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Bidirectional Electric Vehicle Charger for G2V and V2G Mode of Operation

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Abstract:

This work describes an enhanced bidirectional electric vehicle (EV) charging system that functions in grid-to-vehicle (G2V) and vehicle-to-grid (V2G) modes. The system, implemented using MATLAB/Simulink, combines power electronic devices, DC-DC converters, and controllers, and the prototype is integrated using rectifiers, inverters, and a Battery Management System (BMS) with relay-controlled operation for avoiding deep discharge of the battery. Simulation outcomes prove successful operation in G2V and V2G modes, indicating battery charging and discharging with controlled current and voltage parameters and grid and inverter voltage. The hardware prototype confirms the system's ability to charge and discharge the battery to a load efficiently. This research helps make EVs more eco-friendly by lessening the grid demand for peak hours, with prospects for revenues from V2G operations. The designed system provides a viable solution to increase EV infrastructure, decrease costs, and facilitate sustainable energy habits.

Index Terms – Electric vehicle charging, Vehicle-Grid, Grid-Vehicle, Buck-Boost Converter, and I_{DC}-I_{AC}/I_{AC}-I_{DC} Converter

I. INTRODUCTION

The use of electric vehicles (EVs) is increasingly accelerating as the world moves towards a sustainable transport revolution. Yet the mass adoption of EVs puts pressure on power grids in the form of raised peak demand and grid instability. Conventional one-way EV charging systems are behind these challenges because they tap the grid without presenting any energy management flexibility. In response to these challenges, bidirectional charging—when EVs can pull power from as well as inject power back to the grid—is seen as one of the key solutions. This research emphasizes designing and implementing a bidirectional EV charging system to enable both G2V and V2G modes. The G2V mode facilitates charging of the EV battery in an efficient manner, whereas the V2G mode facilitates power return to the grid, mitigating peak demand and improving energy sustainability. Battery management is one of the most critical issues in V2G systems, especially the prevention of deep discharge that tends to reduce battery lifespan. To address this, the proposed system incorporates a Battery Management System (BMS) based on relay-controlled operation, with the aim of safe and efficient energy transfer. The system is then simulated with MATLAB/Simulink, which gives a comprehensive analysis of power flow, voltage, and current in both modes of operation. The simulation results show that the system can successfully regulate voltage and current parameters. A hardware prototype is also created to verify the practicability, using power electronic devices, rectifiers, inverters, and protection circuits.

II. Literature Review

Bidirectional electric vehicle (EV) charging is an emerging technology that enables energy flow in both directions—from the grid to the vehicle (G2V) and from the vehicle back to the grid (V2G). This capability transforms electric vehicles from passive loads into active components of the power grid, offering opportunities for demand response, peak load shaving, and renewable energy integration.
Traditional EV charging systems are unidirectional, allowing energy only from the grid to the vehicle. In contrast, bidirectional systems incorporate power electronics and control mechanisms that facilitate two-way energy flow. The concept of V2G was introduced as a method to utilize EV batteries as distributed energy storage, capable of interacting with the grid in real time.

Grid-to-vehicle (G2V) smart charging techniques aim to optimize the EV charging process based on grid conditions, energy tariffs, and battery health. Advanced scheduling algorithms are used to reduce peak demand and minimize electricity costs. Additionally, adaptive charging strategies are being developed to align EV charging with the availability of renewable energy sources, reducing the overall carbon footprint.

Despite its potential, bidirectional charging faces several technical, economic, and regulatory challenges. Technically, the design of bidirectional inverters and control systems is more complex and costly compared to unidirectional chargers. Economically, the compensation mechanisms for energy returned to the grid are not well-established. Moreover, a lack of unified standards and grid regulations slows down the large-scale implementation of V2G systems.

III. ELECTRIC VEHICLE CHARGER

Electric vehicles can utilize either onboard or off-board charging systems for their power needs. Off-board chargers typically deliver a larger power output to the vehicle using DC power. By employing off-board chargers, the AC-DC conversion devices can be positioned in the outer infrastructure, which adds an advantage to the vehicle as it decreases the overall weight of the EV. In contrast, an on-board charger offers great flexibility to EVs, allowing them to charge in various locations where AC power supply can be available. Level-1 onboard chargers are rated for less than 3 kW, whereas level-2 chargers can reach levels up to 20 kW, exemplified by the Tesla S-twin wall charger. Additionally, wireless inductive chargers also exist, though they are not widely used as conductive chargers due to efficiency and pricing.

IV. G-2-V AND V-2-G

The primary purpose of an EV charging system is recharging the batteries (G-V); they are also capable of enabling a reverse flow of electricity back to the grid (V-G), which seems illogical at first. Considering the need for an electric system to manage fluctuating demand, electricity prices vary throughout the day; generally, demand is lower at night, leading to reduced costs. Since EVs are frequently inactive, they proposed it as a method of energy storage, with several nations investigating this idea. A key objective of the V-G strategy is to manage temporary demands, such as "peak load leveling," when traditional power generation is unable to meet demand. Furthermore, improving frequency stability and optimizing reactive power represent other important aims. There are also efforts to harness V2G technology for storing excess energy in EV batteries during less demand times and using it during high utility periods, thus enhancing the utilization of renewable energy sources. Nevertheless, substantial challenges emerge from connecting to a less-than-ideal grid and the dangers posed by islanding scenarios that could risk the safety of utility workers. This thesis investigates possible solutions to these challenges within single-phase systems, concentrating on advancements in grid synchronization and islanding detection techniques. Other barriers to V-G include overall less efficiency because of battery charge and discharge losses, increase in battery degradation, and the lack of standardized protocol with the system. However, with improvements in battery and the growing integration of utility and vehicle systems through the Internet, the potential for V2G technology appears promising. The block diagram for bidirectional operation.as shown below in Fig.1.

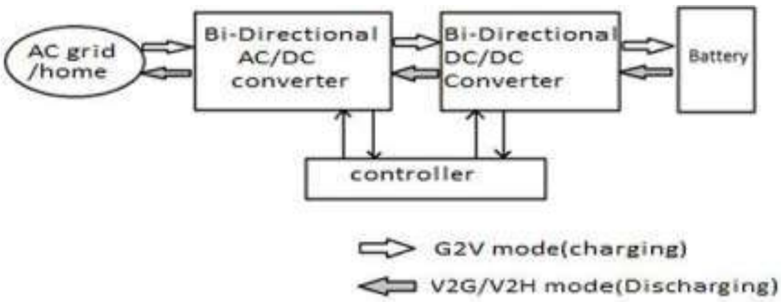


Fig.1. Bidirectional power flow block diagram

V. METHODOLOGY AND SYSTEM DESIGN

5.1 Electric vehicle charger box

The phrase "bidirectional power flow" refers to technology where EVs and the power grid can transfer energy in both directions. This occurs by a two-way transmission channel. For the bidirectional flow, the Electric vehicle charging box is created and designed as in Fig. 2.

Fig.2 Charging Box

The charging box contains five parts, they are Connection control block (charging and discharging control), Converter (AC/DC and DC/AC), Buck-Boost Converter, a DC-DC battery controller and a Battery switching control block shown in Fig.3.

