The 6th International Power Electronics Drive Systems and Technologies Conference (PEDSTC2015)
3-4 February 2015, Shahid Beheshti University, Tehran, Iran

A Technique for producing High Power Factor for HB-LEDs power Supply Based on Boost topology

L.Yarmohammadi
Department of Electrical Eng.,
West Tehran Branch, Islamic Azad University,
Tehran, Iran
leilayarmohammadi@yahoo.com

E.Afjei
Department of Electrical Eng.,
Shahid Beheshti University, G.C.,
Tehran, Iran
e-afjei@sbu.ac.ir

A.Siadatan
Department of Electrical Eng.,
Shahid Beheshti University, G.C.,
Tehran, Iran
A_siadatan @sbu.ac.ir

Abstract— **This topology presents simple and economical method of power factor correction for driving High-Brightness LEDs based on Boost converter. Nowadays, HB-LEDs are discussed as a noticeable lighting instrument because of their great Longevity, multicolored, and Compatible with Environment. It works by sampling of the input and output voltage and current in the boost converter, whereupon, improving the input power factor and reduction the line current's Total Harmonic Distortion (THD). Recently, power factor correction (PFC) has become an essential part of new power supply designs. The proposed converter shows a power supply for HB-LED which could work under a large AC input voltage range and obtains high power quality. It is a single stage, low cost and high efficiency. The UC3854 with fast control loop is used to improve power factor and enabling the PWM dimming. We tested this control method by simulating and both converters built in the laboratory and final results compared to open loop converter.**

Keywords— PFC; HB- LED; THD; Boost; power supply

I. INTRODUCTION

Nowadays, utilization of power switching converter has become usual method of designing a power supply. At main issue of these kinds of converters is the current and voltage outputs have irregular pattern [1]. Currently, manufacturers of lighting fixtures produce the high brightness light emitting diodes (HB LEDs) with high efficiency output above 100 Lumens/Watt [2]. These LED lamps have more advantages such as lower cost, a wide range of color and high luminance intensity. Hence, among the many artificial lighting devices, these are likely to be the best choice for illuminating purposes [3-5].

The drivers of these lamps with output power over 25W have to be compatible with the requirements of IEC61000-3-2 [6]. The Proposed topology makes this power supply to achieve Class C regulations of the same requirement. As we know, obtaining a high PFC is possible by some passive and active circuits [7]. Equation (1), below, shows the relation between power factor and THD.

$$P.F = \frac{\cos\varphi}{\sqrt{1 + THD^2}} \qquad (1)$$

Where φ is the phase angle difference of the voltage and current waveforms.

Mathematically, the input voltage of the duly converter is AC whereas its output is DC, to feeds LED, as shown in the diagram of Fig.1.

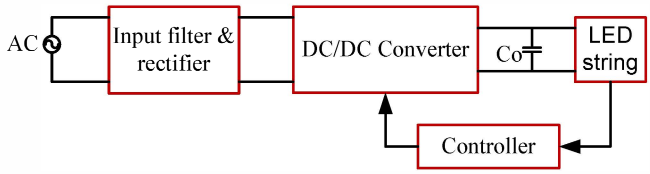

Fig. 1. Block diagram of DC/DC converter power factor correction circuit.

This circuit is a single stage with an active PFC scheme which in comparison to integrated single-stage converters has lower cost, size and THD_i [8]. In the proposed active PFC scheme which precedes a driving power stage, a circuit is used to implement power factor correction function. The input current or PFC voltage stress is not added on to the active switch used in the following power (DC/DC) converter. It is the circuit implementing PFC function that increases the reliability.

This circuit is simple, cheap; in which an IC with power factor Correction close to one is newly applied. Finally, results of tested driver are discussed and compared with IEC 61000 Standard.

II. ANALYSIS OF THE CIRCUIT

Fig. 2 illustrates a boost converter circuit, the mode of dimming control for a LED could be rendered through analog or pulse width modulation (PWM) methods [9-12]. Analog dimming method is not proper for HB-LED lamps owing to color variation, however this is simple and chip method. Therefore PWM dimming is used in this paper.

