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PFC of Fluorescent Light using Buck-Boost Converter based Electronic Ballast

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ABSTRACT: For the better performance of a system, power factor correction is very essential. For a given power requirement if the power factor of the system is poor, then it will draw a large amount of current from the supply. In order to avoid this, power factor correction is required. The power factor correction can be done by two methods; they are active and passive method. The active method of power factor correction is more efficient. The active method of power factor correction can be done by the use of converters. In the case of fluorescent lighting the power factor correction can be done using different converter topologies, such as buck, boost, buck-boost, cuk etc. The buck-boost converter based PFC is explained in this paper. It covers the simulation and analysis of buck-boost converter based electronic ballast.

KEYWORDS: Power Factor Correction, Zero Voltage Switching, Zero Current Switching, Pulse Width Modulation.

I.INTRODUCTION

In artificial lighting the Fluorescent Lamps are most commonly used because of its better luminous efficiency, reduced losses and longer life as compared to incandescent lamp. The fluorescent lamp is a low pressure mercury-vapour gas-discharge lamp. It consists of a glass tube which is filled with argon and mercury vapours. Also the fluorescent lamp consists of two electrodes that are placed at each end of the tube. It uses fluorescence to produce visible light. When electrical current passes through the lamp, the mercury is vaporized and produces ultraviolet light. The phosphor coating inside the lamp absorbs the ultraviolet light and it re-radiates the visible light. The fluorescent lamps require a ballast to provide the starting voltage and limit the electrical current through the lamp. For residential lighting, two types of ballasts are commonly available: magnetic ballast and electronic ballast. Electronic ballasts are more energy-efficient than magnetic ballasts. It has the advantages of smaller in size, weightless, quieter operation, and reduction of flicker. The fluorescent lamp cannot be connected directly to the voltage source because it has negative resistance characteristics inherently in its operating region. Because of this, the lamp will damage if it is connected directly to the source. To avoid this electronic ballast is required. The ballast has two functions; first one for necessary discharge inside the lamp, provide sufficient ignition voltage. And second one is to maintain constant current after the ignition. The electronic ballast may have some problems such as poor power factor and large total harmonic distortion (THD). To avoid this power factor corrected electronic ballast is used. The power factor correction is done either by passive or active methods. The active power factor correction technique is most commonly used. Since passive technique is bulky and provide limited amount of power factor improvement, it is not widely used. The active power factor correction is achieved by the use of converters. Boost and buck-boost are commonly used converter topologies for power factor correction. The buck-boost converter has less inrush current problem as compared with boost converter. It has many advantages such as reduced size, weight and cost of inductor and capacitor. The buck-boost converter based electronic ballast has two stages, first one is converter section and the second is inverter section. By controlling the switching action of converter switch the power factor can be improved. The power factor is a measure of how effectively an electrical load converts power into useful work. It is the ratio of active power to apparent power. By improving the power factor the THD is reduced, since the THD is inversely proportional to the power factor. So the harmonics can be reduced in the system. In this buck-boost converter based electronic ballast the power factor can be improved by the switching action of the converter and by this the THD can be reduced and the efficiency of the system is increased.