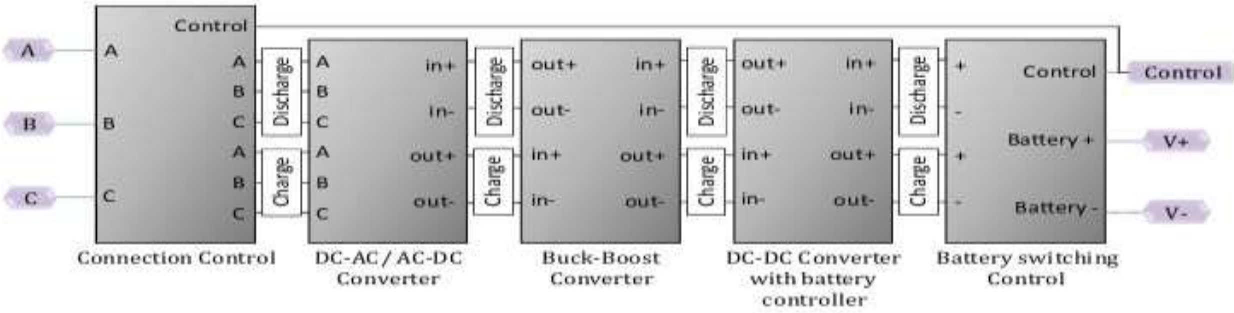


Fig.3. Schematic diagram of the interconnection of various subsystems in the charger box

5.2 Connection control

The initial subsystem is the connection control box, which primarily manages the connections of all associated subsystems. The charger's connection control system is engineered to allow bidirectional power flow, accommodating both grid-vehicle and vehicle-grid functionalities. The control switch defines the mode of operation as follows:
If Switch = 1, V2G mode is enabled.
If Switch = 0, G2V mode is enabled.

This mode selection impacts the direction of power flow and how the converters operate shown in Fig.3a.

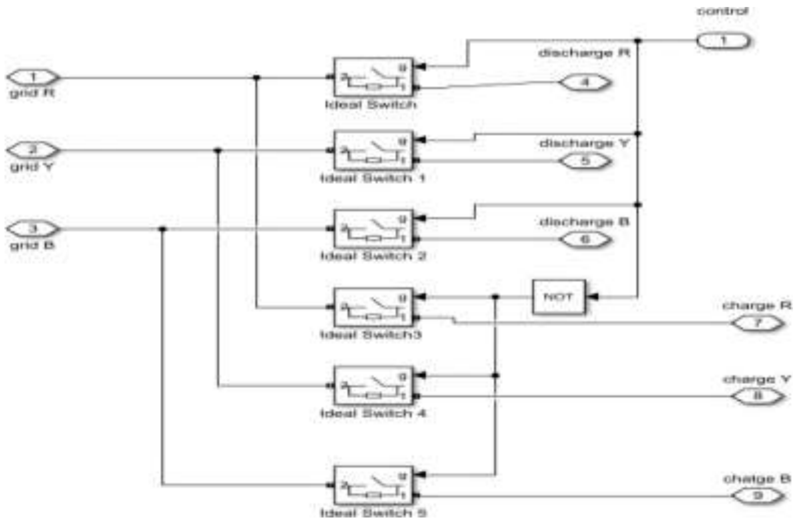


Fig.3a. Block diagram of connection control

Ideal Switch:

The Ideal Switch block does not correspond to a particular physical device. When used with appropriate switching logic, it can be used to model simplified semiconductor devices such as a GTO or a MOSFET, or even a power circuit breaker with current chopping. The switch is simulated as a resistor Ron in series with a switch controlled by a logical gate signal g. in on-state the switch internal resistance is (Ron) and in off-state switch internal resistance is infinite. The internal resistance must be non-zero to set on state the signal will be applied to g.

Parameters:

Internal resistance (Ron): 0.001
Snubber Resistance: 1e5
Initial state (0 for ‘open’, 1 for ‘closed’)

5.3 Bidirectional AC/DC Converter

The AC-DC rectifier successfully transforms three-phase AC into DC while ensuring power factor correction (PFC) and regulating the voltage of the DC bus. Advanced current control loops and voltage control loops secure the stability of DC-link voltage, reduce ripple, and enhance charging efficiency. Additionally, a carefully crafted filtering and regulation stage reduces distortions, ensuring a consistent power flow. For Vehicle-to-Grid (V2G) functionality, a digitally controlled DC-AC inverter facilitates two-way energy movement through a PWM method that synchronizes with a Phase-Locked Loop (PLL). A Proportional- Integral (PI) controller oversees this operation, generating the current reference for PWM pulse creation. It produces PWM pulses that guarantee precise switching during both rectification and inversion processes, ensuring consistency. A custom MATLAB reference generation function modifies phase and amplitude in real time, promoting seamless integration with the grid. The Simulink diagram of the ac/dc-dc/ac converter is shown in Fig. 3b below.

