Asian Journal of Electrical Sciences
ISSN: 2249-6297 (P) Vol.8, No.S1, 2019, pp.19-24

DOI: https://doi.org/10.51983/ajes-2019.8.S1.2314

Double Integrated-Buck Boost Converter versus Double Integrated-Buck Topology for LED Lamps

Sruthi Damodaran[1], Renjini E Nambiar[2] and Jeanmary Jose[3]
[1,2&3]Assistant Professor, Department of Electrical and Electronics Engineering,
MVJ College of Engineering, Bangalore, Karnataka, India
E-Mail: sruthi.damodharan@mvjce.edu.in, renjininambiar@mvjce.edu.in, jeanmary.jose@mvjce.edu.in
(Received 18 February 2019; Revised 6 March 2019; Accepted 28 March 2019; Available online 7 April 2019)

Abstract - **In this paper a comparative study between two different approaches for LED driving based on the double integrated buck boost and a double integrated Buck converter. It presents a single-stage, single-switch, transformer less ac/dc converter suitable for Led lighting applications. High Brightness Light Emitting Diodes (HB LEDs) can be seriously considered for replacing conventional halogen, incandescent and fluorescent lamps in general illumination including streetlights due to the rapid development in LED technology in recent years. In many offline applications, maintaining a high-power factor and low harmonics are of primary importance. Single stage power factor pre-regulation technology is mainly preferred in cost sensitive applications where power factor regulation is necessary, as adding additional power factor correction controller will surely increase the cost. Here a high-power-factor, long life integrated converter able to supply LED lamps from ac mains is presented. This topology integrates a buck-boost type power-factor correction (PFC) cell with a buck–boost dc/dc converter there by providing the necessary high input power factor and low Total Harmonic Distortion (THD). An isolation transformer increases complexities in the implementation of feedback and control. The proposed topology is non-isolated and hence much simpler in implementation. The main advantage of this converter is that this circuit uses only one controllable switch. The converter is used to provide power factor correction in streetlight application. A Double integrated buck converter finds application in fields of solid-state lighting. Buck Converter is widely used for step down dc-dc conversion when there is no isolation requirement. The narrow duty cycle of the buck converter limits its application for high step-down applications. The double integrated buck converter overcomes its limitation. This converter also provides high power factor and output current regulation. A Double integrated buck converter uses for the offline power supply for LED lighting based on the integration of a buck power factor corrector (PFC) and the tapped buck dc/dc converter having high step-down capability and good output current regulation. Due to the high reliability, the simple structure, and the low component count, the proposed topology effectively results to be very suitable for medium power solid-state lighting applications. From Comparative analysis of two circuits integrated double buck boost converter is found to be more efficient with high power factor and low THD.**
Keywords: **High Brightness Light Emitting Diodes, Discontinuous Conduction Mode, Continuous Conduction Mode, Integrated Double Buck Converter, Integrated Double Buck Boost Converter**

I. INTRODUCTION

Energy efficient lighting is the need of the day and is becoming an area of continuous research. Light-Emitting Diodes are being considered as the next source of the lighting systems. The important advantages of LEDs are reduced maintenance costs and high color rendering index. Hence, color reproduction is much better with LEDs than with LPSV lamps, since the latter emit only in the yellow wavelength. Also HBLEDs do not exhibit either warm-up or restart periods, thus avoiding the need for extra control circuitry. They produce more light for the same electrical power and are long lasting compared to conventional bulbs. In addition to their inherent high efficiency, it has no mercury content, and they possess an extremely long operating life. The main aim of this paper is to present a topology for supplying LED streetlights from an ac source. Since streetlights are powered from an ac source, they must comply with the International Electrotechnical Commission (IEC) 61000-3-2:2005 mandatory regulations in terms of harmonic content and power-factor correction (PFC).

LEDs are available for various colours and white power LEDs are becoming an attractive light Source, due to their high reliability, long life, high color rendering index, and small size. All these features make white LED to override fluorescent and other discharge lamps. Power LEDs are mainly designed for nominal currents of 350mA and more. In new LED lighting applications, many single power LEDs are connected in series to form an LED string. Thus, the additional losses and total power consumption can no longer be neglected. Also, the LED current has to be controlled.