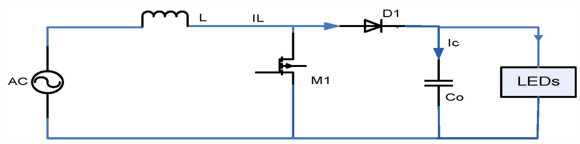

Fig. 2. Circuit diagram of Boost converter.

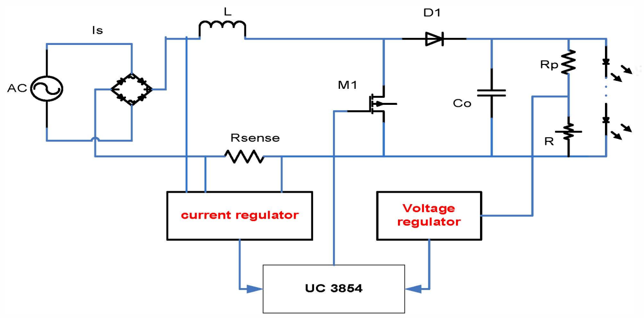

Fig. 3. The circuit of HB-LEDs driving with Boost PFC.

As shown in Fig. 3, the IC applied in this topology is UC3854. In a power factor correction circuit there are two feedback control loops. One loop operates by using the input voltage as a reference to control the input current. This loop is fast and makes the input current instantaneously proportional to input voltage as it would be with a resistive load. A second loop, which is much slower, controls the constant of proportionality to make the average current correct to keep the output voltage of the power factor correction circuit constant. The designed circuit consists of a power MOS switch M1, an inductor L, and a Schottky diode D1 directly connected with the load LEDs, the current sampling resistor R_{sense} and the resistors Rp and R are used to regulate output voltage.

III. RISULT OF SIMULATIONS

The boost converter with PFC is designed and simulated by PSIM software as shown Fig. 4.

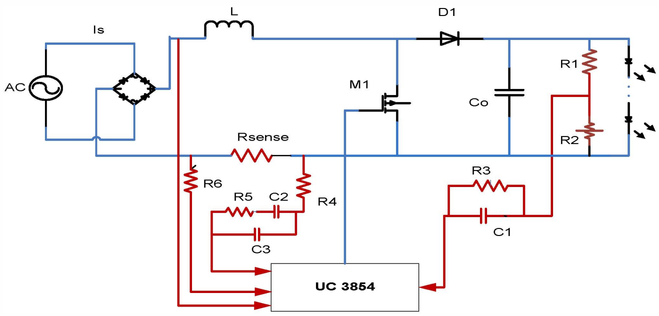

Fig. 4. The experimental circuit of HB-LEDs driving with Boost PFC.

Fig. 5 shows the voltage and current input waveforms of the open loop converter. The obtained value of power factor for this circuit would be 0.78, and the THD value is 45%.

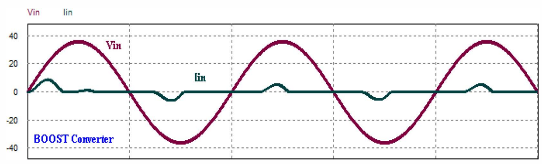

Fig. 5. Input voltage and current waveforms without PFC.

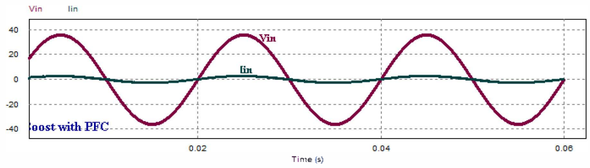

Fig. 6. Input voltage and current waveforms with PFC.

