A High Power Factor LED Driver with PWM Series Dimming Based On IBFC

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Abstract—**This paper deals with a high power factor led driver incorporated with PWM series dimming, upon which the driver is based on an integrated buck fly back converter. Now a days high brightness led s are used for street light applications. Such lighting systems as powered from ac source, has to comply with IEC standards in terms of harmonics and power factor regulation. The proposed system provides an excellent choice for driving such led loads for our street lighting.PWM series dimming is an excellent way in overcoming all the challenges faced by analog dimming and other PWM dimming techniques like enable dimming. The proposed dimming technique is analysed and tested and compared with other modes of dimming and is presented here. It is experimentally proved that it has a high efficiency, improved power factor and reduced THD.**

Index Terms—**Buck–flyback converters, high-brightness light-emitting diode (HB-LED), LED lighting, PWM dimming, power-factor correction.**

INTRODUCTION

Owing to the high efficiency of power led s they are universally accepted as the unique source of lighting applications. As powered from an ac source to provide a reliable operation they should comply with (IEC) 61000-3-2:2005 mandatory regulations in terms of harmonic content and power-factor correction (PFC). Many researches are undergoing in this field of using power led s as street light applications. Among them the most important would be dimming. In short dimming refers to output luminous flux control. The feature of dimming is quite important because it provides power savings ambient lighting for aesthetics, building automation etc.

Here a power factor correction converter which is based on integrated buck fly back converter is used to drive the led load. The objective of this paper is to introduce a high-frequency series (HFS) dimming technique not only for street lighting, but also for general indoor/outdoor lighting. The converter is fed from a universal ac source, i.e., 90 to 265 V_{rms}, 50/60 Hz and which performs power factor correction (PFC) and attains a low input current total harmonic distortion (THD), which fulfills the IEC61000-2-3 regulation.

There are two methods of dimming LED lamps. One is amplitude-modulation dimming or analog dimming which is based on the variation of the output dc current linearly to the desired luminous output. Linearity exists between injected current and LED luminous output which is the principle behind this type of dimming. But high injection currents may lead to a lack of linearity between injected current and luminous flux output. It causes a noticeable shift in chromaticity coordinates, which is undesirable in certain applications. Another method is PWM dimming which is based on the switching of LED lamp alternately on and off at frequencies above the critical flicker fusion frequency hence the human eye blends the light pulses perceiving continuous light. Hence, the human eye sees a decrease in the brightness rather than flickering.

There are mainly 3 PWM dimming methods. First one is PWM enable dimming. In this method, with the help of a logic-level PWM signal, the converter is switched on and off alternately at high frequencies and thereby dimming the lamp light. The main drawback of this technique lies in the slew-rate of the converter. The rise time and delay time will compromise dimming frequency and enlarge the time LED has to spend between dc current level and zero current level. In this region chromatic characteristics of LEDs are not guaranteed. This effect has an important effect upon power factor preregulators. Second method is PWM series dimming, where a series transistor, which is connected in series with the load, is used to switch on and off the load by means of a PWM signal, where the output voltage remains a constant because of the energy stored in the capacitor. Another method is shunt dimming where a transistor is placed in parallel with the load and is controlled by a PWM signal which is switched on and off alternately thus shunting the LED load. This method allows the fastest dimming and highest dimming ratio as possible, which is due to reduced delay and turn on times of converter. The efficiency is slightly reduced as the converter is kept on working even during lamp turn off time. This method of dimming is not suitable when the converter requires the use of an output capacitor, such as boost or buck-boost topologies because in such case the output capacitor will be short-circuited which will generate a very high current spike through the switch.

Here we are analyzing the feasibility of an IBFC to provide a high power factor supply and to incorporate PWM series dimming along with that. This paper is divided into various sections, for the ease of analysis .Here section II introduces the topology and load used for the proposed system, section III deals with analog and series dimming technique section IV deals with the experimental setup and V deals with experimental results.

II. TOPOLOGY AND LED LOAD

The converter which is proposed in this paper utilizes an integrated buck flyback topology for high power factor correction. Here the buck converter acts as a power factor pre regulator followed by a dc -dc converter which is a fly back converter. These two stages are integrated to a single stage controlled by a single switch. Both converters will be operating DCM where buck converter functions as a PFC (power factor correction) stage and later as a power supplier to the LED load.