Hence, new LED lighting equipment needs power electronics to avoid additional losses and to control the LED current. So switched mode power supplies are used. These converters are used for all kind of applications today. Mainly DC to DC converters are designed to stabilize their output voltages whereas LEDs require a stabilised output current. High-power LEDs cannot be subjected to reverse voltage. If exposed to such a condition, then failure is certain. Also, high peak currents should be avoided. Thus, an array of LEDs must be supplied from the mains via an AC/DC converter, which protects them from reverse voltage and surges while regulating output current.

II. INTEGRATED TOPOLOGIES

Single stage topology is the simplest active Power factor correction circuit. Single stage converter with PFC increases the stress on the switch in the converter due to input current and PFC voltage, and there is a power balance problem with this topology. Thus, a two-stage converter is needed in order to perform PFC properly and to obtain a fast-enough output dynamics. This system implementation consists of a PFC pre-regulator followed by a dc–dc converter in cascade. This scheme is usually implemented by means of a boost converter for the first stage and forward buck-boost-derived topologies or flyback converters for the output converter. In addition, even buck converters may be used for the former [8] [9]. These topologies are a very good solution, reaching unity power factor and providing fast output dynamics. The disadvantage of two stage converters are high cost and size and the efficiency of the conversion is reduced because the output power is processed twice. A good solution is to implement the integrated single-stage (ISS) converters, which leads to the integration of the PFC stage together with the dc–dc converter. This is achieved by eliminating one transistor and sharing the remaining transistor between the two stages.

Block diagram of integrated single stage converter is shown in Fig.1. These topologies are not only a good solution when HPF is needed but also can provide a fast output dynamic equivalent to that of two-stage PFC converters. In addition, the size of the whole converter is reduced, and therefore, the costs are reduced too. Moreover, the efficiency is usually very high in case of operation under narrow input voltage-range conditions because part of the power is processed only once, or just a small part is processed twice within a single switching period.

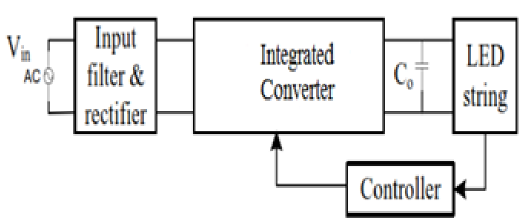

Fig. 1 Integrated single stage converter

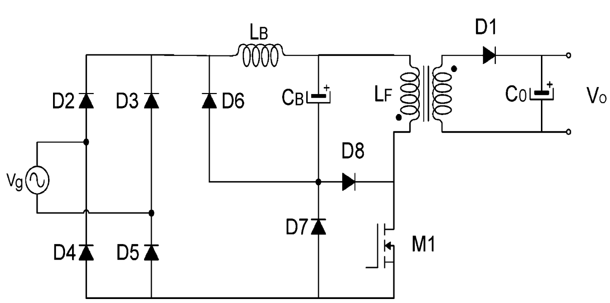

Fig. 2 Integrated buck– flyback ac–dc converter

Fig. 2 shows an integrated buck- flyback ac-dc converter, which is an isolated topology. From the analysis of the above topology THD is found to be 27%. Also, galvanic isolation increases the size, cost and complexity of the converter. Thus, a non-isolated integrated topology is presented in this paper.

III. INTEGRATED DOUBLE BUCKBOOST AND BUCK CONVERTER

In the literature survey single stage and two stage topologies with and without galvanic isolation for led lighting applications were discussed. Galvanic isolation increases size, cost and complexity of the converter. Here two integrated topologies are presented in which two stages are integrated in to one with a single controlled switch which is more suitable for street lighting applications. Former for power factor correction and later supplies power to the led lamp.

Fig.3 shows the circuit diagram of the integrated double buck converter. The purpose is to get a simple, reliable and low-cost power supply, characterized by low voltage operating levels, so as to improve robustness avoiding the use of electrolytic capacitors, and capable of power factor correction, to comply with the harmonic injection and energy saving standards. To reach this goal, the simplest solution to be the use of two buck stages. The first one allows to immediately step down the input line voltage, reducing voltage stresses and improving functional safety, while the second one provides the proper voltage level to feed the LED lamp placed at load side.

The converter behaves as two buck converters in cascade. The input buck converter is made by L1, CB, D1, DA1, DA2 and S, and the output converter comprises C0, D2 and tapped inductor. The integration of two step-down power conversion stages sharing the same controlled switch. The input semi-stage provides PFC, whereas the output semi stage guarantees LED current regulation and light dimming.

