Abstract: Recent developments in LEDs permit them to be used in environmental and task lighting. LED lamp need controlled direct current electrical Power, an appropriate circuit is required to convert alternating current from the supply to the regulated low voltage direct current used by the LEDs. So a power converter is required to control the operation of LED lamp. Power converters involve diode rectifiers with large capacitor to reduce DC voltage ripple. The filter capacitor reduces the ripple present in the output voltage but draw non-sinusoidal line current which reduces the power factor. This paper deals with a power factor corrected (PFC) improved power quality based LED lamp driver. The proposed driver consists of a PFC Boost converter using Fuzzy logic controller which operates in continuous conduction mode with output voltage regulation. A new fuzzy logic control strategy for boost PFC is presented in this paper. Here the controlling action was established through a fuzzy Logic controller. The proposed Fuzzy Logic control system is a two input one output Fuzzy Logic Controller. The proposed PFC control is derived based on Boost converter operates at continuous conduction mode and the switching frequency is much higher than the line frequency. This Proposed system is validated through MATLAB/SIMULINK platform.

Keywords: Power factor correction, Total harmonic distortion, Boost converter, Fuzzy logic control, continuous conduction mode.

I. INTRODUCTION

As light-emitting diodes (LEDs) have many advantages such as small size, high luminous efficiency, long lifetime, fast response, and excellent color rendering, they have been widely used in many lighting applications. LEDs are operated from a low voltage DC supply. In general lighting applications, the LED lamps have to operate from universal AC input, so an AC–DC converter is needed to drive the LED lamp [5]. The efficient drive not only performs unity power factor (PF), but also regulates LED current [6]. The rectifier with filter capacitor is called a conventional AC–DC utility interface. Although a filter capacitor significantly suppresses the ripples from the output voltage, it introduces distortions in the input current and draws current from the supply discontinuously, in short pulses [7]. This introduces several problems including reduction in available power, and the line current becomes non-sinusoidal which increases the total harmonic distortion (THD) and increases losses. This results in a poor power quality, voltage distortion, and poor PF at input ac mains [8–9]. With the development of PFC converters, a sinusoidal line current can be made in phase with the line voltage, and this PFC circuit achieves the requirements of the international harmonic standards. For all lighting products and input power higher than 25 W, AC–DC LED drivers must comply with line current harmonic limit set by IEC61000-3-2 class C [10]. Single-stage PFC topologies are the most suitable converters for lighting applications, as PFC and regulator circuits can be merged together. They have high efficiency, a nearly unity PF, simple control loop, and a small size. In reality, the switching frequency is much higher than the line frequency, and the input AC current waveform is dependent on the type of control being used [11]. The inductor is assumed to be operated in continuous conduction mode (CCM) which is implemented using hysteretic current control method. In this paper, a power factor corrected (PFC) AC-DC Boost converter operating in CCM (Continuous Conduction Mode) is proposed for LED driver. In solid state LED driver, power factor corrected (PFC) AC-DC converter improves the input power facto and reduces total harmonic distortion of AC mains current (THD) and also maintains constant lamp...
The distortion factor \( K_d \) capacitor or inductor, but making the distortion factor \( K_d \) unity is more difficult. When a converter has less than unity power factor, it means that the converter absorbs apparent power higher than the active power. This means that the power source has a higher VA rating than what the load needs. In addition, the harmonic currents generated by the converter in the power source affects other equipment\[12]\.

### II. NECESSITY OF POWER FACTOR IMPROVEMENT

Power factor is a figure of merit that measures how effectively power is transmitted between a source and load network. It always has a value between zero and one. The unity power factor condition occurs when the voltage and current waveforms have the same shape, and are in phase. Power factor is defined as the cosine of the angle between voltage and current in an ac circuit. If the circuit is inductive, the current lags behind the voltage and power factor is referred to as lagging. However, in a capacitive circuit, current leads the voltage and the power factor is said to be leading. Power factor can also be defined as the ratio of active power to the apparent power. The active power is the power which is actually dissipated in the circuit. The reactive power is developed in the inductive reactance of the circuit.

\[
P.F = \frac{\text{Active power}}{\text{Apparent power}}
\]

A load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred. The higher currents increase the energy lost. So power factor improvement is required.

