A Novel Design of Electric Vehicle Battery Charger using Modified Bridgeless Landsman Converter

Pradeep Katta*, Mohammed Ovaiz A, Prabaakaran K, Priya M, Keerthana and Preethi J

1, 2, 3, 4, 5, 6Department of Electrical and Electronics Engineering
1, 2, 3, 4, 5, 6Vel Tech High Tech Dr. Rangarajan Dr. Sakunthala Engineering College, India
1pradeep.2048@gmail.com, 2ovaiz.eee@gmail.com, 3prabaakaran031@gmail.com, 4priyaroshan1998@gmail.com,
5keerthanababu0999@gmail.com, 6preethisheroin@gmail.com

Abstract - This paper includes the design and implementation of a new electric vehicle charger, which is powered using a battery consisting of an enhanced power factor frontend. The traditional diode that is at the source end is omitted in the proposed design using the conventional power factor improvement inverter. The inverter has its parameters closer to the configuration of a basic push pull converter. The above-mentioned converter works with the phenomenon of electric vehicle battery control. Two modes of operation are incorporated out of which the former one is constant current mode and the latter is constant voltage mode. To obtain the desired regulation of DC voltage at the point of coupling and also to improve the operational efficiency to unity power factor, the proposed Landsman converter is operated using a single sensed individual. This method yields improved power quality, less harmonics in comparison with a conventional one. A prototype is constructed and tested by charging a 48V electric vehicle battery of 100Ah size under the transients in input voltage to display the proposed charger to an IEC61000-3-2 standard. All the cases are said to be satisfied by performance of the charger.

Keywords - Battery charger, Modified Landsman Converter, Push Pull Converter, Harmonic Distortion Reduction, Power Quality, Electric Vehicle

1. Introduction

The rechargeable batteries are used to supply power to the electric vehicles. AC-DC converter will recharge these batteries. The electric vehicle battery charger configuration consists of a front-end boost converter and an independent next-end converter [1]. The performance of the battery charger depends on the output voltage and output current and in relation to these parameters there is a tradeoff in the efficiency of the battery charger [2]. The zero-voltage switching power factor correction converters are used to reduce the scale of the inductor and the ripple of the output current. The traditional charger consists of a single-phase alternating current supply source and an uncontrolled bridge rectifier, which are replaced by using two Landsman converters in the proposed design [3]. Two Landsman converters will operate simultaneously during the positive and negative half cycle. As it consists of a smaller number of components during the switching cycle the conduction losses are less [4]. During the battery charging operation, the diode bridge rectifier generates a large amount of harmonic distortion which causes poor power factor. The input wave-shaping can be improved by using modified Landsman converter which consists of two stages of modified bridgeless converter [5]. At different input ranges, the power quality of the suggested battery charger design is enhanced and the LLC resonant converter provides high performance, with low electromagnetic interference providing high power density [6].

The LLC design seems to be computationally intensive and highly complex for practical implementation. Considering this a bidirectional AC-DC integrated on board configured converter system is suggested for high performance index. It is mandatory to confine to the power quality standard IEC61000-3-2 and the conventional design fail to satisfy the same [7]. The input current shape is not sinusoidal which leads to the displacement between voltage and current. The proposed system overcomes all the drawbacks and provides improvement in quality of power, reduces sub harmonics and hence the injection of stress to the devices and utility [8]. The ripple in current and hence the switching loss is controlled by the suggested design of battery charger [9].

