ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Special Issue 5, December 2014

PWM Switched Double Stage Buck Boost Converter with LC Filter for LED Lighting Applications

Akhiljith P.J[1], Leena Thomas[2], Ninu Joy[3]

P.G. student, Mar Athanasius College of Engineering, Kothamangalam, Kerala, India [1]

Professor, Mar Athanasius College of Engineering, Kothamangalam, Kerala, India[2]

Assistant Professor, Mar Athanasius College of Engineering, Kothamangalam, Kerala, India[3]

ABSTRACT: An integrated double buck–boost(IDBB) converter is proposed as a high-power-factor offline power supply for power-LED lamps. The IDBB converter features just one controlled switch and two inductors and is able to supply a solid-state lamp from the mains, providing high power factor and good efficiency. The IDBB converter is analyzed, and a design methodology is proposed. It is demonstrated that, with a careful design of the converter, the filter capacitances can be made small enough so that film capacitors may be used. In this way, the converter mean time between failures can be made as high as that of the solid-state lamp. PWM switching is used for controlling the switching pulses. Feedback circuit is provided with PI controller for accurate result. The converter is simulated using MATLAB 2010 and waveforms are analysed. Simulation results demonstrate that the output voltage of the desired converter can be stably maintained at 200 V and power factor can be improved upto 0.90.

KEYWORDS: Continuous Conduction Mode (CCM), Discontinuous Conduction Mode (DCM), Duty cycle (D), Integrated double Buck–boost (IDBB), white power LED

I. INTRODUCTION

LED lighting is one of the most promising solutions to deal with the increasing energy demands. As natural resources around the world are becoming more expensive and less viable to sustain the needs of increasing populations around the world. Since the encapsulation technology of LEDs has become mature in the recent years, the LEDs are applied to the lighting areas such as the LCD backlight, the street lighting and the car head lightings. Generally, the use of LEDs is in the development direction of the future lighting system. LEDs can be divided into three categories: indicative LEDs, high-brightness LEDs, and power LEDs. Of these White power LEDs are becoming an attractive light source, owing to their high reliability, long life, high color rendering index, and small size [1]. In addition, there are commercially available units that can reach light efficacies as high as100 lm/W. All these features make white LEDs a good candidate to override fluorescent and other discharge lamps. But the problems associated with LED applications are that, they cannot be connected directly to the mains because they only work with dc voltage and their current must be limited. If neglecting the affection of the junction temperature, the illumination of the LEDs is in proportion to its average current, so the LEDs need constant current control. Therefore, some kind of current-limiting device must be used, similarly to the ballast used to limit the current through a discharge lamp. On the other hand, the high efficacy of power LEDs are only maintained under strict operating conditions, which include low direct current and low junction temperature. High-efficient, small switch-mode power supply driving circuits have been developed as power supply to LEDs. The numerous types of switching converter include boost, buck, buck-boost, and Cuk converters [2]. Here a two stage buck boost converter is provided with LC filter as a driver to the LED lamps which has high power factor, long life and better efficiency comparing with fluorescent lamps. The operation is similar to two buck boost converter[3]

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Special Issue 5, December 2014

II. PRINCIPLE OF OPERATION AND ANALYSIS

A. *Principle Of Operation*

Fig. 1 shows the block diagram of an integrated double buck–boost (IDBB) converter. The IDBB converter is proposed to supply power-LED lamps from the ac mains, providing high power factor (PF), low LED current ripple, and high efficiency. This converter behaves as two buck boost in cascade. The input buck boost converter is made up by L_i, D_i, C_B, and M_1, and the output buck–boost converter comprises Lo, D_2, D_3, C_0, and M_1. The reversing polarity produced by the first converter in the capacitor C_B is corrected by the second converter, provide a positive output voltage with respect to ground. This simplifies the measurement of the load current for closed-loop operations.

