DESIGN AND SIMULATION OF ON-BOARD CHARGER AND AUTOMATIC CONTROL OF BI-DIRECTIONAL CONVERTER FOR ELECTRIC VEHICLE APPLICATION

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Abstract-

Electric-Vehicle’s (EV’s) have been an impact in the power grid and the transportation system, as the batteries of the EV’s have to be charged for being operated or utilized, as they use electricity for charging the batteries. In Micro-grid or Grid system, there is a possibility for using the Batteries of Electric and Hybrid electric vehicles as backup Energy Storage Systems. Implementing energy storage to store extra energy in Grid-To-Vehicle(G2V) and sending the energy over to grid (Vehicle-To-Grid, V2G) when there is requirement, they might support the management of micro-grid. In order to execute this concept effectively, it is important to set up suitable control techniques and infrastructure. In this paper, an On-Board Charger which improves power factor of the system and supports fast charging for Electric-Vehicles is designed and simulated using Matlab / Simulink, an Automatic operation of mode changing between the G2V and V2G is designed, simulated and the results have been obtained for the same. Concerning V2G - G2V power transfer, simulation studies are performed according to the data of test results, through the use of G2V-V2G operating modes.

Keywords —
On-Board Charger (OBC), PI-Controller, Energy Storage System, Single Phase Shift (SPS), PWM, Grid-to-Vehicle (G2V), Vehicle-to-Grid (V2G).

I. INTRODUCTION

Contemporary vehicles, primarily reliant on internal combustion engines, raise environmental concerns due to their contribution to air pollution. In response, automotive manufacturers are actively exploring alternative propulsion methods, with plug-in hybrid electric vehicles (PHEVs) emerging as a promising solution. Energy storage systems are important components of a micro-grid as they enable the integration of intermittent renewable energy sources[1]. PHEVs incorporate both an electric motor and an internal combustion engine, with dedicated on-board chargers designed exclusively for in-vehicle use [2]. Within the context of micro-grids, essential components are required for effective energy storage, facilitating the integration of renewable sources into the grid[3]. Batteries serve as a crucial energy storage solution[4], particularly advantageous in micro-grid scenarios where the implementation of larger storage systems may be impractical. The contemporary automotive industry is experiencing a change of opinion, increasingly incorporating electrical components to reduce dependency on traditional mechanical and hydraulic system. This transition not only results in lighter vehicles but also contributes to mitigating air pollution [5]. Compact, user-friendly, and efficient, battery energy storage systems align seamlessly with the demands of micro-grid applications. A exceptional prospect involves the utilization of parked vehicles as energy storage units during prolonged periods of inactivity, ranging from 16 to 18 hours a day. Survey data indicates that a substantial percentage of electric vehicles remain largely unused throughout the day [6,3]. Present-day micro-grids can effectively harness various renewable energy sources [3,4,5]. Electric vehicles, notably, play a essential role in micro-grid energy management by storing surplus energy during period of grid abundance (Grid-to-Vehicle/G2V) and supplying stored energy during peak demand phases (Vehicle-to-Grid/V2G) [1,3,4,6]. Looking ahead, energy utilities aspire to inform consumers about the power consumption of plug-in electric vehicles (PEV’s) and potentially prompt efficient usage practices [7]. Nevertheless, the existing electrical grid infrastructure is not entirely optimized for the charging demands associated with electric vehicles. A 2013 study in the USA emphasize the need for robust equipment in substations to support charging stations, with the impact on the overall grid being less pronounced for stations located near populated areas [8]. The implementation of Vehicle-to-Grid (V2G) mode in the power grid presents certain challenges, it involves a considerable number of electric vehicles - batteries to meet rapid demand requirements. However, even a small number of electric vehicle’s within a micro-grid context can be deployed effectively, though scalability to the broader power grid may present constraints[3].

Electric Vehicle (EV) charging technology has advanced significantly in recent years, and currently, EV chargers are categorized into three levels [1,3,8,9,]. The first level charger,

Level 1, is designed to function with standard household power (120v) and connects to the Electric Vehicle's onboard charger. This charger is the slowest of the three levels, making it suitable for individuals who have the entire night to charge their vehicles and travel less than 60 km per day.

Level 2 chargers are more powerful and are capable of providing power at a range of 220V to 240V and up to 30A. These chargers require a dedicated slot for Electric Vehicle Supply Equipment (EVSE) at the individual's residence or charging station. Level 3 chargers, also known as DC-fast chargers, are the fastest type of charger and can provide power up to 90KW at 200/450V[1,2]. With DC-fast charging, battery charging time can be reduced to 20-30 minutes, making it highly preferred as it support the rapid power transfer, which is necessary when EVs are utilized as energy storage systems in implementing the Electric Vehicle "V2G mode" in micro-grids [1,3]. EVSE’s are regarded as components of the electrical grid which supply AC power to electric vehicle charging facilities. EVSE functions as a charging station, consists of a conductor, plugs, connections for electric vehicles, and appliances for supplying power to them [1,3,7]. These levels of charging technology provide different options for individuals, businesses, and governments to choose from depending on their charging needs, enabling EVs to be charged quickly and efficiently.

INTEGRATION WITH GRID :

Moreover, the introduction of a DC-bus in micro-grids provides an approach for seamless integration with renewable energy sources, facilitating the optimal utilization of Electric Vehicles (EVs) as energy storage units. This integration aligns with the preference for DC-fast charging as the primary charging method. The ongoing development of incorporating Vehicle-to-Grid (V2G) mode into micro-grid infrastructure aims to enhance power generation from intermittent renewable sources[7]. Although still in its initial stages, recent advancements have witnessed the application of Level 1 and Level 2 chargers in V2G mode. However, these chargers face limitations imposed by the power rating of on-board chargers, coupled with the unidirectional energy flow configuration of the distribution grid, making micro-grids more opportune to implement V2G mode[10,11].

The inclusion of solar photovoltaic (PV) arrays into micro-grids is facilitated through the use of the DC-bus interface for EVs. Typically, EV batteries are exclusively operated in V2G mode following a manual switch from Grid-to-Vehicle (G2V) [12]. This paper proposes an automated switching system that can seamlessly transition EVs from G2V to V2G mode without necessitating manual intervention. This automated process utilizes a bi-directional converter.

The proposed automated switching system is highly effective and beneficial in maintaining power balance between the grid and the demand side. The suggested model's performance is evaluated simulations for both V2G and G2V modes of operation through MATLAB/Simulink. The integration of this switching system with the DC-bus interface facilitates the smooth flow of power, allowing for the system's integration of renewable energy sources while utilizing EVs as energy storage devices.

Overall, the proposed system presents a significant opportunity for the development of micro-grids and the efficient utilization of renewable energy sources.