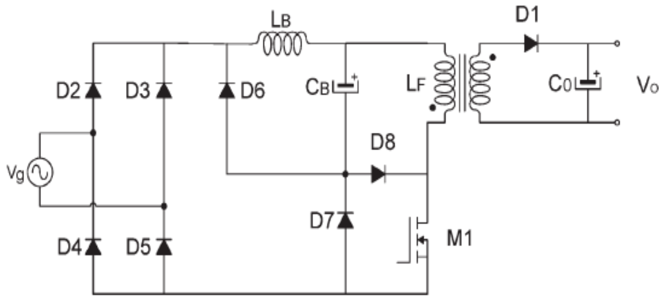

Fig No: 01 IBFC topology

The IBFC topology is designed to satisfy Class C IEC 61000-3-2 standards, operating under universal input ie, 90-265 V_{rms}. The operation is similar to that of two cascaded converters, where buck converter operates only when rectified line voltage V_G is greater than bus voltage V_B which is the voltage across the capacitor. Here the voltage ratio 'm' ,the ratio between bus voltage V_B and line voltage V_G, is independent of the duty cycle, load, and the switching frequency and depends only on the inductance ratio α which is the ratio between buck and flyback inductances, L_B and L_F respectively. The following relation explains the connection between m and α

$$m-\frac{1}{2m\alpha}\left(1-\frac{2\sin^{-1}m}{\pi}\right)+\frac{1}{\pi\alpha}\sqrt{1-m^2}=0 \quad (1)$$

In order to satisfy IEC 61000-3-2 regulations, previous works have shown that a minimum conduction angle of 130° must be achieved. The conduction angle refers to the angular measurement of buck converter period of conduction. The value of m can be calculated using

$$\theta=\pi-2\sin^{-1}m \quad (2)$$

where θ is the conduction angle.

The fly back inductance L_F for a particular output power P_0 can be calculated using

$$L_F=\frac{V_B^2 D}{2P_0 f_s} \quad (3)$$

where D is the duty ratio and f_s is the switching frequency dealing with the load here we chose a 72 W output led load in which 60 series Golden Dragon LED lamp used in was used. These devices have 21 lm/W of luminous efficacy while driving at the 350 mA nominal current capability. Owing to the nonlinear characteristic of LED devices, a static modeling was carried out where a led is represented by a voltage source $V_{\gamma i}$,followed by a dynamic resistance, R_{Di}. Thus, the forward voltage V_o for the entire LED array can be expressed as follows:

$$V_O=N\left(R_{Di}I_D+V_{\gamma i}\right)=R_DI_D+V_\gamma \quad (4)$$

where N is the number of LEDs connected in series; I_D is the forward current.

III ANALOG DIMMING AND PWM SERIES DIMMING

Among the dimming techniques analog dimming is the simplest and cheapest technique used to vary the luminous flux output. Hence first we need to check the performance of this method applied to the IBF converter. An advantage of this technique is the improvement on LED conversion efficiency at low current levels. But, this technique features some drawbacks such as lack of linearity and a shift in the chromaticity coordinates at high injection currents. As we know, analog dimming is based on changing the output current dc value, a 0 to 2.31 V dc variable voltage was applied to the output current reference. The output current was progressively varied from a 20% of the nominal dc current, i.e., 70 mA, to a 100% of the nominal dc current, which is 350 mA, in 35mA steps. For street lighting applications a two level analog dimming was enough, but for extending the application to general indoor/outdoor lighting, analog dimming is insufficient. In this situation obviously PWM technique comes to rescue. Here in this paper PWM series dimming is taken as our concern. This dimming scheme can be simply modeled as shown in the figure.

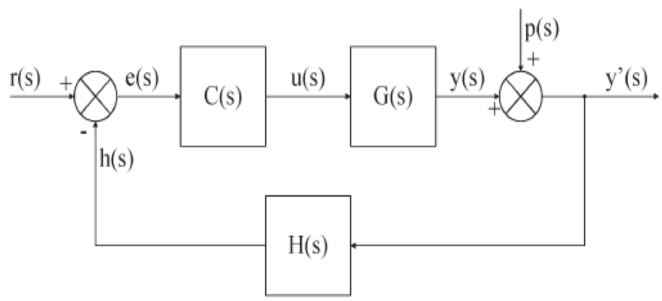

Fig No: 2 Simple closed loop representation of series dimming with an added series transistor