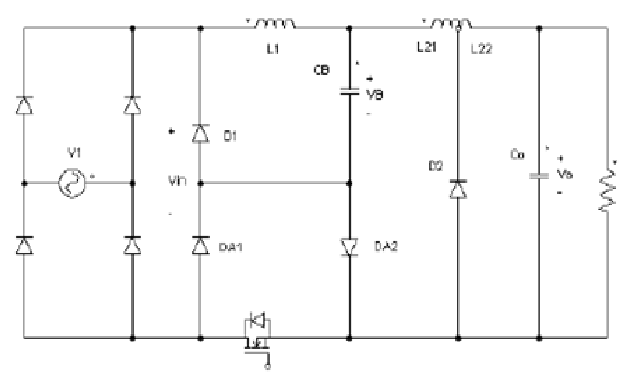

Fig. 3 Schematic diagram of the IDB converter

Fig. 4 shows the (IDBB converter) Integrated Double Buck–Boost (IDBB) converter supplying LED lamps from the ac mains is presented. It consists of two inductors, two capacitors, three diodes, and one ground-referenced controlled switch. It provides high input power factor (PF), low LED current ripple, and high efficiency [10]. Its operation is same as two buck–boost converters in cascade. The input buck–boost converter is made up by Li, D_1, C_B, and M_1, and the output buck boost converter comprises L_O, D_2, D_3, C_o and M_1 in which the controlled switch is shared by the two stages. It is a low cost, single stage, high power factor ac –dc converter with fast output regulation. The reversing polarity produced by the first converter in the capacitor C_B is corrected by the second converter, thereby giving a positive output voltage with respect to ground. This makes the measurement of the load current simple for closed-loop operation, thus reducing sensing circuitry and cost. The output inductance L_0 can be operated either in continuous conduction mode (CCM) or discontinuous conduction mode (DCM). But the operation in DCM presents the disadvantage of higher value of the output capacitance to achieve low current ripple through the load.

The output inductance is operated in CCM, in order to have a reduced value of output capacitance and current ripple. Also, the operation of the second stage in CCM with a duty cycle lower than 0.5 reduces the low-frequency ripples voltage. Thus, film capacitors can be used for output capacitance, thus having a higher life and better efficiency than using electrolytic capacitors. Also, with a careful design, the bus capacitor can also be made low enough to be implemented using film technology, thus avoiding the low-life-rating electrolytic capacitors in the whole converter.

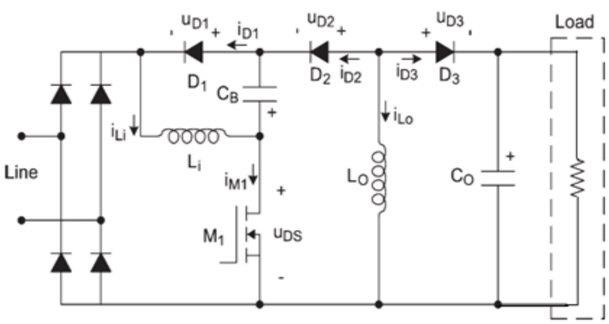

Fig. 4 Schematic diagram of the IDBB converter

The entire operation of the converter with in a switching period is divided in to 3 modes. In mode 1 switch is turned on and the inductor L_i stores energy, thus a large current flow. D_2 is on and C_B supplies L_O. Here L_i and L_o are in charging state. C_o supplies load. In mode 2 switches is turned off. As input inductance L_i is in charged state it discharges and charges bus capacitor C_B. Output inductance L_o supplies C_o and load. t_1 is the time by which current through D_1 that is i_{D1} falls to zero. In mode 3 switches is in off state. As input inductance L_i is a small inductor its charge is over as it is operating in DCM. But output inductance L_o is still in conduction and L_o supplies C_o and load.

V. CONTROL

The converter is operated in closed loop to assure a constant current through the LED array. As HB-LEDs are current-controlled devices, a current control is preferable rather than a voltage control. Otherwise, slight changes in the string forward voltage would lead to great changes in the forward current. The output current is measured and is compared with the current reference thus generating the error signal. A PI controller integrates the error between feedback and reference signal. Compensated error signal is given as the control signal to the pulse width modulator. Here control signal is compared with the repetitive switching frequency triangular waveform and produce pulses which control the switching of the converter.

