Power Factor Improvement in Bridgeless Landsman Converter Fed EV Battery Charger with Using Fuzzy Logic Controller

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ABSTRACT
In this paper a landsman PFC converter is modelled with control on the output voltage through voltage-oriented control. The output from the landsman PFC converter is fed to isolated DC-DC converter for charging the battery. The output voltage of the PFC converter is controlled using PI controller to generate specific required DC voltage given as a reference by the user. The isolated DC-DC converter is controlled by current-oriented control with feedback from the battery terminal voltage and current. Even in the isolated DC-DC converter a PI controller is used to control the charging current of the battery. The PI controller is further replaced with fuzzy interface system for better response and settling of the output voltage of the PFC converter. A comparative analysis of the PFC converter characteristics with PI and fuzzy controller are modelled in MATLAB Simulink environment.

Keywords: Landsman converter, Battery, PI Controller, Fuzzy controller, Pulse Generator, MATAB.

INTRODUCTION

1.1OVERVIEW OF BATTERY CHARGER

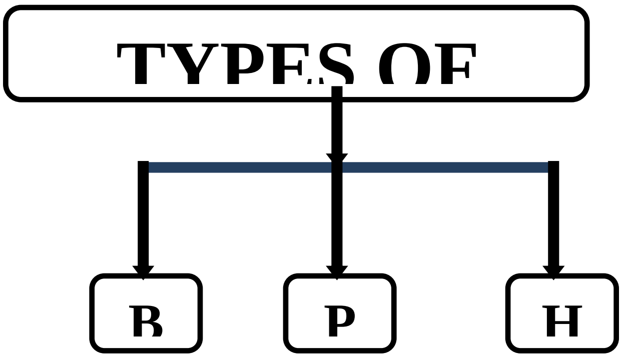
The charging protocol (how much voltage or current for how long, and what to do when charging is complete, for instance) depends on the size and type of the battery being charged.

Some battery types have high tolerance for overcharging (i.e., continued charging after the battery has been fully charged) and can be recharged by connection to a constant voltage source or a constant current source, depending on battery type. Simple chargers of this type must be manually disconnected at the end of the charge cycle, and some battery types absolutely require, or may use a timer, to cut off charging current at some fixed time, approximately when charging is complete. Other batter types cannot withstand over-charging, being damaged (reduced capacity, reduced lifetime), over heating or even exploding. The charger may have temperature or voltage sensing circuits and a microprocessor controller to safely adjust the charging current and voltage, determine the cut off at the end of charge. A trickle charger provides a relatively small amount of current, only enough to counteract self-discharge of a battery that is idle for a long time. Some battery types cannot tolerate trickle charging of any kind; attempts to do so may result in damage. Lithium ion battery cells use a chemistry system which does not permit indefinite trickle charging.

Slow battery chargers may take several hours to complete a charge. High-rate chargers may restore most capacity much faster, but high rate chargers can be more than some battery types can tolerate. Such batteries require active monitoring of the battery to protect it from overcharging. Electric vehicles ideally need high-rate chargers. For public access, installation of such chargers and the distribution support for them is an issue in the proposed adoption of electric cars.

A good battery charger provides the base for batteries that are durable and perform well. In a price-sensitive market, chargers often receive low priority and get the "after-thought" status. Battery and charger must go together like a horse and carriage. Prudent planning gives the power source top priority by placing it at the beginning of the project rather than after the hardware is completed, as is a common practice. Engineers are often unaware of the complexity involving the power source, especially when charging under adverse conditions.

1.2 TYPES OF ELECTRIC VEHICLE BATTERY CHARGER



There are three main types of electric vehicles (EVs), classed by the degree that electricity is used as their energy source. BEVs, or battery electric vehicles, PHEVs of plug-in hybrid electric vehicles, and HEVs, or hybrid electric vehicles. Only BEVs are capable of charging on a level 3, DC fast charge.

