mode 1, switch 1 is turned on while switch 2 is off, allowing energy from the DC bus to charge

the batteries through the inductor L. This causes the inductor current to increase, as depicted in Fig 5.

In Mode 2, shown in Figure 6, both switches are turned off. Consequently, the stored energy in the inductor L is utilized to charge the batteries.

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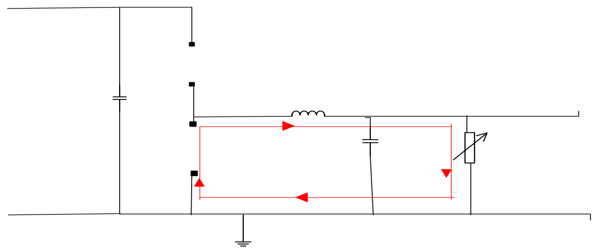


Fig. 6. Mode 2: Charging the batteries by stored energy of the inductor

*B.step-up mode: discharging the batteries*

In the step-up mode, only switch 1 is active, enabling the batteries to be discharged to supply power to the grid. This results in the output voltage of the batteries increasing to feed the power grid.

In Mode 3, switch 2 is turned on while switch 1 is off, causing the batteries to discharge through the inductor L. This results in an increase in the energy stored in the inductor, as depicted in Figure 7.

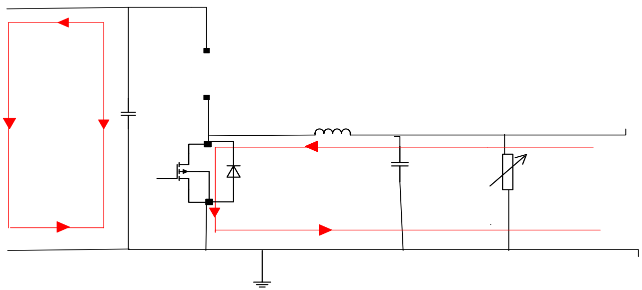


Fig. 7. Mode 3: Discharging the batteries by storing energy in the inductor

In Mode 4, both switches are turned off. Consequently, both the batteries and the stored energy in the inductor feed power to the grid, as illustrated in Figure 8.

