Power factor Enhancement in EV Charger fed by a New Modified BL Converter

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Abstract. Existing EV chargers use a strong non - linear diode bridge rectifier to deliver Direct Current voltage at the DC-DC converter's input, which degrades input AC current power factor. Due to these issues, typical battery chargers must eliminate the input bridge to improve power factor. This research paper main aim to improve the front end power factor by using bridge less landsman converter. It is combination of PFC converter and isolated fly back converter to operate between constant current and constant voltage modes. The modified PFC should achieve the constant DC-link voltage and improve the power factor up to unity. It also provide the improve in power quality, low device stress, low input and output ripples, and low input current harmonics when compared with bridge converter.

1 Introduction

Conventional vehicles help amplify already existing issues like global warming, high carbon footprint, and pollution. Along with this, they're also responsible for the depletion of fossil fuels. Depending on exhaustible resources such as petroleum, natural gas, and coal, severe climate change and increasing energy cost are a few of the major problems across the globe. In the automobile industry, electric vehicles have become popular recently. Electric vehicles help in controlling pollution majorly as the fuel used is electric power. This reduces the use of fossil fuels, which in turn reduces pollution coming from power generation stations [1-2]. The popularity of electric vehicles has increased amongst the automobile industry, buyers, and environmentalists. The decision of an electric vehicle (EV) quells the need for a green source of transportation with low emanations and realistic fuel efficiency in order to cope with rising fuel prices and carry out the natural arrangements with better expectations. Recent studies have demonstrated that the invention of EVs has additional benefits over conventional energy improvements due to the green environment, energy-saving feature, and simpler way of execution [3].

The rechargeable batteries are used to power the EVs and supply the required traction force. Typically, an EV charger, also known as an AC-DC converter, is used to replenish these batteries. The most widely used EV battery charger structure starts with a boost converter

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and moves on to an isolated converter at the next stage [6]. Use PFC converter-based battery chargers with several interleaved zero voltage switching stages to decrease the size of inductor and current ripples [7–10]. Due to interleaving power factor correction converter the cost is high and the current stress is high. But the full bridge PFC converter based EV chargers are better than interleaving converter. Full bridge PFC converters increase power density and have good efficiency, but their complicated design is caused by four switches [11]. High power density, high efficiency, and low noise are all features of the LLC resonant converter, but its design and analysis are challenging [14].

In the front end of EV battery chargers, full wave diode bridge rectifiers are utilized to deliver one-directional isolated single or two stage converters without isolation [15]. The IEC 61000-3-2 power quality (PQ) criterion, however, is not met by the performance of the conventional charger [16].The Bridgeless diode converters are using to overcome the poor power factor, low power quality, low efficiency, noise[17-21]. The design of bridgeless diode converter construction is not complex which is comparing with the full wave diode bridge rectifiers.

In order to address the input current ripples caused by the continuous operation of the input inductors as well as the output current ripples, the improved Bridgeless Landsman converter is introduced. The Diode bridge rectifier is replaced with two parallel converters are connected, they are operate in parallel during positive half cycle and negative half cycle by connecting BL landsman converters to reduce the conduction losses at the components. It is able to be performed in both discontinuous conduction mode (DCM) and continuous conduction mode (CCM). But because the battery is so expensive, it is set to function in discontinuous conduction mode (DCM), and the fly back converters are no different. When the two parallel converters are synchronized and operating in discontinuous conduction mode with their respective mains voltage half cycles, the power factor may be improved to unity. The fly back converters are also designed a dull loop PI controller.

1.1 literature survey

[1] In the paper titled "Power Factor Correction of EV Charger using Modified Buck-Boost Converter," S. Sathiya and S. Raja proposed a modified buck-boost converter for power factor correction in EV charger applications. In addition to galvanic isolation between the input and output, the suggested converter also has excellent efficiency and power factor. Obtaining a power factor of 0.99 has been shown experimentally for the suggested converter of 0.98 and an efficiency of 93% for a 1 kW output power.