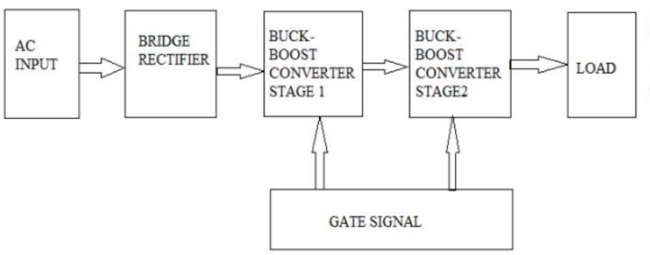


Fig.1 Block diagram of proposed converter

By operating the input inductor Li in discontinuous conduction mode (DCM), the average current through the line will be proportional to the line voltage, therefore providing a near unity PF. In the output side of converter output inductance can be operated either in continuous conduction mode (CCM) or DCM. The operation in DCM has the advantage of providing a bus voltage across C_B independent of the duty cycle and output power. However, it presents the disadvantage of requiring a higher value of the output capacitance to achieve low current ripple through the load. In order to have a reduced value for the outp ut capacitance, the output inductance is operated in CCM, because the current ripple is lower in this operation mode. In addition, the operation of the second stage in CCM with a duty cycle lower than 0.5 reduces the low-frequency ripple voltage since it is multiplied by the buck–boost converter voltage ratio. In this way, it will be possible to use a film capacitor to implement the output capacitance, thus having a higher life rating and better efficiency than using electrolytic capacitors .PWM switching is used to provide pulses to the MOSFET.

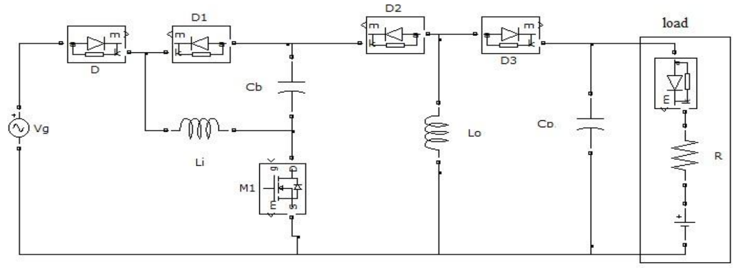


Fig.2 Circuit diagram

Under the exposed operation conditions, the equivalent circuits for the operation of the IDBB converter within a switching period are shown in Fig.2.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Special Issue 5, December 2014

Mode 1:0<t<DT_s

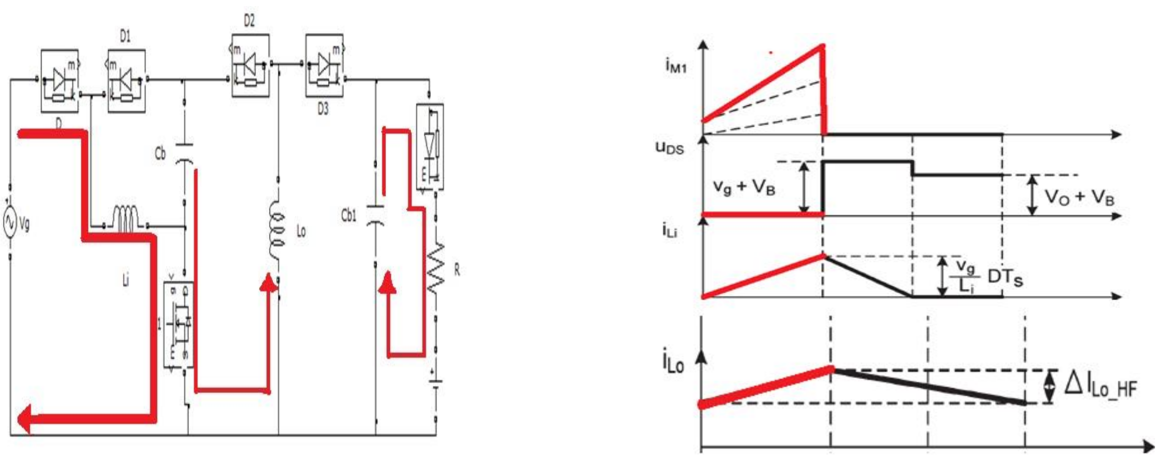
The inductor Li is charged to rectified voltage Vs since the switch is on. The bus capacitor C_B which is previously charged to Vs is discharged so that the output inductor is charged with bottom positive polarity. The load current is supplied by the output capacitor.