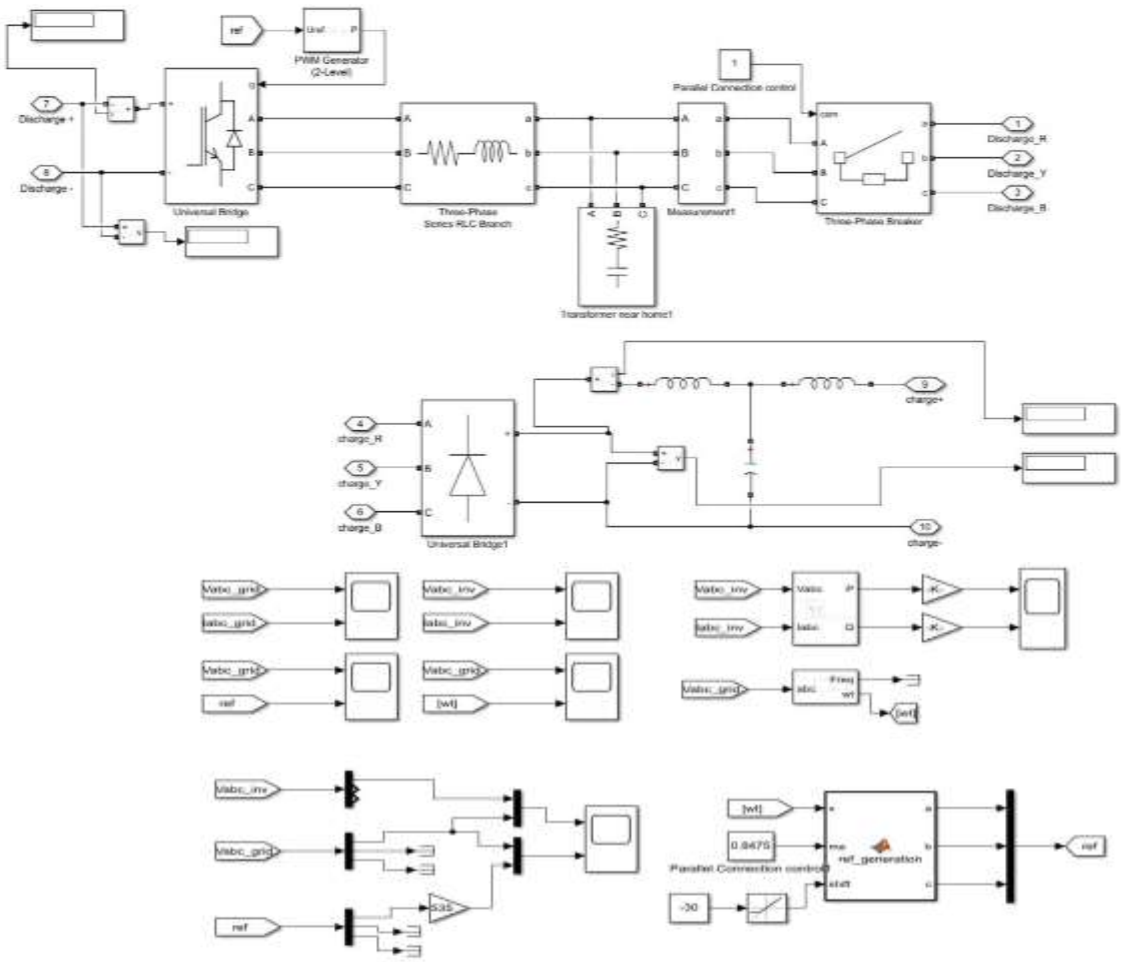


Fig.3b. Block diagram of AC/DC and DC/AC Converter

a) Universal Bridge:

This block implements the bridge of selected power electronics devices. Series RC snubber circuits are connected in parallel with each switch device.

Parameters:
Snubber resistance Rs (Ohms):1e5
Ron (Ohms):1e-3

b) Series RLC branch:

Implements RLC branch consists of series connected Resistor, inductor and capacitor.

Parameters:
Resistance R (Ohms): 0.004332
Inductance L (H): 0.0013789184

c) Series RLC load:

This series RLC load block implements a three-phase balanced load combination of RLC elements.at specified frequency, the load exhibits a constant impedance. The active and reactive powers are absorbed by the load are proportional to the square times of applied voltage.

Parameters:
Nominal phase-to-phase voltage Vn (Vrms):380
Nominal frequency fn (Hz):50
Active power P (W):100
Inductive reactive power QL (positive var):0
Capacitive reactive power Qc (negative var):500

d) Three phase Breaker:

This block connected between the inputs and the outputs of the block. You can use this block in series with the three-phase element you want to switch. Implements a three-phase circuit breaker. When the external switching time mode is selected, a Simulink logical signal is used to control the breaker operation.
Parameters:
Breaker resistance Ron (Ohm):0.01
Snubber resistance Rs (Ohm):1e6

e) PWM Generator:

Generate pulses for PWM-controlled 2-Level converter, using carrier-based two-level PWM method. The block can control switching devices of single-phase half-bridge, single-phase full-bridge (unipolar or bipolar modulation) or three-phase bridge.

Parameters:
Frequency (Hz):4950
Sample time (s): 2.02e-6

f) LCL-filter Circuit:
The filter circuit is designed through the interconnection of various RLC elements in the combination of two series inductors and a shunt capacitor helps to reduce the harmonics at the output side.

Parameters:
Inductance1 (H): 5.6e-3
Inductance2 (H): 2.8e-3
Capacitance (F): 6.4e-6

g) MATLAB Function:

```
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))));
```

h) Phase Locked loop block:

This Phase Locked Loop (PLL) system can be used to synchronize on a set of variable frequency, three-phase sinusoidal signals. If the Automatic Gain Control is enabled, the input (phase error) of the PLL regulator is scaled according to the input signals magnitude.

Parameters:
Minimum frequency (Hz):45
Maximum rate of change of frequency (Hz/s):12
Filter cut-off frequency for frequency measurement (Hz):25
Sample time:0

5.4 Buck-Boost Converter

Buck converter is used for decreasing the voltage, whereas boost converter is used for enhancing the voltage. Voltage reduction and enhancement can be achieved through the buck-boost and Cuk converters. The DC-DC converter is essential in modifying the voltage to meet the battery's specifications, functioning in both boost and buck modes. In boost mode (V2G), the battery releases energy into the grid, while in buck mode (G2V), it takes energy from the grid. The control strategy is comprised of two main loops: outer voltage control loop and inner current control loop. Voltage control loop assesses battery voltage against a reference value and utilizes a PI controller to produce the current reference. The inner current control loop then evaluates the actual battery current against the reference current and adjusts the duty cycle of the DC- DC converter switches using a PI-controlled PWM signal. This guarantees accurate management of power flow, ensuring consistency and effectiveness in bidirectional charging. Shown in Fig.3c. And .3d.

5.5 Control Strategy:

This control system is designed for a bi-directional charging system, typically used in electric vehicle (EV) applications to support both Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G) operations. The system uses a combination of voltage, power, and current controllers based on Proportional-Integral (PI) control blocks.

a. Discharging (V2G) Control

The discharge control loop regulates power delivery by comparing a fixed voltage reference (48V) with the load voltage. The error is fed into a PI controller to generate a discharge current reference:

$$I_b(ref)\_disc = PI\ (V_{ref} - V_{load})$$

b. Charging (G2V) Control

The charging loop compares a voltage reference (25.98V) with the actual battery voltage. The PI controller's output is inverted to reflect current flow into the battery:

$$I_b(ref)\_char = -\ PI(V_{ref} - V_b)$$

c. Mode Selection Logic

The control signal chooses between charging and discharging modes. Based on the mode, either I_b(ref)_char or I_b(ref)_disc is passed as the current reference I_b(ref).

$$I_b(ref) = I_b(ref)\_char \text{ (if control = 1, Charging Mode)}$$
$$I_b(ref) = I_b(ref)\_disc \text{ (if control = 0, Charging Mode)}$$

d. Current Control Loop

The current control loop compares the reference current I_b(ref) with the actual battery current Ib. The error is passed through a PI controller to generate a duty cycle signal for PWM switching.

$$ei = Ib\_ref - Ib \qquad D = Kpei + Ki\int eidt$$

e. Voltage Control Loop

The voltage control loop compares the reference voltage V_{ref} with the actual battery voltage V_b. The error is passed through a PI controller to generate a duty cycle signal for PWM switching.

$$Ev = V_{ref} - V_b \qquad C = -\ (Kp*ev + Ki\int ev\, dt)$$

Summary of Control Modes

Mode	Control Signal	Active PI Block	Ref Current Signal	Notes
G2V	1	Voltage PI (Bottom)	Ib_ref_charge	Negative current logic (charging)
V2G	0	Load PI (Top)	Ib_ref_dis	Positive current logic (discharge)

