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POWER FACTOR IMPROVEMENT IN MODIFIED BRIDGELESS LANDSMAN CONVERTER FED EV BATTERY CHARGER

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Abstract - The Modified Bridgeless Landsman Converter (MBLC) is a type of AC-DC converter that can be used for Electric Vehicle (EV) battery charging applications. The MBLC is capable of improving power factor (PF) and reducing total harmonic distortion (THD), which results in more efficient and reliable operation. In the MBLC topology, two capacitors are added to the Landsman Converter to form a bridgeless configuration. This modification allows the converter to operate with reduced conduction and switching losses, resulting in improved efficiency and power factor. The proposed system in this abstract is an MBLC-based EV battery charger that uses a single-stage conversion approach, resulting in reduced cost, complexity, and size. The charger is capable of providing a regulated DC voltage to the battery with improved power factor and reduced THD.The proposed system is simulated and analysed using MATLAB/Simulink software, and the results demonstrate improved performance compared to the conventional Landsman Converter. The proposed MBLC-based EV battery charger provides a cost-effective and efficient solution for charging EV batteries.

I. INTRODUCTION

Power factor improvement is an important consideration in modern electric vehicle (EV) battery chargers, which are designed to be efficient, reliable, and cost-effective. One approach to improving power factor in an EV battery charger is to use a modified bridgeless Landsman converter, which is a type of DC-DC converter that can convert AC power from the grid to DC power that can be used to charge the EV battery. The Landsman converter topology is a modification of the classic bridge rectifier, which can improve the performance of AC-DC converters by reducing losses and improving efficiency. The modified bridgeless Landsman converter combines this topology with a boost converter to provide a higher voltage output that is suitable for charging an EV battery. The converter also includes a power factor correction (PFC) circuit to improve the power factor of the charger. Improving the power factor of an EV battery charger can help to reduce the harmonic distortion and reactive power consumption, which can lead to higher energy efficiency and lower operating costs. The modified bridgeless Landsman converter can provide a high-power factor and high efficiency, making it a promising solution for EV battery chargers in the future. Any battery used in an electric locomotive's charging process is essentially dictated by its capacity.dimensions and category, such as the amount and duration of the voltage/current to be applied, the method after full charging, and so on. Several battery types are far more versatile andcapable of continual charging even after full charge. Depending on the situation, they are normally recharged using either a constant current or a constant voltage source. Few other batteries require/use a timer to turn off the charging current at a certain time, usually when the charge is full, and the chargers must be manually separated virtually every charging cycle. Other battery concerns include overcharging, damage (lower capacity, shorter lifespan), overheating, and even exploding.microprocessor, to securely fine-tune the charging current/voltage and diagnose the cut-off at the end of the charge. A slow battery charger may take several hours to reach full charge. High-capacity chargers can promptly rebuild the majority of a battery's capacity; however, they may be too powerful for some battery types. To safeguard the battery from overcharging, such batteries require active monitoring. High-rate chargers are appropriate for electric vehicles. Setting up those chargers, as well as providing the necessary assistance, is a concern, particularly for public accessing electric locomotives. A competent battery

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charger is the foundation for long-lasting and reliable batteries. Chargers are frequently given minimal importance and are seen as an "afterthought" in a pricesensitive market. The battery and charger, like a horse and carriage, must function together. The power supply is prioritized through prudent planning and is critical at the initial phase, well before implementation. Technologists are more often clueless of the complexities of the power source, particularly while charging in complicated environments. A trickle-charger delivers a limited electric current to a battery that has been sitting for a long time, just enough to keep it from self-discharging. Trickle charging is not compatible with all battery types, and attempting to do so may result in harm. Indefinite trickle charging is not possible due to the chemical technique utilized in lithium ion battery cell

II. RELATED WORKS

Three aspects are discussed in many study publications that are pertinent to our issue. to begin with,the demand for EVs in the face of accelerating global warming. Various articles claim that EVs can drastically lower emissions and operate more cheaply than internal combustion engines.vehicles. The transition from ICE to EV vehicles may be gradual, but it is unavoidable. Additionally, [3] offers a study based on the current situation and advancements in technology for electric vehicle (EV) propulsion in this regard. Compared to conventional fuel and petrol vehicles, using electricity for transportation has a number of advantages. To completely incorporate transport electrification, however, a researcher's total attention is necessary. Certain efficient control methods must be developed in order to integrate them into the current distribution system. A few of the aforementioned techniques are related to the issues with power quality that EV chargers address during the charging process.