Here C(s) is the controller, H(s) is the feedback filter, G(s) is the converter transfer function. Also U(s) is the control signal, y(s) is the output signal, p(s) is the dimming signal and y'(s) is the output signal which is feedback through the feedback filter H(s) to the converter for dimming purpose. The feedback signal provided by sensing filter is a dc level which is proportional to the dimming duty cycle and output-peak current value. So these signals are varied as to obtain a dimming duty cycle related reference which keeps output current peak value constant. This is achieved by multiplying output current reference $V_{PK\ ref}$ by dimming duty cycle D_{avg}, which is a feed-forward action, by which a new output current reference V_{ref} can be generated. Then this signal is compared with the feedback signal V_b so as to obtain error signal V_{error} This error signal is processed in the controller block C to generate the control signal V_{reg}. The PWM dimming signal is

D_{dim} which is filtered by G_D block for obtaining the value of dimming duty cycle D_{avg} , which is multiplied by $V_{PK\ ref}$, the output current reference. We can simplify this scheme by avoiding multiplier where the new output current reference is generated by gain block G_R.

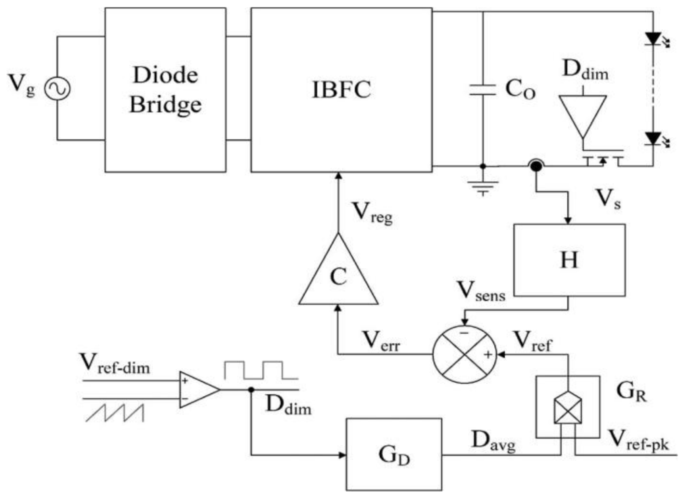

Fig No: 3 Block diagram for proposed dimming technique

IV EXPERIMENTAL SETUP

For practical implementation the dimming frequency was set as 100 KHz which is same as switching frequency. In fact dimming frequencies above 20 or 25 KHz are advantageous because the audible emissions get eliminated at those frequencies. However taking dimming frequency same as switching frequency avoids the production of additional EMI harmonics as both switches as operating synchronously. The control scheme used in the laboratory test is as shown figure.