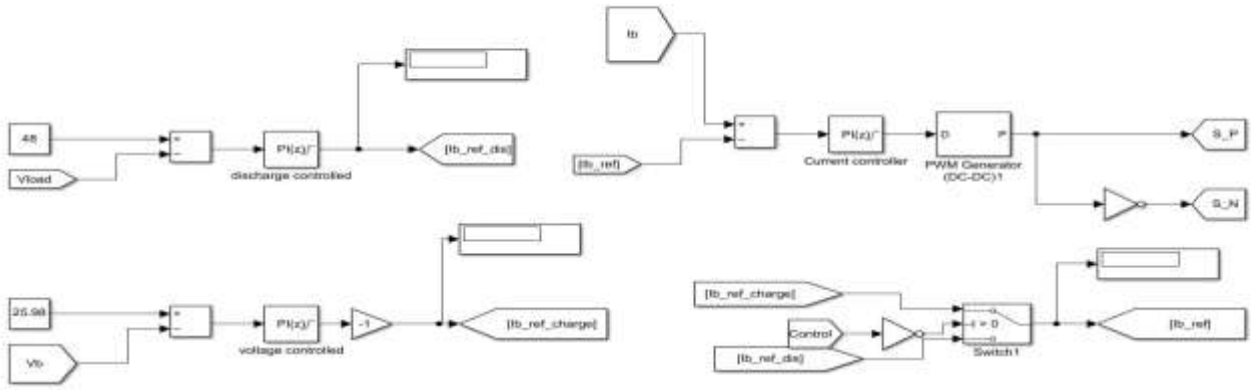


Fig.3c. Block diagram of Current control and voltage control

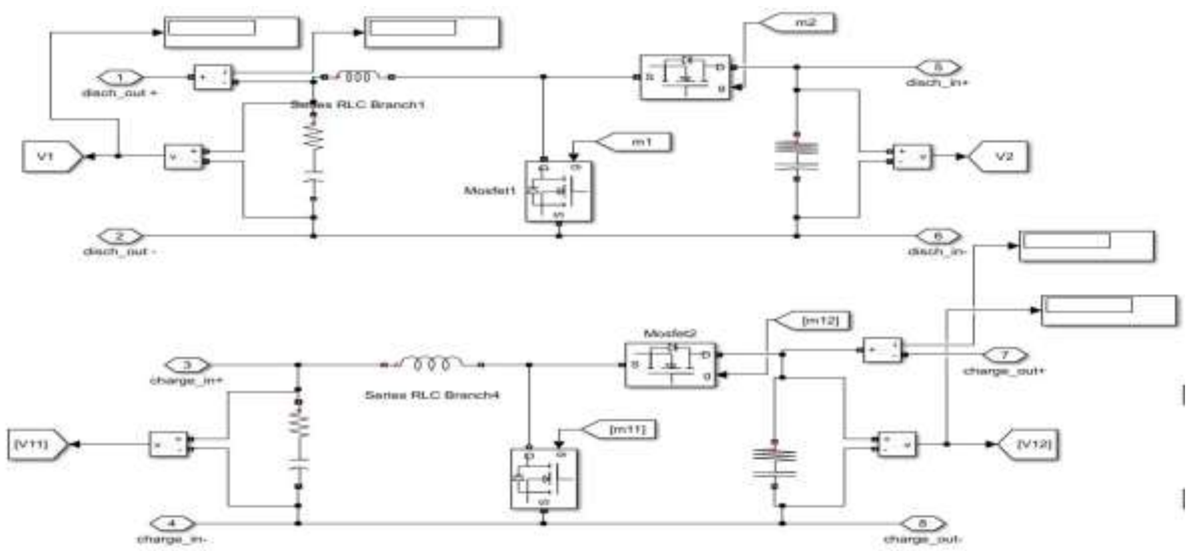


Fig.3d. Block diagram of Buck-boost converter

5.6 PI and PID controllers:

To activate the DC-DC converters we can use PI and PID controllers for various distinct DC-DC converters
PI-controller for Current control:
This block implements continuous- and discrete-time PID control algorithms and includes advanced features such as anti-windup, external reset, and signal tracking.

Parameters:
Proportional (P):0.005

Integral (I):10
PI-controller for Voltage control:
Proportional (P):40
Integral (I):2000

5.7. Pulse Width Modulation Generator:

PWM Generator block utilizes dual setup to generate the pulses for carrier PWM converter. This PWM block is capable of supplying power to 1-ϕ, 2-ϕ, 3-ϕ, and two-level bridge configurations by using commutating devices such as FET, GTO, or IGBT. Pulses are obtained by overlapping triangular waveform with a reference signal. These modulating signals may come from either PWM generator or external signals connected to the input of system. For single or two arm bridge, a single reference modulating signal is necessary for pulse generation, while 3-ϕ, single or double bridge requires three reference modulating signals are needed for producing pulses. Output voltage of the bridge linked with PWM Generator block is regulated by amplitude (modulation), phase and frequency of these reference signals.

Parameters:
Switching frequency (Hz):10e3
Sample time:5e-6

5.8 DC-DC Converter along with Battery Controller

DC-DC converter regulates voltage levels and it increases source voltage to align with bus voltage. Battery energy storage system helps to work as bridge between input DC grid and output DC bus. A DC-DC converter paired with a battery controller offers both voltage transformation and battery safeguarding. It controls the input voltage, changes it to the necessary output, and ensures output consistency. It simultaneously monitors battery parameters, including temperature and current, to prevent damage from overcharging or undercharging, ensuring safe and efficient operation.in Fig.3e.

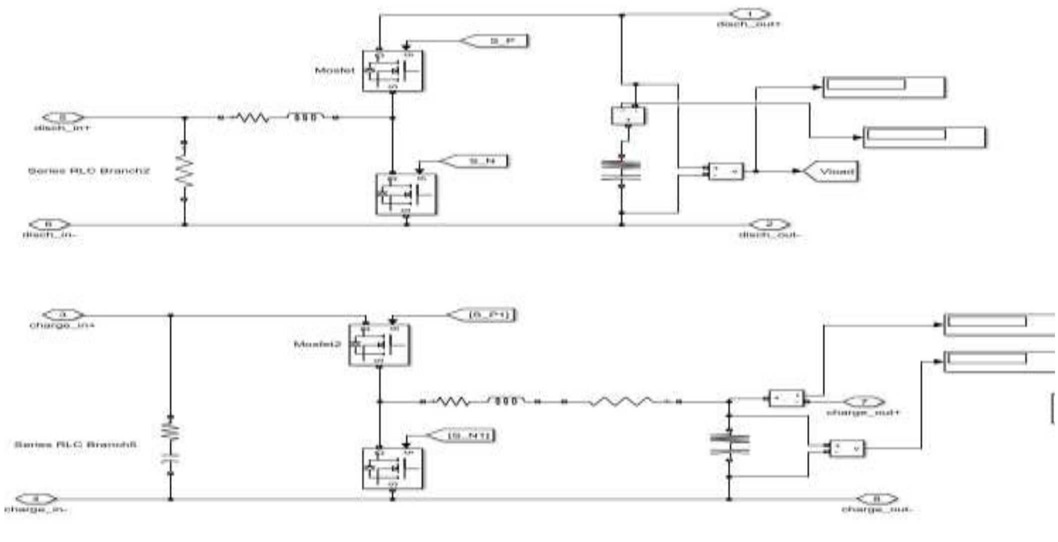


Fig.3e. Block diagram of DC-DC Converter with Battery Controller

i) MOSFET:

MOSFET and internal diode in parallel with a series RC snubber circuit. When a gate signal is applied the MOSFET conducts and acts as a resistance (Ron) in both directions. If the gate signal falls to zero when current is negative, current is transferred to the antiparallel diode.

