Power Factor Enhancement in Modified Bridgeless Landsman Converter with Fuzzy Logic Controller Fed EV Battery Charger

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ABSTRACT: *This work deals with the design and implementation of a new charger for battery operated electric vehicle (BEV) with power factor improvement at the frontend. In the proposed configuration, the conventional diode converter at the source end of existing electric vehicle (EV) battery charger is eliminated with modified Landsman power factor correction (PFC) converter. The PFC converter is cascaded to a fly back isolated converter, which yields the EV battery control to charge it, first in constant current mode then switching to constant voltage mode. In the report a landsman PFC converter is modeled with control on the output voltage through voltage-oriented control. The output form 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 modeled in MATLAB Simulink environment.*

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

1. Introduction

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. 5 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.

2. Electric Vehicle Battery Charger

In recent years the problems of "range anxiety" associated with electric vehicles (EVs) have been alleviated by the introduction hybrids (HEVs) and plug in hybrids (PHEVs) and the development of higher energy density batteries capable of storing more energy in the same space. With the increasing popularity of electric vehicles, "range anxiety" is now being replaced by "charging anxiety". This page addresses the issues associated with providing suitable chargers and the charging infrastructure necessary to support the growing population of EVs.

It takes about three minutes fill up a petrol or diesel engine car at a filling station with enough fuel to travel about 300 miles, costing about $35 in th USA and about £52 ($80) in the UK. To travel 300 miles in a small EV passenger car would need three full charges of a typical 25kWh battery used to power these vehicles costing about $2.50 per charge in the USA with electricity priced at $0.10 per unit (kWh) and £2.50 ($3.90) in the UK with electricity priced at £0.10 per unit. The low energy cost is one of the attractions of owning an EV.

Unfortunately to put the 25 kWh of energy needed to travel each 100 miles into the battery in the same time (1 minute) that the equivalent amount of diesel fuel is pumped into the tank would require a power supply capable of delivering a power of 1.5 Megawatts. To put this into perspective, 25 kWh is the amount of energy an average household consumes in a whole day. Providing electrical distribution facilities to allow users to consume this amount of energy from the electricity grid in one minute is not practical and even if it was, no EV battery could accept energy at this rate. On the other hand neither is it practical to take 24 hours to charge the battery in a passenger electric vehicle.

The solutions don't just involve the development of chargers, they involve the design and roll out of a network of public and private charging stations with associated user authentication and billing systems, public safety and planning issues, the negotiation of international standards and beefing up the electricity grid to carry the increased load. There are no single answers to these issues. On the one hand, national and international standards organizations attempt to find definitive solutions to these issues, but there are so many competing national standards. On the other hand commercial enterprises attempt to leapfrog the competition by coming up with new and unique innovative solutions to differentiate their offerings. Some of these issues are explored here.

Charger Requirements

First we need to scope out the requirements of the vehicles we are trying to accommodate and the batteries they use. The range is very wide with energy storage requirements ranging from 0.5 kWh to 50 kWh and current carrying capacity ranging from 20 Amps to 200 Amps requiring chargers purpose built to suit the applications. Chargers provide a DC charging voltage from an AC source whether from a common socket outlet or more recently from a purpose built DC charging station. Most important are the methods of controlling the charge and protecting the battery from over-voltage, over-current and over-temperature. These charger functions are integrated with and unique to the battery.

Chargers for electric bikes are usually low cost, separate units. To save weight they are not usually mounted on the bike and charging takes place at home. Their power handling capacity is only sufficient for charging the relatively low power bike batteries and entirely unsuitable for passenger car applications.

Chargers for passenger cars are normally mounted inside the car. This is because the vehicle may be used a long way from home, further than the range possible from a single battery charge. For this reason they have to carry the charger with them on board the vehicle. Charging can be carried out at home from a standard domestic electricity socket outlet but the available power is very low and charging takes a long time, possibly ten hours or more depending on the size of the battery. Since charging is usually carried out overnight this is not necessarily a problem, but it could be if the car is away from its home base.

Such low power charging is normally used in an emergency and most cars are fitted with a higher power charging option which can be used in commercial locations or with a higher power domestic installation. In many countries this higher power facility is implemented by means of a three phase electricity supply. Commercial electric vehicles need bigger batteries which need higher power charging stations to achieve reasonable charging times but they also have extra options. Many of them follow prescribed delivery routes within a limited range from base and return to base in the evening.

In these cases off board charging is possible saving weight and space on the vehicle. Such applications can also be adapted to battery swap options. Each vehicle may have two batteries with one being charged while the other is in use. When used in long distance shuttle applications this can double the effective range of the vehicle. The vehicle depletes the battery during each journey and picks up a fully charged battery at the terminus leaving the discharged battery to be recharged ready for the next trip. This shuttle option however needs three batteries per vehicle.