[2] R. O. Marques, J. A. Pomilio, and R. A. Romero-Troncoso presented a modified boost converter for article titled "Power factor correction in an on-board EV charger using a modified boost converter." To stabilise the output voltage and increase the power factor, the suggested converter employs a sliding mode control method. Obtaining a power factor of 0.99 has been shown experimentally for the suggested converter of 0.97 and an efficiency of 93% for a 1 kW output power.

[3] S. Wang and Z. Qian proposed a high power factor single-phase on-board charger for electric vehicles using a modified PFC boost converter in their paper titled "A high power factor single-phase on-board charger for electric vehicles using a modified PFC boost converter." The suggested converter's high power factor and high efficiency are the results of a revised control method. The testing findings demonstrate that the suggested converter is capable of producing 3 kW at a power factor of 0.99 and an efficiency of 94%.

[4] In the paper titled "A modified BL-Luo converter for high power factor and high efficiency EV charger application," M. Bouzid, M. Belmili, and S. K. Khadem proposed a modified BL-Luo converter for power factor correction in EV charger applications. The proposed converter uses a novel control strategy and high efficiency. The experimental

results show that the proposed converter can achieve a power factor of 0.99 and an efficiency of 95% for a 3-kW output power.

1.2 limitations

- ***Limited range of input voltage:*** The modified BL converter may have limited range of input voltage, which can restrict its use in EV charger applications where the input voltage can vary widely.
- ***Complexity of control strategy:*** The control strategy for the modified BL converter can be complex, requiring advanced knowledge in power electronics and control theory. This can increase the design and implementation costs, and make it challenging to integrate into existing EV charger systems.
- ***High switching frequency:*** The modified BL converter may operate at high switching frequency, which can generate significant amounts of electromagnetic interference (EMI). This can require additional filtering components to reduce the EMI, which can add to the overall system cost.
- ***Limited power output:*** The modified BL converter may have limited power output, which can restrict its use in high-power EV charger applications. This can require additional converters to be used in parallel, which can add complexity to the system design.
- ***Thermal issues:*** The modified BL converter can generate significant amounts of heat during operation, which can lead to thermal issues such as overheating and reduced efficiency. Proper thermal management techniques such as heat sinks and fans may need to be employed to ensure safe and efficient operation.

2 Methodology

2.1 Proposed System

- ***AC-DC converter:*** The AC-DC converter is responsible for converting the AC input voltage to a DC voltage suitable for charging the EV battery. The modified BL converter is used in this stage to improve the power factor and reduce the total harmonic distortion.
- ***DC-DC converter:*** The DC-DC converter is responsible for regulating the DC voltage to the appropriate level for charging the EV battery. This can involve using a buck converter, boost converter, or a combination of both.
- ***Battery management system (BMS):*** The BMS is responsible for managing the charging and discharging of the EV battery, as well as monitoring the battery status and protecting it from overcharging or over-discharging. The BMS can be integrated with the DC-DC converter for efficient control and monitoring.
- ***Control system:*** The control system is responsible for regulating the power flow in the system and ensuring efficient operation. This can involve using advanced control techniques such as PI controllers, fuzzy logic, or model predictive control (MPC).
- ***Display and user interface:*** The display and user interface are responsible for providing information on the charging status, battery status, and any error conditions. This can involve using a graphical display, LED indicators, or a smart phone app for remote monitoring.