Mode 2:DTs<t<DTs+t_1

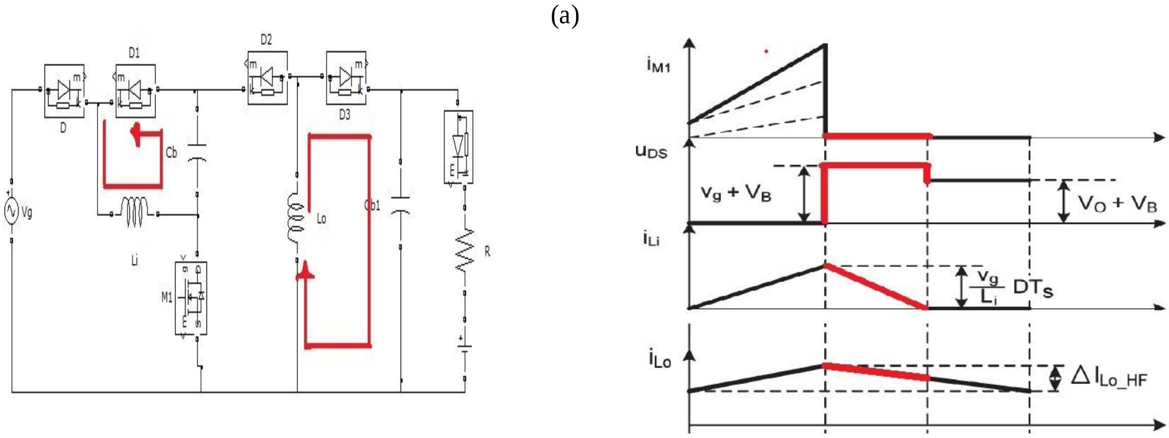
When the switch is turned off, the inductor Li is discharged through diode D_1. The charge stored in the output inductor L_0 is given to output capacitor C_o and load through diode D_3. At the end of this time inductor L_i is completely discharged.

Mode 3: DTs+t_1<t<Ts

There is no current flow in input side. The output inductor supply the load since D_3 is forward biased.



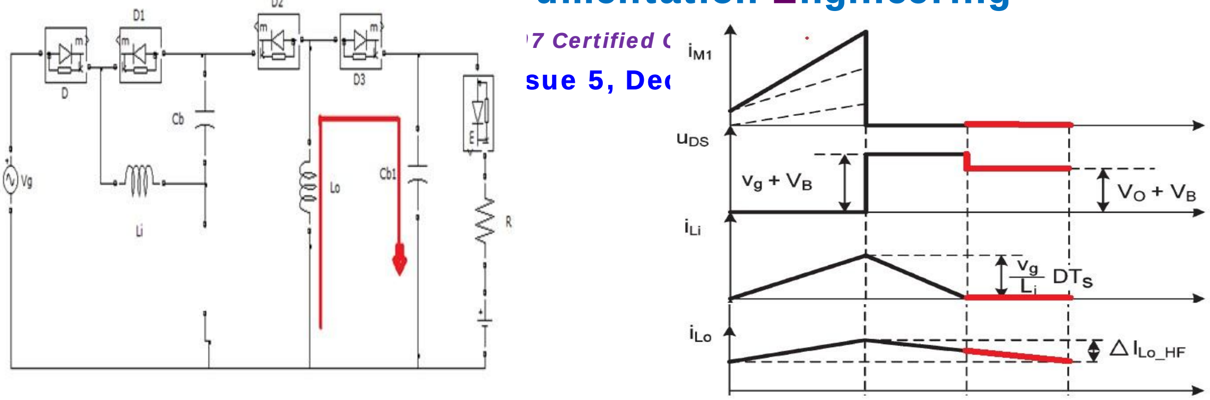
(a)