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II.BUCK-BOOST CONVERTER BASED ELECTRONIC BALLAST

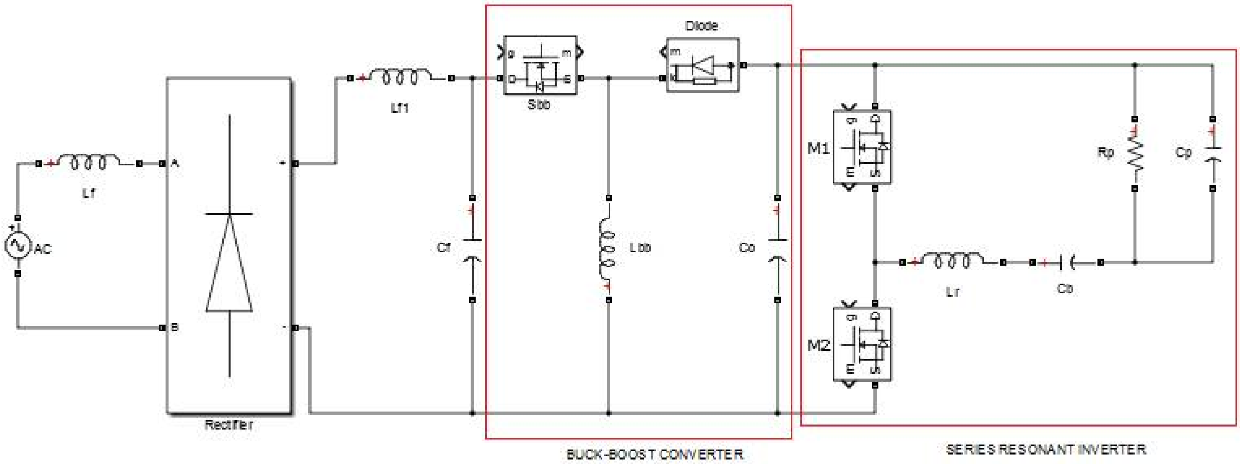

Fig.1: Buck-boost converter based electronic ballast

The fig.1 shows the circuit diagram of buck-boost converter based electronic ballast. The ac voltage is applied to the converter circuit through a diode bridge rectifier. A filter circuit is also placed before the converter section. The output of the buck-boost converter is dc. In order to given this signal to the lamp a series resonant inverter is used for converting this signal to ac.

Operation of resonant inverter

The operating modes and the resonant inverter are shown below. It consists of 4 modes. The sinusoidal input voltage is considered as constant in each switching cycle, since the switching frequency is much higher than the line frequency.

Mode 1($t_0 < t < t_1$)

Fig.2 shows the mode –1 operation.

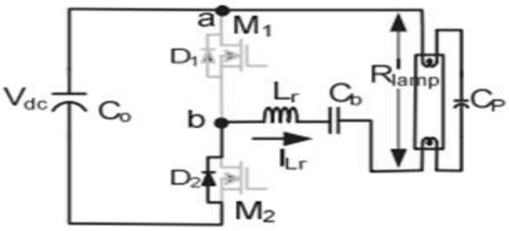

Fig.2: Mode 1

At t_0, body diode D_2 starts conducting and the dc link capacitor is charged and during this interval the gate pulse (S_2) is also applied to active switch M_2.The path of current is given.

$$C_0 \Rightarrow D_2 \Rightarrow L_r \Rightarrow C_b \Rightarrow (R_{lamp}||C_p) \Rightarrow C_o$$

Mode 2($t_1 < t < t_2$)

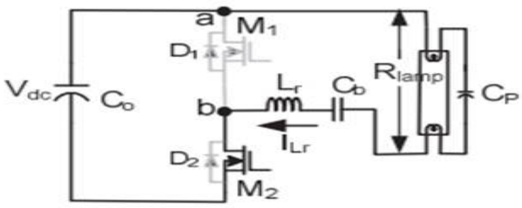

Fig.3: Mode 2

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The above fig.3 Shows the mode 2 . At t_1 MOSFET M_2 is turned on at ZVS-capacitor discharged-direction of inductor current changes Current path is given by,
$C_o \Rightarrow (R_{lamp}||C_p) \Rightarrow C_b \Rightarrow L_r \Rightarrow M_2 \Rightarrow C_o$

Mode 3($t_2 < t < t_3$)

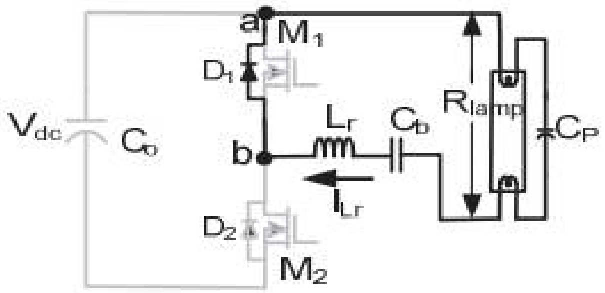

Fig.4: Mode 3

MOSFET M_2 is turned off at t_2 - diode D_1 starts conducting- current flow in the same direction due to resonant nature of the circuit. During this interval the gate pulse (S_1) is also applied to active switch M_1.
The path of the current is,
$D_1 \Rightarrow (R_{lamp}||C_p) \Rightarrow C_b \Rightarrow L_r \Rightarrow D_1$

Mode 4($t_3 < t < t_4$)

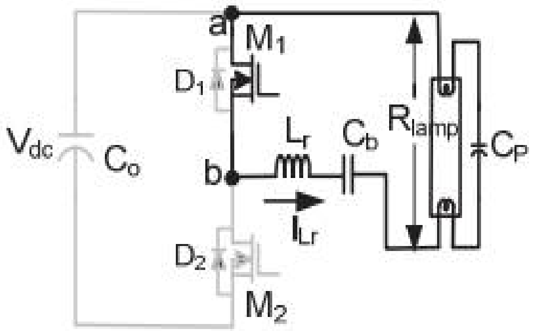

Fig.5: Mode 4

At t_3 the MOSFET M_1 starts conducting and it is evident that it is tuned on at ZVS, This ensures the change in the direction of the resonant current. The path of current is given. This mode ends up at t_4 and then mode-1 to mode -4 repeat for the next switching cycle.