II MODIFIED BRIDGELESS LANDSMAN CONVERTER

This work deals with power factor correction (PFC) in high-brightness (HB) light emitting diode (LED) module using a bridgeless canonical switching cell (BL-CSC) converter. This application is designed for large area LED projection application with full brightness control of HB red-green-blue LED module. A PWM technique is used for brightness control of LED driver. This BL-CSC PFC converter is used to feed dual flyback DC-DC converter which supplies power to the cooling unit and the LED module with galvanic isolation. Synchronous buck converters are used for brightness control using PWM dimming technique of the multiple LED strings. The BL-CSC PFC converter is designed for discontinuous inductor current mode operation to provide natural PFC at AC mains. A working prototype of the proposed LED driver is developed for experimental verifications. The performance parameters of the proposed HB LED driver is evaluated for a full brightness control capability with high power factor at universal input AC (90–265 V). The improved power quality parameters observed at AC mains are found within the acceptable limits of international power quality standard IEC 61000-3-2.

When switch (Sw) is on, an energy from the supply and stored energy in the intermediate capacitor (C1) are transferred to input inductor (Li). The output inductor (Lo) starts discharging and the voltage of intermediate capacitor (vC1) starts reducing while DC-link voltage (Vdc) starts increasing. The value of intermediate capacitor is large enough to store required energy such that the voltage across the capacitor does not become discontinuous. Mode-2 In this mode of converter operation, switch is turned-off. An intermediate capacitor (C1) and DClink side inductor (Lo) are charging through the supply current while output inductor (Li) starts discharging. Hence, vC1 starts increasing in this mode. Moreover, the voltage across the DC capacitor (Vdc) decreases. Mode-3 This is the DCM for converter operation as the input inductor (Li) is discharged completely and current iLi becomes zero. The current of DC bus side inductor (iLo) starts increasing and the voltage of intermediary capacitor (vC1) continues to decrease in this mode.

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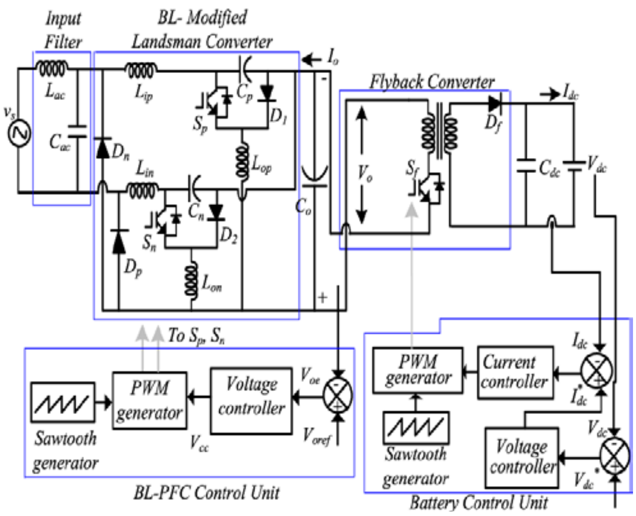

Figure 1: Modified Bridgeless Landsman Converter.

This work deals with the design and implementation of a new charger for a battery-operated electric vehicle (EV) with power factor improvement at the front end. In the proposed configuration, the conventional diode converter at the source end of existing EV battery charger is eliminated with the modified Landsman power factor correction (PFC) converter. The PFC converter is cascaded to a flyback isolated converter, which yields the EV battery control to charge it, first in constant current mode then switching to constant voltage mode. The proposed PFC converter is controlled using single sensed entity to achieve the robust regulation of dc-link voltage as well as to ensure the unity power factor operation. The proposed topology offers improved power quality, low device stress, and low input and output current ripple with low input current harmonics when compared to the conventional.

III.PROPOSED METHODOLOGY

3.1 PROPOSED SYSTEM

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.

BL converter fed EV battery charger with regulated DC link voltage at an intermediate stage. The input side of the proposed charger is fed by a single phase AC source. The input DBR is eliminated by two Landsman converters, which operates in parallel during the positive half line and negative half line, separately. Therefore, the conduction losses are reduced to half due to reduced number of components conducting in one switching cycle. For improved performance based switching, two converters, in synchronization.