II. CONTROL SYSTEM

Battery Charger Configuration:

DC-fast charging plays a crucial role in the charging infrastructure for Electric Vehicles (EVs), requiring the utilization of off-board Electric Vehicle Supply Equipment (EVSE) to ensure efficient charging. Central to this off-board charging system is the bi-directional DC-DC converter, serving as the interface between the micro-grid and the EV-battery system. This converter is an essential component, employing two IGBT/MOSFET switches that are in a constant state of activation due to interdependent control signals, as illustrated in Figure 1. The primary function of this converter is to maintain a consistent voltage level compatible with the EV-battery system while facilitating the bi-directional flow of power between the EV-battery and the micro-grid. The converter's role is vital in optimizing the charging process, enabling faster charging times and enhancing the overall efficiency of energy transfer. Its capability to handle high power levels is particularly significant in micro-grid applications, where energy demands can undergo rapid fluctuations. The continuous activation of the IGBT/MOSFET switches ensures a seamless and continuous flow of power, contributing to the reliability and effectiveness of the charging process within the micro-grid context.

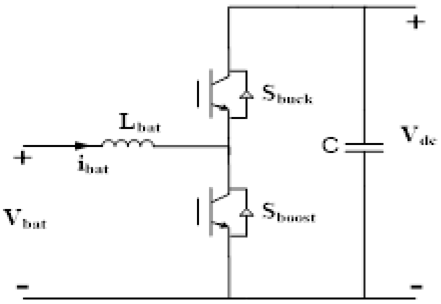


Figure.1. Battery charger configuration.

Off-board - Charger :

Using PI-controllers, the constant current control method is an efficient way to control the battery charger's charging and discharging in the bi-directional DC-DC converter. The control strategy determines whether the operation is charging or discharging, by comparing battery current to zero. The current signal is compared to a reference current value after the mode of operation is established, and the resulting error is fed into a PI-controller. The required switching signals for the switches Sbuck and Sboost are generated by PI-controller. During the charging process, the Sboost switch is turned off, whereas during discharging, the Sbuck switch is turned off throughout the process. This approach ensures that the battery is charged or discharged at a constant rate, thereby extending its lifespan and enhancing its efficiency[13]. Figure 2 illustrates the control strategy's configuration, which helps to maintain the charging and discharging process at a consistent rate, regardless of the EV's battery state of charge (SOC).

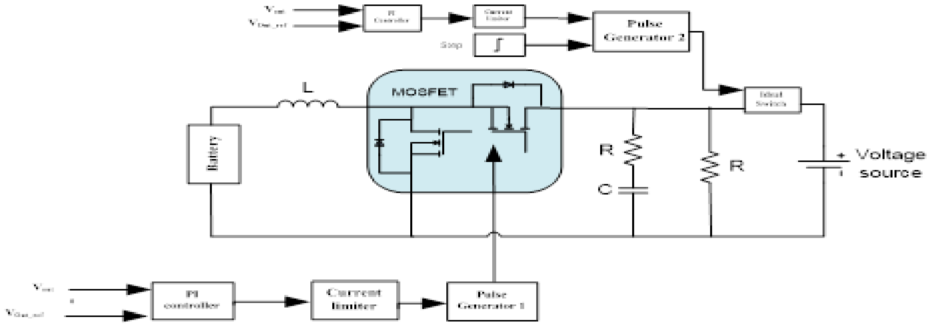


Figure.2. Control strategy for constant current.

On-Board Charger:

An On-Board Charger (OBC) is a power electronics device in electric vehicles (EVs) that converts AC power from external sources, such as residential outlets, to DC power to charge the vehicle's battery pack. The role of an On-Board Charger (OBC) is to manage the flow of electricity from the grid to the battery[14,15]. This means that the OBC must comply with the requirements of the grid in locations where it will be used. The main function of an EV on-board charger is power conversion so that the vehicle can get fully charged no matter the original type of power that was plugged in. On-Board Charger’s inside the EV eliminate the need for buying extra equipment for power conversion[15].

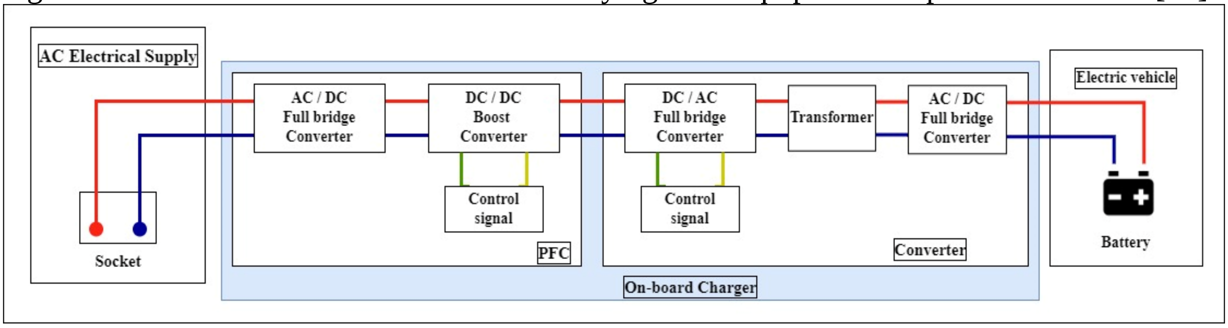


Figure.3. Block diagram of On-board Charger.

The On-board charger specified in this paper consists of two stages, Power-Factor Corrector (PFC) and DC-DC converter. The general house hold supply 230 volts is taken as for the input supply to the charger. As 230 volts is the most commonly available supply at any house hold. The power factor corrector (PFC) improves the power factor of the input supply upto 1 (unity). Which makes the charger efficient and reliable for the charging operation. The DC-DC converter is used for achieving ripple free voltage and current supply. Battery life will be improved by 100% if the battery is charged using the specified charger in this paper. The DC-DC converter circuit also consists of the buck converter, for achieving fast charging. The buck converter will step down the voltage and improve the current, by which the fast charging operation can be achieved.

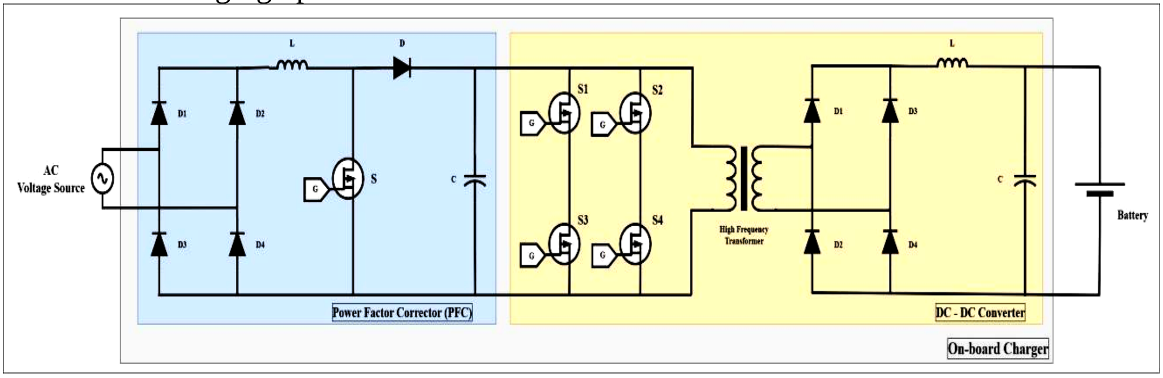


Figure.4. Circuit diagram of On-board Charger.