Early HEVs used Nickel Metal Hydride batteries, but they are mostly being superseded by a range of variants of Lithium ion batteries which is the technology of choice for most new EV applications since they can store more energy and deliver higher power. For this reason most EV chargers are designed to work exclusively with Lithium ion batteries.

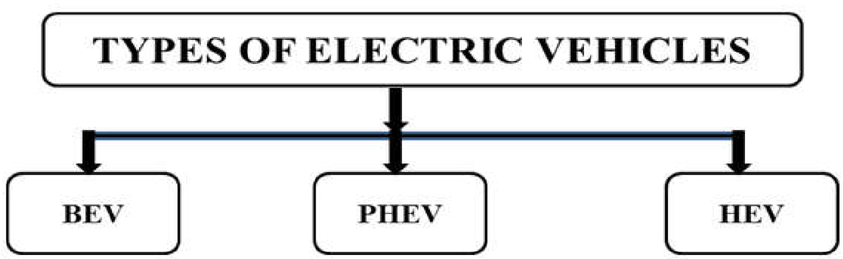

Figure 1: Classification of EV

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.

3. Motivation of Research Work

Electric vehicles are also slowly being introduced in companies' fleets. The benefits they convey involve four main aspects, environmental (e.g. less energy spent), financial (e.g. lower running costs), operational (e.g. driving comfort) and company status (associated with the business image contributing to enhance its reputation). The adoption of electric vehicles will bring new challenges, associated with the substantial investments in the technology and the deployment of a charging infrastructure within the facilities and with the unknown future regarding vehicle life expectancy and robustness that might convey long-term costs.

Other challenges are more related with fleet management in terms of type of trips, driving contexts, drivers' willingness to accept and use the vehicle and their expectations and adoptions to it, which requires the development of strategic plans for electric vehicle adoption in the company. A survey conducted in the USA to 2302 drivers revealed that only 35% would buy a plug-in electric vehicle, an indicator that the interest in adopting such technologies is shaped predominantly by the perceptions of their disadvantages. Results from an on-line based survey developed in Portugal to assess plugin vehicle acceptance revealed that from the 852 respondents, 13% and 25% are willing to buy an EV and PHEV, respectively.

4. Bridgeless Landsman Converter

This work presents a modified bridgeless Landsman converter-fed power factor correction (PFC) for light emitting diode (LED) driver. The application is targeted for high brightness (HB) projection applications with brightness control of high brightness red-green-blue (HB-RGB) LEDs. The pulse width modulation (PWM) technique is used for current control to achieve effective brightness control of LED driver without compromising the efficiency.

The modified BL- Landsman PFC converter is used to feed a dual fly back DC-DC converter which supplies power to the forced LED cooling unit and the LED lighting module with a galvanic isolation. The brightness control of LED is performed by synchronous-buck converter with current modulation. The proposed PFC based modified BL- Landsman converter design is based on discontinuous conduction mode of output inductor current for high power factor (PF). A hardware prototype of the LED driver is verified experimentally.

The proposed LED driver performance evaluation at full and light load conditions is good for universal AC mains (90V-265V). The power quality parameters measured with calibrated instruments are within the acceptable limits of standard IEC 61000-3- 2 Class C for lighting systems.

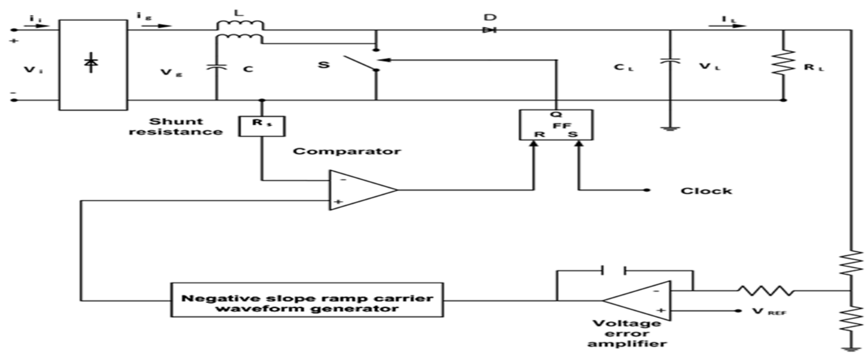

Figure 2: Bridgeless Landsman Converter

A power factor correction (PFC) based Landsman converter in bridgeless (BL) configuration feeding a brushless DC motor (BLDCM) drive is proposed for low power household appliances. The speed of BLDCM is controlled by varying the DC bus voltage of the voltage source inverter (VSI) feeding to a BLDCM. Switching losses of six solid-state switches of VSI are reduced by the use of low frequency switching signals in electronic commutation for the motor.