PWM dimming can be carried out in three ways. That is series dimming, shunt dimming and enable dimming. In series dimming, a series switch is used to interrupt the lamp current as commanded by the dimming signal. Its main drawback is the high electrical stresses generated in the series switch. In Shunt Dimming a switch in parallel to the load to divert the lamp current as commanded by the dimming signal is used. Its main drawback is the dissipation of energy stored in the output capacitor, which reduces the converter efficiency. In Enable Dimming, turning on and off the whole converter is by means of an Enable/Disable input. Enable Dimming is the simplest one.

VI. SIMULATION OF THE SYSTEM

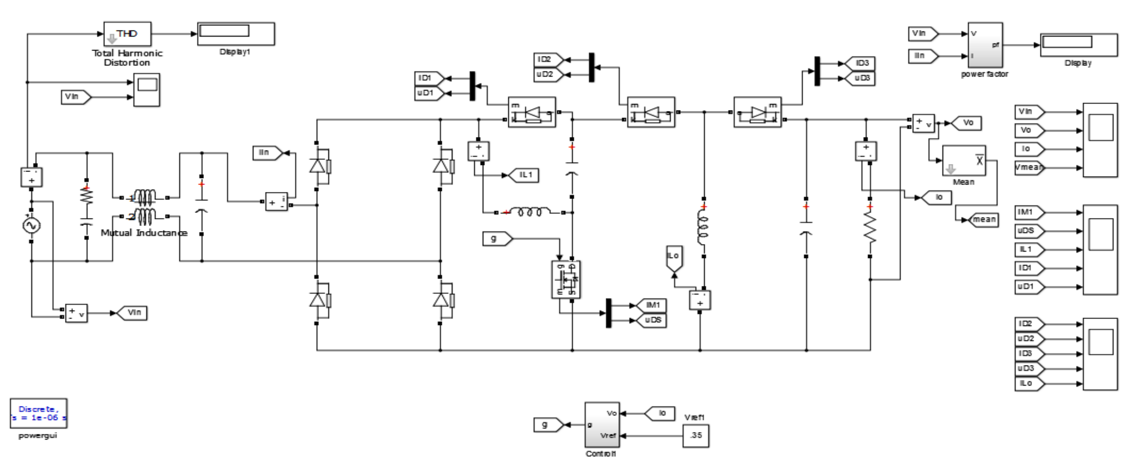

Fig. 5 MATLAB simulation diagram of the closed loop system with EMI filter, diode bridge rectifier, and integrated double buck boost converter

It is assumed that the line voltage is a sinusoidal waveform. For an output power of 70W (60 Led's) and load rated current of 350mA. 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. The simulation of the integrated double buck boost and integrated double buck converter with high step-down capability, output current regulation and high power factor has been carried out and the simulation model is shown in Fig. 6.

The proposed systems have been modeled and simulated using the Mat lab/Simulink/SimPowerSystems environment. Fig. 5 shows the MATLAB simulation diagram of integrated double buck boost converter.