Specifications of the On-Board Charger :

PARAMETER	VALUE
Supply input voltage (Vi)	230 v
Maximum supply voltage (Vm)	322.22 v
Input power (Pi)	3.5 Kw
Frequency	50 Hz
Switching frequency (Fs)	20 KHz
Power Factor .	$\cong$ 1 (unity)
Iripple	20% of Iout max

V_{ripple}	1% of Vout max

Power Factor Corrector (PFC) :

Power Factor Correction is done for electrical equipment or installations to reduce the wasting of electricity. This means that lesser amperage is drawn by equipment as compared to non-correcting ones. This also ensures that heating effect of PFC chargers is comparatively less. Power factor correction (PFC) aims to improve power factor, and therefore power quality[16]. It reduces the load on the electrical distribution system, increases energy efficiency and reduces electricity costs. It also decreases the likelihood of instability and failure of equipment[17].

The Power Factor Corrector (PFC) consists of a full bridge converter for converting the input AC-supply to DC, a boost converter for voltage step-up. Using the circuit formation, the power factor of the circuit will be improved. When the input supply is taken then the power factor of the system is around 0.6 and when the circuit is connected as designed in this paper, the power factor of the circuit will be improved to around 0.99 which is very close to unity(1). The improvement in power factor of the system leads to the improvement in the efficiency of the total system minimizing the losses. The improvement in power factor also will make the system stable and improves the reliability. The AC-voltage from the supply is converted into DC using full bridge converter, boost converter in this circuit is used for improving the voltage from 230v to 450v. The end of PFC circuit, a voltage of 450 v should be achieved as the output from the power factor corrector circuit.

Power factor bridge :

Duty ratio (D) = $1 - \frac{Vs}{Vo}$.

D = 0.49 $\cong$ 0.5 .

Output voltage from Full bridge Converter = 0.636 * Vrms * $\sqrt{2}$.

Input current (Ii) = $\frac{P_i}{PF * V_i}$.

Ii = 15 A .

Boost converter :-

Load resistance (R) = $\frac{Vo}{Io}$.

Inductance (L) = $\frac{D * (1-D)^2 * R}{0.2 * f}$.

Capacitance (C) = $\frac{D}{R * (\frac{\Delta Vo}{Vo}) * f}$.

Power Factor (PF) = $\frac{\cos\emptyset}{\sqrt{1 + THD^2}}$.

THD - Total Harmonic Distortion.

DC-DC Converter :

The working principle of the DC-to-DC converter is that the inductor in the input resistance has the unexpected variation in the input current. If the switch is on, then the inductor feeds the energy from the input and it stores the energy of magnetic energy. If the switch is closed, it discharges the energy. For driving electric vehicles (EVs), a particular voltage level is required. otherwise, the device can be destroyed if the power is more significant than its required operating power or the device won't be able to run if the power level is deficient. The buck converter is a very simple type of DC-DC converter that produces an output voltage that is less than its input. The buck converter is so named because the inductor always " bucks " or acts against the input voltage. The buck converter uses a transistor as a switch that alternately connects and disconnects the input voltage to an inductor.

Formula's used for calculating the parameter values :

$$\text{Transformer turns ratio} = (\frac{Ns}{Np}) .$$

$$\text{Inductance (L)} = VL * \frac{D * T_S}{I_{ripple}} .$$

$$\text{Voltage across inductor (VL) = Vin} * \left(\frac{Ns}{Np}\right) - \text{Vo} .$$

$$\text{Capacitance (C) = Iripple} * \frac{D * T_S}{V_{\text{ripple}}} .$$

Single Phase Shift (SPS) Control Strategy :

In this paper, during the simulation of the DC-DC converter the input voltage is taken from the output of the power factor corrector (PFC) circuit. The 450 v DC input voltage is inverted in to AC-voltage using the full-bridge rectifier and an isolation transformer which is used for the voltage regulation. Mosfet's are used for switching action in the full bridge rectifier. The circuit from the full bridge rectifier using Mosfets to the full bridge converter using Diodes including the high frequency transformer is also called as Dual Active Bridge circuit(DAB), which is mostly used in the case of bi-directionality function of the system. Dual Active Bridge Converter(DAB) functioning can be controlled using Single Phase Shift (SPS) control strategy. Various control strategies exist for DAB (Dual Active Bridge) converters, including single-phase-shift (SPS), extended-phase-shift (EPS), double-phase-shift (DPS), and triple-phase-shift (TPS).The SPS control strategy was chosen for its simplicity. In the SPS method, The regulation of the output power in a DAB (Dual Active Bridge) is achieved by adjusting the phase-shift between the primary (leading) and secondary (lagging) bridges. Operating with a consistent duty cycle of 50% and a constant switching frequency, these bridges play a crucial role. The voltage ratio, denoted as 'd,' is defined as the ratio of the secondary voltage to the primary side voltage. The voltage ratio achieved is less than unity, thus allowing the converter to operate in Buck mode.

The expression for the converter's output power in relation to the phase-shift angle and switching frequency is provided as follows:

$$\text{Po(avg)} = \frac{V_{in}^2}{\omega\, L} .$$

The optimal average power can be determined by taking the derivative of above equation concerning the phase-shift angle. Consequently, the maximum power is attained when ϕ = 90°, as calculated from above equation. Therefore, the phase-shift angle, ϕ, is constrained within the range of 0° to 90°. Simulation encompassed the complete span of phase-shift angles. The correlation between the voltage ratio and phase-shift is expressed as follows:

$$|\,\phi\,| \geq \frac{\pi * (1-d)}{2} .$$

Bi-directional Converter :

In electric vehicles, for achieving the G2V and V2G operations bi-directional converters are very crucial. Battery life can also be improved and the battery run time can also be extended. The duty cycle of the converter controls charging and discharging based on the state of charge of the battery and current direction. Using the Bi-directional DC - DC converter can improve the efficiency upto 80% . Bi-directional DC/DC converter benefits from current-ripple cancellation in the switching of different power conversion sections with the same frequency but with different phases to control noise, output and ripple[1,3,4]. Selecting the right phase number can minimize or even fully cancel current ripple.

Duty ratio (D) = 1 - $\frac{Vs}{Vo}$.

Inductance (L) = (Vout * (Vin - Vout)) / (Iripple * Fswitch * Vin) .

Capacitance (C) = Iripple / (8 * Fswitch * Vripple) .