Third, an EV charger is made up of power electronics components such as converters. Now, converters come in a variety of shapes and sizes, each with its own set of pros and disadvantages. Bridge converter topologies reduce power factor and increase losses. Many bridgeless topologies, such as buck, boost, sepic, and cuk converters, are proposed to mitigate this. Sepic and cuk have the disadvantage of employing two semiconductor switches, resulting in higher losses. When the duty cycle is increased, the efficiency of boost converters decreases. At the source end of the existing charger configuration, a Diode Bridge Rectifier is employed; in the proposed configuration, DBR is replaced with a landsman converter. The Landsman setup eliminates the negative impact of DBR. The suggested architecture provides increased power quality, minimal device stress, and inexpensive device cost.Concerning the power factor is the fourth. The primary objective of this is to increase the power factor. Project. Non-linear loads in a charging circuit cause harmonic distortion in the 12circuit. Poor power factor is a direct result of these harmonics. Through Active Boost Power Factor Control, the Landsman Converter eliminates the harmonics effect.The fifth point concerns the fly-back converter. A fly-back converter is set up like an AC transformer with two equal-turn inductors on either side that are separated by ferromagnetic material. The output DC voltage can more easily be regulated when using a flyback converter. Depending on the needs, a fly back converter can either buck or raise the input voltage. In SMPS, these converters are also utilized.The sixth concern is the controller unit.

III. PROPOSED SYSTEM

The proposed system landman converter is designed for electric vehicle charging applications,The proposed modified Landsman converter fed batterycharger is composed of two stages: a modified BL converter for improved input wave-shaping and an isolated converter for EV battery charging under constant current (CC) constant voltage (CV) conditions. Based on the application need of cheap cost or low device stress, the modified converter is operated in DCM or CCM mode. Because the cost of the battery charger is the primary factor these days, a DCM mode is used for this application. Furthermore, the fly back converter functions in the discontinuous region of the switching cycle to implement battery control with a decreased number of sensors in the circuit. As a result, the proposed charger's size issues are also minimised. The proposed scheme and operating principle of the converter's two sections are for voltage charging and discharging applications,

	Ripple	THD	P.F (source)
Diode Bridge Rectifier	-	58%	0.8
Landsman Converter (PI)	-	5%	0.997
Landsman converter(fuzzy)	-	-	0.99
Interleaved Landsman	-	9%	-

TABLE 1: comparison of different converter

In proposed system landsman converter with fly back converter is designed for high voltage applications, the proposed modified Landsman converter fed battery charger consists of two stages, a modified BL converter for improved input wave-shaping and an isolated converter for the charging of EV battery during constant current (CC) constant voltage (CV) conditions. The operation of the modified converter is selected in DCM or CCM mode based on the application requirement of low cost or low device stress, respectively. Since, the cost of the battery charger is main consideration nowadays, a DCM mode is adopted for this application. Moreover, the flyback converter also operates in discontinuous region of switching cycle to implement the control of the battery using reduced number of sensors in the circuit. Therefore, the size issues are also minimized for the proposed charger. The proposed scheme and operating principle of the two parts of the converter, are discussed here offers an EV battery charger powered by a BL converter with regulated DC connection voltage at a transitional period. A single phase AC source supplies the input side of the proposed charger. Two Landsman converters that operate in parallel during the positive half line and negative half line, respectively, eliminate the input DBR. As a result of fewer components conducting during one switching cycle, conduction losses are cut in half. Two converters are switched at 20 kHz in synchrony for better performance-based switching. When operating on the positive half line and the negative half line, respectively, the currents in the output inductors Lop and Lon are intended to discontinue during the course of one switching cycle.