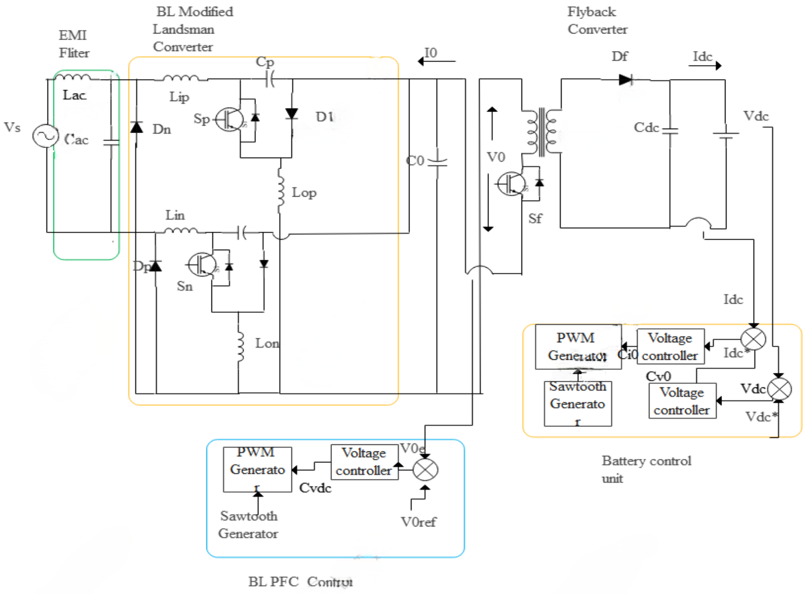
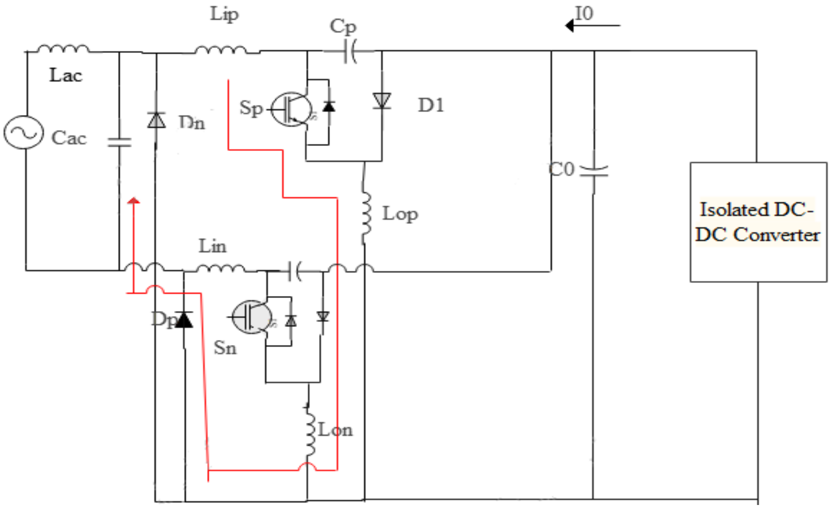


Figure 1: Electric Vehicle Battery Charger Utilizing a Modified Bridgeless Landsman PFC Converter

2.1 The modes of operation of the modified bridgeless Landsman PFC converters are as follows:

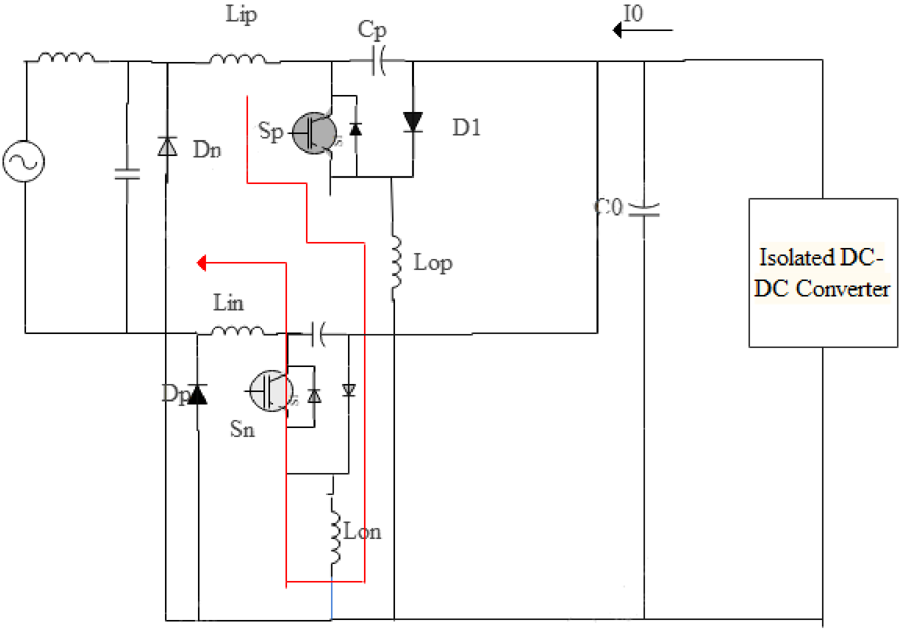
2.1.1During the positive half of the AC input voltage cycle:

a. When the AC input voltage is in the positive half-cycle, the forward biasing occurs in diodes D1 and D3 while diodes D2 and D4 experience reverse biasing.



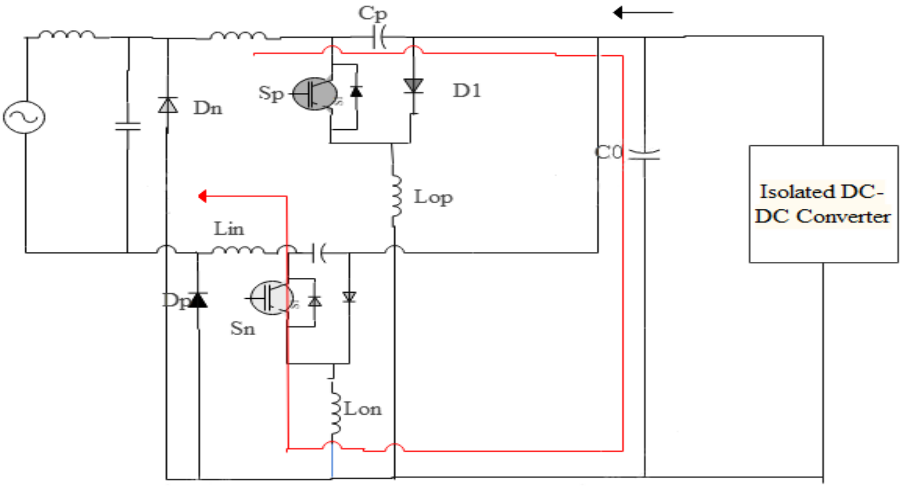
2.(a)

b. The rectified voltage is applied to the inductor L1 and charges the input capacitor C1.



2.(b)

c.Subsequently, the modified Bridgeless Landsman PFC Converter receives the input voltage, rectifies It, and performs power factor correction while mitigating input current harmonics.

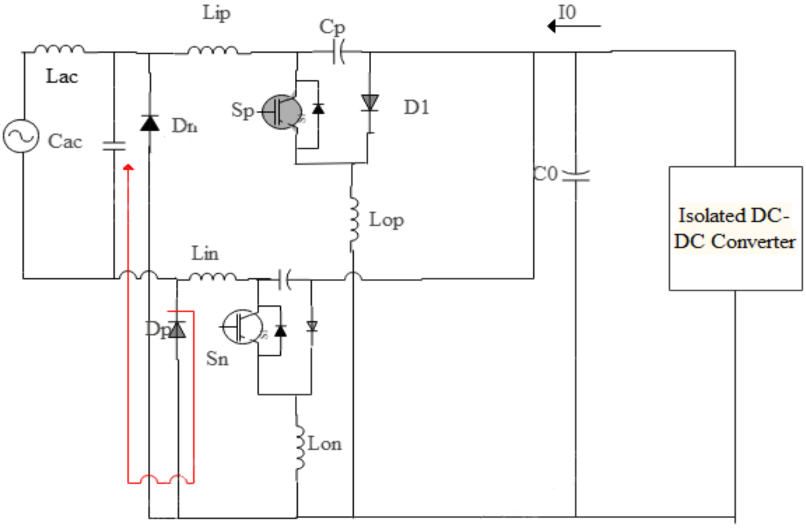


2.(c)