The front-end bridgeless PFC based Landsman converter operating in discontinuous inductor current mode (DICM) is used for DC bus voltage control and PFC is achieved inherently with reduced conduction losses and switch stress. The DC bus voltage of drive is sensed by a single DC voltage sensor. A prototype is developed for performance evaluation of the drive for speed control over a broad range. The experimental performance of BLDCM is presented for its functions at wide voltages of AC mains (90V-265 V) to adhere the limits of standard IEC 61000-3-2.

The Landsman converter based on a power factor correction (PFC) in bridgeless (BL) configuration feeding a brushless dc motor (BLDCM) drive is proposed for low-power household appliances. The conduction losses associated with diodes are reduced by BL configuration and switching losses of solid-state switches of voltage source inverter are reduced by the use of low frequency switching signals in electronic commutation for the BLDCM. The front-end BL PFC based Landsman converter operating in the discontinuous inductor current mode is used for controlling the dc link voltage, and

PFC is attained naturally with reduced conduction losses and switch stress. A single voltage sensor is used for controlling the dc bus voltage.

A prototype is developed to study performance of the system for wide range speed control and power quality improvement. The experimental performance of BLDCM is presented for its functions at varying voltages of ac mains (90-265 V) to adhere to the limits defined by IEC61000-3-2 standard.

The air-conditioning is energy intensive application which normally uses single phase induction motors for driving its compressor and fans. The efficiency of these motors is between 70-80%. More over the on-off control employed for the temperature control is not energy efficient and introduces many disturbances in the distribution system along with increased wear and tear of the motor and reduce power factor. The use of PMBLDCM for driving the compressor results in energy efficiency improvement of the Air-Con. Moreover, the temperature in the air-conditioned zone can be maintained at these references smoothly while operating the Air-Condenser speed control. This paper presents to improve the power factor using Landsman Converter for PMBLDC motor application.

Mainly in air conditioning systems to achieve the below, which is difficult in conventional system. Smooth start-up of air conditioning systems without fluctuations in input voltage .Achieve the study and smooth speed control to maintain the constant Room temperature. Avoid the Harmonics in the power system due to the continuous switching millions of Air conditioners and main higher efficiency.

5. 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 fly back 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.

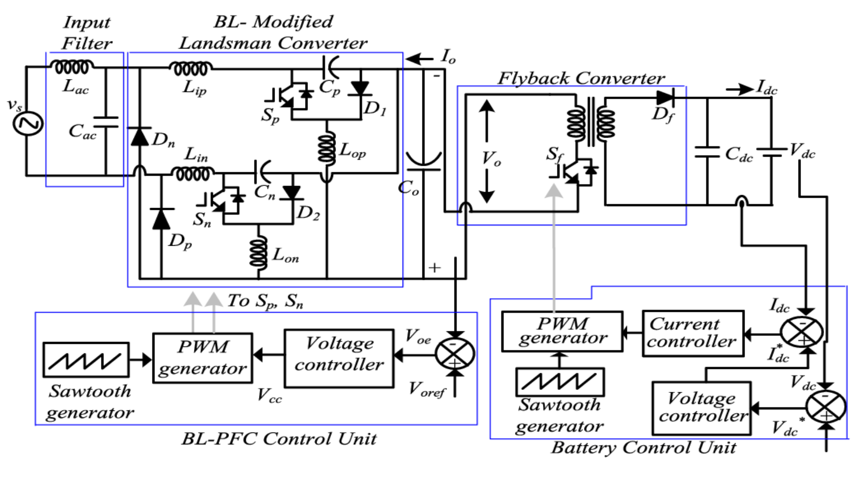

Figure 3: Modified Bridgeless Landsman Converter

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 DC-link 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 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.

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 one. Moreover, to demonstrate the conformity of the proposed charger to an IEC 61000-3-2 standard, a prototype is built and tested to charge a 48 V EV battery of 100 Ah capacities, under transients in input voltage. The performance of the charger is found satisfactory for all the cases.

The experimental set-up consists of four components. They are MOSFET control inverter, BLDC Motor, fluffy rationale controller and RF Transmitter and Receiver units. The BLDC engine is an electronically commutated engine. The inherent lobby sensors produce three signs as indicated by the rotor position. Here the information is given as accessible single-stage AC source. It been passed to stage controlled rectifier where it is changed over from AC to DC. The channel exhibit is utilized to expel the sounds in the DC source. At that point it is gone through the single stage to three stage inverter where the uncontrolled DC is changed over to throbbed or controlled DC.