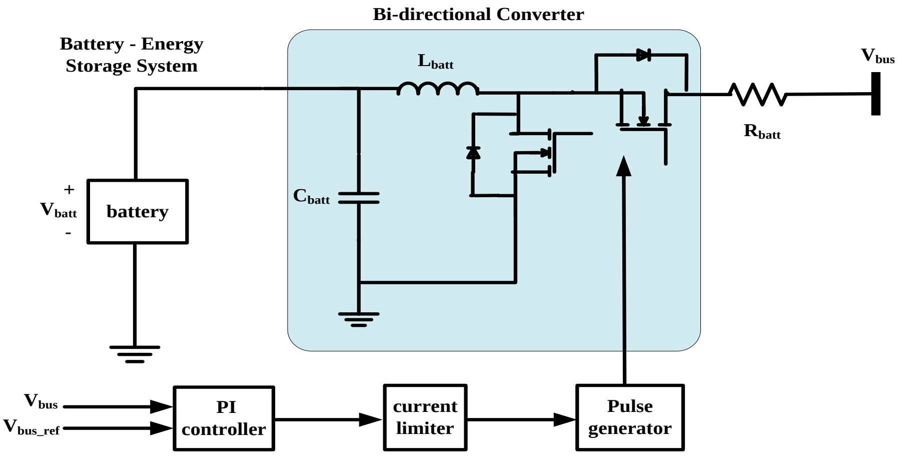
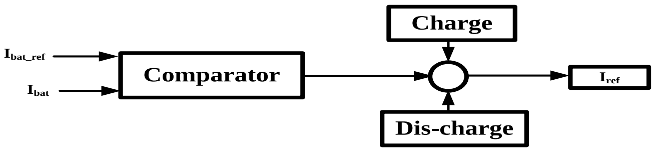


Figure.5. Bi-Directional Converter Circuit.



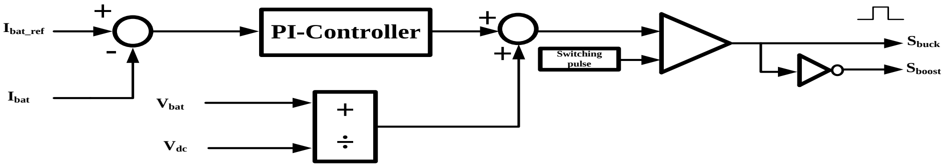


Figure.6. Bi-directional converter circuit for automatic switching.

PID - controller Tuning :

Proportional-integral-derivative control is a combination of all three types of control methods. PID-control is most commonly used because it combines the advantages of each type of control. This includes a quicker response time because of the P-only control, along with the decreased/zero offset from the combined derivative and integral controllers. This offset was removed by additionally using the I-control. The addition of D-control greatly increases the controller's response when used in combination because it predicts disturbances to the system by measuring the change in error. On the contrary, as mentioned previously, when used individually, it has a slower response time compared to the quicker P-only control. However, although the PID controller seems to be the most adequate controller, it is also the most expensive controller. Therefore, it is not used unless the process requires the accuracy and stability provided by the PID controller.

$$\text{Transfer Function} = \frac{V_i}{L * C * s^2 + \frac{L}{R} * s + 1} .$$

III. SIMULATION

The study aimed to develop a proto-type model of an On-Board Charger for fast charging applications of Electric-Vehicle(EV) / Hybrid Electric-Vehicle(HEV) using PWM-technique & PI-controller. A PI-controller for tuning the PWM-Generator and buck converter for fast charging of the battery, and an automated switching mechanism that enables electric vehicles to switch between V2G and G2V modes of operation using PWM-technique & PI-controller, Mosfet-based bi-directional converter. A PI-controller for tuning the PWM-Generator, and an Ideal Switch block for switching between Buck and Boost modes of operation.

On-Board Charger (OBC) :

To conduct the simulation, MATLAB was used, and different batteries with various ratings were taken into consideration. OBC is combination of two stages,

Power Factor Corrector(PFC),

DC-DC Converter.

Firstly, For the study of PFC, an AC-supply of 230v is considered as it the most commonly available power supply. Then, the AC-power from the supply is converted into DC by using the AC-DC full bridge converter. MOSFET is used for switching action, the converted 230v DC-voltage should step-up to 450v DC. For this step-up operation, boost converter is designed and connected. For achieving a complete ripple less DC-voltage of 450v, tuning of the output voltage is carried using PI-controller. The power factor of the circuit is improved to 0.99 (close to unity-1) by using the specified control strategy. Using certain notations and required formulas the controller input signals is designed. Using the signals and the feedback from the output, the required voltage of 450v DC should be achieved.

For the study of DC-DC converter, a battery having nominal voltage of 310 V with rated capacity of 60 Ah, and maximum discharge voltage of 331 V, was selected. The estimated rated power for the charger is 3.5KW, the reason for selecting this range of values is because the basic chargers in the present day are in the range starting from 3.3KW, like Bharat EV Charger. For achieving the fast charging, buck-converter is used in the circuit. The current increases rationally, the possibility of fast charging can be achieved.

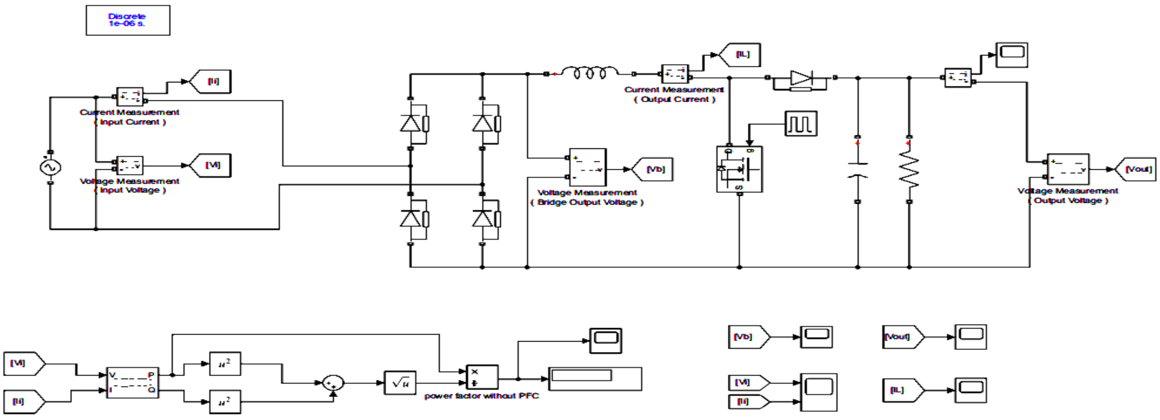


Figure. 8. Circuit Without Power Factor Correction.

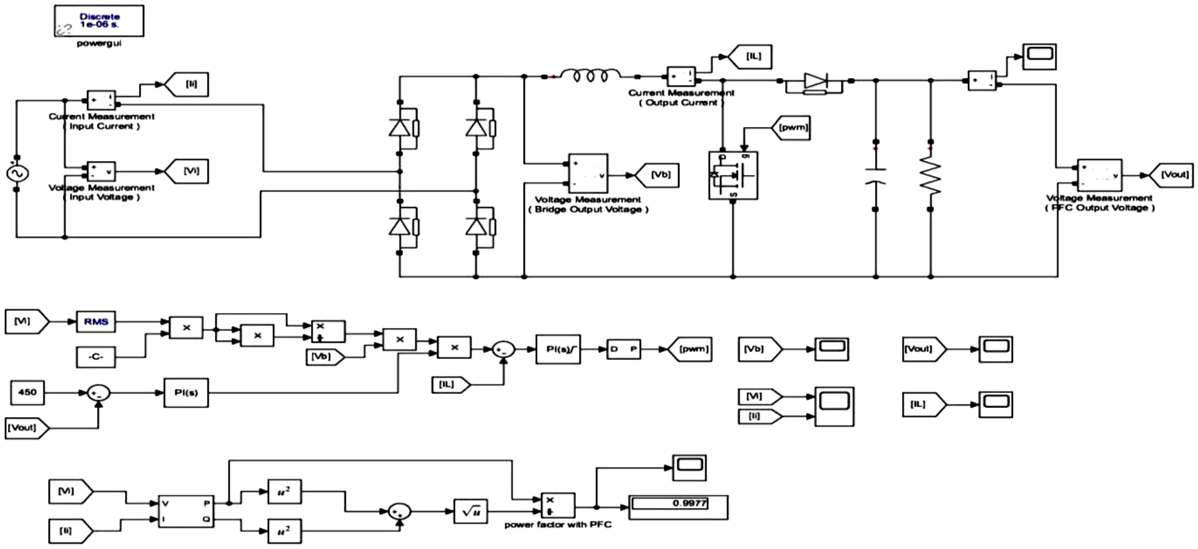


Figure.9. Power Factor Corrector simulation diagram .