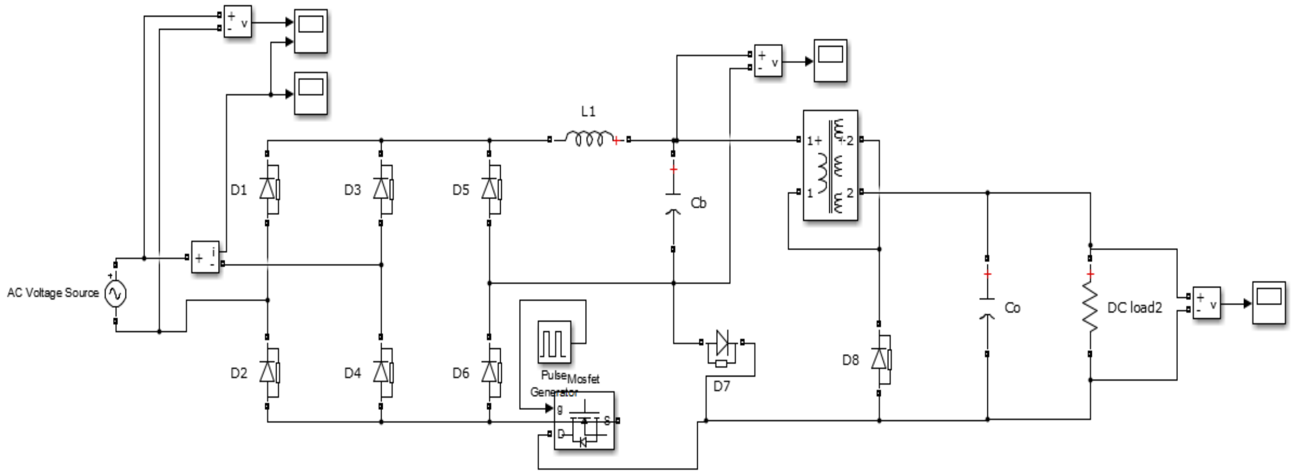

Fig. 6 MATLAB simulation diagram of integrated double buck converter

VII. RESULTS AND DISCUSSION

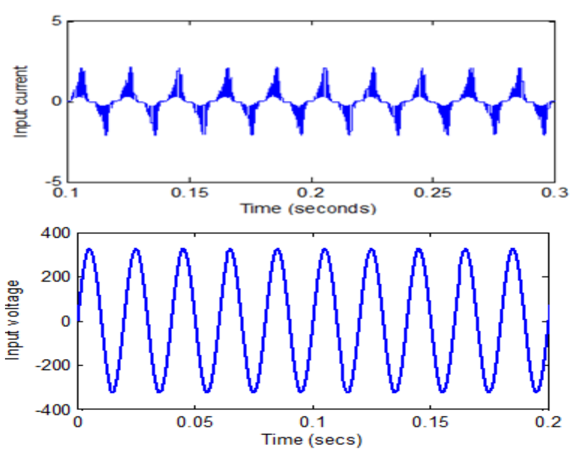

Fig. 7 MATLAB simulation results of input voltage and input current of double integrated buck converter

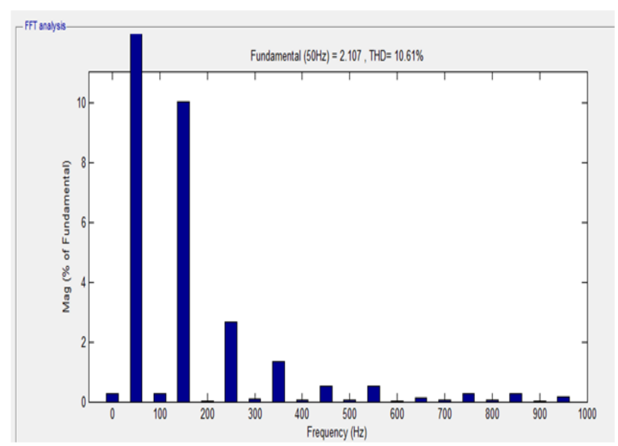

Fig. 9 MATLAB simulation results of measured input current THD of integrated double buck boost converter

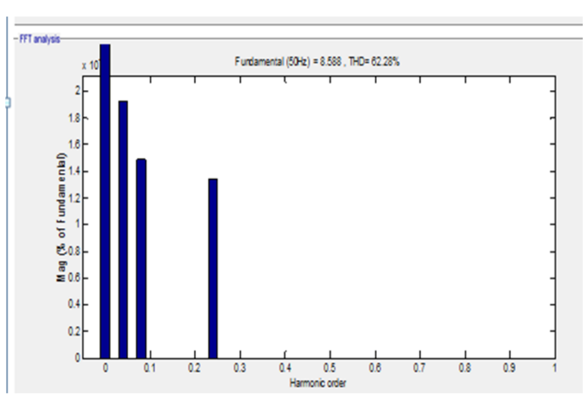

Fig. 8 MATLAB simulation results of measured input current THD of integrated double buck converter

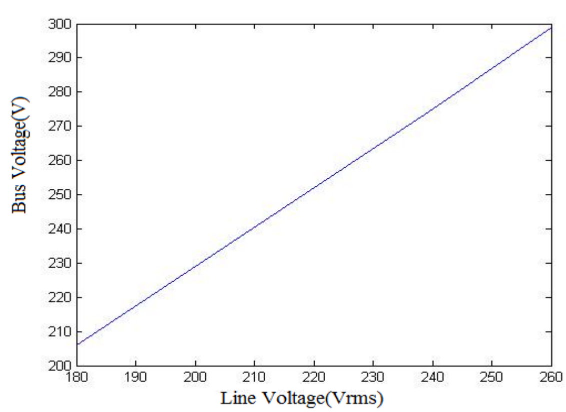

Fig. 10 Bus Voltage as a function of Line Voltage for integrated double buck boost converter