$M_1 \Rightarrow L_r \Rightarrow C_b \Rightarrow (R_{lamp}||C_p) \Rightarrow M_1$

It is shown from the different operating modes over a switching cycle of the above circuit that both MOSFETs (M_1 and M_2) are operating at zero voltage switching (ZVS). Moreover, to achieve zero voltage switching (ZVS) operation of both active power switches the necessary condition is that the inverter circuit must operate at lagging power factor. Hence switching frequency should be kept more than the resonant frequency of the inverter (i.e $f_s > f_r$) , such that the resonant circuit behaves as inductive circuit. The theoretical waveform of resonant inverter stage is given in fig.6 [6],

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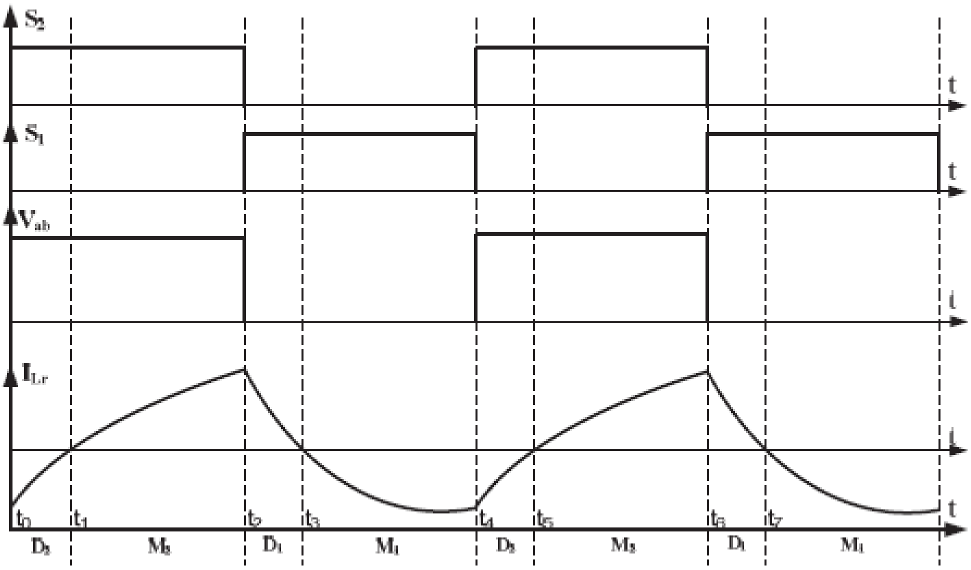

Fig.6: Theoretical waveforms of series resonant inverter of the electronic ballast