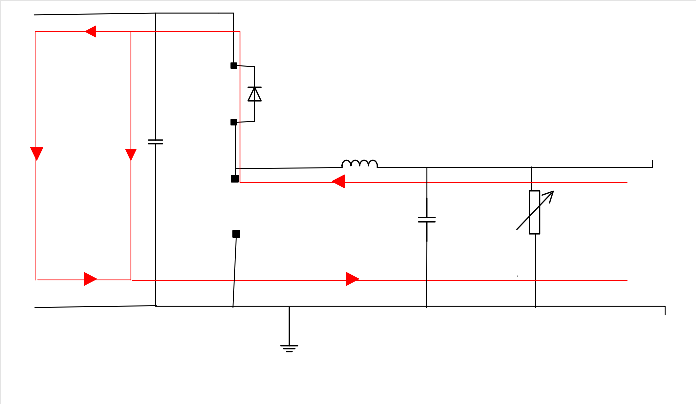


Fig. 8. Mode 4: Discharging the batteries by feeding the power grid

**V. Step up DC-DC converter**

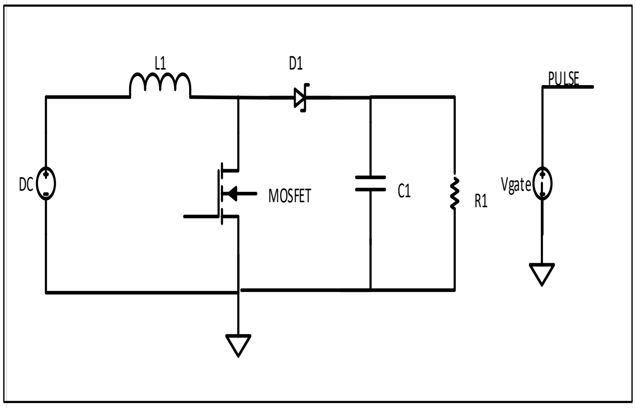



Fig. 9. Step up converter

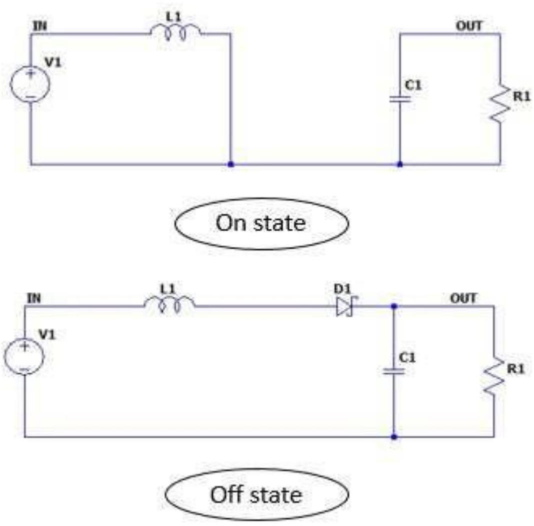



Fig. 10. Two different mode of operation

The step-up converter described in Figure 9 is used to increase the voltage of a photovoltaic (PV) system to 400 volts for the DC bus. Figure 10 illustrates two modes of operation for this converter

In the first mode, when the switch is on, the inductor L1 is charged by the direct current (DC) voltage from the PV. As a result, the current flowing through the inductor increases.

In the second mode, when the switch is off, the stored energy in the inductor as well as the energy from the PV source are utilized to supply the DC bus with power.

## VI.LCL filter

The output signal of the inverter in a DC-to-AC conversion process typically contains harmonics, necessitating the use of a filter. In this case, an LCL filter is employed after the inverter. This choice is preferred due to its lower voltage drop and suitability for operation at the low switching frequency of 60 Hz, which matches the frequency of the power grid.Equations (1), (2), and (3) define the base impedance, base capacitance, and the capacitance of the LCL filter, respectively.

$$Z_{base} = \frac{V_{pL}^2}{S_{base}} \tag{1}$$

$$C_{base} = \frac{1}{W_g . Z_{base}} \tag{2}$$

$$C_{filter} = 10\,\%\ C_{base} \tag{3}$$

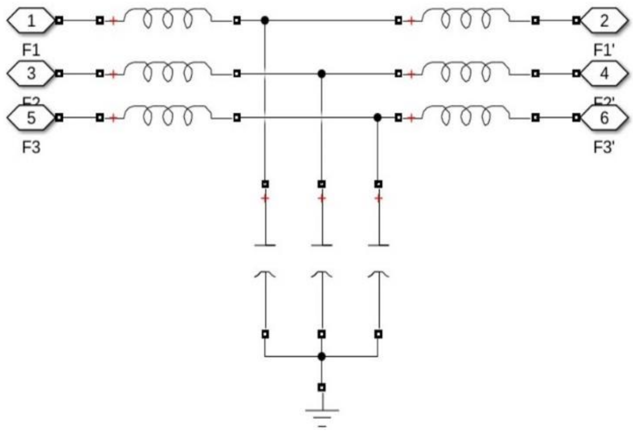
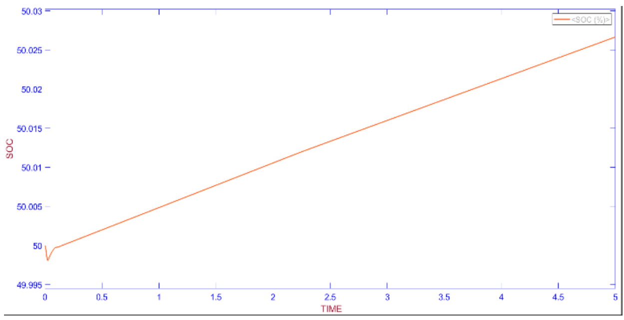



Fig.11. LCL filter

These equations provide essential parameters for designing and sizing the components of the LCL filter system. [26, 27]

$$\Delta I_{L.max} = 20\,\%. I_{output} \tag{4}$$

$$L_{inverter} = \frac{V_{dc}}{6. f_{switcLing} . \Delta I_{L.max}} \tag{5}$$




Eq. (4) and (5), indicates the peak-peak output ripple current and the inductor of the inverter side.