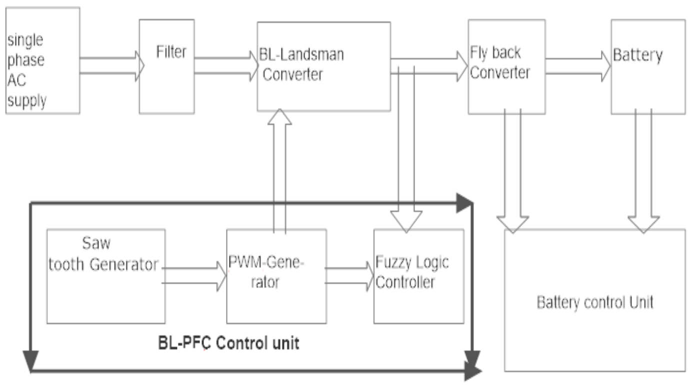

Figure 2: Block Diagram of proposed model.

3.2 FUZZY LOGIC CONTROLLER

Fuzzy logic or fuzzy set theory was introduced by Lotfi Zadeh, a computer scientist at the University of California, Berkeley, in 1965, as a means of representing and manipulating data that is not precise, but rather fuzzy or vague. In the beginning he was censured by the professional community, but progressively, Fuzzy logic (FL) captured the mind's eye of the professional society and in due course emerged as an utterly new discipline of Artificial Intelligence. The FL became a fascinating area of research because it does a good job of trading off between significance and precision – something that humans have been managing for a very long time.

The FL provides an inference that facilitates approximate human reasoning capabilities to be applied to knowledge-based systems. The theory of FL provides a mathematical strength to capture the uncertainties allied with information, such as thinking and reasoning. The classical set theory is based on Boolean logic, where a particular object or variable is either absolutely belongs to a set $(\mu(x)=1)$, or absolutely does not belong to the set $(\mu(x)=0)$. On the other hand, in fuzzy set theory based on FL, a particular object has a degree of membership in a given set that may be anywhere in the range of 0 (absolutely does not belong to set) to 1 (absolutely belong to set). For this reason, FL is often defined as multi-valued logic (0 to 1), compared to bi-valued Boolean logic. Therefore, the approaches based on FL do provide an appropriate conceptual framework for dealing with the representation of common sense knowledge.

Over the past few decades, fuzzy logichas been used in a wide range of problem domains. Although the fuzzy logic is relatively young theory, the areas of applications are very wide. In 1965, L.A. Zadeh laid the foundations of fuzzy set theory [1] as a method to deal with the imprecision of practical systems.

Bellman and Zadeh write: "Much of the decision making in the real world takes place in an environment in which the goals, the constraints and the consequences of possible actions are not known precisely". This "imprecision" or fuzziness is the core of fuzzy sets or fuzzy logic applications. Fuzzy sets were proposed as a generalization of conventional set theory. Partially as result of this fact, fuzzy logic remained the purview of highly specialized and mathematical technical journals for many years. This changed abruptly with the highly visible success of several control applications in the late 1980s. Heuristics, intuition, expert knowledge, experience, and linguistic descriptions are obviously important to power engineers. Virtually any practical engineering problem requires some “imprecision” in the problem formulation and subsequent analysis.

fuzzy control provides a formal methodology to represent, manipulate and implement human’s heuristic knowledge about how to control a system. Figure 3.2 depicts the block diagram of a fuzzy logic controller, in which a closed-loop control system is embedded. The process outputs are denoted by y (t); its inputs are denoted by u (t); and the reference input to the fuzzy controller is denoted by r (t).

The fuzzy controller has four main components: The rule-base, which holds the knowledge, in the form of a set of rules, describing the best way to control a system. The membership functions are used to quantify knowledge. The inference mechanism evaluates which control rules are relevant at the current time and then decides what input of the plant should be enabled. The fuzzification interface modifies the inputs, so that they can be interpreted and compared to the rules in the rule-base. The defuzzification interface transforms the conclusions reached by the inference mechanism into the inputs of the plant. Shown in fig. 5.3 is schematic diagram of fuzzy logic controller.

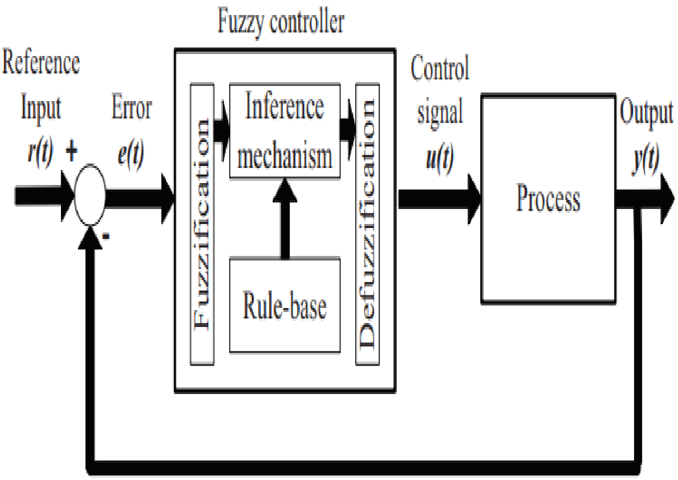

Figure 3: Scheme of a fuzzy logic controller.