The throbbed DC current is utilized to begin or run the BLDC engine. The rotor position is sense by the Hall Effect sensor and the flag is been opened up by the flag condition. The opened up flag is passed to the microcontrollers. Utilizing implanted c coding program is scorched in the IC 16F877A by utilizing CCS complier. The set speed is transmits by the RF transmitter and at the less than desirable end, the beneficiary gets this simple incentive on a solitary information line and passes this information to the decoder. It changes over the single piece information into eight piece information and offers it to the microcontroller which does the further preparing. Here the controller compares the reference set speed and the real speed and it varies according to it and determines the error speed and produces the control signal which sends them to the MOSFET inverter circuits. These signals are energize the appropriate windings by switching the appropriate switches in the power inverter. Thus the speed of the BLDC motor is controlled by using the microcontroller.

6. 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

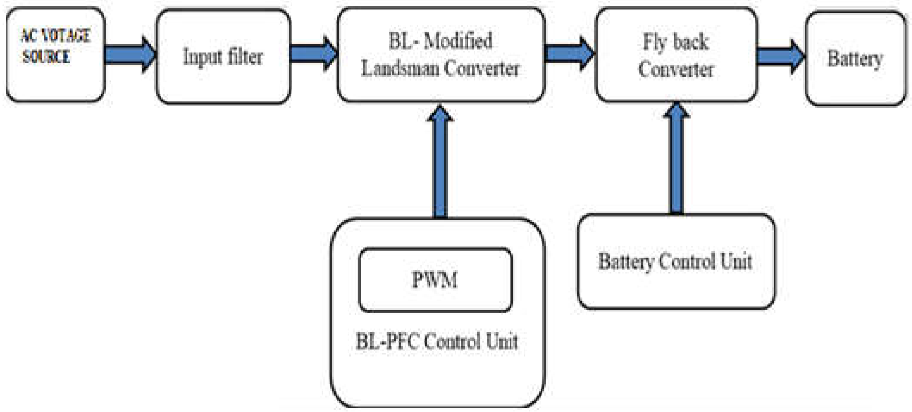

Figure 4: Block Diagram of Proposed Model

7. Simulation results and its Parameters

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.

TABLE 1: Parameter Used In Simulation

Parameter	Value
AC Voltage (V_{ac})	220V
Diode Resistance	0.001 ohm
IGBT Internal Resistance	0.001 ohm
Capacitance	580 nf
Inductance	1.7mh
PWM Switching frequency	20000
Battery Voltage	280V
Battery Rated capacity	20Ah
Proportional Gain	0.01
Integral Gain	0.001