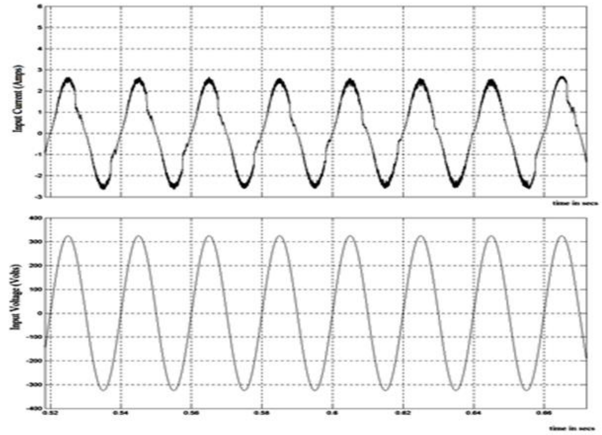

Fig. 11 MATLAB simulation results of input current and input voltage of integrated double buck boost converter

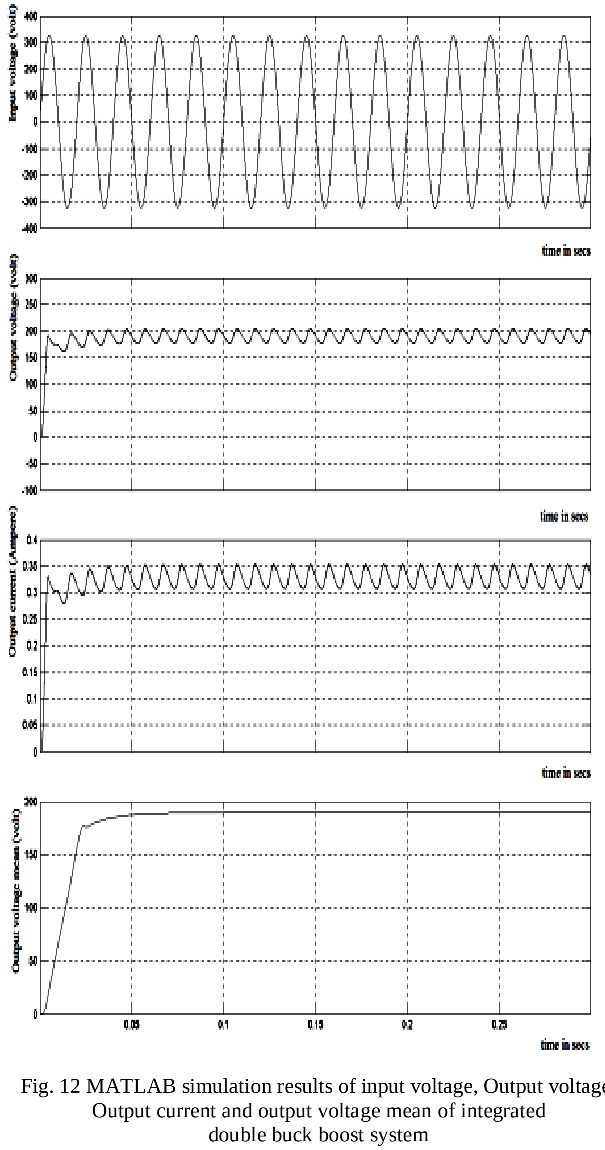

Fig. 12 MATLAB simulation results of input voltage, Output voltage, Output current and output voltage mean of integrated double buck boost system

The input current harmonic content at the nominal line voltage (230V) and output current (350mA) for integrated buck and integrated double buck boost converter is shown in Fig. 8 and 9 respectively. Selected switching frequency is 50 kHz. From the THD spectrum of input current the measured THD is 10.61% for integrated double buck boost and 64.29% for integrated double buck system respectively. From this it is clear that the THD is within the limit of EN61000-3-2 for integrated double buck boost converter. Fig.10 shows the variation of bus voltage with line voltage which must be considered while selecting bus capacitance value for integrated double buck boost converter.

Simulation Results are shown in fig. 7, 8, 9, 10, 11 and 12. Input voltage, Output voltage, output current and Output voltage mean of integrated double buck-boost converter are shown in fig. 12 respectively. Fig. 7 and 11 shows input voltage and current at 230V_{rms} of integrated double buck and double buck boost converter respectively. As can be seen the input current is nearly sinusoidal and the input voltage and currents are in phase. Thus, we get a high-power factor for integrated double buck boost converter and the measured power factor is 0.99. The measured power factor for integrated buck system is 0.85.