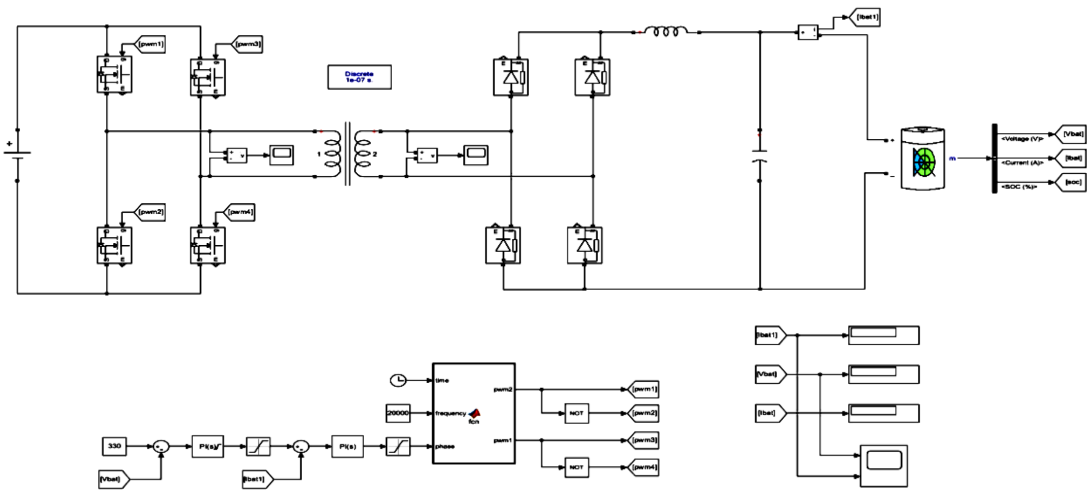


Figure.10. DC-DC converter simulation diagram.

Automated Bi-Directional Converter :

To conduct the simulation, MATLAB was used, and different batteries with various ratings were taken into consideration. For this study, a battery having nominal voltage of 11 V with rated capacity of 37 Ah, and maximum discharge voltage of 12.8 V is used. The charging time for the battery was evaluated under various configurations, and for simplicity and clarity, the charging and discharging time was fixed at 10 seconds each. The sub-system was designed to generate switching pulses for the Ideal-Switch to achieve the desired battery charging or discharging operation. Overall, the study provided insights into the performance of the switching mechanism for electric vehicle batteries and highlighted the importance of developing efficient charging and discharging systems for electric vehicles.

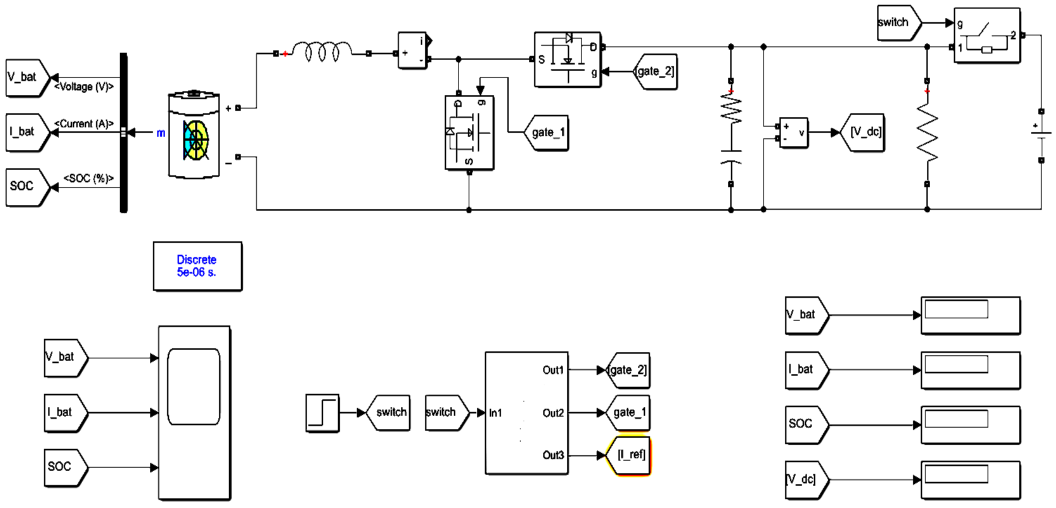


Figure.10. Proposed Simulation diagram of Automated Bi-directional converter.

IV. RESULTS AND DISCUSSIONS

Obtained result for On-Board Charger :-

Without Power Factor Corrector (PFC) :

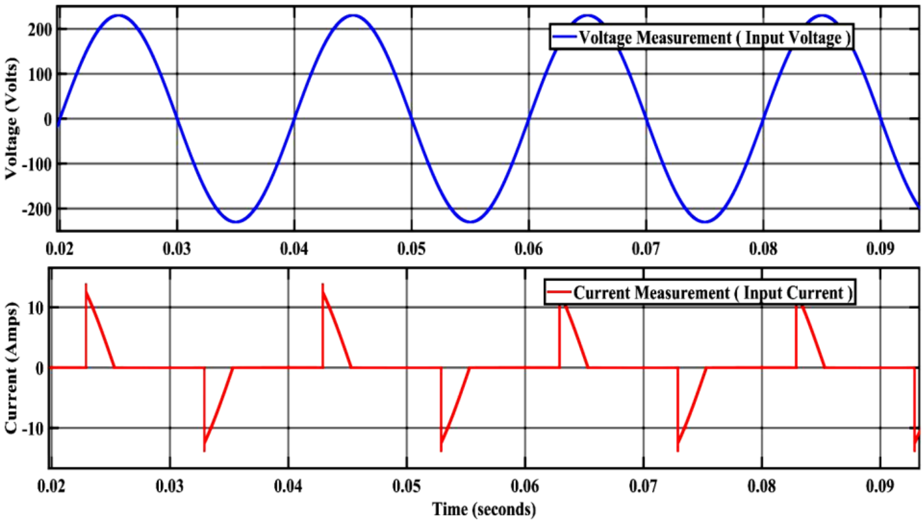


Figure.12. Variation of input voltage and current wave-forms without power factor correction.