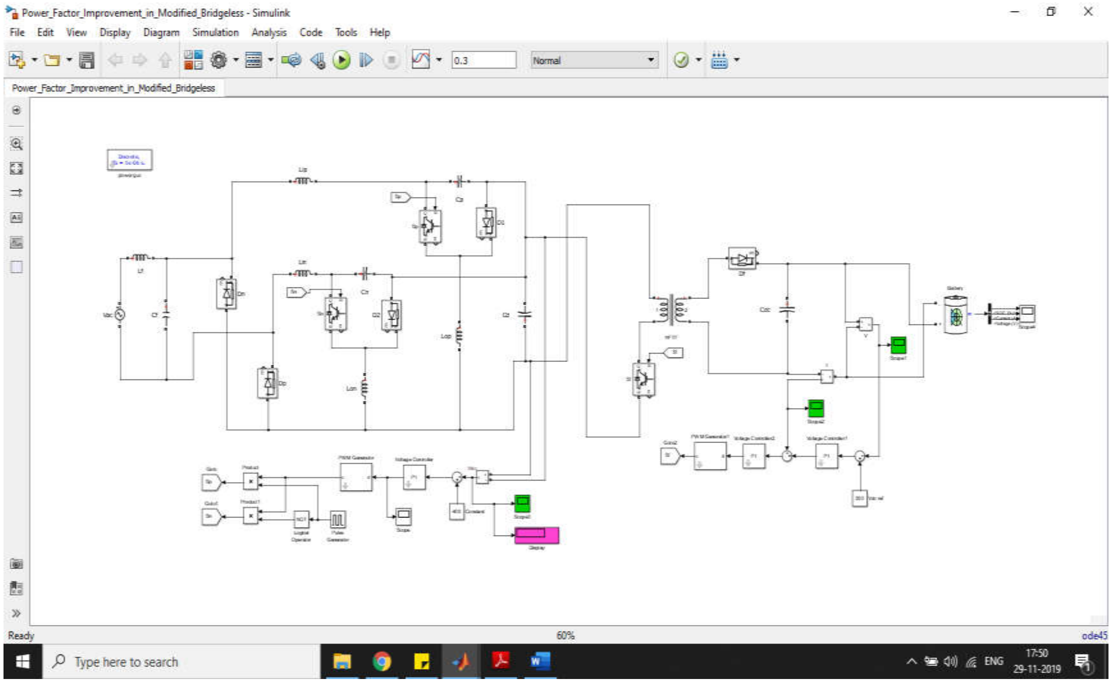

Figure 5: Modeling of Topology with PI Controller

PFC test system with PI controller charging the battery with 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%.

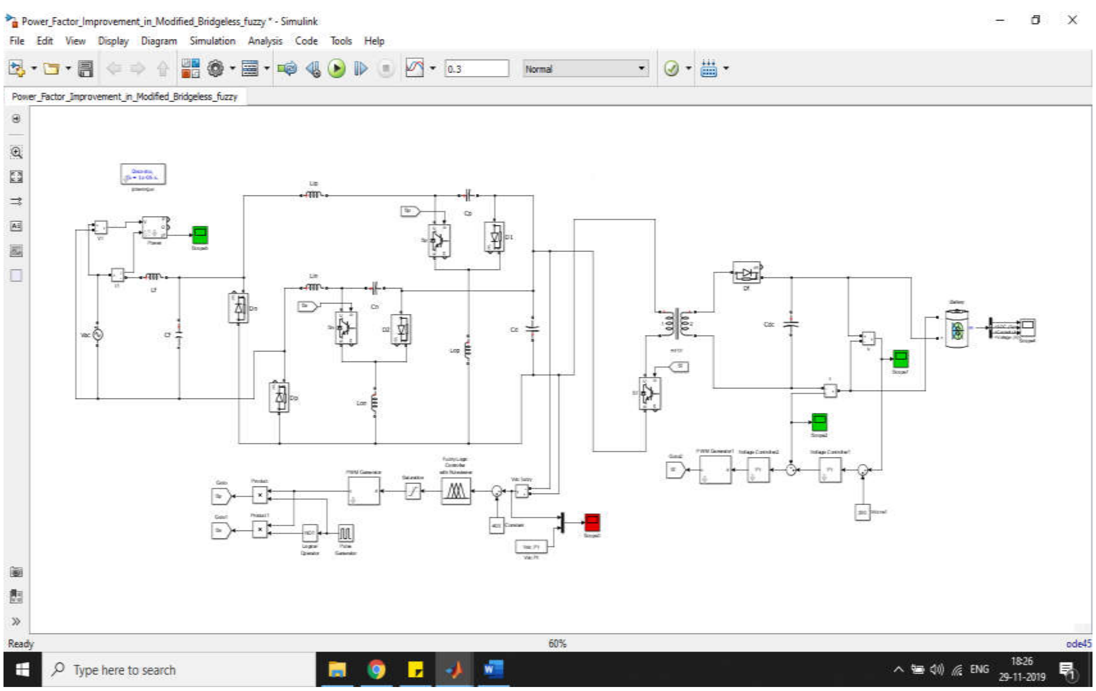

Figure 6: Modeling of Proposed Topology with Fuzzy Interface System

The interleaved converters 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.

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.