Assuming an ideal sinusoidal input voltage source, the Power factor can be expressed as the product of the distortion factor and the displacement factor, as given by equation (3). The distortion factor \( K_d \) is the ratio of the fundamental root mean-square (RMS) current \( I_{rms(1)} \) to the total RMS current \( I_{rms} \). The displacement factor \( K_{\Phi} \) is the cosine of the displacement angle \( \Phi \) between the fundamental input current and the input voltage. For sinusoidal voltage and non-sinusoidal current, equation (1) can be expressed as:

\[
P.F = \frac{\frac{V_{rms}}{V_{rms}}} \times \frac{I_{rms}}{I_{rms}} \cos \Phi = K_d \cos \Phi
\]

\[1\]

The distortion factor \( K_d \) is given by the following equation:

\[
K_d = \frac{I_{rms(1)}}{I_{rms}}
\]  

The displacement factor \( K_{\Phi} \) is given by the following Equation:

\[
K_{\Phi} = \cos \Phi
\]

The displacement factor \( K_{\Phi} \) can be made unity with a capacitor or inductor, but making the distortion factor \( K_d \) unity is more difficult. When a converter has less than unity power factor, it means that the converter absorbs apparent power higher than the active power. This means that the power source has a higher VA rating than what the load needs. In addition, the harmonic currents generated by the converter in the power source affects other equipment\[12]\.

### III. POWER FACTOR CORRECTION TECHNIQUE

The single-phase diode rectifier associated with the boost converter, as shown in Fig. 1(d), is widely employed in active PFC. In principle, the combination of the diode bridge rectifier and a dc-dc converter with filtering and energy storage elements can be extended to other topologies, such as buck, buck-boost, and Cuk converter\[13]\.

The boost topology is very simple and allows low-distorted input currents, with almost unity power factor using different dedicated control techniques. Typical strategies are hysteresis control, average current mode control and peak current control\[14]\.

More recently, one cycle control and self control have also been employed. Some strategies employed three levels PWM AC/DC converter to compensate the current harmonics generated by the diode rectifier. Some strategies employed active power filter to compensate the harmonic current generated by the non-linear load. Disadvantages of these strategies are; (a) for each nonlinear load, one separate converter should be
employed, (b) due to presence of more switching devices used in some strategies, switching losses occurs is more, as the switching losses depend upon the no of switching devices (c) some strategies use very complex control algorithm. To overcome all these type of problems, a new power factor correction technique using PFC boost converter is proposed.

IV. PROPOSED POWER FACTOR CORRECTION TECHNIQUE

Fig (1) shows the block diagram of PFC Boost converter with fuzzy logic controller. In this technique two control loops are used outer loop is voltage that tracks the output voltage while inner loop is current loop that tracks the inductor current.

A. Boost converter

There are different topologies used in PFC converters. The topology used in this study, is an ac-dc boost converter. Many applications require an ac-dc conversion from the line voltage. In its most simple form, this conversion is performed by means of a bridge rectifier and a bulk capacitor. The bulk capacitor filters the rectified voltage and provides certain energy storage in case of a line failure. But resultant line current pulsates, causing a low power factor due to its harmonics and its displacement with respect to the line voltage. In many applications, this low quality in the power usage is not acceptable above certain power levels, and the corresponding standards require improved technical solutions.

One of topologies most commonly used to deal with this problem so is called single phase boost converter. The simplified boost converter circuit is shown in figure 2.

The boost inductor in the boost converter circuit is in series with the ac power line. This topology inherently accepts a wide input voltage range without an input voltage selector switch. The equivalent circuits of the system are derived based on the “on” and “off” states of the converter switch and shown in figure 2-a and figure 2-b respectively.

The output voltage of a boost converter should be higher than the peak value of the maximum input voltage. Only the single–phase boost converter circuit operating in the continuous conduction mode is discussed with hysteresis control techniques in this study.

B. Hysteresis Current mode control technique

HCMC techniques has the constant on-time and the constant–off time control, in which only one current command is used to limit either the minimum input current or the maximum input current [15-17]. A simple diagram of a typical hysteresis current controller is shown in Fig.3.
The boost inductor current is continuously compared with the reference current waveform (which is obtained from the voltage control loop) and the error signal (after amplification) is fed into a hysteresis comparator. When the actual inductor current goes above the reference current by the comparator hysteresis band, the comparator changes its state to switch off the boost switch and the current ramp goes down. When the actual current goes below the reference current by the comparator hysteresis band, it changes state again and turns the boost switch on. Thus, the inductor current is always maintained within ±H, where 2H is the total hysteresis band.