Boost Converter with Power Factor Corrector (PFC) :

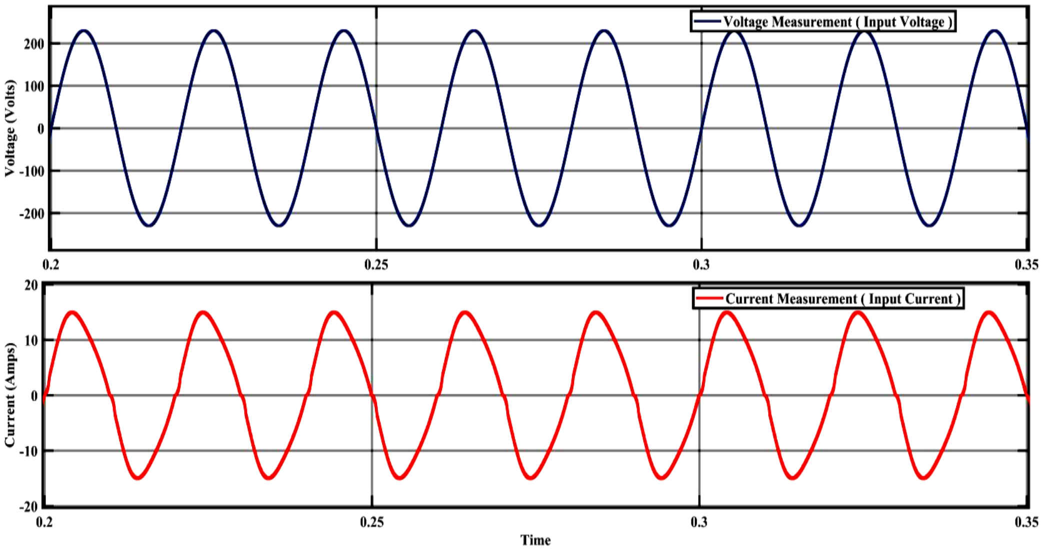


Figure.13. Variation of input voltage and current wave-forms after power factor correction.

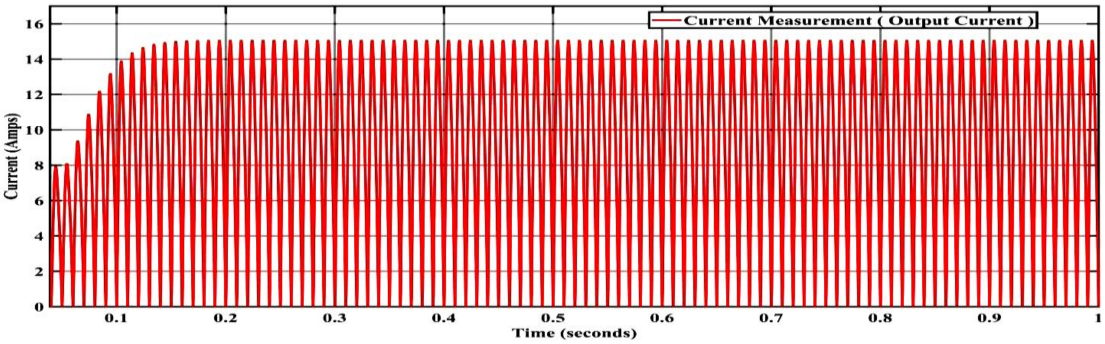


Figure.14. Maximum current from the Power Factor Corrector circuit.

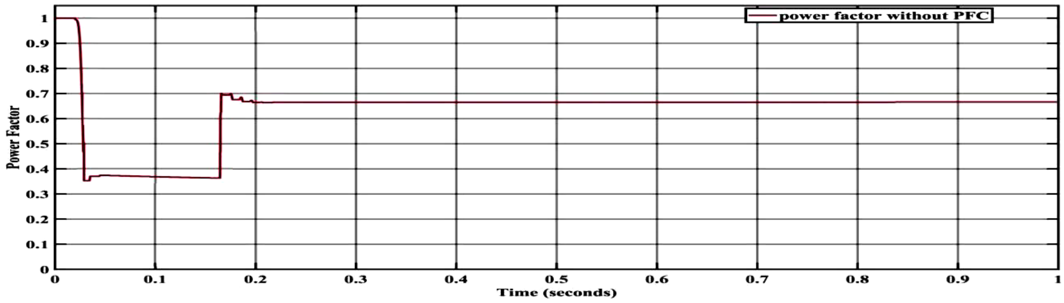


Figure.15. Power Factor without PFC circuit.

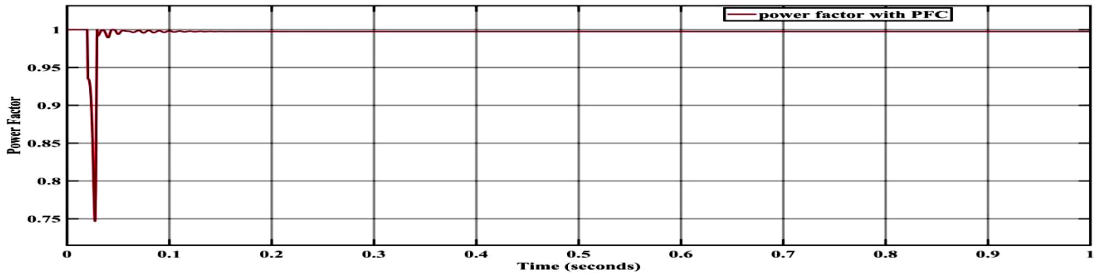


Figure.16. Power Factor improvement with PFC circuit.`

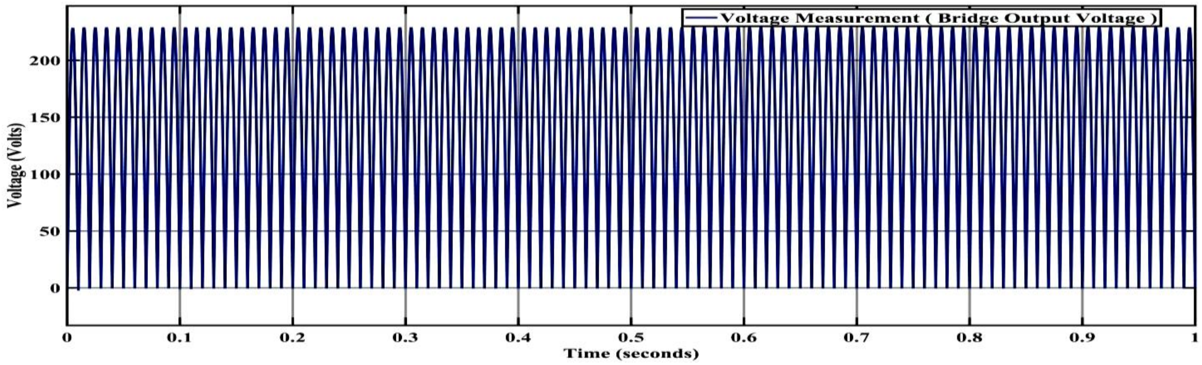


Figure.17. Voltage at the output of full bridge converter.