3.3 Advantages of Fuzzy Control

The advantages of fuzzy control over the adaptive control can be summarized as follows the linguistic, not numerical; variables make the process similar to that of human think process.

It relates output to input, without understanding all the variables, permitting the design of system more accurate and stable than the conventional control system.

IV SIMULATON RESULT AND DISCUSSION

The implementation of the proposed algorithm is done over MATLAB (R2016). The signal processing toolbox helps us to use the functions available in MATLAB Library for various methods like Windows, shifting, scaling etc.

Case I: Power factor improvement in bridgeless landsman converter fed EV Battery charger with using PI logic controller. The proposed model is shown in fig. no.4.

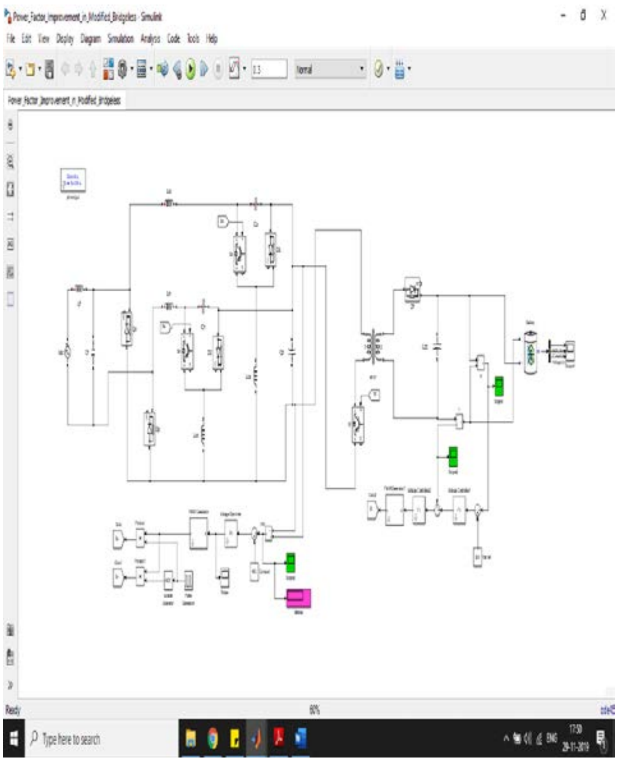

Figure 4: Modeling of proposed topology with PI controller.

Here show in fig. no. 4 PFC test system with PI controller charging the battery with state of charge (SOC 20%). The PFC converter uses voltage oriented control with PI controller which generates duty ratio for the switches Sp and Sn. The switches Sp and Sn operate alternatively with respect to the input voltage. The Sp switch operates during positive cycle and Sn operates during negative cycle of the input voltage. This is controlled by pulse generator with time period 1/50 and time of conduction of 50%. The reference voltage of PFC converter is take as 400V and the reference voltage of the interleaved converter is taken as 300V as the battery used is a 300V battery. The results for the same are observed below.

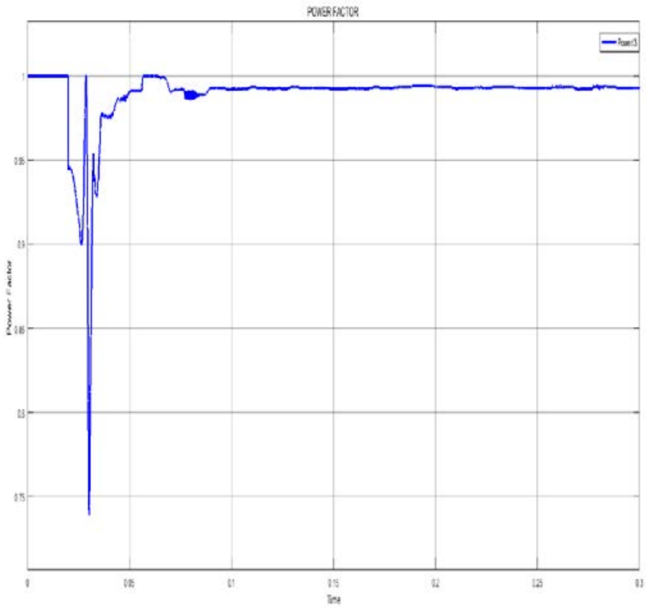

Figure 5: Power factor of source with PI controller.

