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Isolated AC/DC Offline High Power Factor Single-Switch Led Driver Using Fuzzy Logic Controller

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Abstract: In recent years high brightness LED lamps are opening up new opportunities of cost and energy saving towards variety of lighting applications. However they also require LED driver circuit compare to gas filled lamps which introduces power quality issues at input AC mains. Thus an efficient driver circuit is essential for its optimal performance. In this paper an isolated high power factor single switch LED driver circuit controlled by fuzzy logic controller was studied. The proposed work help to design a new efficient driver circuit as power factor correction stage by replacing conventionally used electrolytic capacitor as film capacitor in converter circuit and fuzzy based voltage controller is implemented with fuzzy rules in order that converter output voltage can go after the command voltage with enhanced dynamic performance and its power factor improvement values are experimentally verified.

Key words: HB LED lamp · Converter · Fuzzy logic control · Power factor

INTRODUCTION

The past few decades have been a revolutionary increase in LED performance and LED lamp have becomes increasingly pervasive in all aspects of modern life. One of the historical consequences of increasing LED performance is associated in less power rating, long life, environment friendly due to absence of mercury, non sensitive to environment temperature, humidity, very durable, long life span, better efficiency compared to compact fluorescent lamp and incandescent lamp for lighting application. Since they are driven from a DC source, several categories of power switching converter can be employed to adapt primary energy sources to the constraints of HB LEDs [1]. Several researchers have formulated different DC–DC converter topologies in accordance with the conventional DC–DC switching power converters [2, 3, 4]. On the other hand, while DC–DC converters are classically intended to manage their output voltages, HB LEDs necessitate a controlled output current.

In contrast, when the primary energy source is the AC line, subsequently certain category of AC–DC converter must be positioned between the line and the HB LEDs [5, 6]. It is found that, when the total power managed by these converters is above 25 W, at that time the low-frequency harmonic content of the line current have to satisfy particular rules. For the purpose of lighting equipment, the most extensively employed standard is EN 61000-3-2, Class C [7]. This class creates an extremely severe harmonic content, in order that only extremely sinusoidal line waveforms are capable of satisfying the abovementioned rule. As a result, the only sensible technique to satisfy the EN61000-3-2 Class C rule is to make use of active high-power-factor (PF) converters, usually known as Power Factor Correctors (PFCs).

The bridge rectifiers contribute to high Total Harmonic Distortion (THD), small PF and low efficiency to the power system. These harmonic currents source for numerous complications like voltage distortion, noises, heating etc., which results in diminished efficiency of the power system. Owing to this

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fact, there is a requirement for power supplies that obtain current with low harmonic content & moreover have PF close to unity [8].

As HB LEDs are adopted into more and more applications, situations will arise when the input voltage varies above and below the forward voltage of the LED string. For these cases, a current regulator is needed that can both buck and boost as required by the input and output conditions. Possible topologies include the buck-boost, SEPIC, Cuk, flyback and V_{IN} referenced buck-boost (also called the floating buck-boost). All these are aiming to control light output in LED lamp.

The traditional boost topology is the most extensively employed topology for the purpose of PFC applications. It includes a front-end full-bridge diode rectifier next to the boost converter. The diode bridge rectifier is employed for the purpose of rectifying the AC input voltage to DC, which is subsequently provided to the boost segment. This scheme is excellent for a low to medium power range applications. During upper power levels, the diode bridge is a significant part of the application and it is essential to cope with the complication of heat dissipation in limited surface area [9, 10]. The selection of type of operation of a PFC converter is a significant subject since it directly have an effect on the cost and rating of the elements employed in the PFC converter. In order to further enhance the efficiency, bridgeless (BL) converters are employed which permit the exclusion of DBR in the front end [11, 12]. A buck-boost converter arrangement is well-matched among several BL converter topologies for applications needs an extensive range of DC link voltage control (i.e., bucking and boosting mode).

Y.Hu.et.al. have designed and investigated a low cost with less passive components single stage fly back PFC front end circuit for a 78watts high brightness LED application and achieved power factor (PF) of 0.98 and efficiency of 87.5%. Although this converter has less size its THD generated is the range of 14% which can further be reduced by another approach. Sohel Uddin et.al. experimentally tested various LED lamps available in market with different power rating from various manufacturers and evaluated harmonic performance and reported that due to power electronic converter based driver circuits, all LED lamps generate harmonics and need further development to meet IEC 61000-3-2 harmonic standard for high wattage LED lamps for lighting application.