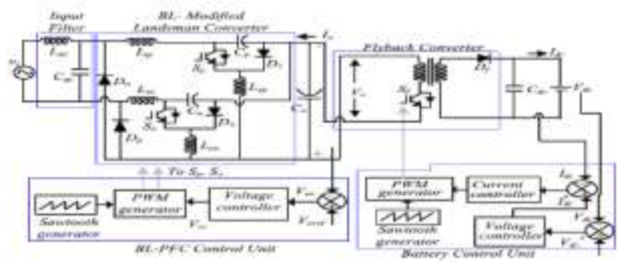


Figure: land converter PFC converter

1) OPERATION PRINCIPLE

Modified bridgeless landsman PFC converter fed battery charger for an electric car. II. OPERATION OF A MODIFIED BL CONVERTERFED CHARGERThe proposed modified Landsman converter fed batterycharger is composed of two stages: a modified BL converter for improved input wave-shaping and an isolated converter for EV battery charging under constant current (CC) constant voltage (CV) conditions. Based on the application need of cheap cost or low device stress, the modified converter is operated in DCM or CCM mode.Because the cost of the battery charger is the primary factor these days, a DCM mode is used for this application. Furthermore, the flyback converter operates in the discontinuous portion of the switching cycle to execute control of the voltage and current

2)Mode of operation

P-I mode (t0 -t1): During the positive half cycle of the mains voltage,The operation of the converter begins with mode P-I. The switch SP, which is connected to the upper line, is turned on, and the inductor Lop is turned off.begins charging along the path depicted ,During this time, the isolated converter linked to the load side drains the intermediate DC link capacitor, Co. However, because of the stored charge in the inductor, the high frequency diode, D1, has no conducting channel during this period and hence has a reverse bias voltage across it.

Mode P-II (t1 -t2): When the gate pulse to the switch is stopped, the high frequency diode, D1, functions in mode P-II. Lop, the inductor, follows the path shown in Fig. 3(bMode P-III (t2 - t3): The stored charge is used during mode P-III operation.in a shunt Upon completion of the switching cycle, the lop is totally depleted. For the remainder, the inductor current discontinues. Cycle of flipping. The intermediate DC link capacitor is supplying the output power during this time and discharging) to discharge.