Figure 2: During the positive half cycle of the AC input voltage

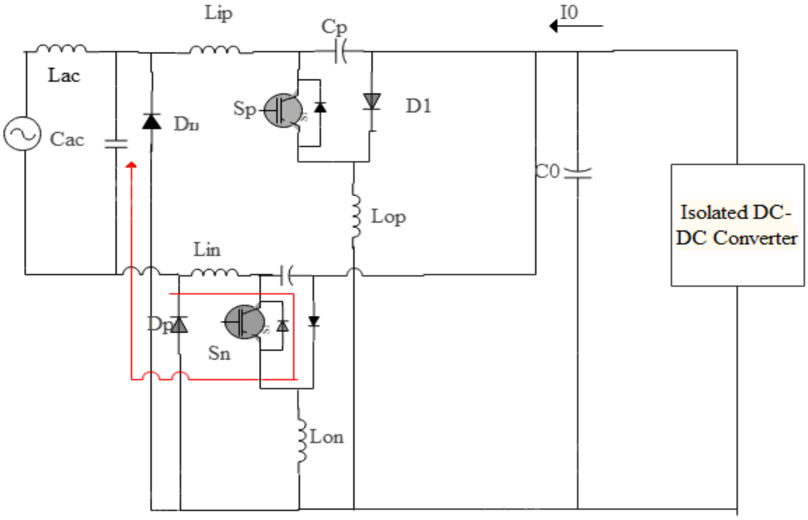
2.1.2 During the negative half cycle of the AC input voltage:

a. When the input voltage is negative, diodes D2 and D4 are forward biased, and diodes D1 and D3 are reverse biased.



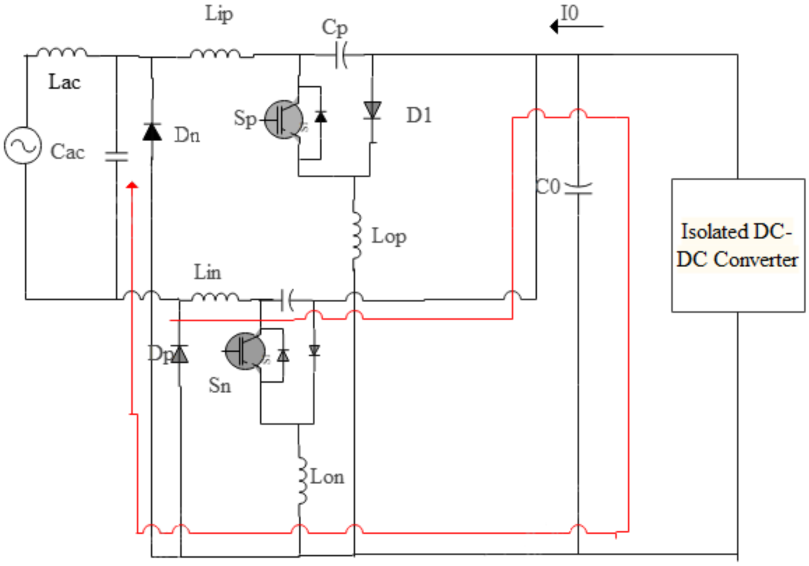
3.(a)

b. The rectified voltage is blocked by the bridgeless rectifier and no current flows through the system.



3.(b)

c. The input capacitor C1 discharges through the inductor L1, providing continuous input power to the modified bridgeless Landsman PFC converter.



3.(c)

Figure 3: During the negative half cycle of the AC input voltage

Overall, the modified converter operates in a continuous conduction mode, providing regulated output voltage to the DC-DC converter and managing the charging process through the battery management system and control system.