## VII.CONCLUSION

The paper discusses the integration of battery electric vehicles (BEVs) into the power grid withina micro-grid system, focusing on utilizing level 3 charging stations in buildings with both electric vehicles and solar panels. It explores various topologies, including PV to EVs, PV to the power grid, EVs to the power grid, and power grid to EVs, facilitated by voltage converters and grid-connected inverters. The study demonstrates satisfactory outcomes across different scenarios and suggests that the proposed method can effectively operate within micro-grid systems. Furthermore, by incorporating demand response mechanisms, the system can address peak-time demands by utilizing the battery storage systems (BSS) of electric cars to shift demands from peak to off-peak hours.

## VIII. RESULTS

In thecharging mode of operation, the input voltage is 400 Vequal to DC bus, and the output voltage is 120 V,which is equal to voltage of the batteries. Fig. 12 demonstrates the buck mode of the system.

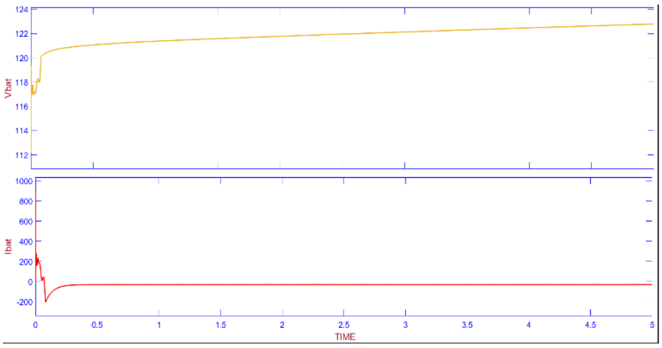
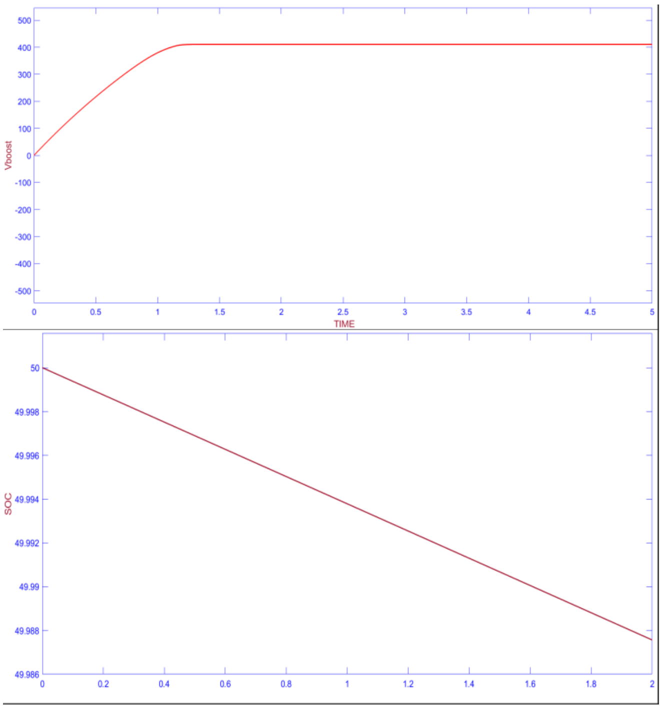


Fig 12. PV to Vehicle Mode

According to Fig. 12, the output voltage across the batteries is 120 V, which charges the storage system of the BEV.