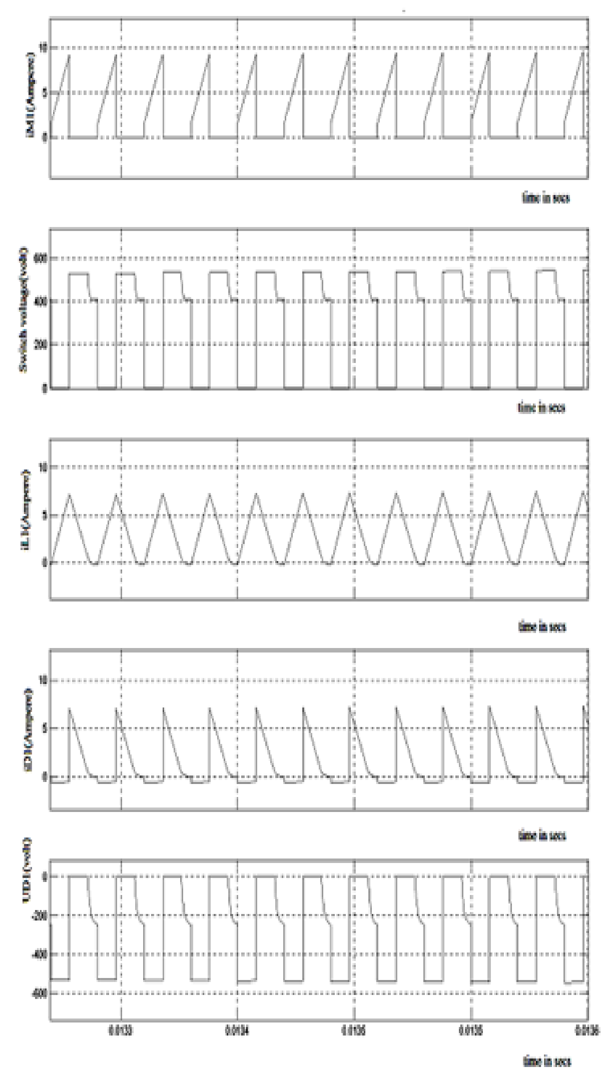

Fig. 13 MATLAB simulation results of Switch current i_{M1} (A), Switch voltage U_{DS} (volt), Inductor1 current i_{L1} (A), Diode1 current i_{D1} (A), Diode1 voltageU_{D1} (volt) for integrated buck boost converter

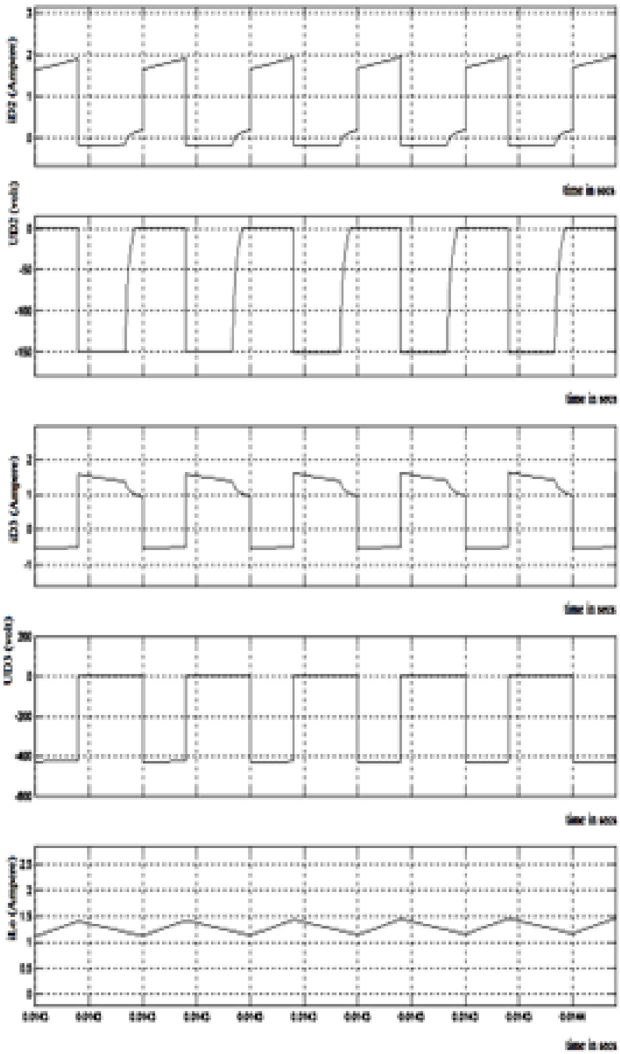

Fig. 14 MATLAB simulation results of Diode2 current i_{D2} (A), Diode2 voltage U_{D2} (volt), Diode3 current i_{D3} (A), Diode3 voltage U_{D3} (volt), Output inductor current i_{Lo} (A) for integrated buck boost converter