2.2 Design of Modified BL Landsman Converter

The Modified BL Landsman Converter is a type of DC-DC converter that can be used in various applications, including electric vehicle (EV) charging systems. Here are the steps involved in designing a Modified BL Landsman Converter:

- ***Determine the Input and Output Voltage:*** The first step in designing the Modified BL Landsman Converter is to determine the input and output voltage. This will depend on the specific application requirements, such as the battery voltage and the required charging voltage for the EV.
- ***Choose the Converter Topology:*** The next step is to choose the converter topology. The Modified BL Landsman Converter is a modified version of the BL (Boundary Layer) converter, which uses a switched-capacitor circuit to achieve voltage conversion.
- ***Select the Switching Frequency:*** The switching frequency of the converter determines the size of the passive components, such as the inductors and capacitors. A higher switching frequency results in smaller components, but also increases switching losses.
- ***Determine the Duty Cycle:*** The duty cycle of the converter is the ratio of the on-time to the total switching period. It determines the output voltage and the efficiency of the converter.
- ***Calculate the Inductor and Capacitor Values:*** The inductor and capacitor values can be calculated based on the input and output voltage, switching frequency, and duty

cycle. The inductor is used to store energy, while the capacitor is used to filter the output voltage.

- ***Choose the Switching Devices:*** The switching devices used in the Modified BL Landsman Converter can be MOSFETs or IGBTs. The choice will depend on the specific application requirements, such as the voltage and current ratings.
- ***Design the Control Circuit:*** The control circuit of the converter is responsible for regulating the output voltage and maintaining the desired charging current for the EV. It can be implemented using a microcontroller or a dedicated control IC.
- ***Simulate and Test the Converter:*** Once the converter is designed, it can be simulated using software tools such as SPICE. The simulation results can be used to optimize the design parameters and ensure the converter meets the performance requirements. Finally, the converter can be tested in a real-world environment to verify its performance and reliability.

2.3 Design of Fly back Converter

The Fly back Converter can be used as a front-end converter in an electric vehicle (EV) charger to enhance power factor correction. Here are the steps involved in designing a Fly back Converter for power factor enhancement in an EV charger fed by a new modified BL Converter:

- ***Determine the Input and Output Voltage:*** The first step is to determine the input and output voltage of the Fly back Converter. The input voltage will be the output voltage of the Modified BL Converter, while the output voltage will depend on the specific application requirements.
- ***Choose the Converter Topology:*** The Fly back Converter can be used as a boost or buck-boost converter to correct the power factor of the EV charger. The choice of topology will depend on the specific application requirements, such as the input and output voltage range.
- ***Select the Switching Frequency:*** To keep the Fly back Converter's passive parts count down and its switching losses down, the switching frequency must be optimised. Smaller parts are possible with greater switching frequencies, although switching losses may also rise.
- ***Calculate the Transformer Turns Ratio:*** The output voltage and voltage stress on the switching device are both determined by the turn's ratio of the transformer. The input and output voltages can be used to determine, the duty cycle, and the transformer core properties.
- ***Choose the Switching Devices:*** The switching devices used in the Fly back Converter can be MOSFETs or IGBTs. The choice will depend on the specific application requirements, such as the voltage and current ratings.
- ***Design the Output Filter:*** The purpose of the output filter is to limit the ripple present in the output voltage. It can be implemented using passive components such as capacitors and inductors.
- ***Design the Control Circuit:*** The control circuit of the Fly back Converter is responsible for regulating the output voltage and maintaining the desired output current. It can be implemented using a feedback loop that compares the output voltage to a reference voltage and adjusts the duty cycle of the switching device.
- ***Simulate and Test the Converter:*** Once the Fly back Converter is designed, it can be simulated using software tools such as SPICE. Finally, the converter can be tested in a real-world environment to verify its performance and reliability.

2.4 Advantages

- ***Higher Efficiency:*** Power factor enhancement helps to improve the efficiency of the charging process, reducing energy losses and ultimately resulting in lower electricity bills for the user.
- ***Reduced Harmonic Distortion:*** The modified BL converter helps to reduce harmonic distortion in the electrical system, which can help to prevent damage to other equipment connected to the same power supply.
- ***Increased Power Density:*** The modified BL converter can allow for higher power densities, which can enable faster charging times for electric vehicles.
- ***Improved Reliability:*** The enhanced power factor can help to reduce stress on the electrical components of the charger, which can improve the reliability and lifespan of the equipment.
- ***Compliance with Regulatory Standards:*** Power factor correction is often required by regulatory standards, and using a modified BL converter can help to ensure compliance with these standards.