(b)

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering



(c)

Fig 4. Principle of operation (a) .mode 1 (b) mode 2 (c) mode 3

B. *Analysis*

It is assumed that the line voltage is a sinusoidal waveform given as $v_g = V_g \sin \omega_L t$. The input current i_g corresponds to the current through the inductance L_i during the time interval 0 – DT_S, where D is the transistor duty cycle and T_S is the transistor switching period. Thus, the value of the input current averaged at line frequency can be calculated as follows

$$i_g = \frac{D^2 V_g \sin \omega t}{2L_i f_s} \quad (1)$$

f_s is the switching frequency, V_g is the peak line voltage, and ω is the line angular frequency. The average input current is a sinusoidal waveform that will provide an input PF close to unity once filtered by the input L C filter. The mean input power P_g can now be calculated, taking into account that both input waveforms will be sinusoidal.

$$P_g = \frac{D^2 V_g}{4L_i f_s} \quad (2)$$

The output voltage V_o for the converter can be obtained by equating input and output powers $P_0 = \frac{V_0^2}{R}$, with R being the static equivalent esistance of the LED load, which can be obtained by the ratio between the dc values of LED voltage (VLED) and current (ILED) at each operating point. Then assuming 100% efficiency, the output voltage is finally obtained as

$$V_0 = \frac{DV_g}{2\sqrt{K}} \quad (3)$$

Where K is a non dimensional factor given by $K = \frac{f_S L_i}{R}$

Since the output stage corresponds to a buck–boost converter operating in CCM, the bus voltage V_B can be calculated using the voltage conversion ratio for this converter;

$$V_B = \frac{1-D}{D} V_0 \quad (4)$$

When operating the input stage in DCM and the output stage in CCM, the bus and output voltages are reversely dependent on the duty cycle. For example, if the duty cycle increases, the output voltage increases, and the bus voltage decreases in the same amount. The input inductance *Li* can be calculated for a given output power assuming 100% efficiency

$$L_i = \frac{D^2 V_g^2}{4P_0 f_S} \quad (5)$$

The bus capacitor C_B is calculated to limit the low-frequency ripple of the bus voltage, which is the voltage applied to the second stage. The current through this capacitor is given by the currents through diodes *D*1 and *D*2.

$$C_B = \frac{D^2 V_g^2}{8\pi V_B L_I \Delta V_{B\,LF} f_S f_L} \quad (6)$$

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Special Issue 5, December 2014

As long as the output buck–boost converter operates in CCM, the LED current ripple at low frequency depends only on the bus voltage ripple and, thus, on the bus capacitance C_B. The output capacitance C_O has no effect on this low frequency ripple. Finally, the output inductance and capacitance L_O and C_O are obtained using the well-known expressions for a buck–boost converter operating in

$$C_o = \frac{D\, I_O}{\Delta V_O f_S} \tag{7}$$

$$L_o = \frac{2D V_B}{\Delta I_{L_{oHF}} f_s} \tag{8}$$

where I_{Lo} is the high-frequency peak-to-peak current ripple, V_O is the high-frequency peak-to-peak output voltage ripple, and *Io* is the dc current through the LED load.

III. SIMULINK MODEL

For simulation of the proposed converter, parameters of the different circuit components are taken as: The load rating current is 350 mA, with an output power of 70W. $V\gamma$ = 170 V and $R\gamma$ = 87Ω. The equivalent load resistance at nominal power is R = 570Ω. The selected switching frequency is 50kHz. The line voltage is 230 Vrms with a 50-Hz line frequency. The converter must admit at least 10% line voltage variation, assuring constant current through the load. selecting a 45% duty cycle for the nominal operating point, a value L_i = 1.7 mH is calculated. The bus capacitance C_B =80uF,output inductance L_0= 7mH, output capacitance C_o= 40uF.