III.SIMULATION

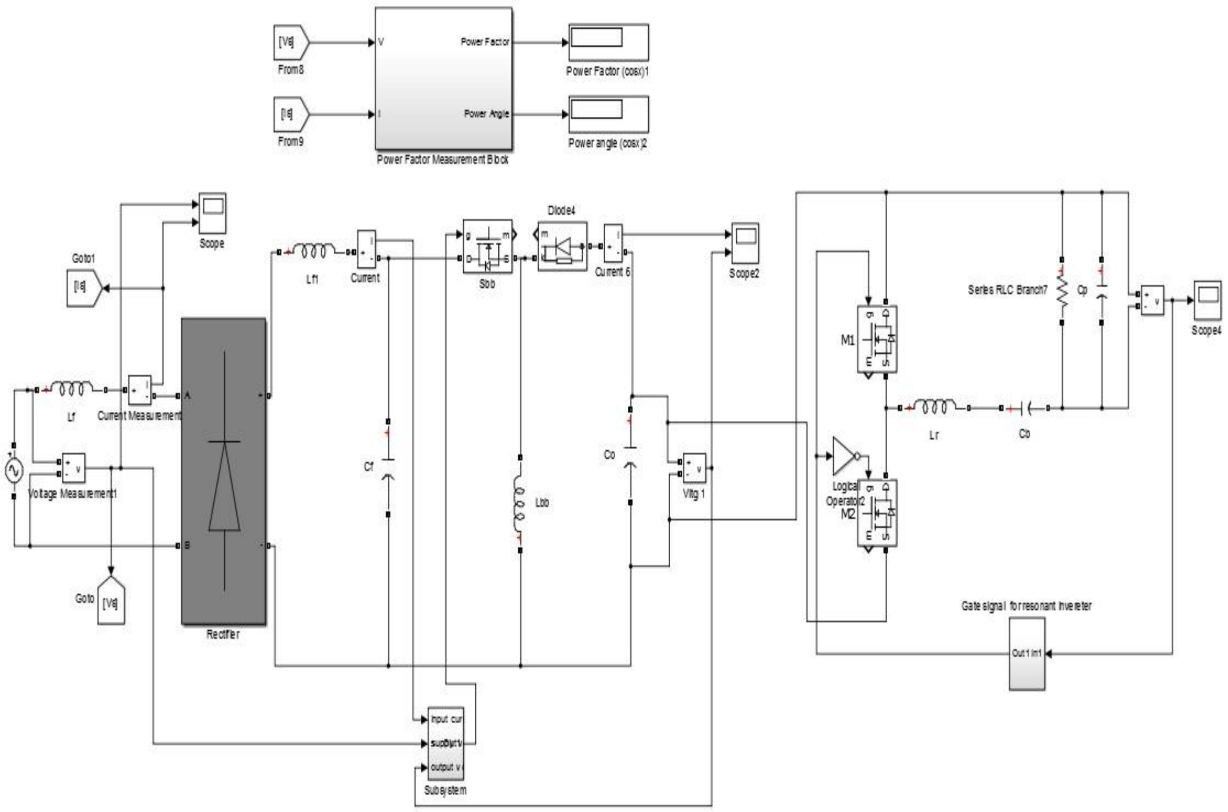

Fig.7: Simulation diagram of buck-boost converter based electronic ballast

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Power factor measurement block

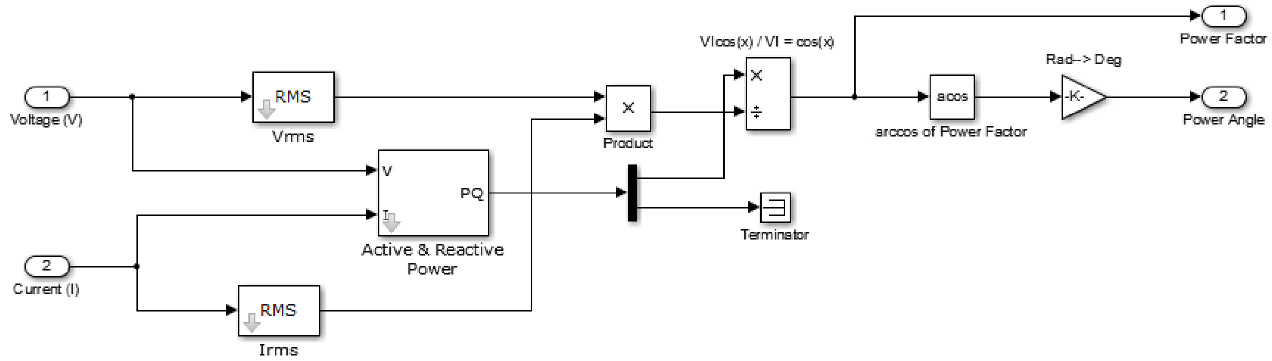

Fig.8: Power factor measurement block

Fig.8 shows the power factor measurement block. The input power factor of power factor corrected electronic ballast can be improved close to the unity. From the figure we can see that the input current and voltage are taken for the power factor correction. The power factor is defined as the ratio of actual power to the apparent power. Here the actual power and apparent power are obtained using MATLAB blocks and the power factor and power angle is also obtained.