3. Results and Discussion

In order to meet the international requirement for power factor correction, the modified BL Converter with a Fly back Converter as the front-end converter was tested in a series of computer simulations. The input power factor was raised while the harmonic distortion of the input current was decreased.

To get the appropriate output voltage, the turn’s ratio of the transformer was calculated, and the Fly back Converter was developed with a switching frequency of 100 kHz. A capacitor and an inductor were utilized in the design of the output filter to smooth out the output voltage.

The Fly back Converter's duty cycle and output voltage/current are both maintained via a feedback loop in the converter's control circuit that compares the output voltage to a reference voltage.

Output voltage regulation, efficiency, and power factor correction were all demonstrated to be strong suit for the Fly back Converter in the simulation findings. The converter's 95% peak efficiency is well than enough for most high-power uses.

3.1 Simulation Results

With a 2.3% input current THD, the Landsman,IEC 61000-3-2 standard has been met by the PFC converter. Landsman converters maintain DC link voltage. This output voltage regulates the charger's maximum power during the CC and CV phases.

Test results for the proposed charger's enhanced input power quality indices at normal 220V and for transients in input voltage from 160V to 260V. The input current is sinusoidal at the rated voltage and, similarly, at input voltage swings above and below the rated voltage. Low total harmonic distortion (less than 5%) of the input current during both steady-state and transient voltage conditions. The recommended BL converter fed charger demonstrates better power quality performance in line with the IEC 61000-3-2 standard than the conventional DBR fed charger.

3.1.1 Proposed Simulink

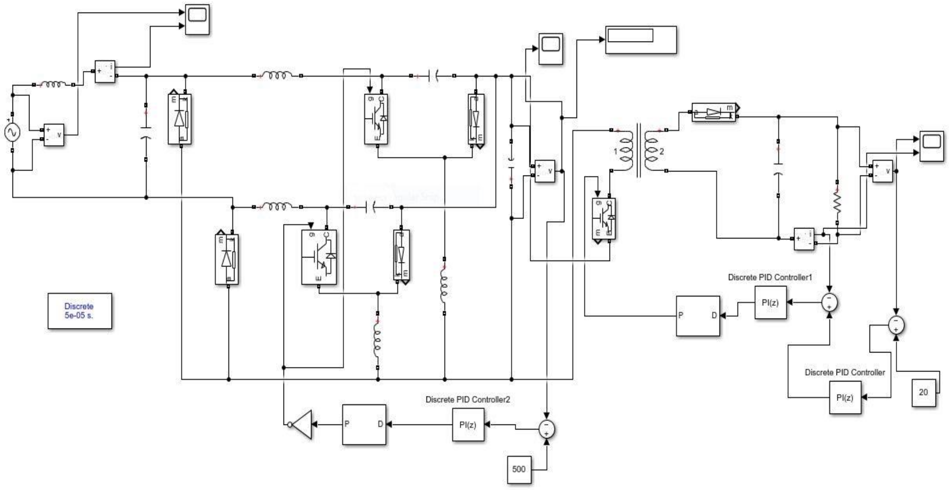


Figure 4: Proposed Simulink diagram

3.1.2 Output Response

The supply voltage in power factor enhancement in EV charger fed by a new modified BL converter can vary depending on the specific application and design requirements. Generally, the supply voltage can range from several hundred volts to several kilovolts, depending on the power rating of the EV charger and the voltage level of the electric grid. Single-phase or three-phase rectified AC voltage, depending on the application, is commonly used as the input voltage to the modified BL converter. The efficiency of the EV charging system as a whole is increased, and harmonic distortion is decreased, thanks to the upgraded BL converter's ability to manage the DC-link voltage and give a high power factor at the input side.