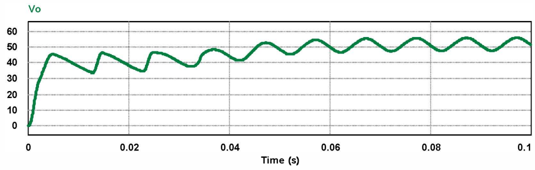

Fig. 7. Output voltage waveform with PFC.

Fig. 6 demonstrates the waveforms of converter with PFC circuit, the calculated values of the power factor are 0.997, and THD is lowered to 11.3%.

Fig. 7 illustrates the output voltage waveform.

Fig. 8 illustrates the diagrams of bode and Nyquist plots of controlling loops in the PFC boost converter circuit by using SmartCtrl software. It could be shown, values of components in purposed feedback circuits was selected correctly and it provides the crossover frequency and the phase margin that leads to a stable solution.

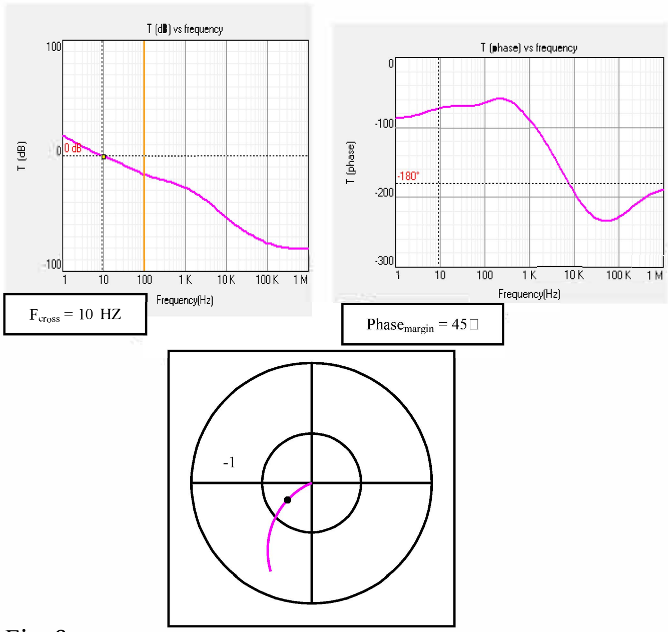

Fig. 8. Bode and Nyquist diagrams of the control system performance.

IV. EXAMPLE DESIGN AND EXPERIMENTAL RESULTS

In this section, an LED constant current driver with high power efficiency is designed and implemented according to the following configuration:

Input voltage: AC 18 - 36 V (nominal 25 V)
LED string voltage: DC 53 V
LED current: 350 mA
Expected efficiency: 90%
P.F: 0.997

HB-LEDs are usually low-power devices, ranging from 1W to 5W at currents from 350 up to 2000 mA. Now, their luminous efficiency is around100 lm/W at 350 mA in the latest devices. The load finally chosen is made of 16 High powers 1W LED Dragon Types at 350 mA. In order to properly design the power converter, the LED load has to be modeled.
The most accurate approximation is the model consisting of a threshold voltage and a dynamic resistance in series, as shown in Fig. 9.
Thus, the LED load *I-V* model would be the following:

$$V_D = R_{Di}\, I_D + V_{\gamma i} \tag{2}$$

Where V_D is the forward voltage drop of the LED, R_{Di} is the dynamic resistance, I_D is the LED current, and V□*i* is the threshold voltage. Non-standard LEDs are preferred due to their lower cost, but they exhibit higher forward voltage deviations among devices. However, the variation of forward voltages can be considered a random variable. Therefore, placing a large number of devices in series will cause the random variables to sum together. This has the effect of lowering the standard deviation of the forward voltage across the whole LED array [13].
Boost topology driving IC UC3854 from SYNCOAM with a input DC supply voltage range from 15 V to 40 V is chosen as a controller and the schematic diagram shown in Fig. 4, And it is used to drive an LED string with 16 LEDs with a 3.3 V working voltage. For the output voltage, considering the whole string in series can be simplified as follows:

$$V_o = N\,(R_{Di}\, I_D + V_{\gamma i}) = R_D\, I_D + V_\gamma \tag{3}$$

Where *Vo* is the voltage of the entire string and N *is* the number of LEDs in series. The converter was designed to provide a total output power of 16 W, with a rated lamp current of 350 mA. The main purpose of this work is to investigate and evaluate the feasibility of this converter to drive LED lamps and to incorporate the PWM dimming capability. In order to minimize the passive components, a 40 kHz switching frequency was selected.
The circuit setup of closed loop BFPC is shown in Fig. 4. The circuit component values used in simulation of the proposed PFC method are listed in table 2.

TABLE 2. The names and values of circuit component

name	L	C_o	R_1	R_2	R_3	R_5	R4 R6	C_1	C_2	C_3
value	1 mH	100 µF	560 kΩ	92 kΩ	68 kΩ	20 kΩ	2.2 kΩ	227 nF	1 nF	270 pF

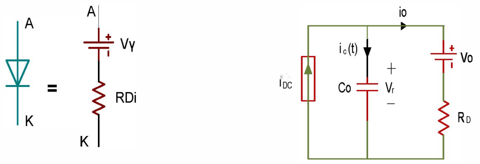

Fig. 9. (Left) Equivalent circuit of an LED: Linear model. (Right) Output DC current equivalent circuit.

The input voltage and current waveforms resulted from experimental implementation of the conventional converter and the proposed power factor correction methods are presented in Fig. 10 and Fig. 11 respectively, and the experimental output voltage waveform boost converter with PFC is shown in Fig. 12.

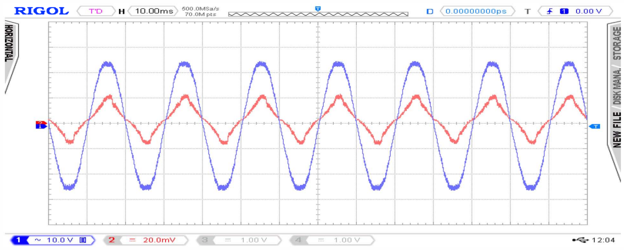

Fig. 10. The experimental Input voltage and current waveforms boost converter without PFC.

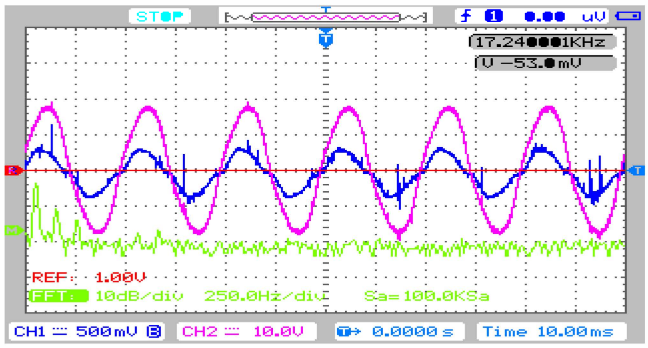

Fig. 11. The experimental Input voltage and current waveforms boost converter with PFC.

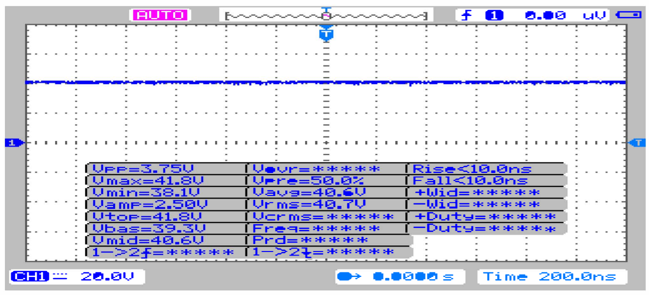

Fig. 12. The experimental output voltage waveform boost converter with PFC.

The result of simulations and laboratory experiments, for both of the conventional Boost converter without and with PFC based on the IC UC3854 are presented in table 1.