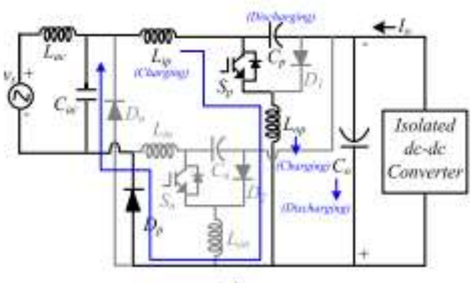


Figure: isolated dc-dc converter

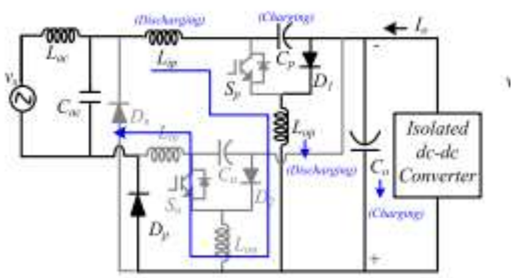


Figure : mode 2 operation

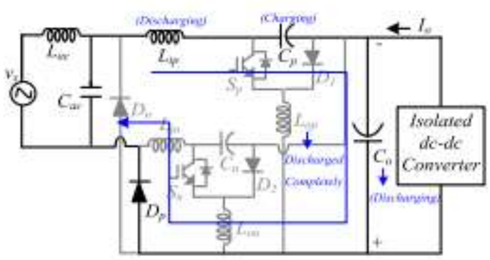


Figure : mode3 operation

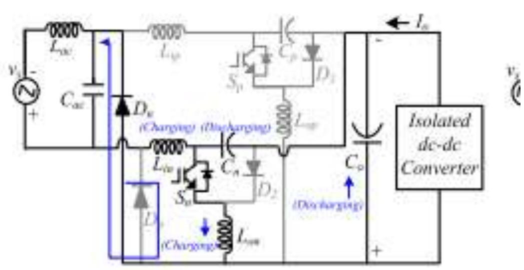


Figure: mod4 operation

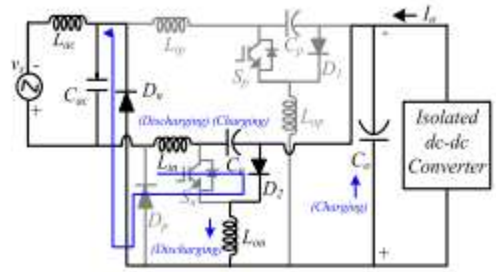


Figure: mode 5 operation

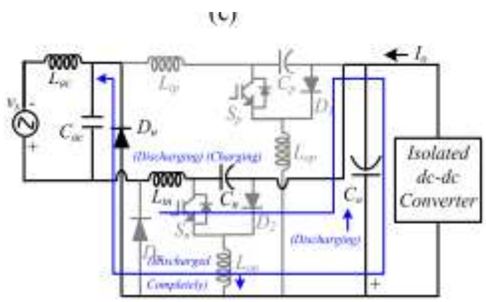


Figure: mode operation

3)Proposed Isolated Converter Operation:

Due to its simple structure, the flyback converter is widely used for the implementation of battery chargers for low-cost battery-powered vehicles such as E-rickshaws.When switch Sf is turned on in mode-I, the current rises through the magnetizing inductance and the energy is stored in the ferrite core used in the high frequency transformer. The polarity noted on the flyback transformer and the arrangement of the output diode in the circuit indicate that no energy is transferred to the battery side. The output DC link capacitor supplies the necessary charging current to the battery.

When the pulse to the switch Sf is interrupted during mode II, the polarity of the voltage on the transformer primary winding and hence on the secondary winding is altered.

IV. SIMULATION RESULTS

In simulation result we designed the flyback converter with landsman converter is designed here,A flyback converter with an output voltage of 65 V is intended to manage the charging current in two charging modes while also isolating the battery. The flyback converter's key selection criteria are the magnetising inductance Lmag and the best switch rating. A duty ratio (Dif) of 0.394 is chosen to give the battery the appropriate charging voltage for the necessary stepping down of the input voltage to 65 V. The turns ratio (Nsec/Npri) is therefore

Components name	Parameter
Mosfet	IRF244
Battery	12v ,1.5 amps current
Transformer	3 amps transformer
Ferite core inductor	5uf
Capacitor	10 uf

$$\frac{N_{sec}}{N_{pri}} = \left(\frac{1-D_{if}}{D_{if}}\right)\frac{V_{dc}}{V_o} = \left(\frac{1-0.394}{0.394}\right)\frac{65}{300} = 0.333$$

As explained in mode-I of the flyback converter operation, the current in the transformer's magnetising inductance begins to increase when switch Sf is turned on. The formula for the inductor current ILmag f is:

where, The output DC voltage of the PFC bridgeless converter that powers the flyback converter is denoted by Vdc. The current in the primary of the flyback transformer during the ON state of switch Sf is denoted by ILmag f. Furthermore, the transformer size is reduced by employing a switching frequency of 50 kHz, abbreviated as fsf for flyback converter. The output charging voltage to the battery is given by a wide range in duty cycle Dif, equating to the full SOC value to about 60% SOC.

Fig. 5 displays the battery's charge profile for two charging modes in relation to the matching SOC. The isolated converter's intermittent operation is demonstrated over one switching cycle using the magnetising inductance Lmag f design, which is described as Inductance of flyback conveter

$$L_{mag\,f} = \frac{V_o \times D_{if}}{I_{Lmf} f_{sf}} = \frac{300 \times 0.394}{14.38 \times 50000} = 164.39\mu H$$