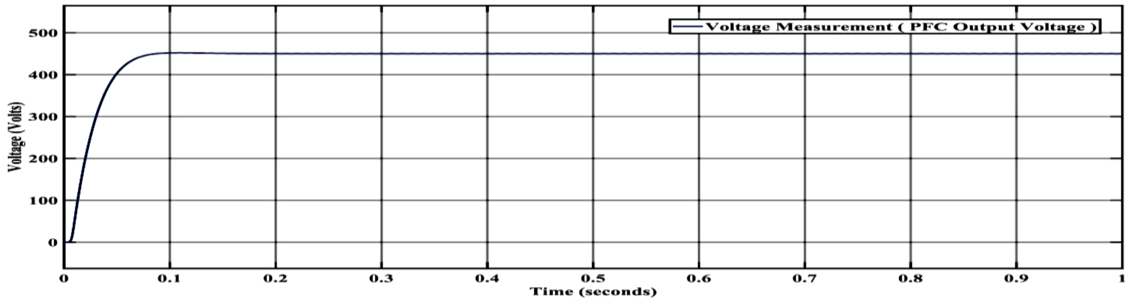


Figure.18. Output voltage from Boost converter in Power Factor Corrector circuit.

The experimental findings of this simulation describe that the power factor of the system before the connection of Power Factor Corrector (PFC) circuit is around 0.68 as shown in Figure.15. and when the system is equipped with the Power Factor Circuit (PFC) the power factor of the system is improved to 0.9977, which is very close to unity(1) as shown in Figure.16. By which the efficiency of the total system is improved. From the output Figure.13, the voltage and current waveforms without power factor correction circuit are not in phase and the current waveform is not sinusoidal due to harmonics. From Figure.13, it is observed that the voltage and current wave forms are in phase, which means the power factor of the system is improved close to unity(1). The maximum current from PFC circuit is shown in Figure.14. is achieved by using control strategy and connecting the circuit with specified parameters. The input AC-voltage is converted into DC using the diode bridge, which can be observed from the Figure.17. The output voltage from the bridge is a DC-voltage which will be step-up to 450v using a boost converter. Mosfet is used for switching operation. Here, PI - tuner is used for tuning of the Mosfet. The gate pulses for the mosfet is generated from the tuner. Using the formulations, a controller circuit for achieving the required output is designed. Using constant block, feedback from the output end the tuning of the Mosfets for required output. The output of the boost converter is 450v which is the required voltage obtained from the calculations. The output of 450v is achieved from the circuit, which can be observed in the Figure.18, the constant output voltage of 450v is achieved from the circuit in 0.1 seconds of time.

DC-DC Converter :

The experimental findings of this study reveals that, the improved form of voltage and current is achieved from the simulation. The output voltage of 450v from the Power Factor Corrector (PFC) is taken as the input voltage to the DC-DC converter circuit. The DC voltage of 450v is inverted into AC voltage using the Mosfet devices. The switching pulses for the operation of Mosfets is given through PI-controller. Then, the AC voltage of 450v is connected to an isolated transformer. The isolation transformer which has range of high operating frequency and specifications close to ideal transformer is selected. The required level of control of voltage regulation is achieved through Pulse Width Modulation (PWM) technique. The control of amplitude of the voltage is achieved using the Pulse Width Modulation (PWM) technique. The conversion - inversion of the voltages between the devices is made for achieving the pulse less pure DC-voltage. The required complete ripple free DC voltage is achieved from the simulation, which can improve the life of battery by 95%. Using Single Phase Shift(SPS) and Pulse Width Modulation(PWM) technique / control strategy the phase shift between the primary side and secondary side is achieved by which the controlled voltage regulation is achieved as shown in Figure.19 & Figure.20. The obtained DC voltage of 400 v from the secondary side of the transformer is again connected to a buck converter for obtaining the required level of output current from the circuit. The output voltage and current waveforms of the DC-DC converter is shown in Figure.21.

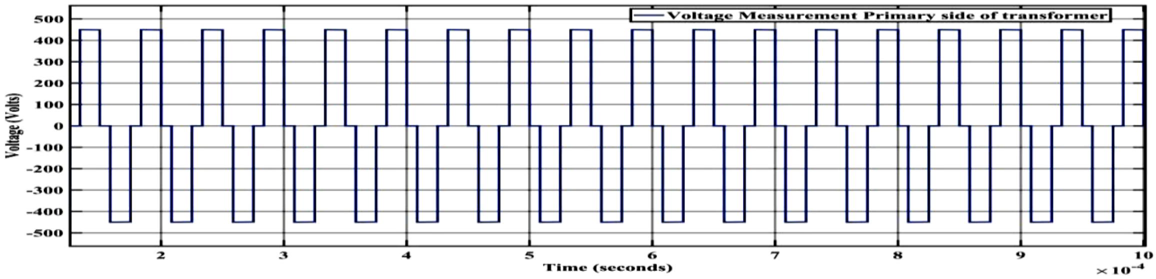


Figure.19. Voltage at the transformer primary side.

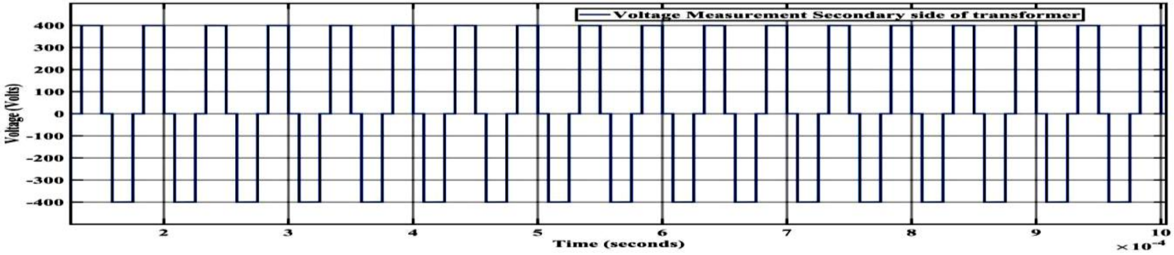


Figure.20. Voltage at the transformer secondary side.

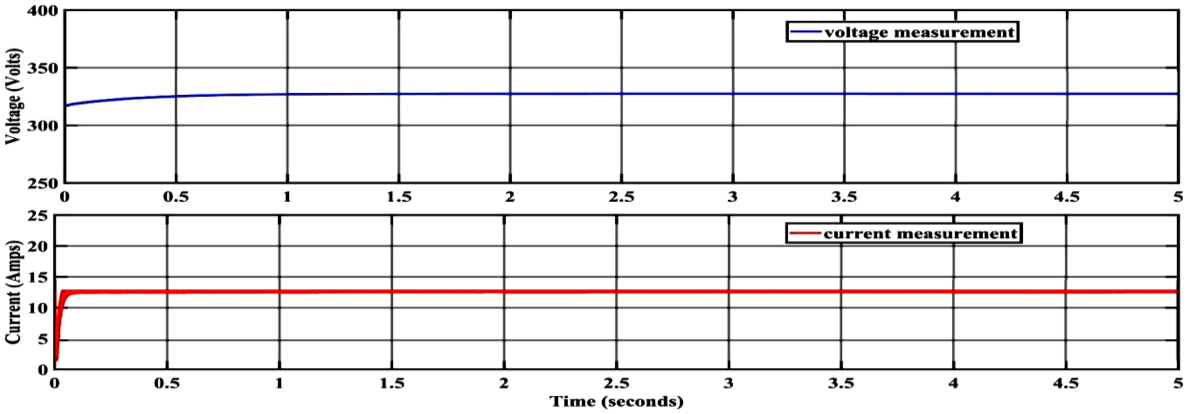


Figure.21. Output voltage and current from the DC-DC converter circuit.