Case II:

Power factor improvement in bridgeless landsman converter fed EV Battery charger with using fuzzy logic controller. The proposed model is shown in fig. no.5., The proposed model is consisting of seven major component .such as single phase grid, landsman converter, fuzzy logic controller, fly back converter, magnetic coupling inductor, and battery and pwm generator.

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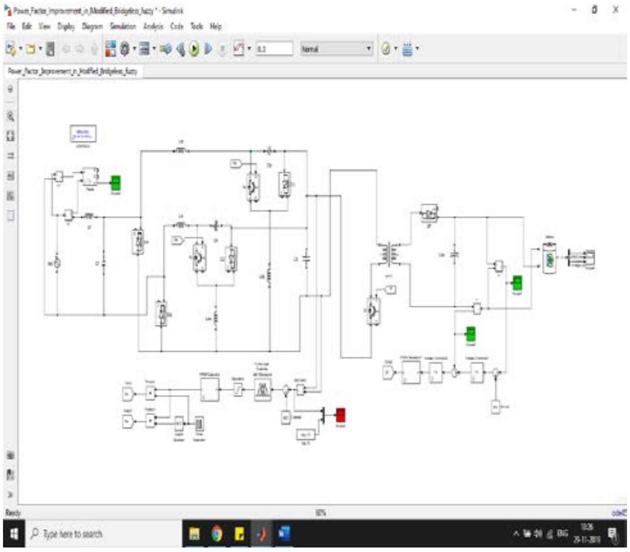

Figure 6: Modelling of proposed topology with fuzzy interface system.

Here shown in fig no 5 modelling of proposed topology with fuzzy interface system .The interleaved converter is controlled by a switch Sf which reduces or increase the voltage at the output. The output of the converter is controlled by current oriented control with voltage and current feedback from the output. The PI controller generates required duty ratio for the interleaved converter with respect to charging current of the battery.

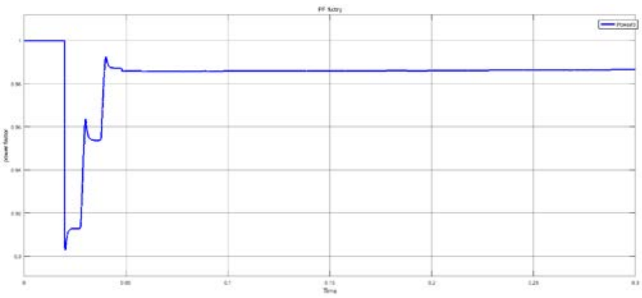

Figure 6: Power factor of source with fuzzy controller.

We are observed that from fig.no.5 and fig. no. 6 the power factor of the source is more stable at the initial stage in fuzzy controlled feedback system as compared to PI controller. We are compared from fig no.4.3 and 4.4. Then output of the PI (for PF) curve is change from 0 to 0.07 seconds. After that the power factor curve is settle down. And corresponding the output of the fuzzy (for PF) curve is change from 0 to 0.04 seconds after that the power factor curve is settle down. It means the transients in the power factor are reduced to minimal value and also maintained near to unity.