2. Modified Bridgeless Landsman and Push Pull Converters

![Fig. 1: Circuit Diagram of Modified Bridgeless Landsman and Push Pull Converters](image)

In Figure 1, the structure of the proposed system consist of the modified landsman converter with R-load is
given to prove the simulated analysis and operation modes of proposed converters using the MATLAB simulation. 240V, 50Hz AC input voltages are given as source. MOSFET switch is used in this modified landsman converter [10]. 24mF capacitor is used as a DC link capacitor. In the fly back converter, IGBT is used as the switch. 25KHz frequency is given in the isolated transformer/coupled inductor, 12mF is used as a load capacitor, 20ohm resistor is acting as the load resistor [11]. Figure 2, shows the design of push pull converter

![Fig. 2: Design of Push Pull Converter](image)

The operation of the circuit means that both transistors are actually pushing, and the pulling is done by lowpass filter [12]. Q1 and Q2 are operating in overlapping mode. The duty cycle is said to be more than 0.5. The two windings of the transformers namely primary and secondary are to conduct mutually in opposite direction [13]. Figure 3, illustrates the CMOS Technology.

![Fig. 3: CMOS Technology](image)

3. Simulation Results
MATLAB SIMULINK R2020 is used to arrive at the simulation architecture of the suggested system is implemented [14],[15]. The suggested modified Landsman converter with the R-load is given to prove the simulated analysis using MATLAB. The simulated diagram is shown in Figure 4.

240V, 50Hz AC input voltage is given as source, MOSFET switch is used in modified Landsman converter [16]. The device level validation on design can be executed by using simulink utilising the S-domain and laplace domain modelling and by using adaptive modelling [17]. User defined functions can be coined to generate coding and hence the analysis becomes less complex [18].

The graphical editing toolbox in simulink facilitates modelling and compiling of dynamic loads by exploring the various library options available in built [19],[20]. The whole software analysis becomes even more convienient by validating the simulink model with MATLAB S-function coding and the feature of mutual interface between the two domains [21],[22]. Figure 5, shows the Power supply unit.

![Fig. 5: Power Supply Unit](image)

This section describes how +5V DC power and +12V DC power supply can be produced.

![Fig. 6: Input Supply Voltage Waveform](image)
The supply voltage of the AC waveform is 230V and frequency is 50Hz is shown in Figure 6.

**Fig. 7: Landsman Converter Output Voltage Waveform**

The DC output voltage waveform of the landsman converter has an amplitude of 400V is shown in Figure 7.

**Fig 8: Fly Back Converter Output Voltage**

The voltage waveform of the flyback converter has an amplitude of 80V is shown in Figure 8.

**Fig 9: Pulse Generator Waveform of Landsman Converter**

First pulse for positive Landsman converter and second pulse for negative Landsman converter is shown in Figure 9.

**Fig. 10: Pulse Generator Waveform Of Flyback Converter**

Pulse Generator Waveform Of Flyback Converter is shown in Figure 10.

**Fig .11: THD Analysis**

Total Harmonic Distortion: percentage THD is defined as the calculation of the harmonic distortion present in a device to the base frequency of the device. In general, the ratio of integral of the power of all multiple frequency harmonic components to the power of the fundamental frequency can be defined as %THD. The factors like linear nature of audio system and power factor can be characterized by the total harmonic distortion. An efficient audio system has low distortion in loud speaker, amplifier or microphone. The spectrum sharing and spectrum sensing should be in concern with the ecofriendly radio emissions. Figure 11, shows the THD analysis.

4. Conclusion

In this work, a modified design of Electric Vehicle charger is explored by incorporating Landsman converter with a push pull inverter. The same is evaluated, and validated to charge an inherent PF correction EV battery. The number of sensors was considerably reduced in the control circuit and the design is made to be in the simplest way in a DCM mode. The nonlinearity introduced by the inductors being a drawback to the system the proposed BL converter decreased the percentage of ripple in input and output current.

A prototype model was developed and through which charger's operation was confirmed by validating the experimental results considering steady state and transient input voltage variations. Experimental results show that the performance of the suggested charger is considered adequate for improved performance in EV battery charging and back up hours based on power efficiency.

The IEC 61000-3-2 standard guidelines for power efficiency, the input current THD is maintained in the proposed design with an input current THD of 4.2 percent. Therefore, the proposed fed charger BL converter aims to replace the traditional high loss and low efficient EV battery charger with a cost-effective, reliable and acceptable alternative.

References


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