Parameters:
FET resistance Ron (Ohms) :0.1, Internal diode resistance Rd (Ohms) :0.01
Snubber resistance Rs (Ohms) :1e5

a. Battery switching control

This block generates a user-defined, repeating series of digital values, allowing for the programmatic allocation of specific values to V2G and G2V operations. For instance, a '0' may define G2V, while a '1' indicates V2G, or vice-versa. To improve flexibility, a logical 'not' gate is included, which facilitates the inversion of the control signal, thereby reversing the connection between the digital values and the flow direction of power. This adaptive control guarantees smooth transitions between charging and discharging modes, maximizing energy transfer and aiding in grid stability. In Fig.3f.

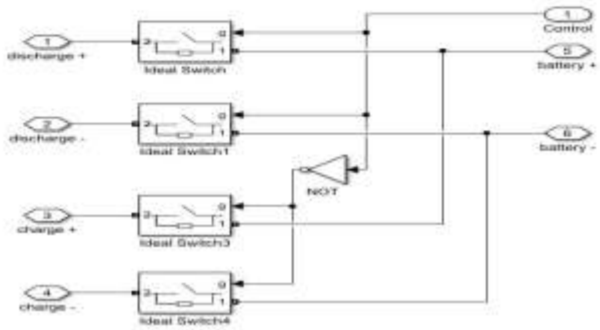


Fig.3f. Block diagram of Battery Switching Control

VI.Illustration of Simulation Design for Grid –to- Vehicle and Vehicle-to-Grid operation

The circuit for Grid to Vehicle and Vehicle to Grid Bi-directional EV Charger with implementation of all interconnected controllers has been simulated with the help of MATLAB as shown in fig.4.

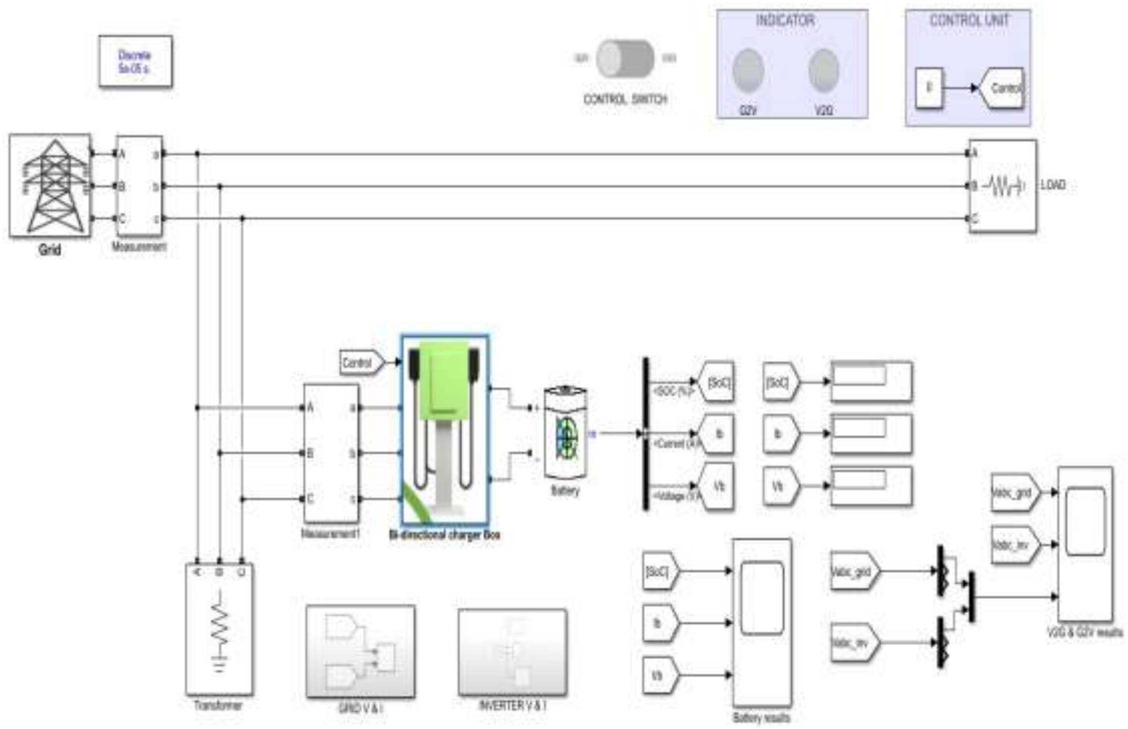


Fig.4. simulation circuit for Grid to Vehicle and Vehicle to Grid Bidirectional EV Charger

Table.1. Simulation model parameters

Parameter	Rating
Grid Phase-to-phase voltage (Vrms)	380
Frequency (Hz):	50
Battery type	Lithium-ion
Nominal voltage (V)	230
Rated capacity (Ah)	100
Simulation Time of Circuit(sec)	0.5
Charging Power Capacity (KW)	16
Discharging Power Capacity (KW)	6.3

VII.Results and discussions

Simulation evaluates proposed bi-directional controller performance in grid to vehicle and vehicle to grid scenarios. The battery initial state of charge is set to 60%. The figure is determined to ensure that the battery can receive and transmit power when required. This operation is performed in two modes the mode can be selected using a control switch either G2V or V2G and the indicator will show the mode of circuit operation performed.

7.1 Grid to Vehicle mode:

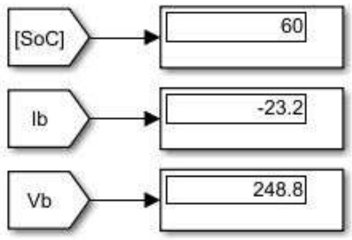


Fig.5. Results of Battery in G2V

i. For operating in **G2V mode**, switch must be set at **0**. By using the control switch, we can set the control signal to logic 0, and the indicator will show the RED light that indicates it operates in G2V mode (Charging).

ii. State of Charge (SOC) gradually increases from **58%**, as the initial SOC is set to **60%**.

iii. Charging current ranges from -22A to -23.2A, with the negative sign indicating that the battery is absorbing energy.

iv. The grid voltage (V_{Grid}) remains around 248.8V (±3V) and the inverter voltage (V_{inv}) should ideally be 0V. However, a leakage voltage is present in V_{inv}, which can be eliminated by selecting the perfect filter circuit value after rectification process.