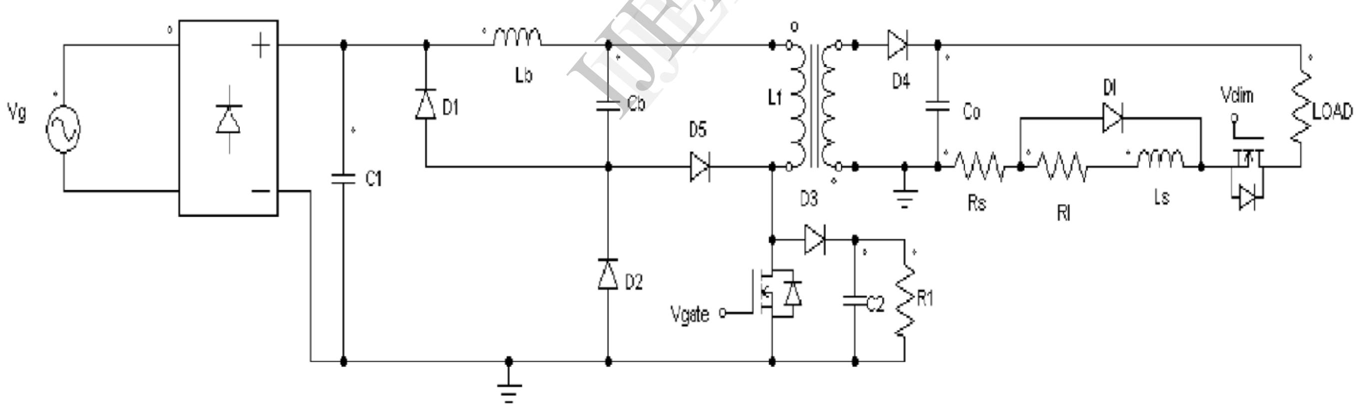

Fig No: 04 IBFC for LED load incorporating PWM series dimming

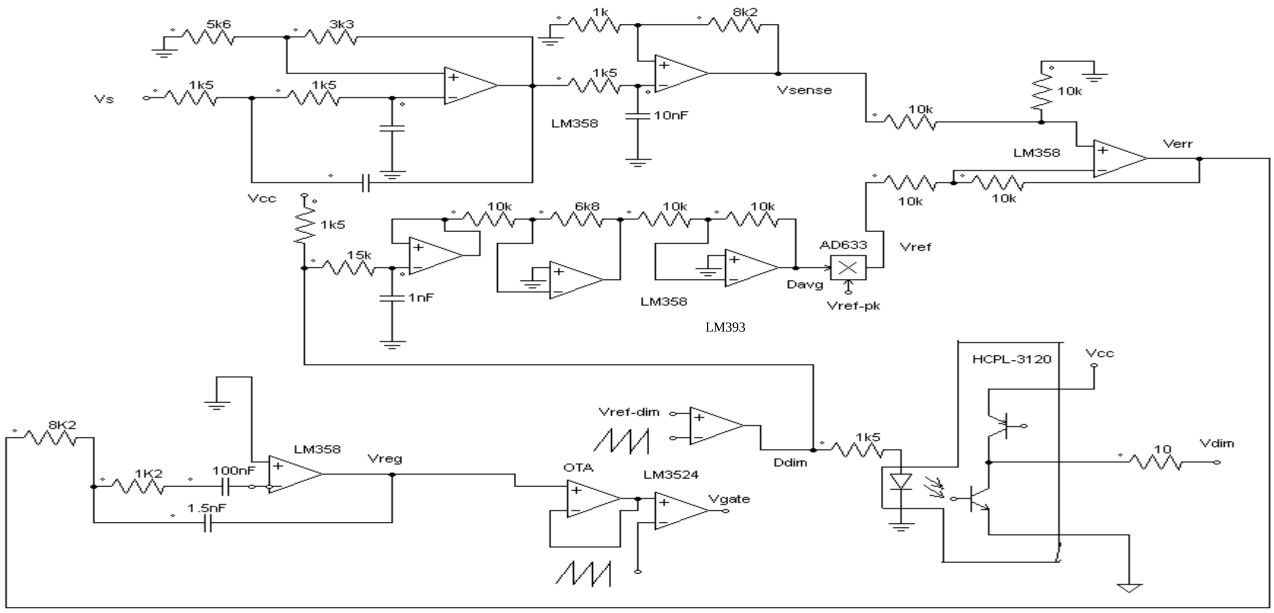

Fig no: 05 Control structure for the proposed system

A saw tooth wave ranging from 0.6 to 3.8v and 100KHz is generated by LM3524 IC .This is compared with a dimming reference,ie,$V_{ref-dim}$ by a LM 393 comparator for generating PWM dimming signal ,ie,D_{dim}. This signal is applied to IRF840 transistor. Using LM358IC, an average PWM dimming value D_{avg} is extracted utilizing a first order low pass filter. In order to remove the high frequency ripple completely, the filter cut off frequency was set to be 10Hz.Then this D_{avg} and the output current reference V_{ref-pk} is multiplied using an AD633 analog multiplier to obtain new current reference V_{ref}. After that this current reference and the current sensor output is compared using a subtractor block to obtain the error signal V_{err}. Then finally a decoupled dimming driver was built using HCPL-3120optocoupler.

TABLE 1
LIST OF COMPONENTS

COMPONENTS	VALUE
Buck inductor,L_B	26.1uH
Flyback inductor,L_F	19.3uH
M1	SPW17N80C2
M2	IRF840
D1	STTH512
D6,D7	MUR860
D8	MUR860
C_B	570uF/250V
C_0	1uF/250V

V.EXPERIMENTAL RESULTS

In order to check the dimming results and power factor correction results the converter was tested in closed loop at 150 V_{rms} .PWM Series dimming exhibits a high peak current stess because of output capacitor instantaneous discharge through the load. So inorder to overcome damage due ti this high current, an overcurrent snubber was incorporated in the circuit.L_S is snubber inductor,R_L is the series resistance and D_l is the freewheeling diode. It helps to reduce overcurrent stress for a wide dimming range. The following waveforms show the input voltage and current waveforms for three different dimming ratios.