V. EXPERIMENTAL RESULTS

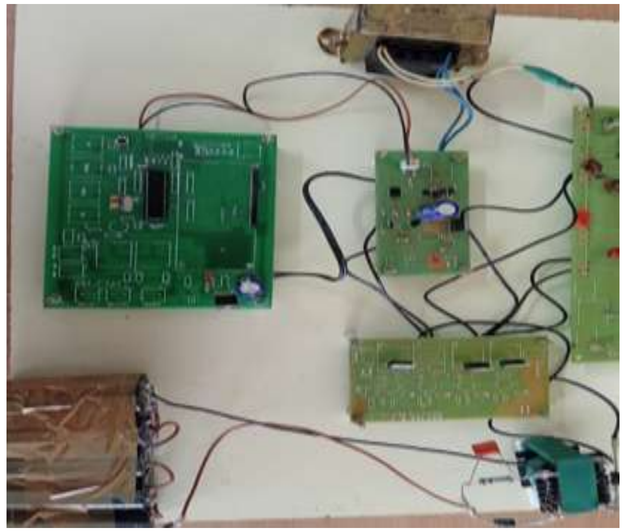
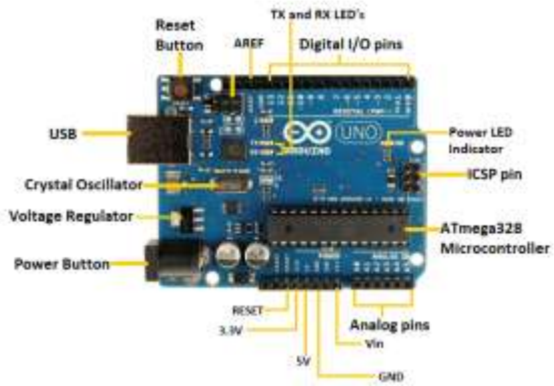


Figure: experimental figure

VI. HARDWARE DESCRIPTION

1) ARDUINO UNO

The Arduino UNO is a standard Arduino board. In this context, UNO denotes 'one' in Italian. The original release of Arduino Software was labelled as UNO. It was also the first USB board made available by Arduino. It is regarded as a powerful board that is employed in a variety of tasks. The Arduino UNO board was created by Arduino.cc. The Arduino UNO is built on the ATmega328P microprocessor. In comparison to other boards, such as the Arduino Mega, it is simple to use. The board is made up of digital and analogue I/O pins, shields, and other circuitry. The Arduino UNO has six analogue input pins, fourteen digital pins, a USB connection, a power jack, and an ICSP (In-Circuit Serial Programming) header. It's written in IDE, which stands for Integrated Development Environment. It is compatible with both online and offline platforms.

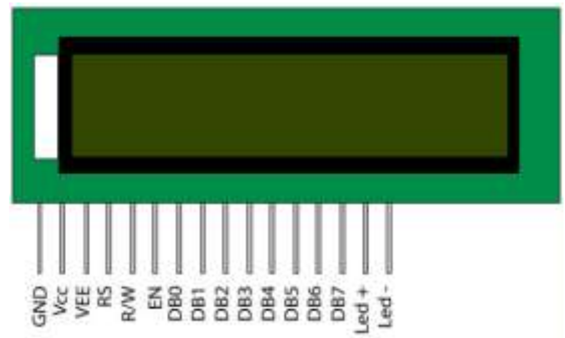


2)*PINSGeneral Pin functions*

- LED: There is a built-in LED driven by digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.
- VIN: The input voltage to the Arduino/Genuino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- 5V: This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 20V), the USB connector (5V), or the VIN pin of the board (7-20V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage the board.
- 3V3: A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- GND: Ground pins.
- IOREF: This pin on the Arduino/Genuino board provides the voltage reference with which the microcontroller operates. A properly configured shield can read the IOREF pin voltage and select the appropriate power source or enable voltage translators on the outputs to work with the 5V or 3.3V.
- Reset: Typically used to add a reset button to shields which block the one on the board.

3)LCD DISPLAY

LCD is an abbreviation for liquid crystal display. It is a type of electronic display module that is used in a wide variety of applications such as various circuits and devices such as mobile phones, calculators, computers, TV sets, and so on. These displays are mostly used for light-emitting diodes with multiple segments and seven segments. The primary advantages of adopting this module are that it is affordable, easily configurable, has no constraints for displaying unique characters, special and even animations.