C. Design consideration

If output voltage is represented as \( V_o \) and input voltage is represented as \( V_{DC} \), the duty ratio (D) of a typical boost converter is given by

\[
D = \frac{V_o - V_{DC}}{V_o}
\]

(10)

The inductor can be designed using the equation (11)

\[
L = \frac{R D (1-D)^2}{2f}
\]

(11)

Where \( f \) – switching frequency and \( R \)- Load resistance.

The value of capacitance is given by

\[
C = \frac{V_o D}{\Delta V R}
\]

(12)

Where \( \Delta V \) is output voltage ripple.

Table I

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tr>
<td>Input voltage (V_{DC})</td>
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<tr>
<td>Output voltage (V_o)</td>
<td>60V</td>
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<td>Duty Ratio (D)</td>
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<td>Capacitance(C)</td>
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<td>Load Resistor (R)</td>
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<td>Switching Frequency</td>
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V. INTRODUCTION TO FUZZY LOGIC CONTROLLER

L. A. Zadeh presented the first paper on fuzzy set theory in 1965. Since then, a new language was developed to describe the fuzzy properties of reality, which are very difficult and sometime even impossible to be described using conventional methods. Fuzzy set theory has been widely used in the control area with some application to dc-to-dc converter system. A definitions and the control rule set; a decision-making logic which, simulating a human decision process, infer the fuzzy control action from the knowledge of the control rules and linguistic variable definitions; a defuzzification interface which yields non fuzzy control action from an inferred fuzzy control action [18].

Figure 4. General structure of the fuzzy logic controller on closed-loop system

The fuzzy control systems are based on expert knowledge that converts the human linguistic concepts into an automatic control strategy without any complicated mathematical model [19]. Simulation is performed in buck converter to verify the proposed fuzzy logic controllers.

A. Fuzzy Logic Membership Functions:

The ac-dc converter is a nonlinear function of the duty cycle because of the small signal model and its control method was applied to the control of boost converters. Fuzzy controllers
do not require an exact mathematical model. Instead, they are designed based on general knowledge of the plant. Fuzzy controllers are designed to adapt to varying operating points. Fuzzy Logic Controller is designed to control the output of boost ac-dc converter using Mamdani style fuzzy inference system. Two input variables, error (e) and change of error (de) are used in this fuzzy logic system. The single output variable (u) is duty cycle of PWM output.

B. Fuzzy Logic Rules:

The objective of this dissertation is to control the output voltage of the boost converter. The error and change of error of the output voltage will be the inputs of fuzzy logic controller. These 2 inputs are divided into five groups; NB:

<table>
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VI. SIMULATION RESULT AND DISCUSSION

Case 1 Boost converter with conventional PI controller:

The simulation of the power factor correction converter is done using PI controller and various parameters are analyzed. The PI controller is manually tuned. Fig 8 shows the Matlap/simulink Model of Boost converter with conventional PI controller.
Figure 8. Matlab/Simulink Model of Boost converter with conventional PI controller

As above fig 9 shows the input voltage and input current of boost converter with conventional PI controller. Fig 10 shows output voltage of the boost converter with conventional PI controller.

Figure 10. Output voltage wave form

Figure 11. THD Analysis of source current with boost converter using conventional PI controller

Fig 11 shows the FET Analysis of source current with Boost converter using Conventional PI controller, we get 5.25%.

Case 2 Proposed Boost Converter with Fuzzy Logic Controller

Figure 12 shows the Matlab/Simulink Model of Proposed Boost Converter with Fuzzy Logic Controller.
The output voltage and the current waveform shown if Fig 14 shows that the voltage and current gets controlled nearer to the reference value using the fuzzy controller.

![FFT analysis graph]

**Figure 15. THD Analysis of source current with Proposed Boost Converter Using Fuzzy Logic Controller**

Fig 15 Shows the FET Analysis of Source Current with Proposed Boost converter using Fuzzy Logic Controller, we get 4.81%.

**VI CONCLUSION**

A variety of circuit topologies and control methods have been developed for the PFC application. Here presented one new and interesting AC/DC boost-type converters for PFC applications with conventional & Intelligence controller. Without using any dedicated converter, one converter can be used to eliminate the harmonic current generated by the other non-linear load. With the help of simulation study, it can be concluded that, this configuration removes almost all lower order harmonics, hence with this configuration we can achieve power factor nearer to unity, THD less than 5%, using Fuzzy controller we get fast dynamic response. However, this technique can be limited to application where the non-linear load (pulsating) current is less and fixed. THD Analysis of both controllers well within IEEE Standards

**REFERENCES**