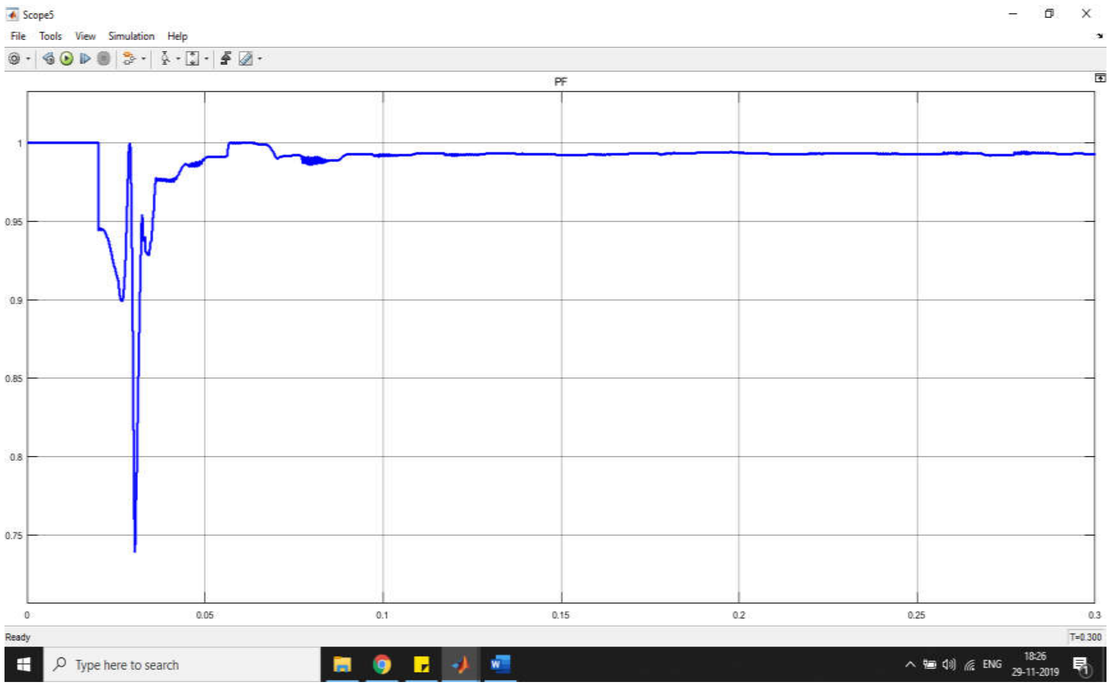

Figure 7: Power Factor of Source with PI Controller

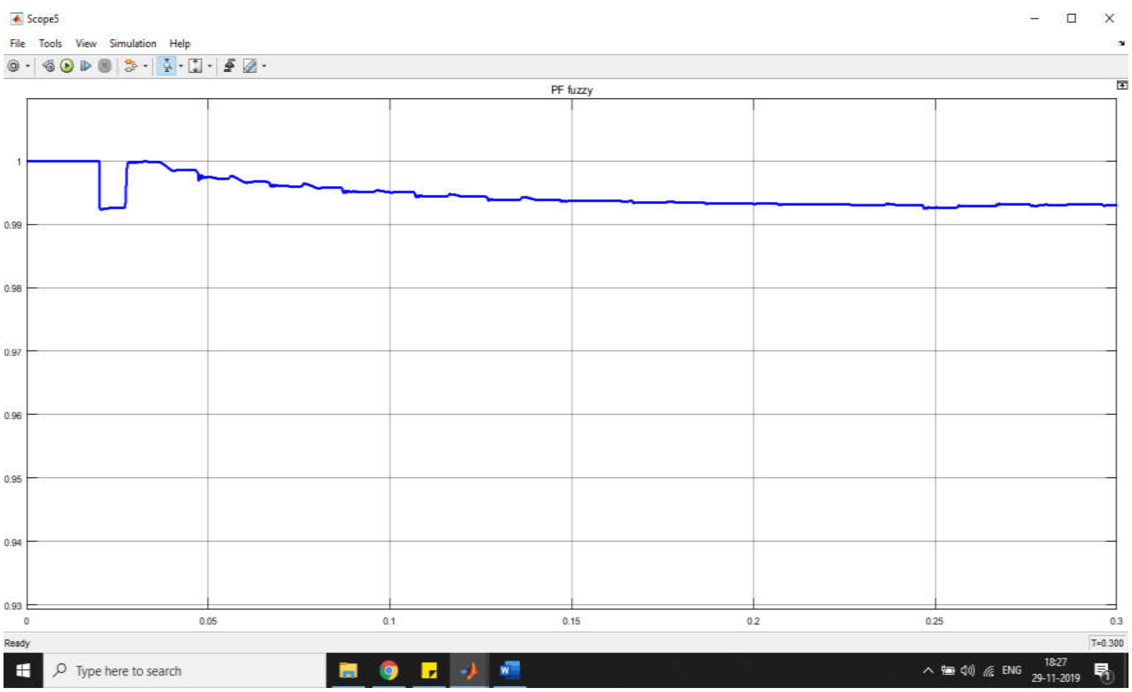

Figure 8: Power Factor of Source with Fuzzy Controller

It is clear from figure no. 7 and 8 the power factor of the source is more stable at the initial stage in fuzzy controlled feedback system as compared to PI controller. The transients in the power factor are reduced to minimal value and also maintained near to unity.