A. *PWM Switched Model*

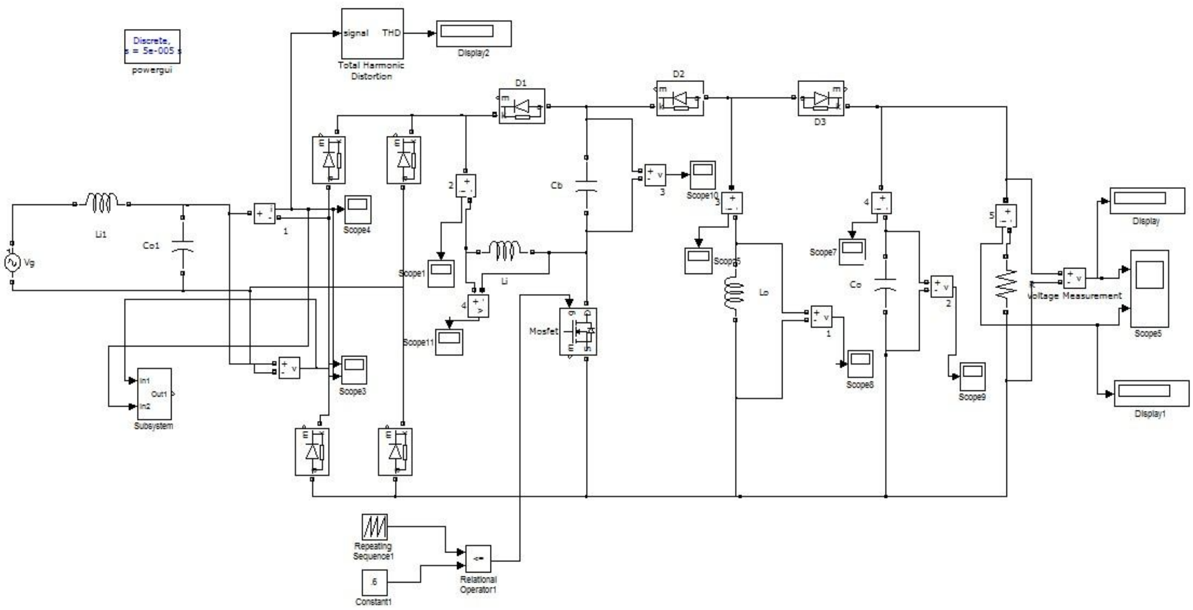


Fig 5.Simulink model of the proposed circuit

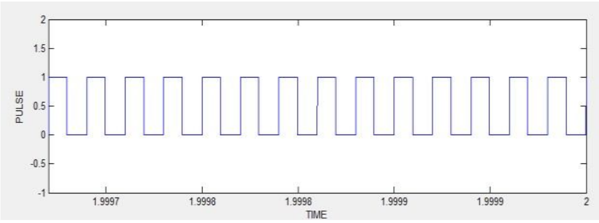
ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

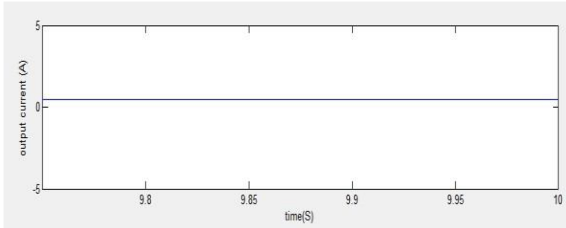
(An ISO 3297: 2007 Certified Organization)