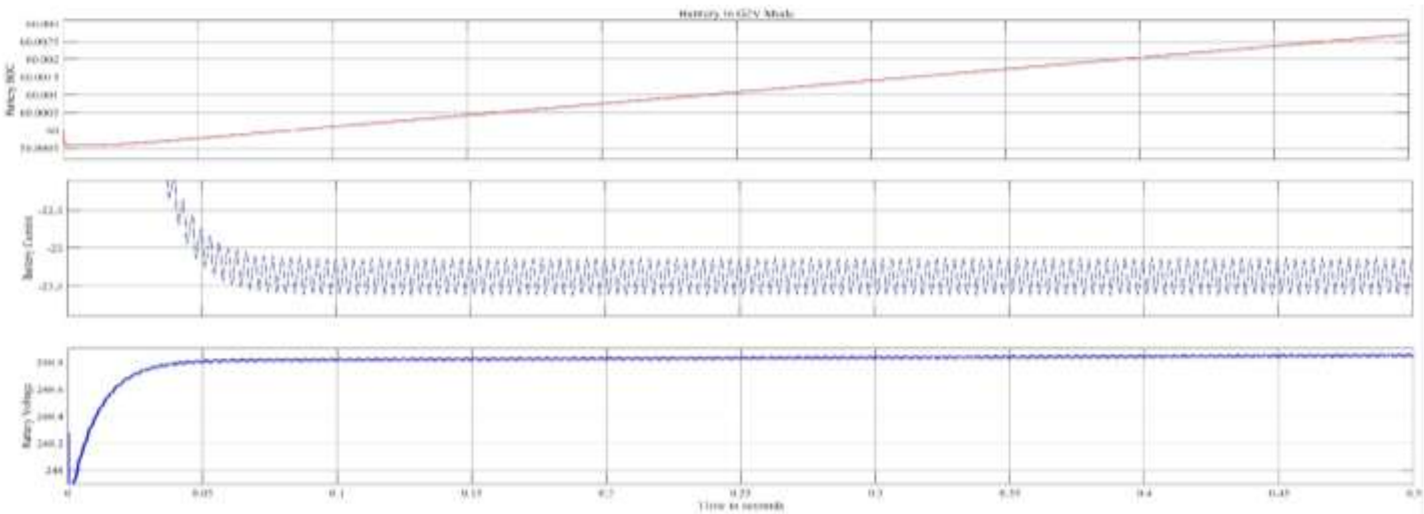


Fig.5a. Simulation Graph for Gird to Vehicle battery with respect to Time (in sec)

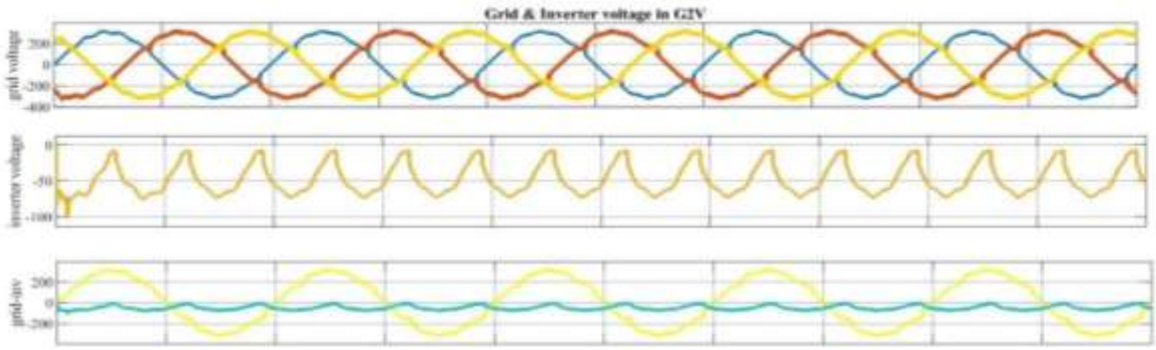


Fig.5b. Simulation Graph for Grid to Vehicle Voltage with respect to Time (in sec)

7.2 THD calculation:

The harmonic distortions are calculated for Voltage and Currents:

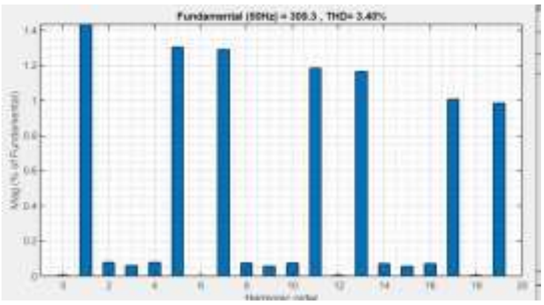


Fig.5c. THD of Voltage

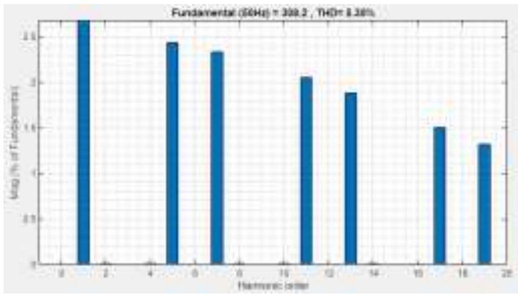


Fig.5d. THD of Current

7.3 Vehicle to Grid mode:

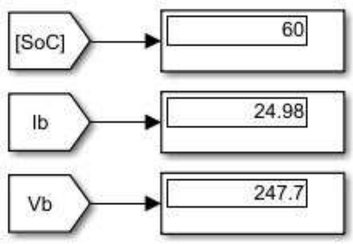


Fig.5e. Results of Battery in V2G

i. For operating in **G2V mode**, switch must be set at **1** by using the control switch we can set the control signal to logic **1** and the indicator show the GREEN light that indicates it operates on V2G mode (Discharging).

ii. State of charge gradually decreases from 58%, initial state of charge to set to 60%.

iii. Current changes from 24.92A to 24.98A with positive value referring that the battery is discharging.

iv. V_{grid} =247.7(±3V).

v. V_grid and V _inv need to synchronous because we are sending back the power to grid so, the voltage magnitude should be equal and need to be in Phase. (Similar concept when we try to perform two transformer in parallel, we need to check for the synchronous between them).

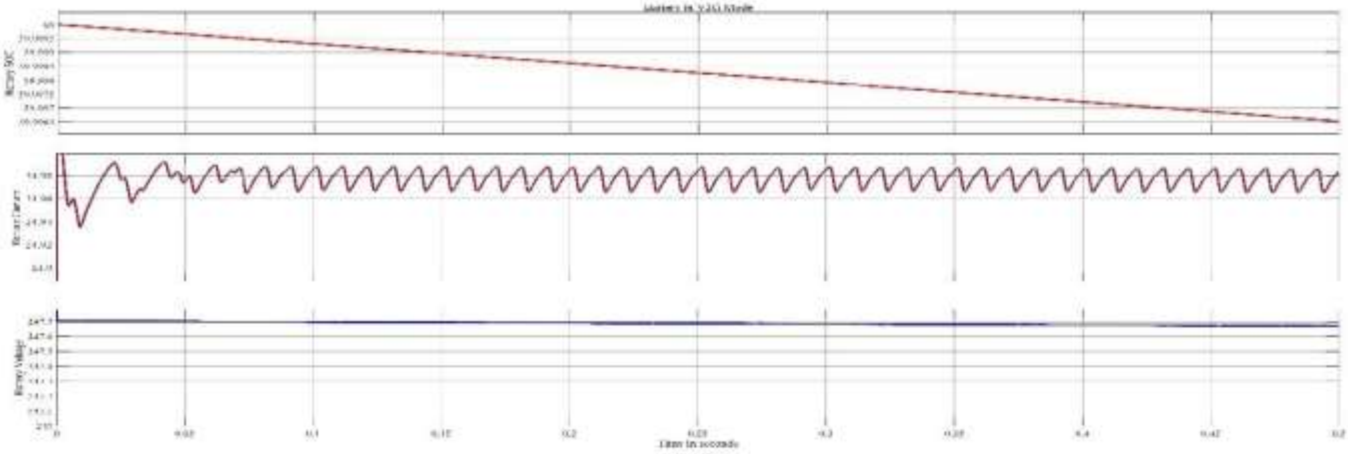


Fig.5f.Simulation Result of Battery Graph for Vehicle to Grid with respect to Time (Seconds)