- Pin1 (Ground/Source Pin): This is a GND pin of display, used to connect the GND terminal of the microcontroller unit or power source.
- Pin2 (VCC/Source Pin): This is the voltage supply pin of the display, used to connect the supply pin of the power source.
- Pin3 (V0/VEE/Control Pin): This pin regulates the difference of the display, used to connect a changeable POT that can supply 0 to 5V.
- Pin4 (Register Select/Control Pin): This pin toggles among command or data register, used to connect a microcontroller unit pin and obtains either 0 or 1(0 = data mode, and 1 = command mode).
- Pin5 (Read/Write/Control Pin): This pin toggles the display among the read or writes operation, and it is connected to a microcontroller unit pin to get either 0 or 1 (0 = Write Operation, and 1 = Read Operation).
- Pin 6 (Enable/Control Pin): This pin should be held high to execute Read/Write process, and it is connected to the microcontroller unit & constantly held high.
- Pins 7-14 (Data Pins): These pins are used to send data to the display. These pins are connected in two-wire modes like 4-wire mode and 8-wire mode. In 4-wire mode, only four pins are connected to the microcontroller unit like 0 to 3, whereas in 8-wire mode, 8-pins are connected to microcontroller unit like 0 to 7.
- Pin15 (+ve pin of the LED): This pin is connected to +5V

- Pin 16 (-ve pin of the LED): This pin is connected to GND.

4) FERRITE CORE INDUCTOR

Ferrite core inductors are inductors that have a ferrite core inside their coil. Because of the electrical conductivity of the metal, when these solid metal cores are employed in inductors, the changing magnetic field produces enormous eddy currents. Along with the closed-loop of electric current, these currents cycle within the inductors. Inductors with ferrite cores are utilised in a variety of electric circuit applications such as power conversion, broadband, and interference suppression.

In 2000 volts primary / secondary insulation 60°C ambient temperature For reinforced insulation, the construction complies with IEC950, IEC335, and IEC61558. UL94-V0 listed materials are used exclusively. A ferrite core inductor is a type of inductor that increases its inductance by using a ferrite core. When an electric current flows through an inductor, it stores energy in the form of a magnetic field. An inductor's inductance is proportional to the number of wire turns in the coil and the permeability of the core material.A ferrite core inductor is made out of a wire coil wrapped around a ferrite core. Ferrite is a ceramic substance with high permeability but poor electrical conductivity. The ferrite core boosts the coil's inductance by providing a low reluctance channel for the magnetic field to pass through. Because of the high permeability of the ferrite core, the inductor can store more magnetic energy for a given amount of current. Because of their great performance and small size, ferrite core inductors are commonly employed in electronic circuits. They're frequently found in power supply, filters, and signal processing circuits. Ferrite core inductors come in a variety of sizes and forms to suit a variety of applications.

The inductance of a ferrite core inductor is determined by the number of turns of wire in the coil, the wire diameter, and the permeability of the ferrite core. The following formula may be used to determine inductance:

L = (N^2 * μ * A)/L

Where:

L = inductance in henries (H)

N = number of turns

μ = permeability of the core material

A = cross-sectional area of the core

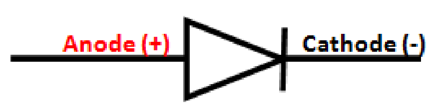
l = length of the core

Ferrite core inductors can be purchased with pre-calculated inductance values, or they can be custom-made to meet specific requirements.

Figure: Ferrite core inductor

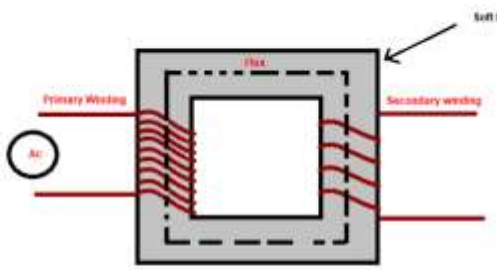
5)DIDOE IN4007

A diode is a device that only enables current to flow in one direction. In other words, current should always travel from anode to cathode. A grey bar, as illustrated in the image above, identifies the cathode terminal. The maximum current carrying capability of the 1N4007 diode is 1A, and it can endure peaks of up to 30A. As a result, we may utilise this in circuits designed for less than 1A. The reverse current is just 5uA, which is insignificant. This diode has a power dissipation of 3W.