Now today's lamps for automotive application are rapidly developing and focusing LED lighting technology. In view of this, L.Lukacs *et al*. followed new approach of adaptive front lighting (AFL) using fuzzy logic control for head lamp controlling to avoid glare and provide safer driving during dark hours according to road and driver' s need. Also this paper highlights the advantages of LED lamp compared to halogen lamp its life period, power consumption, performance, color temperature etc,. Another energy efficient design was developed by K.Saravanan using FLC to vary and control brightness of lamp according to environment condition. This scheme intendly designed for street light and automotive application and incorporated with MATLAB and FLC with LABVIEW programming gave new approach of light control.

Another FLC design has been implemented by M.Salehi *et al*. for traffic control by minimizing the vehicles waiting time and more suitable for mixed traffic includes high proportion of motor cycles and emergency vehicles. One more simple control technique illustrated by M. Kavitha and K. R.Valluvan (2015) using FLC system which controls the illumination of LEDs used in room by PWM technique automatically for users comfortable and reduces energy consumed efficiently. The author proposed a sensor that senses human presence and intensity for measuring light intensity and detecting the persons and programmed using microcontroller MSP 430 with FLC system to make pleasant environment.

In this paper, a Power Factor Corrected (PFC) Single-Switch LED Driver using Fuzzy Logic Controller based converter based power supply is proposed for HB-LED lamp with universal input voltage. In proposed LED driver, PFC AC-DC converter assists in enhancing the input PF and also helps in reducing Total Harmonic Distortion (THDi) of AC mains current to the required level in accordance with the limits provided by various international standards. The circuit maintains stable lamp voltage to accomplish stable operation of lamp. In view of the fact that PFC converter is controlled at high switching frequency of 60 kHz, it diminishes the size and weight of passive components like inductor and capacitor.

Proposed Circuit Design: In the proposed design a single switch LED driver is designed between rectifier stage and LED string stage where lamp is constant voltage load. Also this driver circuit is monitored by the fuzzy logic controller circuit. In circuit diagram the converter is fly back converter where input voltage is higher than output by buck operation. Then output voltage is feed back to comparator it compare with reference and feedback signal.