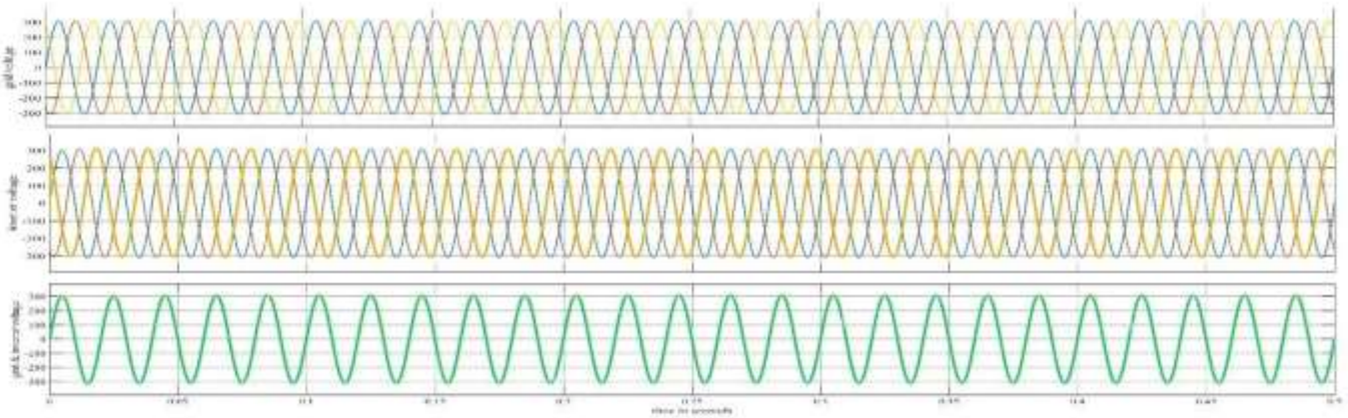


Fig.5g. Simulation Result of voltage Graph for Vehicle to Grid to Time (Seconds)

7.4 THD calculation:

The harmonic distortions are calculated for Voltage and Currents:

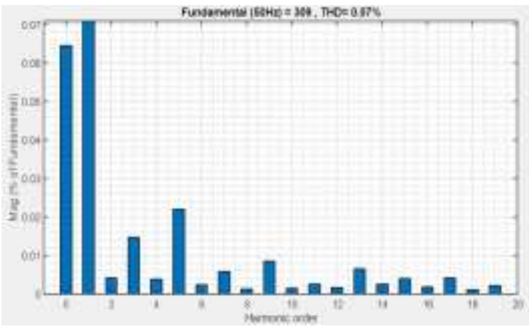


Fig.5h. THD of Voltage

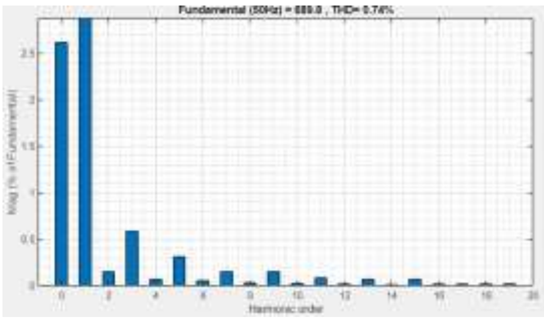


Fig.5i. THD of current

VIII.Hardware design

6.1 Design Layout

The hardware layout, as shown in **Fig.6.**demonstrates the physical arrangement of the components and the wiring connections. The layout includes the transformer, rectifier circuit, DC-DC converter, and battery pack, potentiometers, and control circuitry. The 6-pin DPDT toggle switch is strategically positioned for mode selection, while the potentiometers allow for precise control over voltage and current.

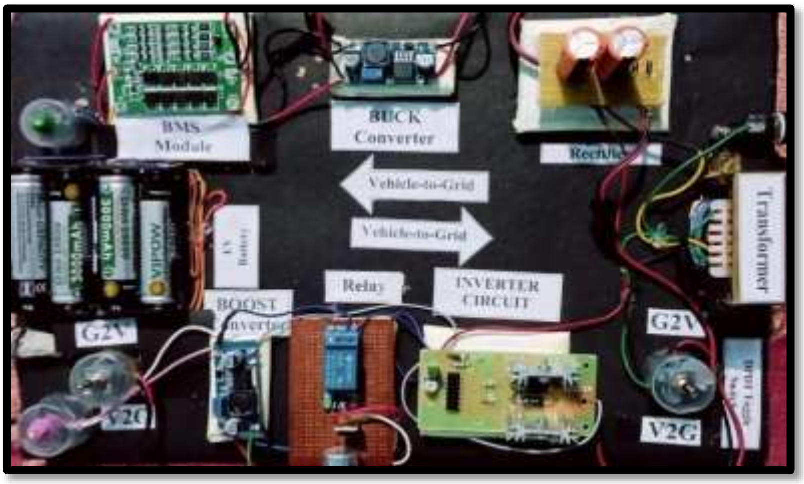


Fig.6.Hardware design to demonstrate the operation of G2V and V2G

6.2 Working

a. Grid-to-vehicle mode

In the Grid-to-Vehicle (G2V) configuration, the bi-directional electric vehicle charger facilitates effective energy transfer from the grid (transformer) to the battery pack (Vehicle). The process initiates with the activation of a 6-pin DPDT switch, which sets the system to G2V mode, confirmed by an LED indicator. The grid's 230V AC input is initially reduced to 12V AC via a transformer. This lower AC voltage is then directed into a Full wave rectifier, converting it to DC. To achieve a smooth and stable DC output, 4700µF capacitors with a 25V rating are employed for filtering. The rectified dc voltage is subsequently regulated by Buck converter, which adjusts it to the required BMS DC for the control circuits. The Battery Management System (BMS) module (16.8V, 40A) continuously oversees the battery's charge state, voltage, and temperature to prevent overcharging and excessive current. The battery pack, made up of four 3.7V 18650 lithium-ion cells (totaling 14.8V, 30000mAh capacity), receives the regulated DC power for efficient charging. The BMS ensures balanced charging and safeguards against overcurrent or thermal runaway. Real-time voltage and current measurements are shown on a two-wire digital voltmeter, while a protection circuit with a 2A fuse guards against overheating or short circuits. This manual control system allows for precise power flow regulation without automation. The LED indicator stays lit GREEN throughout the charging process, providing visual feedback on the operational status as in fig 12.1.