Obtained result for Automated Bi-directional converter:-

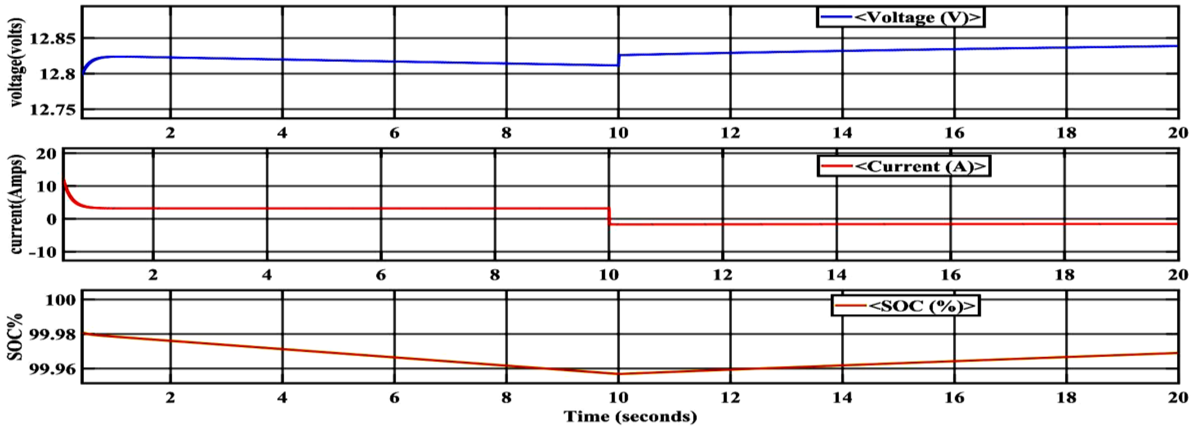


Figure.22. Output graph of Battery Voltage(v), Current(i), SOC% of Automated Bi-directional converter.

The study's experimental findings have demonstrated the successful automation in Electric-Vehicles for the switching mechanism between Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G) modes. For simulation purposes, a lithium-ion battery was chosen due to its widespread use in EVs. The bi-directional converter was designed to have the capability to automatically switch between G2V and V2G modes, as shown in the Figure.22. Initially, the EV is operated in G2V mode for the first 10 seconds, allowing the battery to be charged. After the lapse of 10 seconds, battery is fully charged, now converter switches to V2G mode, causing the battery to discharge. The Figure.22. depicts graphs that show the successful automatic control of switching between the modes, indicating that the system can be optimized to function efficiently under real-world conditions. The study findings can provide valuable insights for further research on improving the performance of electric vehicle charging and discharging systems.

V. Conclusion

The design and simulation of the On-board Charger(OBC) for fast charging of Electric Vehicles is simulated and the expected results are achieved. The improvement in the quality of the power supply is improved to 99.7% by designing the Power Factor Corrector(PFC) for improving the power factor of the circuit and also improving the voltage for the On-board Charger (OBC). The improvement in the power factor of the system is clearly shown in the Figure.13 , as it is observed both the voltage waveform and current waveform are in phase and also similar to each-other. By achieving the improvement in the power factor, the total system efficiency can be improved upto 99.7%. The improvement in power factor by equipping the PFC circuit is shown in Figure.16. PFC also has the boost converter from which the voltage of 450v is obtained, which is the same from the theoretical calculations. The DC-DC converter circuit is equipped with PI-controller for controlling the gate signals of the Mosfet's. Phase Shifted Full Bridge(PSFB) Converter is studied, designed and used in this circuit. Single Phase Shift (SPS) control strategy is implemented in this simulation and study. The required voltage regulation in the circuit is achieved using the PSFB - SPS - PWM techniques. The required phase shift and voltage regulation for the required output using the PI-controller is obtained. The required range of voltage and current obtained from the simulation output result matches the theoretical calculations.

Also, the development of a bi-directional converter is a significant step in the advancement of electric vehicle technology. The converter has been designed to allow for Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G) operations, making it possible for EV batteries to interface with the micro-grid. The converter is controlled by three Proportional-Integral (PI) controllers, which generate the gate pulse in a conventional form. The simulation results demonstrate the successful implementation of the converter, showing a seamless power transfer between the EV battery and micro-grid. The battery's parameters and specifications, including charging and discharging times, were carefully studied and incorporated into the simulation model. The bi-directional converter automatically switches between G2V and V2G modes based on the specified reference value for the operation time. Overall, the controller's design provides high dynamic performance, allowing for efficient and effective power transfer, and holds great potential for the future of electric vehicle technology.

VI. FUTURE EXTENSION

One of the most promising future developments in Electric-Vehicle charging technology is wireless charging, flash charging technology. Instead of having to physically plug in their vehicle, drivers could simply park over a charging pad that uses electromagnetic fields to transfer energy to the vehicle's battery. To make the power transfer more flexible, in the recent years, the trend was to eliminate physically connecting wire system during the charging process. The wireless power transfer systems (WPTS) use electromagnetic waves to transfer the energy. The main problem electromagnetic field strength decreases with increase of distance. The near field region is the surface that reaches out up to wavelength from the transmitter (source). In this zone, the magnetic field and the electric field can coexist individually despite taking into consideration a single shared source for field creation. Inductive and capacitive energy transfer techniques can be utilized in this area, and this is where power transfer is most commonly used [11,9]. Also the wireless charging can be classified into two types, Stationary(Static) wireless charging and On the move (Dynamic) wireless charging. Static wireless charging can be referred to the wireless charging of EV in the parking lots, whereas the On the move wireless charging of the EV can be explained as, The transmitter coil generates a high frequency magnetic field that is experienced by the receiver coil. The EV speed impacts the voltage that is generated in the receiving coil. Flash charging improves the speed and efficiency of fast charging by increasing the current output, rather than the voltage. Both Flash charging and fast charging are interconnected, and the charging speed will depend on which particular specifications that EV have, its battery capacity and what type of charging system is being used. Flash charging can be achieved using rapid devices. To charge an electric vehicle as quickly as possible, rapid devices offer high power direct or alternating current (DC or AC). An electric vehicle may be charged to 80% of its capacity in a short period of 10-15 minutes, depending on the type of EV. Fast charging and flash charging are both designed to boost the charging voltage and current, but the main objective of both is to boost the charging power, and the rate of the two charging techniques won't be significantly different. Fast charging occurs at high voltage whereas flash charging occurs under low voltage.

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