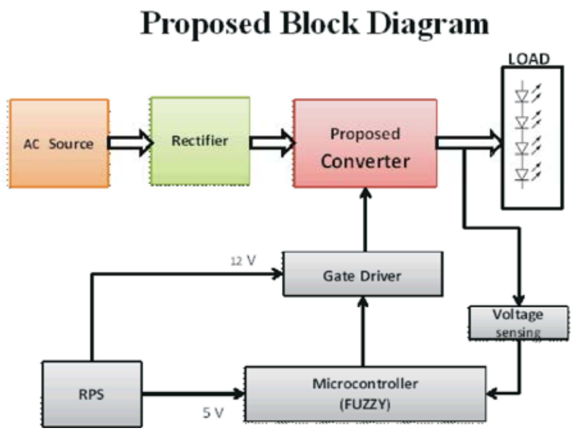

Fig. 1: Block diagram with FLC feedback loop

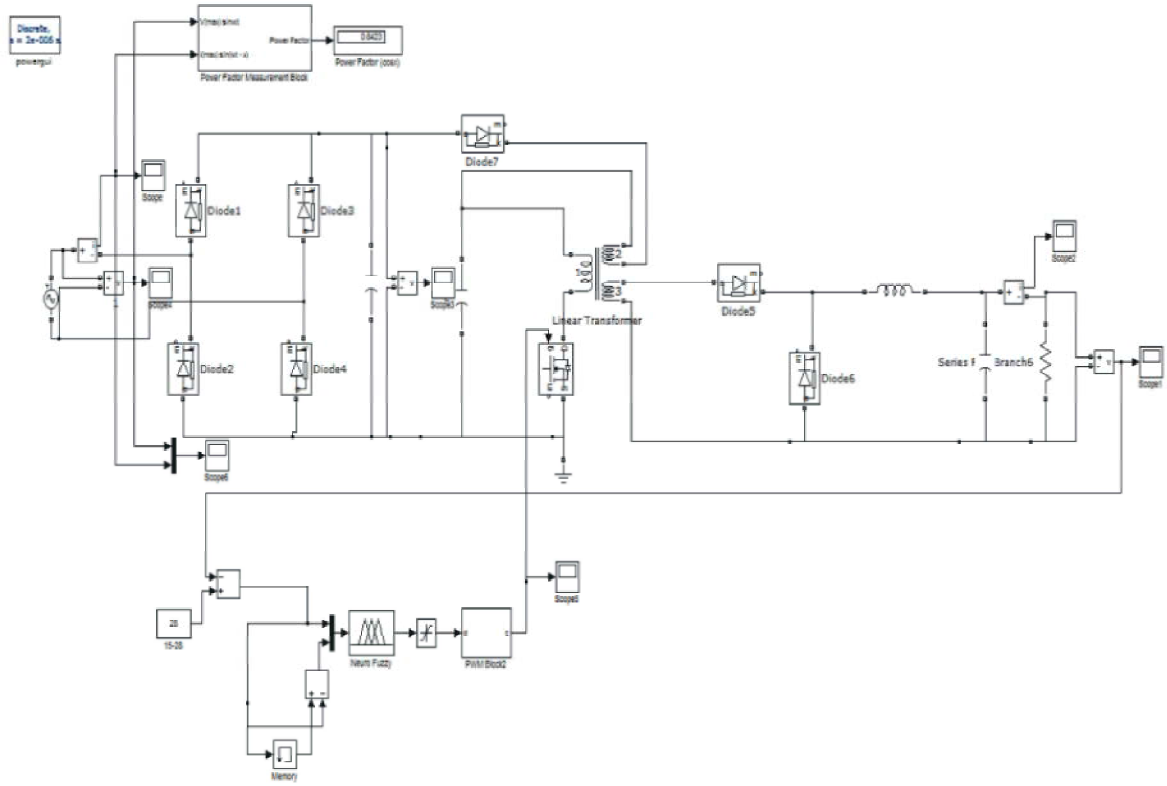

Fig. 2: Simulation diagram

Also in converter stage to provide isolation the proposed driver is made to work in discontinuous current mode and output current flows through C_o follows low frequency envelope. The performance of the Proposed BL Isolated Interleaved Zeta Converter is simulated in a MATLAB / Simulink environment using the Sim Power-System Toolbox. The proposed system is evaluated based on the steady state performance and the dynamic performance of BL Isolated single switch Converter and the achieved power quality indices obtained at AC mains. Thus with an array of LEDs, the main challenge is to ensure every LED in the array is driven with the same current. Placing all the LEDs in a series string ensures that exactly the same current flows through each device.

Fuzzy Based Voltage Controller: In the process of fuzzy based voltage controller, two inputs are taken into account, specifically, variation of actual and set converter voltage error(e) and delayed error (de).

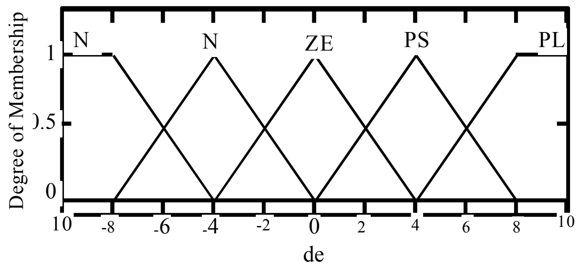

Fig. 3: Fuzzy membership functions

There are five membership functions for both inputs (e) and (de) as shown in figure 3. By design, there will be 25 rules. Triangular membership functions are taken into account for both inputs and output, with the intention that the Modulation Index will be transformed easily. The non-linear mapping from the input to the output of FLC is done through the basis of trial and error experience. Initially, the membership functions and fuzzy rules were formulated in simulation program through trial-and-error method, in order that the converter output voltage can go after the command voltage with enhanced dynamic performance.

Simulation Circuit:

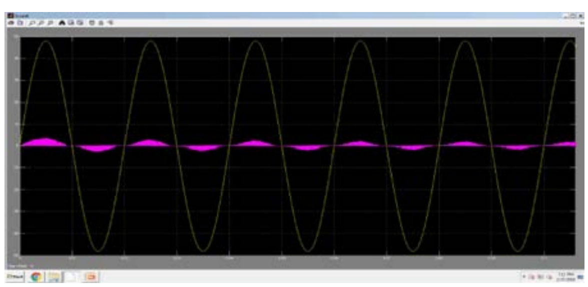

Fig. 4(a): Input voltage

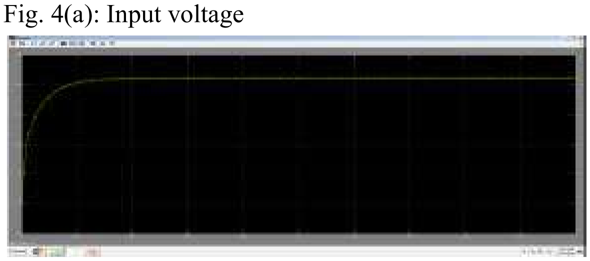

Fig. 4(b): Output voltage

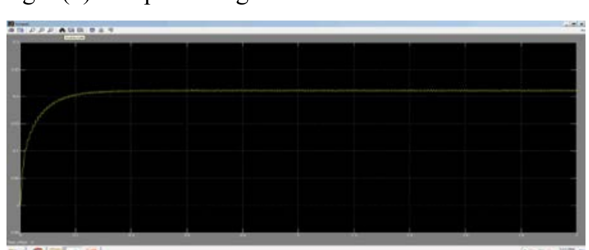

Fig. 4(c): Output current

Due to the presence of FLC control LED is supplied with PWM controlled current shown in figure 4 (c) combined with microcontroller based driver bring additional benefits such as operational flexibility, efficiency, reliability, controllability and intelligence system. It gives programmable output range at wide input range and short circuit protection.