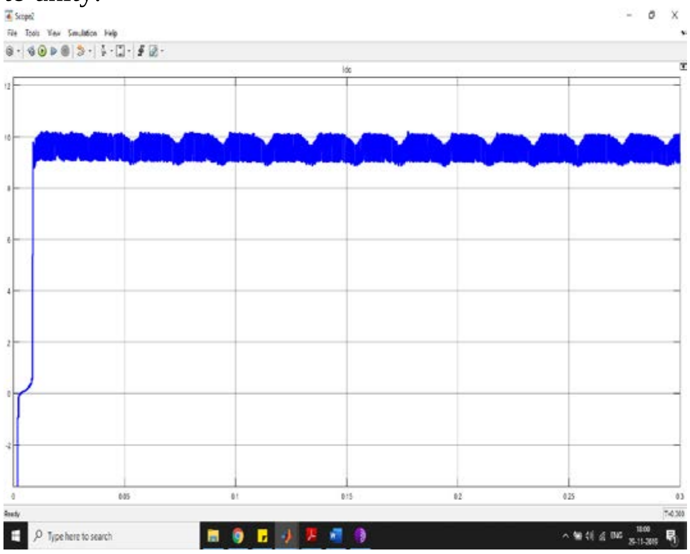

Figure 7: DC-DC Isolated converter current (Idc)

The Isolated converter current is maintained at reference value given by the user with current oriented feedback control system.

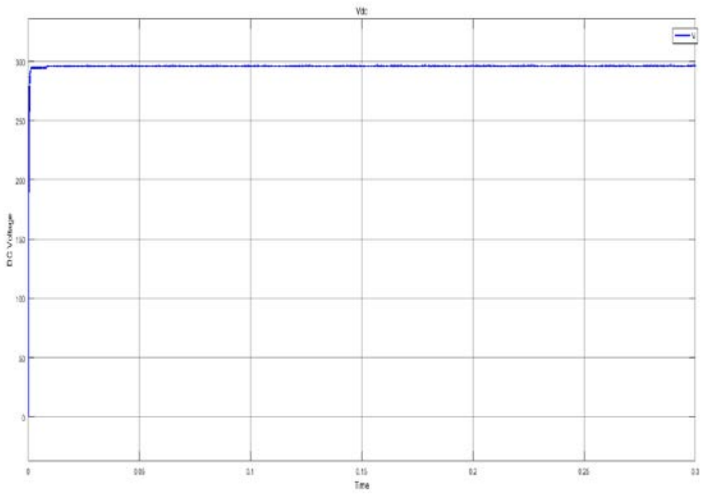

Figure 8: DC-DC isolated converter output voltage (Vdc).

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The DC-DC isolated converter output voltage is maintained at 300V at stable condition charging the battery connected to it. it is shown in fig no.8.

When the battery is charging mode then graph of state of charging (%soc) will be increased with respect to time t.and current will go to negative direction. The Voltage is constant maintain at 300V. Which is shown in fig.9 of the battery characteristic.

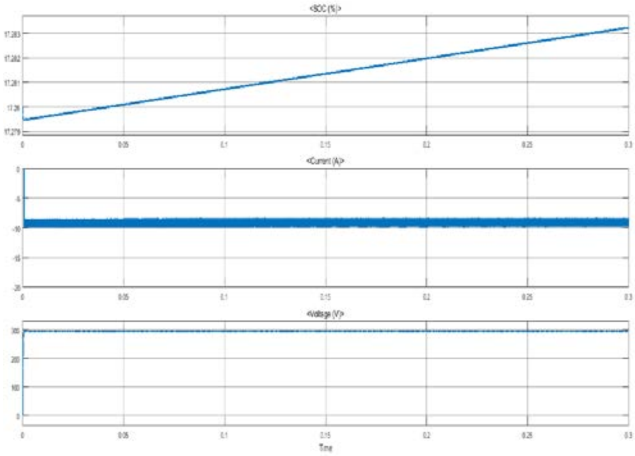

Figure 9: Battery characteristics.

4.1 Comparative analysis between PI and Fuzzy logic controller:

The model is updated with fuzzy controller replacing PI controller and the output voltages of the PFC converter are compared below.

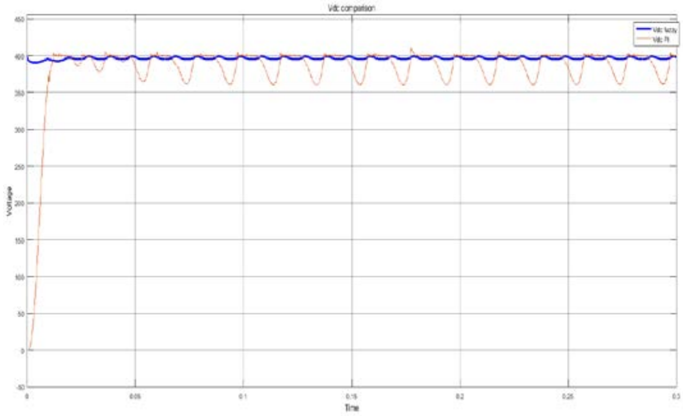

Figure 10: Output voltage comparison of landsman PFC converter with PI and fuzzy.