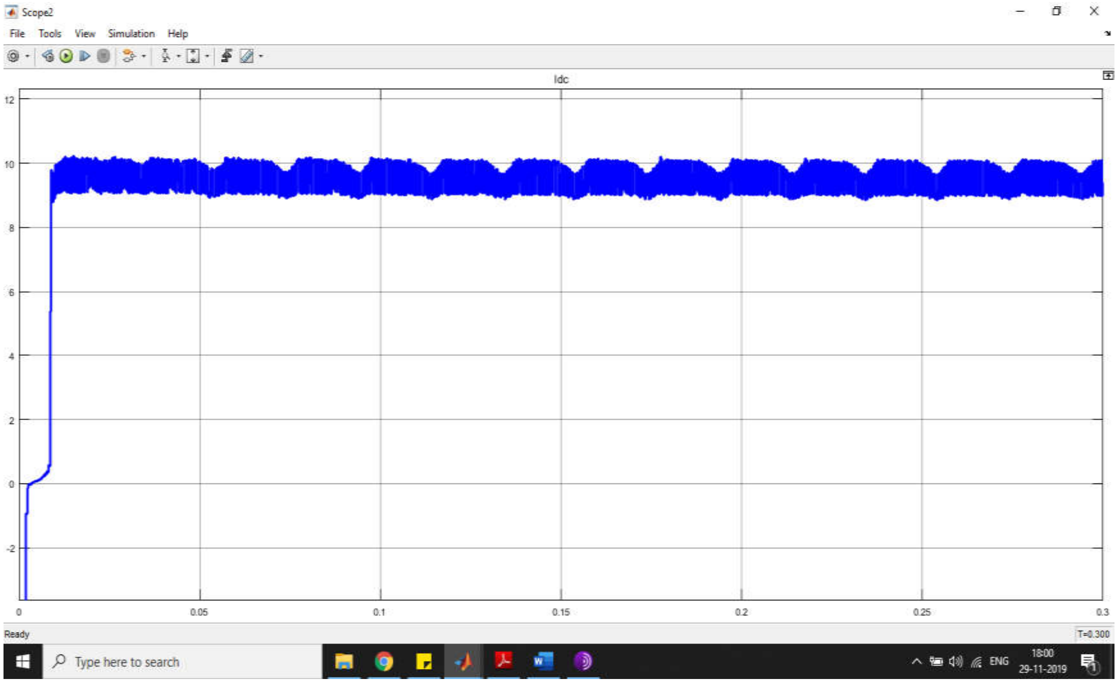

Figure 9: DC-DC Isolated Converter Current

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

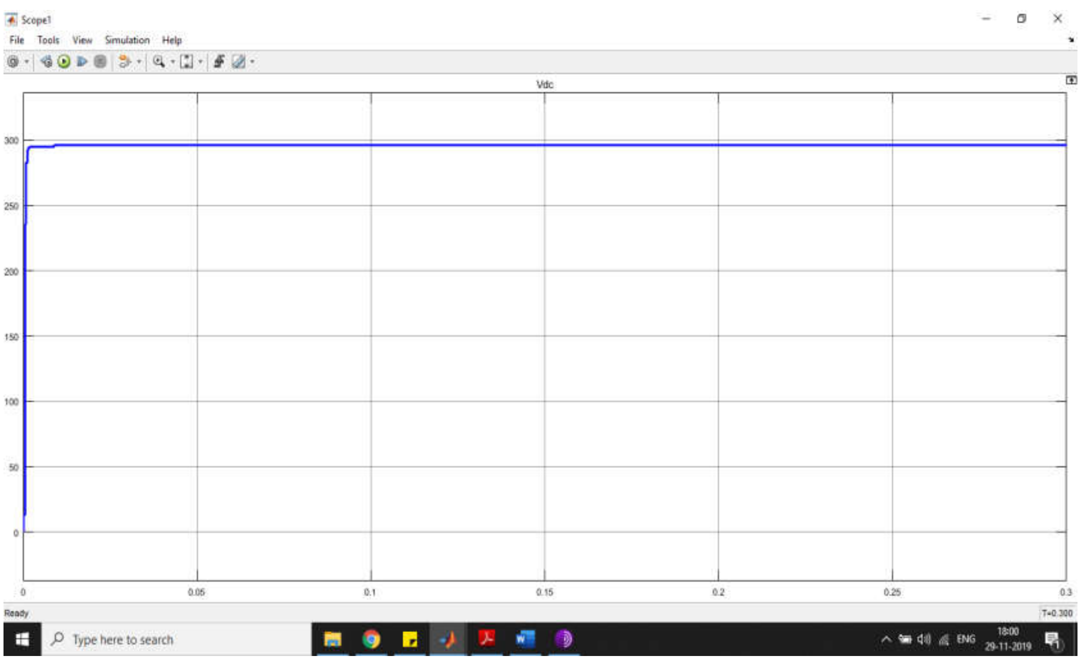

Figure 10: DC-DC Isolated Converter Output Voltage

The DC-DC isolated converter output voltage is maintained at 300V at stable condition charging the battery connected to it. The characteristics of the battery in charging mode can be seen below.