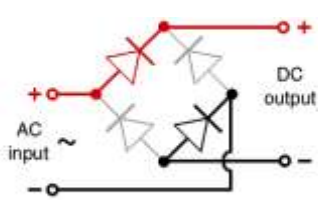
6)STEP DOWN TRANSFORMER

A step-down transformer is one that has a higher number of turns in the primary winding and a lesser number in the secondary winding. As we can see from the preceding calculation for the relationship between the number of turns in winding and voltage, if the number of turns in the primary is more than the number of turns in the secondary, the EMF generated in the secondary is less than the primary input. As a result, the secondary coil of a step-down voltage transformer has a lower voltage. The step-down transformer, as the name implies, is used to convert higher voltage electricity to lower voltage power.



7) RECTIFIER

The rectifier circuit is used to convert AC (Alternating Current) to DC (Direct Current). Rectifiers are grouped into three types: half-wave, full-wave, and bridge rectifier. The primary job of all of these rectifiers is to convert current, although they do not do so effectively. Both the centre tapped full wave rectifier and the bridge rectifier convert well. A bridge rectifier circuit is a ubiquitous component of electronic power systems. Many electronic circuits require a rectified DC power source to power the numerous electronic fundamental components from an available AC mains supply. This rectifier may be found in a broad range of electronic AC power devices, including household appliances, motor controllers, modulation processes, welding applications.



8)VOLTAGE SENSOR

This sensor measures, calculates, and determines the voltage supply. This sensor can detect the amount of AC or DC voltage. This sensor's input can be voltage, and its output can be switches, analogue voltage signals, current signals, audio signals, and so on. Some sensors provide outputs such as sine waveforms or pulse waveforms, while others can create outputs such as AM (Amplitude Modulation), PWM (Pulse Width Modulation), or FM (Frequency Modulation). The voltage divider can affect the measurement of these sensors.

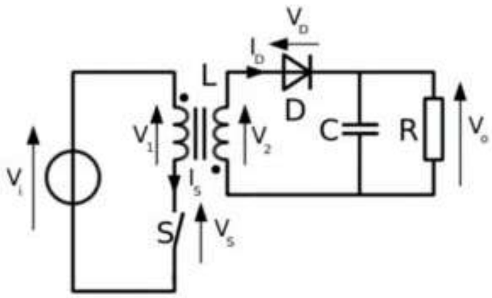
A simple but very useful module which uses a potential divider to reduce any input voltage by a factor of 5. This allows you to use the analogue input of a microcontroller to monitor voltages much higher than it capable of sensing. For example with a 0-5V analogue input range you are able to measure a voltage up to 25V. The module also includes convenient screw terminals for easy and secure connection of a wire.

Figure: current sensor

9)FLYBACK CONVERTER

The flyback converter design is straightforward, with only a flyback transformer, switch, rectifier, filter, and a control device to operate the switch and accomplish regulation. The switch is used to turn the primary circuit on and off, which can magnetise or demagnetize the transformer. The controller's PWM signal regulates the functioning of the switch. The switch in most flyback transformer designs is a FET, MOSFET, or a simple transistor.

Rectifier rectifies the voltage of the secondary winding to provide pulsing DC output and disconnects the load from the transformer's secondary winding. The capacitor filters the rectifier output voltage and raises the DC output level to the required level. The magnetic energy is stored in the flyback transformer, which acts as an inductor. It is built as a two-coupled inductor with primary and secondary windings. It runs at almost 50KHz frequencies.



VII. CONCLUSION

We designed the electric vehicle charging applications using flyback landsman converter for electric vehicle applications,This work proposes, analyses, and validates an improved EV charger with a modified BL Landsman converter followed by a flyback converter to charge an EV battery with inherent PF Correction. The proposed EV charger's design and operation in DCM mode provided the benefit of a decreased number of sensors at the output. Furthermore, the suggested BL converter has decreased the input and output current ripples caused by inductors in the converter's input and output.A prototype was created, and the charger's operation was validated by experimental findings under steady-state and abrupt changes in input voltage. The hardware validation findings reveal that the suggested charger's performance is suitable for increased power.