Vol. 3, Special Issue 5, December 2014

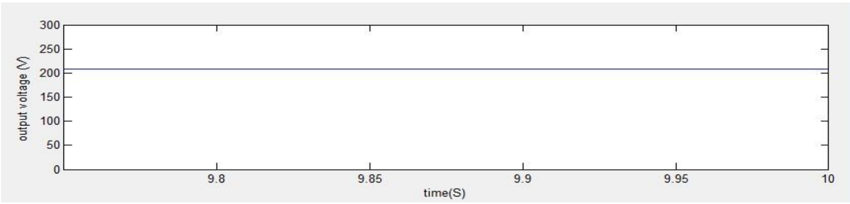
B. *Simulation Results*



(a)



(b)



c)

Fig 6. Simulation results a). Gate signals b) Output current c) Output voltage

C. *Closed Loop Configuration*

In order to increase the performance of the system closed path is provided. PI controller is used for controller purpose. The figure 6 shows the closed loop configuration of inverter using PI controller, with K_P=0.35 and K_i=40. Pulse is created with the help of relational operator. Direct output of relational operator is given to M_1.

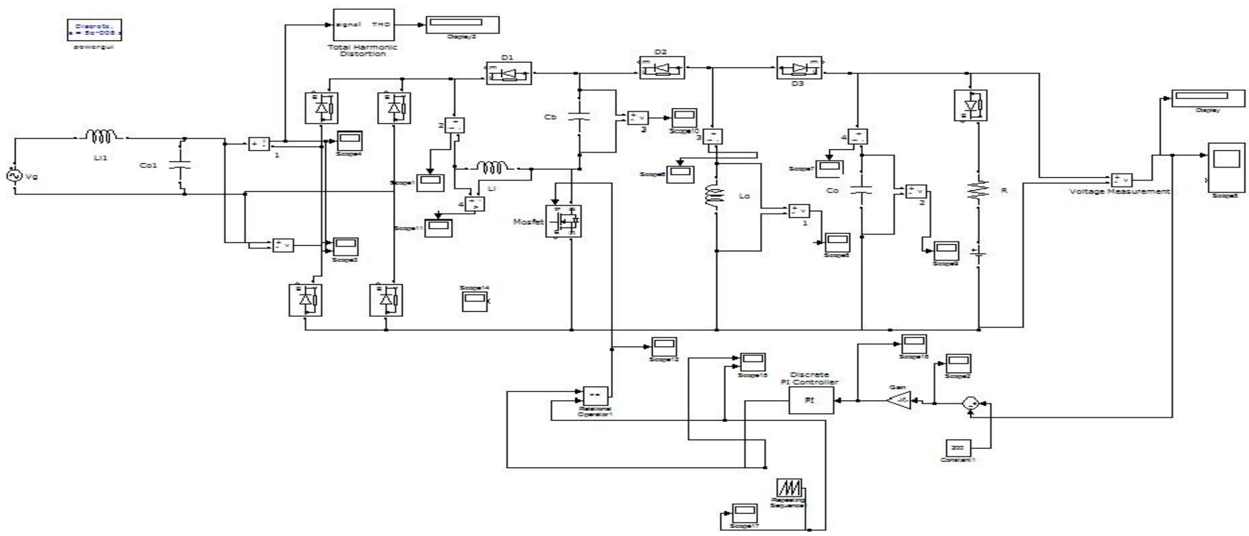


Fig .6 Simulink model of closed loop configuration

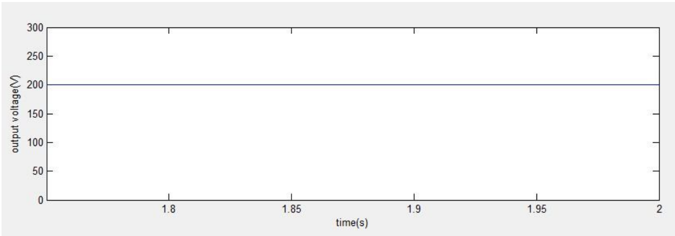
ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