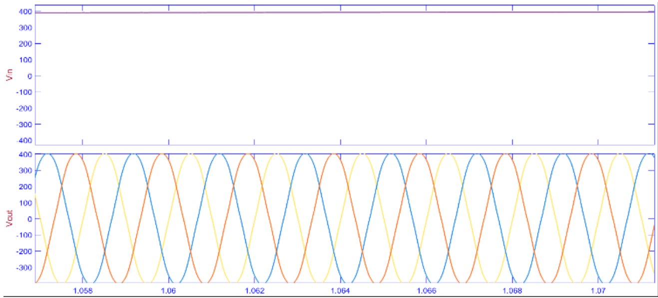
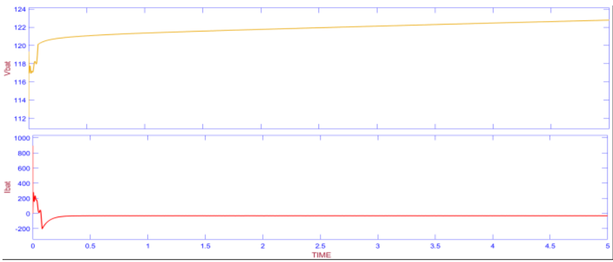


Fig 13. PV to Grid Mode

In the discharging mode of operation in which the batteries of the BEV feed the DC bus in order to feed the power grid. The output voltage across the DC bus is 400 V, which feeds the power grid.



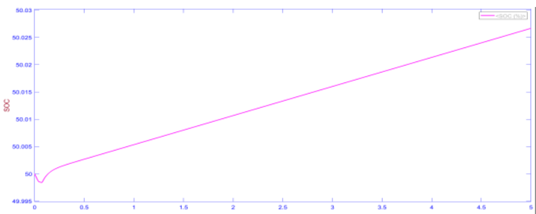
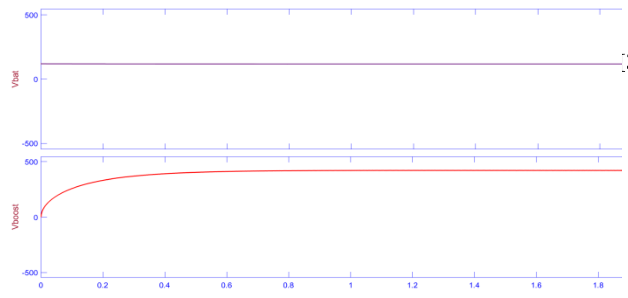


Fig 14. Grid to Vehicle Mode



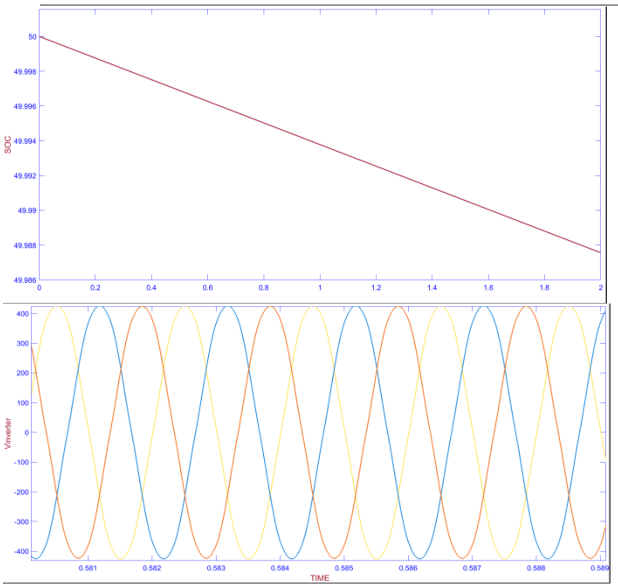




Fig 15. Vehicle to Grid Mode

The above fig shows the output of three-phase line to line voltage of the inverter which can be injected to the power grid. By using grid connected inverter with LCL filter the three-phase output voltage of the proposed system are sinusoidal.

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