Also some demand applications require dimming control in lamp which is easily possible in PWM dimming over analogue dimming by voltage variation, wastage of power on variable resistor etc. The various dimming operation is performed in experiments results shown.

Experimental Results: For experimental results, a prototype was developed for 6 number of LED string as array of lamp to give required luminous output. It uses 24 V DC from converter after rectified from 230 V input supply. The load is 6 LEDs each power rating is 4W total 24W power with voltage and current reating of 4V and 0.25A respectively. Also this prototupe is designed to give dimming operation which is not possible in gas filled lamps. This dimming operation is performed by buck topology thus constant current source to load and reduces the ripple current.

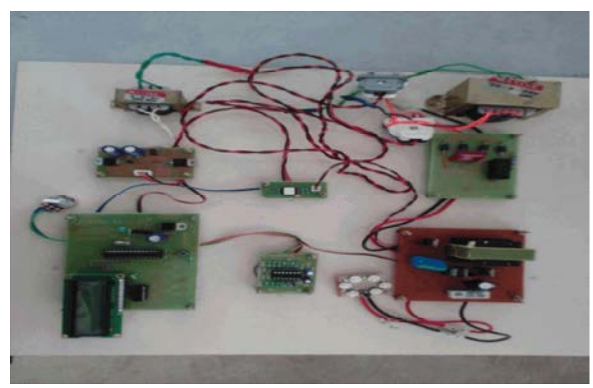

Fig. 5(a): Proto type of lamp driver with LEDs OFF condition

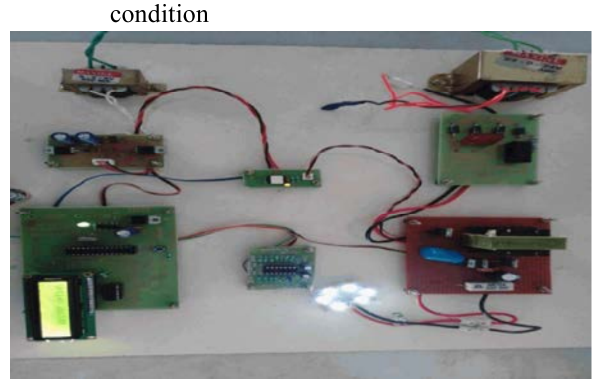

Fig. 5(b): Driver circuit with LEDs in low brightness as diming operation

The power factor is calculated is calculated from equations 1 and 2.

$$PF = Vrms_1\ Irms_1 / Vrms\ Irms\ \cos(\square_1 - \square_1) \quad (1)$$

$$PF = Irms1 / Irms\ \cos(\square_1 - \square_1) = K_{disp}\ .Kdist \quad (2)$$

Without power factor correction: 0.7043
With power factor correction > 0.905

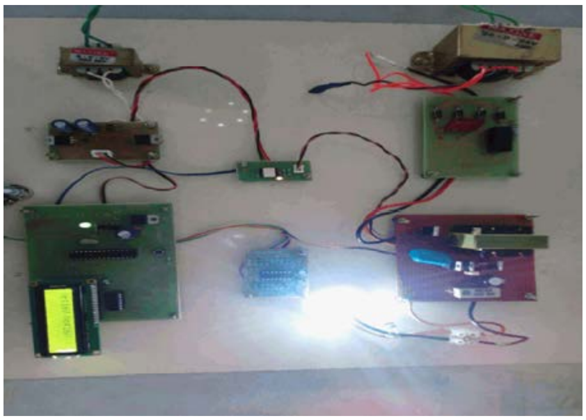

Fig. 5(c): Driver circuit with LEDs in high brightness.

CONCLUSION

This paper presents a simple design of converter with very high efficiency with electrolytic capacitor in converter so that its overall performance and life time of lamp is extended. Besides control technique from regulating brightness of LEDs is performed with improved power factor correction thus choose the best option for lamp towards variety of applications like street light, industrial light, automotive head lights, advertising light etc.

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