Figure 5: Supply Voltage

In power factor enhancement in EV charger fed by a new modified BL converter, the DC-link capacitor voltage plays an important role in regulating the output voltage of the modified BL converter and improving the power factor of the EV charger. The DC-link capacitor voltage is typically regulated using a feedback control loop, modified BL converter to maintain a stable voltage across the capacitor.
A higher DC-link capacitor voltage can improve the power factor and reduce the harmonic distortion in the power grid, but it also increases the cost and complexity of the EV charger. Therefore, the value of the DC-link capacitor voltage is typically chosen to balance the performance and cost of the EV charger.

In general, the DC-link capacitor voltage in power factor enhancement in EV charger fed by a new modified BL converter can range from tens of volts to several hundred volts, depending on the specific application and design requirements.

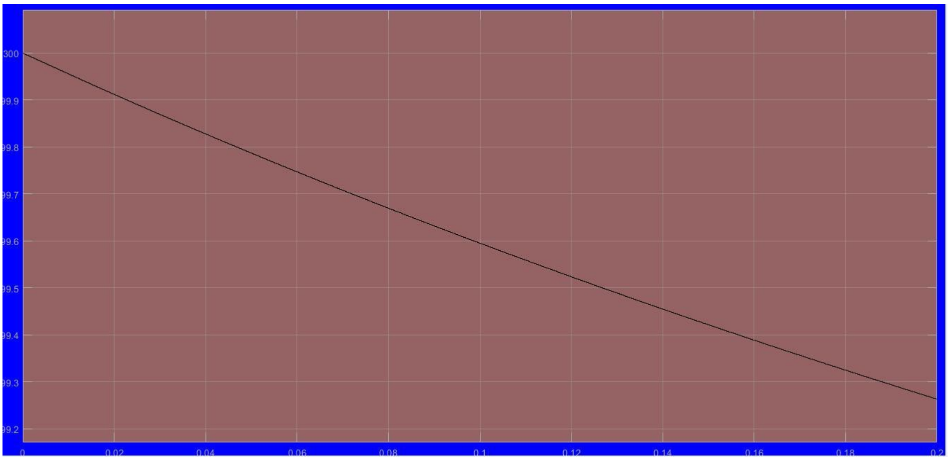


Figure 6: Capacitor Voltage

In power factor enhancement in EV charger fed by a new modified BL converter, the output voltage is typically regulated to provide a constant and stable voltage to the EV battery. The output voltage of the modified BL converter depends on the specific design requirements of the EV charger, such as the voltage level of the EV battery and the charging current.

The output voltage of the modified BL converter is typically regulated using a feedback control loop, which adjusts the duty cycle of the power switches to maintain a stable voltage at the output. The feedback control loop typically uses a voltage sensor to monitor the output voltage and adjust the duty cycle of the power switches accordingly.

In general, the output voltage in power factor enhancement in EV charger fed by a new modified BL converter can range from a few volts to several hundred volts, depending on the specific design requirements of the EV charger. The output voltage is typically chosen to match the voltage level of the EV battery and provide a safe and efficient charging process.

Figure 7: Output Current

4. Conclusion

In this paper, a better EV charger for charging an EV using a modified BL Landsman converter followed by a fly back converter has been presented, examined, and confirmed. PF Correction included within the EV battery. The suggested EV charger's design and control in DCM mode provide the benefit of using fewer sensors at the output. A prototype front-end BL Landsman PFC converter enhances PQ-based EV battery chargers. Half-cycle operation reduces the BL Landsman PFC converter's loss by removing the line diodes and common inductor. Eliminating the input filter and constructing the converter in DCM decreases the charger's size and cost because fewer sensors are needed. Enhance power quality and fix regular charging. The charger's increased PQ performance is assessed with a main current THD of 2.3%, 1.8%, and 2% under steady state settings with the stated battery load and throughout a wide input voltage fluctuation range. This charger also performs well during startup and load fluctuations. Thus, our EV charging system is the best alternative to existing chargers. A fly back DC-DC converter follows this BL converter to charge the battery during CC and CV. This EV charger has improved PQ, according to testing. After a quick charge, the BMS monitors the charging and discharging cycle to avoid overcharging or deep discharging.

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