TABLE I INPUT VOLTAGE VARIATION (REFERENCE CURRENT 0.35A)

Input Voltage	Bus Voltage	Output Voltage	Power factor	THD	Output Current
220	252	199.8	0.9972	7.23	0.3463
230	264	198.4	0.9922	12.32	0.3438
240	273.9	198.2	0.9886	14.94	0.3435
260	295.3	198	0.9861	16.61	0.3431

TABLE II REFERENCE CURRENT VARIATION

Reference Current	Output Voltage	Power factor	THD	Output Current
0.15	77.52	0.9949	9.67	0.1343
0.25	144.3	0.9871	15.9	0.25
0.35	198.4	0.9922	12.32	0.3528
0.45	260.4	0.9923	12.15	0.4518

Table I shows the variation of bus voltage, output voltage, power factor, THD, and output current with input voltage and Table II shows the variation of output voltage, output current, power factor and THD with reference current for integrated double buck boost converter system.

VIII. CONCLUSION

On comparing different topologies for Led Lighting applications, IDBB converter has been proposed as a low-cost solution for performing PFC in LED Street-lighting applications. Since the converter is formed of two stages integrated in a single one, its dynamics response can be made quite fast. The IDBB converter was analyzed and designed.

By operating the input converter in DCM, a high input PF can be obtained. Operation of the second stage in CCM assures a low-ripple current through the LED load without using a very high output capacitance. Thus, the converter can be implemented using only film capacitors, thereby avoiding the use of electrolytic capacitors. Open loop and closed loop simulations are performed in MATLAB. In closed loop mode suitable controller namely the PI controller was used. The analysis performed lead to the conclusion that the proposed system can effectively provide input high power factor and low THD.

REFERENCES

[1] H. Yuequan and M. M. Jovanovic, "LED Driver with Self Adaptive Drive Voltage", *IEEE Transactions on Power Electronics*, Vol. 23, pp. 3116-3125, 2008.

[2] D. G. Lamar, J. Sebastián, A. Rodríguez, M. Rodríguez, and M. M. Hernando, "A Very Simple Control Strategy for Power Factor Correctors Driving High-Brightness LEDs", *IEEE Transactions on Power Electronics*, Vol. 24, pp. 2032-2042, 2009.

[3] S. Y. R. Hui, S. N. Li, X. H. Tao, W. Chen, and W. M. Ng, "A novel passive off-line light-emitting diode (LED) driver with long lifetime", *presented at Applied Power Electronics Conference and Exposition* (APEC) Twenty-Fifth Annual IEEE, 2010.

[4] D. G. Lamar, J. Sebastian, M. Arias, and A. Fernandez, "Reduction of the output capacitor in Power Factor Correctors by distorting the line input current*", presented at Applied Power Electronics Conference and Exposition (APEC), Twenty-Fifth Annual IEEE*, 2010.

[5] X. Qu, S. C. Wong, and C. K. Tse, "Resonance-Assisted Buck Converter for Offline Driving of Power LED Replacement Lamps", *IEEE Transactions on Power Electronics*, Vol. 26, pp. 532-540, 2011.

[6] W. Jian-Min, W. Sen-Tung, J. Yanfeng, and C. Huang-Jen, "A Dual-Mode Controller for the Boost PFC Converter", *IEEE Transactions on Industrial Electronics*, Vol. 58, pp. 369-372, 2011.

[7] K. I. Hwu, Y. T. Yau, and L. Li-Ling, "Powering LED Using High-Efficiency SR flyback Converter", *IEEE Transactions on Industry Applications*, Vol. 47, pp. 376-386, 2011.

[8] 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 Transactions on Industrial Electronics*, Vol. 58, pp. 589-599, 2011.

[9] Y. Li and C. Chen, "A Novel Single-Stage High- PowerFactor AC-to-DC LED Driving Circuit with Leakage Inductance Energy Recycling", *IEEE Transactions on Industrial Electronics*, Vol. 59, No. 2, pp. 793-802, Feb. 2012.

[10] 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 Transactions on Industrial Electronics*, Vol. 59, No. 4, April 2012.