IV.SIMULATION RESULTS

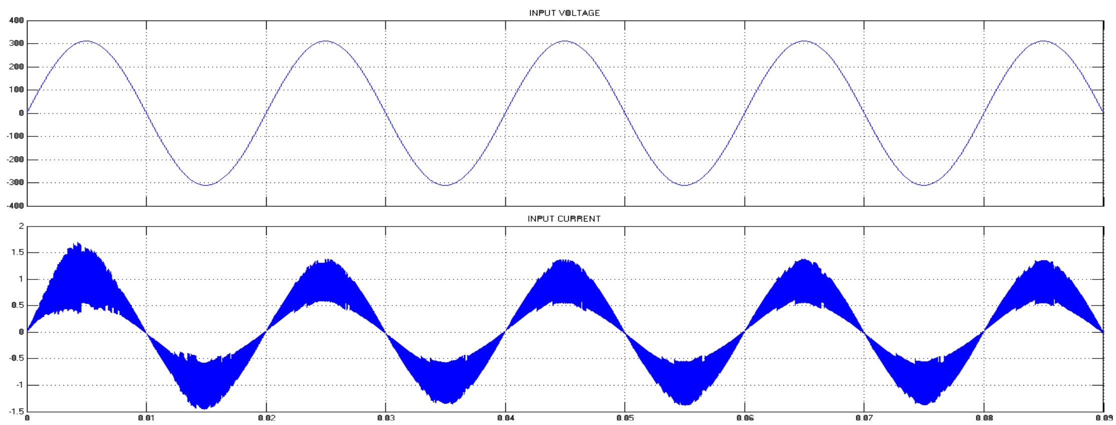

Fig.9: Input voltage and input current waveform

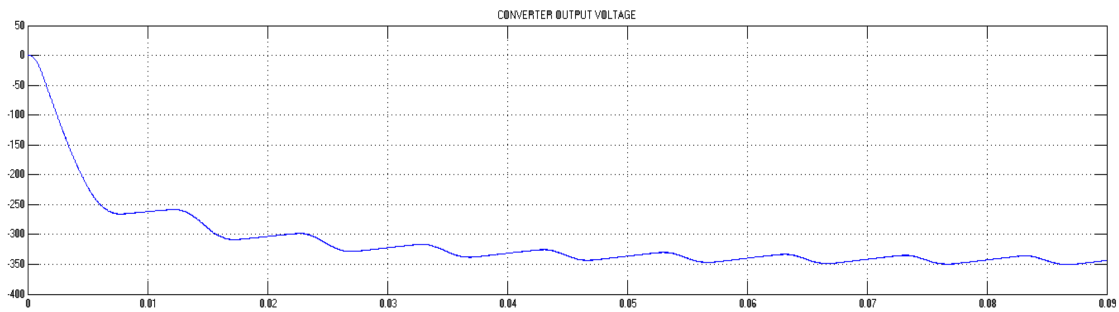

Fig.10: Converter output voltage waveform

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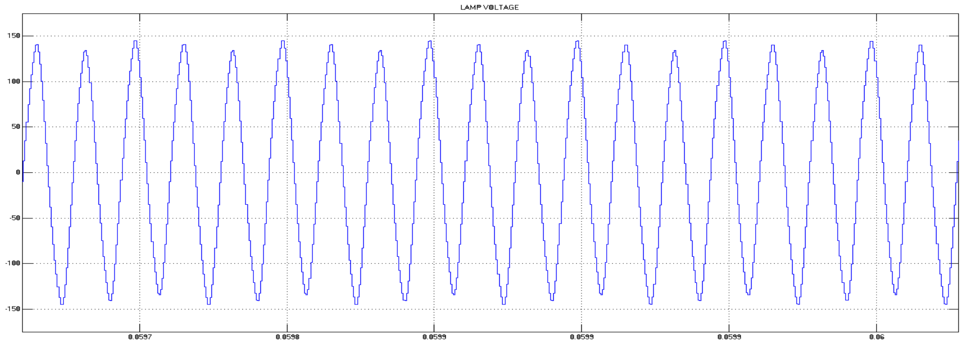

Fig.11: Voltage across Lamp

V.CONCLUSION

Power factor is a very important parameter. It is a measure of how effectively an electrical load converts power into useful work. It is defined as the ratio of actual power to the apparent power. Power factor correction can be achieved using passive and active techniques. Active PFC techniques is considered better than passive PFC technique, passive technique is bulky and provides limited level of power quality improvements, however, active PFC converter design and its proper control are little complicated as compared to the passive approach. Various converter topologies used for power factor correction, such as buck, boost, buck-boost and cuk. Here buck-boost converter based electronic ballast is explained. From the simulation analysis we arrived at the result that the power factor is improved and also THD is reduced.

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