VIII. REFERENCES

1) Wencong Su, Habiballah Eichi, Wente Zeng and Mo-Yuen Chow, "A survey on the electrification of transportation in a smart grid environment," IEEE Transactions Industrial Informatics, vol. 8, no. 1, pp. 1-10, Feb. 2012.
2) Ching Chuen Chan, "The state of the art of electric, hybrid, and fuel cell vehicles," Proc. IEEE, vol. 95, no. 4, pp. 704–718, Apr. 2007.
3) Kaushik Rajashekara, "Present status and future trends in electric vehicle propulsion technologies," IEEE J. Emerg. Sel. Topics Power Electronics., vol. 1, no. 1, pp. 3–10, Mar. 2013
4) Juan C. Gomez and Medhat M. Morcos, "Impact of EV battery chargers on the power quality of distribution systems," IEEE Transactions Power Del., vol. 18, no. 3, pp. 975–981, Jul. 2003.
5) Luca Solero, "Nonconventional on-board charger for electric vehicle propulsion batteries," IEEE Transactions Vehicular Technology, vol. 50, no. 1, pp. 144-149, Jan 2001.
6) Devendra Patil and Vivek Agarwal, "Compact onboard singlephase EV battery charger with novel low-frequency ripple compensator and optimum filter design," IEEE Transactions Vehicular Technology, vol. 65, no. 4, pp. 1948-1956, April 2016..
7) Hye-Jin Kim, Gab-Su Seo, Bo-Hyung Cho, and Hangseok Choi, "A simple average current control with on-time doubler for multiphase CCM PFC converter," IEEE Trans. Power Electron., vol. 30, no. 3, pp. 1683–1693, Mar. 2015.
8) Adria Marcos-Pastor, Enric Vidal-Idiarte, Angel Cid-Pastor and L. Martinez-Salamero, "Interleaved digital power factor correction based on the sliding-mode approach," IEEE Transactions Power Electronics, vol. 31, no. 6, pp. 4641-4653, June 2016.
9) Muntasir Alam, Wilson Eberle, Deepak S. Gautam and Chris Botting, "A soft-switching bridgeless AC–DC power factor correction converter," IEEE Transactions Power Electronics, vol. 32, no. 10, pp. 7716-7726, Oct. 2017..
10) Siddharth Kulasekaran and Raja Ayyanar, "A 500-kHz, 3.3-kW power factor correction circuit with low-loss auxiliary ZVT circuit," IEEE Transactions Power Electronics, vol. 33, no. 6, pp. 4783-4795, June 2018.
11) Jae-Hyun Kim, Chong-Eun Kim, Jae-Kuk Kim, Jae-Bum Lee, and Gun-Woo Moon, "Analysis on load-adaptive phase-shift control for high efficiency full-bridge LLC resonant converter under lightloadconditions," IEEE Trans. Power Electron., vol. 31, no. 7, pp. 4942–4955, Jul. 2016.
12) Chuan Shi, Haoyu Wang, Serkan Dusmez and Alireza Khaligh, "A SiC-based high-efficiency isolated onboard PEV charger with ultrawide DC-link voltage range," IEEE Transactions Industry Applications, vol. 53, no. 1, pp. 501-511, Jan.-Feb. 2017.
13) Junjun Deng, Siqi Li, Sideng Hu, Chunting C. Mi and Ruiqing Ma, "Design methodology of LLC resonant converters for electric vehicle battery chargers," IEEE Transactions Vehicular Technology, vol. 63, no. 4, pp. 1581-1592, May 2014.
14) Chuan Shi, Yichao Tang and Alireza Khaligh, "A single-phase integrated onboard battery charger using propulsion system for plug-in electric vehicles," IEEE Transactions Vehicular Technology, vol. 66, no.
15) 12, pp. 10899-10910, Dec. 2017. [15] Bhim Singh, Sanjeev Singh, Ambarish Chandra and Kamal Al- Haddad, "Comprehensive study of single-phase AC-DC power factor corrected converters with high-frequency isolation," IEEE Transactions Industrial Informatics, vol. 7, no. 4, pp. 540-556, Nov. 2011