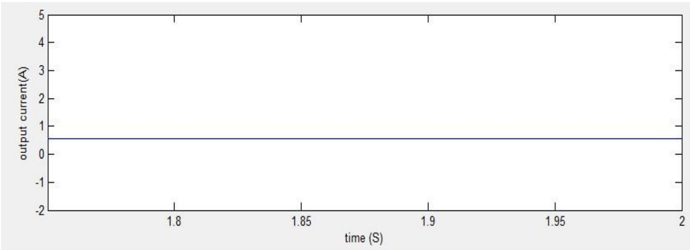
(An ISO 3297: 2007 Certified Organization)

Vol. 3, Special Issue 5, December 2014

D.*Simulation Results*



a)



b)

Fig 7. Simulaton results a).Output voltage b) Output current

IV. CONCLUSION

An IDBB converter with LC filter has been investigated to supply power for LED lighting applications. The two buck– boost converter is cascaded by using only one controlled switch. By operating the input converter in DCM, a high input PF of can be obtained. On the other hand, the operation of the second stage in CCM assures a low-ripple current through LED load without using a very high output capacitance. In this way, the converter can be implemented using only film capacitors, avoiding the use of electrolytic capacitors and increasing the converter mean time between failures. Modelling of the double buck boost converter with feedback is done and simulated the model and different waveforms are obtained. Simulation results demonstrate that the output voltage of the desired converter can be stably maintained at 200 V. Thus the proposed converter can provide high power factor upto 0.90 and good efficiency.

REFERENCES

[1] J. Marcos Alonso, Juan Viña, David Gacio Vaquero, Gilberto Martínez, and René Osorio, "Analysis and Design of the Integrated Double Buck–Boost
Converter as a High-Power-Factor Driver for Power-LED Lamps " *IEEE Trans*, April 2012, pp. 1689-1696
[2] R. A. Pinto, M. R. Cosetin, M. F. da Silva, G. W. Denardin , J. Fraytag , A. Campos, and R. N. do Prado, "Compact emergency lamp using power LEDs,"
in *Proc. 35th Annu. IEEE IECON* , Nov. 3–5, 2009,3494-3499
[3] H. Yuequan and M. M. Jovanovic, "A novel LED driver with adaptive drive voltage," in *Proc. 23rd Annu. IEEE APEC*, Feb. 24–28, 2008, pp. 565-571 [4] . Liang, C.-M. Huang, and J.-F. Chen, "Two-stage high-power-factor electronic ballast for metal-halide lamps," *IEEE Trans. Power Electron.*, vol.
24, no. 12, pp. 2959–2966, Dec. 2009
[5] L. Gu, X. Ruan, M. Xu, and K. Yao, "Means of eliminating electrolytic capacitor in AC/DC power supplies for LED lightings," *IEEE Trans. Power*
Electron., vol. 24, no. 5, pp. 1399–1408, May 2009
[6] K. I. Hwu, Y. T. Yau, and L.-L. Lee, "Powering LED using high-efficiency SR flyback converter," in *Proc. 24th Annu. IEEE APEC*, Feb. 15–19, 2009, pp. 563–569.
[7] D. Gacio, J. M. Alonso, A. J. Calleja, J. Garcia, and M. Rico-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

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Special Issue 5, December 2014

[8] Y. X. Qin and S. Y. R. Hui, "Comparative study on the structural designs of LED devices and systems based on the general phot o-electrothermal theory,"
IEEE Trans. Power Electron, vol. 25, no. 2, pp. 507–513, Feb. 2010.
[9] Chang W.H, Nien H.S., Chen C.H., "A Digital boost converter to drive white LEDs", *IEEE Applied Power Electronics Conference and Exposition*,(2008), 558-564
[10] Kening Zhou; Jian Guo Zhang; Yuvarajan, S.; Da Feng Weng, "Quasi-Active Power Factor Correction Circuit for HB LED Driver", *IEEE Transactions*
Power Electronics, Volume 23, Issue 3, May 2008, pp.1410 – 1415