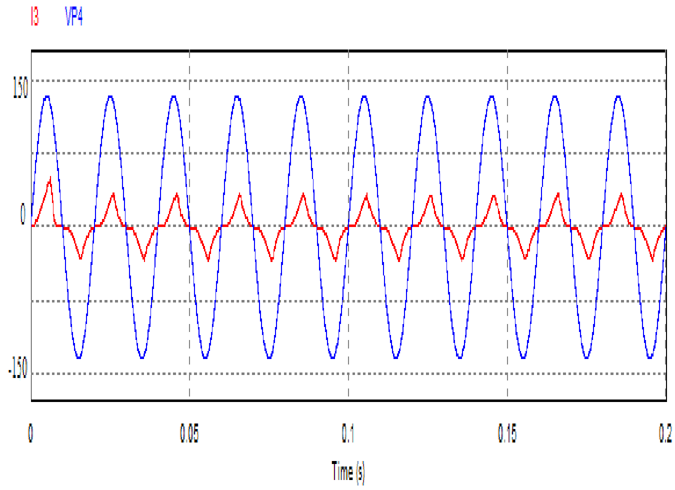

Fig no: 06 Input current and voltage for 100% luminous output i.e., (1:1) dimming ratio

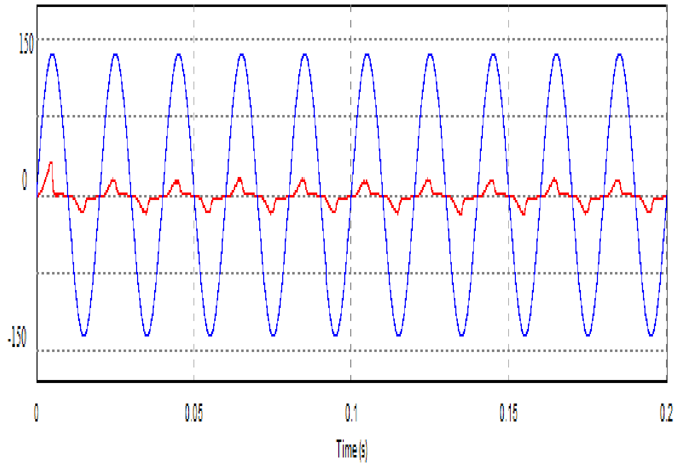

Fig no: 07 Input current and voltage for 50% luminous output i.e., (2:1) dimming ratio

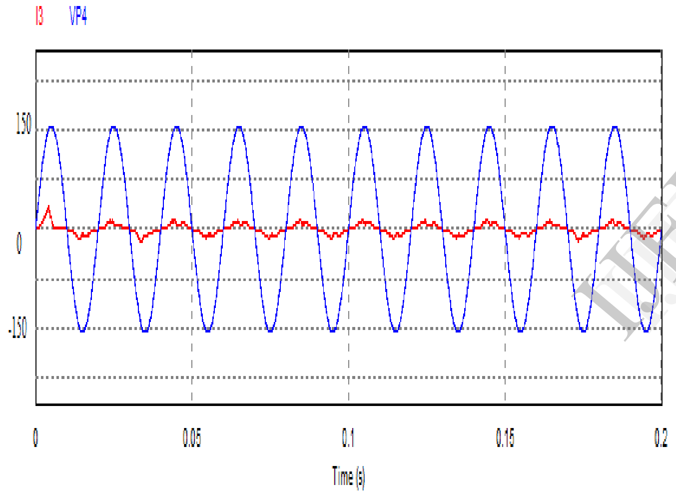

Fig no: 08 Input current and voltage for 10% luminous output i.e., (10:1) dimming ratio

VI CONCLUSION

This paper deals with a power factor correction converter based on IBFC which was used to drive a 72 W LED load from universal input-voltage source. Now many important studies are foregoing on the basis of energy saving. So on that context, the study of PWM dimming in addition to IBFC LED driver makes a sense. For slow dynamics LED drivers PWM series dimming is considered to be more appropriate. Also three main dimming schemes were discussed briefly. The experimental setup of PWM series dimming and the results was also shown. The results show that the dimming ratio as low as 10:1 can be achieved which is suitable for residential lighting. In fact it is a highly reliable dimming scheme which can be well applied to slow dynamics converters.

VII REFERENCE

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