TABLE 1. Simulation and Experimental Results

Table Head	Simulations		Laboratory Experiments	
	Boost converter without PFC	*Boost converter with PFC*	*Boost converter without PFC*	*Boost converter with PFC*
Cos Φ	0.78	0.997	0.78	0.999
THD	45%	11.3%	50%	11.5%

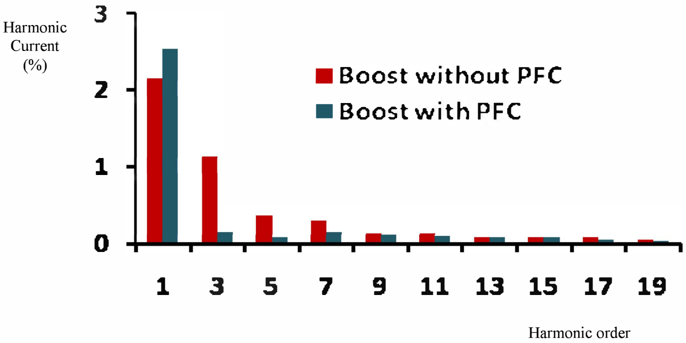

Fig. 13. Input current FFT Boost converter with and without PFC

The input current harmonics of boost converter with and without power factor correction are shown in Fig. 13, this diagram shows that converter with power factor correction has reduced percent of harmonic current. Fig.14 illustrates Harmonic content of the input current along with the mask for complying with IEC Class C regulations.

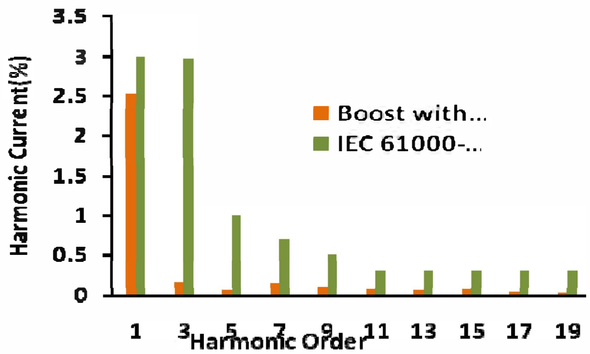

Fig. 14. Harmonic content of the input current, showing the results obtained And the limits stated in the IEC 61000-3-2 Regulations.

The PFC circuit is fabricated in general PCB. Input voltage is 18 V, 50 Hz and the output is 53 V DC. The switching pulse of 40 kHz is generated using IC UC3854. The circuit setup of closed loop Boost with FPC is shown in Fig. 15.

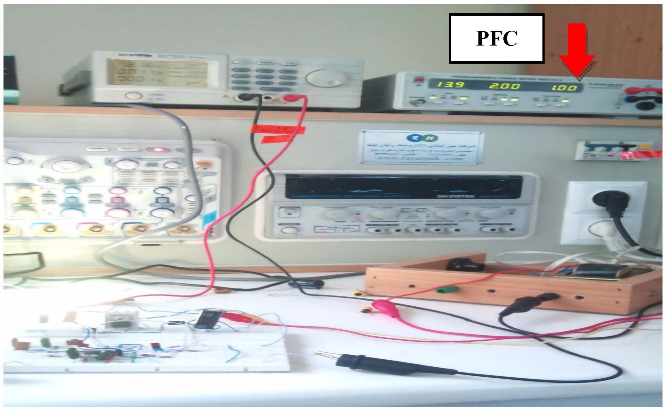

Fig. 15. Circuit setup of Boost with PFC.

V. CONCLUSIONS

HB-LEDs constant current drive circuit with high power factor is presented in this paper. Control algorithm is applied by IC UC3854. This topology provides high power factor, fast output voltage regulation and improving THD. The method is based on sampling input and output current and voltage waveform, and uses the current sampling resistor to produce the PWM signal of the switch to regulate output voltage, improve power factor and reduction of the THD value.