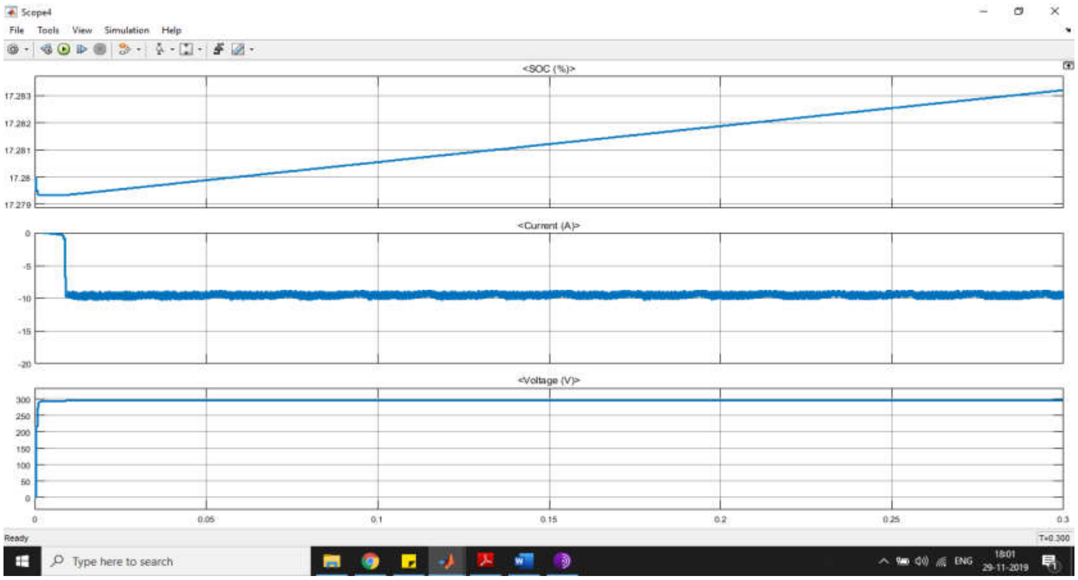

Figure 11: Battery Characteristics

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

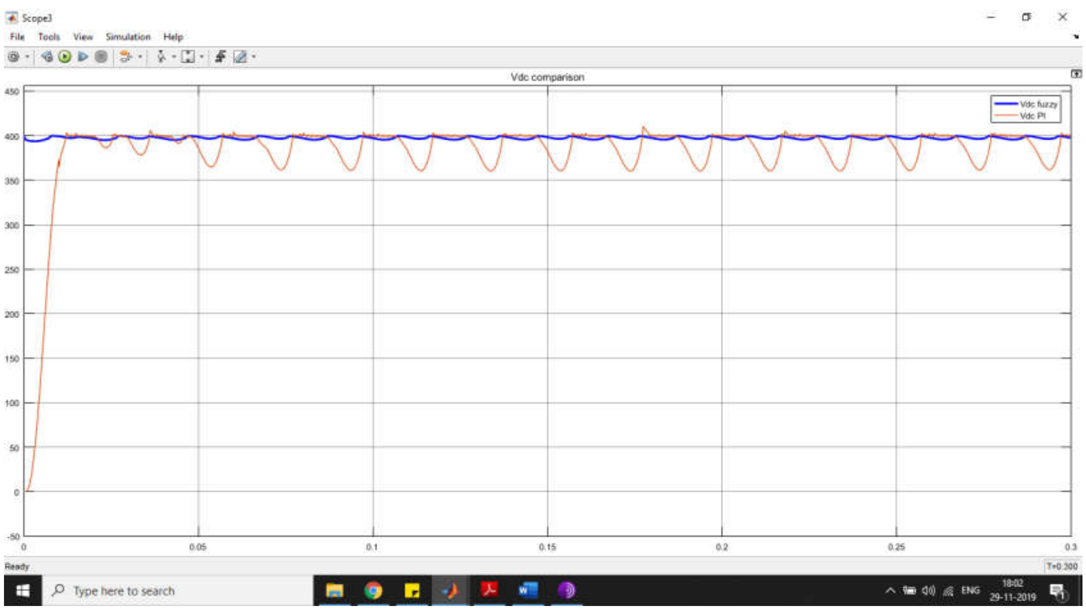

Figure 12: Output Voltage Comparison of Landsman PFC Converter with PI and Fuzzy

8. Conclusion

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.

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.

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