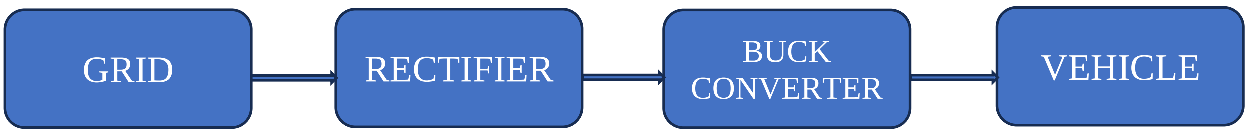


Fig.6a. Block representation of Grid to Vehicle Mode

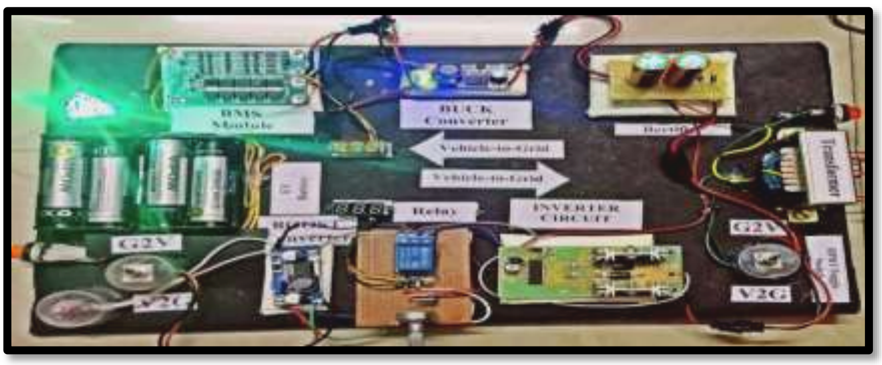


Fig.6b. Grid to vehicle Mode Operation

Fig.6c. Befor charging

Fig.6d. after charging

b. Vehicle to Grid mode

In this configuration, DPDT switch is toggled to the discharge setting. The 14.8V battery pack (Vehicle) releases its stored energy, which is then increased and regulated by the DC-DC converter (Boost converter). This output is then fed back into the grid via the inverter circuit and transformer, converting it to AC. The relay circuit ensures that discharge occurs only when the battery is adequately charged its more than 25% of battery voltage, preventing deep discharge. A digital voltmeter displays real-time voltage, while protection circuitry guards against overload and overheating. The converted AC voltage is fed to the Load through the transformer (Grid). An LED indicator shows RED that the system is actively operating as in Fig.12.2.

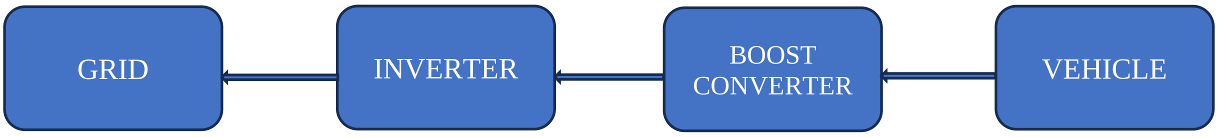
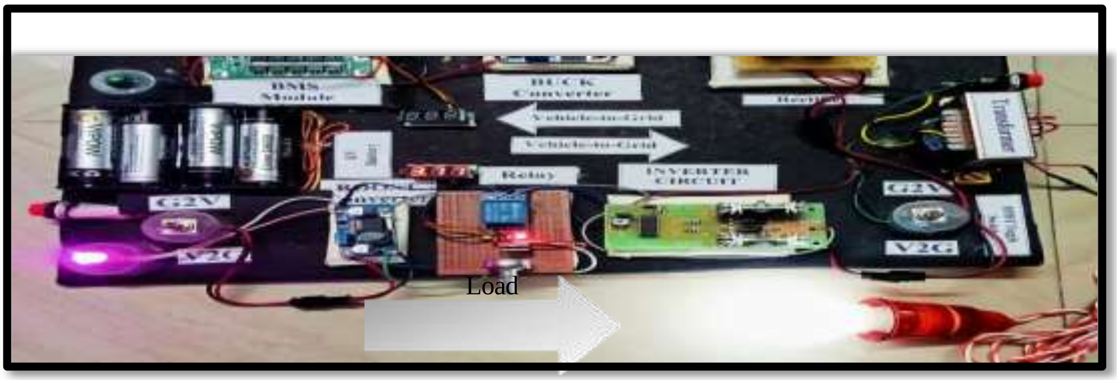


Fig.6e. Block representation of Vehicle to Grid



Mode

Fig.6f. operation of Vehicle-to-grid/Load mode

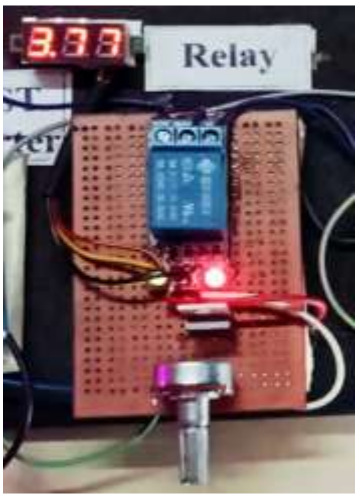


Fig.6g. operating voltage of relay

Table.2. Ratings of Various components

Component	Specification / Model	Purpose
Transformer	230V to 12-0-12V center-tapped, 1A (0.024 kVA)	Converts AC mains voltage to lower AC voltage with center tap for dual polarity
Full-Wave Rectifier (Diodes)	1N4007 (×2)	Converts AC to DC using a center-tapped transformer and diodes
Capacitors	4700µF, 25V	Smoothens DC voltage
Lithium-ion Battery	3.7V 3000mAh (4 × 18650)	Stores and supplies energy
Battery Management System (BMS)	4S, 40A,16.8V	Protects battery from overcharge, over-discharge, and short circuit
DC-DC Converter 1 (Step-down - Buck)	XL4015 (4-38V input, 1.25-36V output, 5A max	Steps down rectified DC voltage for battery charging
DC-DC Converter 2 (Step-up - Boost)	MT3608 (2-24V input, up to 28V output, 2A max)	Boosts battery voltage if required
MOSFET Variable Voltage Regulator	MOSFET + 10kΩ Potentiometer	Adjusts output voltage as required
Relay Module	5V coil	Controls switching between battery and grid
Inverter Circuit	100W power, 100V input, 1A input current	Converts DC to AC for grid/load interfacing
Fuse	250V, 2A	Overcurrent protection
Resistors	220Ω, 1kΩ	Current limiting, voltage division
Two-Wire Voltmeters	Digital display modules	Measure system voltage at different points
Indicator LEDs	Separate LEDs for modes	Shows system status (Charging/Discharging)
Toggle Switch	6-pin DPDT	Manually switches between G2V and V2G modes
Load (AC Bulb)	Mains-operated AC bulb 0.5W	Represents power consumption from grid

CONCLUSION:

This work demonstrates the feasible design of Bidirectional Power flow to enable charging via Grid-to-vehicle under reduced load conditions when power return to the Grid or load support during peak demand to lower the peak demand and ensure power reliability. This configuration can be modeled using MATLAB/SIMULINK to confirm the operational mode and a prototype has been created for low power applications. Bi-directional technology, which allows electricity to flow in and out of electric vehicles, has only recently progressed to a stage where it can be widely adopted. As time goes by and technology keeps evolving, its capabilities will also grow. Selecting a bi-directional charger as an EV owner offers multiple benefits. This technology provides various advantages, including potential to earn extra income by selling electricity back to the grid and achieving energy autonomy.

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