A high efficiency Boost LED driver with AC input voltage which could drive an LED lamp consists of 16 LUMILEDS LEDs, is designed and tested. The measured results on a laboratory prototype show a high efficiency of 92%, high power factor 0.999 at and a good low-frequency harmonic Reduction, complying with IEC 61000-3-2:2005 Class C. This is considered adequate, taking into account that the proposed converter was designed for HB-LED which could operate under a wide AC input voltage range.

References

[1] Sujata Verma, S.K Singh and A.G. Rao, “Overview of control Techniques for DC-DC converters, ” *Research Journal of Engineering Sciences*, Vol. 2, No. 8, 2013, pp. 18-21.

[2] Weir B. and Cathell F, “LED streetlight demands smart power supply, ” *Power Electronic Technol.*, Vol. 34, No.2, pp. 34–39, Feb 2008.

[3] Y. K. Cheng and K. W. E. Cheng, “General Study for Using LED to replace Traditional Lighting Devices,” 2nd International Conference on Power Electronics Systems and Applications, Hong Kong, 12-14 November 2006, pp. 173-177.

[4] E.-W. Wu, T.-Fu. Wu, J.-R. Tsai, Y.-M. Chen and C.-C. Chen, “Multistring LED Backlight Driving System for LCD Panels with Color Sequential Display and Area Control,” IEEE Transactions on Industrial Electronics, Vol. 54, No. 10, 2008, pp. 3791-3800.

[5] M. Rico-Secades, A. J. Calleja, J. Ribas, E. L. Corominas, J. M. Alonso, J. Cardesin and J. Garcia-Garcia, “Evalua-tion of a Low-Cost Permanent Emergency Lighting Sys-tem Based on High-Efficiency LEDs,” IEEE Transac-tions on Industry Applications, Vol. 41, No. 5, 2005, pp. 1386-1390

[6] M. OLeary, “Plug in safeguard AC power line quality,” *EDN*, pp.57–66, Mar. 18, 2004.

[7] W. H.Wolfle and G. Hurley, “Quasi-active power factor correction with a variable inductive filter: Theory, design, and practice,” IEEE Trans. Power Electron., vol. 18, no. 1, pp. 248–255, Jan. 2000.

[8] Elizabeth Paul, Prof. Aleyas M. V. and Prof. Annie P. Oommen, “A Single Stage High Power Factor Supply Based on Integrated Buck Flyback Converter, ” International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 2, No. 1, 2013, pp. 680-688.

[9] K. H. Loo, W.-K. Lun, S.-C. Tan, Y. M. Lai and C. K. Tse, “On Driving Techniques for LEDs: Toward a Gen-eralized Methodology,” *IEEE Transactions on Power Electronics*, Vol. 24, No. 12, 2009, pp. 2967-2976..

[10] M. Nishika, Y. Ishizuka, H. Matsuo, *et al*., “An LED Drive Circuit with Constant Output Current Control and Constant Luminance Control,” 28*th Telecommunications Energy Conference*, Providence, September 2006, pp. 1-6.

[11] H. V. D. Broeck, G. Sauerlander and M. Wendt, “Power Driver Topologies and Control Schemes for LEDs,” *Twenty Second Annual IEEE of Applied Power Electron-ics Conference*, Anaheim, 25 February-1 March 2007, pp. 1319-1325.

[12] F.-F. Ma, W.-Z. Chen and J.-C. Wu, “A Monolithic Cur-rent-Mode Buck Converter with Advanced Control and Protection Circuits,” *IEEE Transactions on Power Elec-tronics*, Vol. 22, No. 5, 2007, pp. 1836-1846.

[13] D. Gacio, J. M. Alonso, A. J. Calleja, J. García, and M. R. Secades, ”A universal input single stage high power factor power supply for HB LEDs based on integrated buck flyback converter”, *IEEE Trans. Ind. Electron.,* vol. 58, no.2, pp 589-599, Feb. 2011.