As per the graphs generated with respect to time the power factor of the source is more stable at the initial stage with fuzzy logic controller as compared to PI controller. The fuzzy controlled updated in voltage-oriented control of the landsman PFC converter is increasing the stability in input power factor and also the output voltage of the converter. The ripple in the output DC voltage is also suppressed in the updated fuzzy interface controlling system.

4.2 Efficiency of the converter:

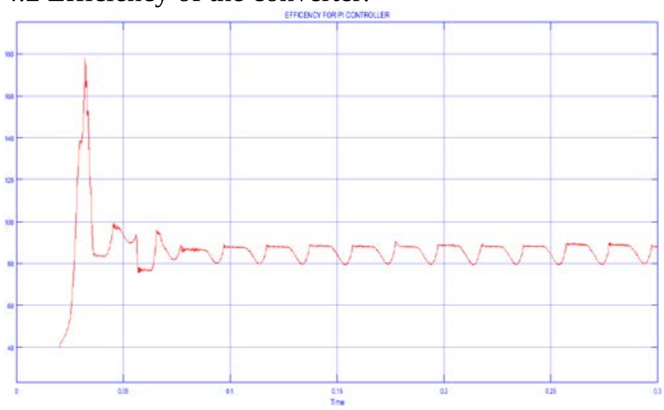

Figure 11: Efficiency Graph of landsman converter for PI controller.

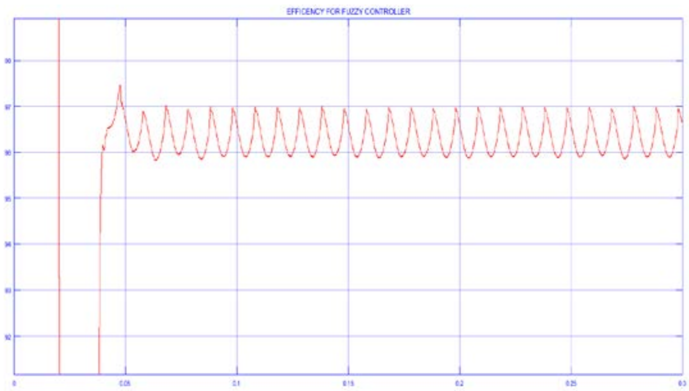

Figure 12: Efficiency Graph of landsman converter for Fuzzy controller.

We have compared from fig no. 11 and 12 the efficiency of landsman converter for PI controller is a 85 percentage .whereas the efficiency of landsman converter for fuzzy logic controller is a

97 percentage. We are observed that if pi controller is replaced by fuzzy log controller then efficiency of lands main converter will be improved.

V CONCLUSION AND FUTURE SCOPE

The power factor correction has been effectively implemented using the Bridge less Landsman Converter followed by a fly back converter. In this work to charge an Electrical vehicle battery with inherent power factor correction. The proposed EV charger in discontinuous mode has offered the advantage of reduced number of sensors at the output. Moreover, the proposed BL converter has reduced the input and output current ripples due to inductors both in input and output of the converter. The simulation model is a developed by matlab software. As per the graphs generated with respect to time the power factor of the source is more stable at the initial stage with fuzzy logic controller as compared to PI controller. It is show that the performance of proposed charger is found satisfactory for improved power quality based charging of EV battery. The proposed BL converter fed charger aims at cost effective, reliable and suitable option to replace the conventional lossy and inefficient EV battery charger. The controller can further be updated with adaptive controlling systems or optimization controllers. The PFC landsman converter is also be used for different applications like operating DC machines or AC machines with controllable AC inverter. The future scope for the proposed work is enlisted as follows.

The use of wide band gap semiconductor devices (SiC and GaN based devices) leads to better converter efficiency at high power rating owing to reduced voltage drops and switching transition times. This work can be extended to control motor drives like BLDC and SRM motor drive for EV propulsion.

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