Analysis and Simulation of CFL Ballast circuit With MOSFET &IGBT based Inverters

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ABSTRACT:-

This paper discusses a method for switching device selection for CFL ballast to determine the best overall output with reduced switching losses at higher frequencies.The inputs to selection process are lamp power, expected product life, and a range of semiconductor devices that satisfy electrical requirements of conventional, half bridge series resonant ballast topology.The selection process is illustrated on the example of N-channel MOSFET pair and a pair of IGBTs. While this paper addresses switching device selection for CFL applications, the approach is more universal and it can be implemented to guide switching device selection in order to minimize cost for other electronic equipment as well. A systematic approach is developed to produce a compact fluorescent lamp model using Matlab/Simulink.

Keywords:-CFL, MOSFET, IGBT, GTO, BALLAST, DIMMING, SIMULATION.

INTRODUCTION:-

Compact fluorescent lamps (CFLs) are replacing incandescent light bulbs at a rapid rate due to their tremendous energy savings and longer lifetime. Additional energy savings can be achieved by dimming, but the electronic ballast required to control the lamp has a higher cost and is difficult to design.This article explains how CFL works under different switching devices like MOSFET & IGBT. High-frequency operation of fluorescent lamps is a technique with increasing use, with the objective of upgrading the quality of fluorescent lighting systems. It is well known that fluorescent lamps operating at high frequencies present a higher luminous efficacy. The low operating frequency also causes light flickering, and it is impossible to implement dimming operations with a magnetic ballast. As a result, electronic ballast becomes the most suitable candidate to be used in CFL applications. Since fluorescent lamps present a negative resistance characteristic, a current controlling ballast is necessary, in order to limit de discharge current. Computational fluorescent-lamp models, which accurately simulate the real behaviour of fluorescent lamps, became extremely necessary. These high-frequency fluorescent-lamp models are used for optimization studies on conception of electronic ballasts. Traditionally, CFL models are implemented incircuit-simulation programs, such as SPICE-basedprograms. In this paper the chosen environment isMatlab/Simulink,which allows more complicated and intensivemathematical calculations, providing a full new horizonin terms of simulating this type of fluorescent lightingsystems.The simulation of a fluorescent lighting system whichincludes an electronic ballast with wide dimming range . Electronic ballasts with dimmingare increasingly used. This dimming capability may beachieved by several techniques. One of the most commonis based on the control of the inverter frequency thatfeeds the series-resonant parallel load which includes thefluorescent lamp. Here , it is presented how the implementation of the compact fluorescent-lamp model is done, and compares simulation results with the ones experimentally obtained, in order tovalidate this Matlab-Simulink implementation of themodel.

The compact fluorescent lamp ballasts, where most circuits utilize a similar half-bridge series-resonant inverter arrangement, the objective is to reduce component cost, while meeting product life and regulatory requirements. One variable that is being optimized to reduce ballast cost is its switching frequency. The frequency selection has a direct impact on cost of reactive components and cost of switching devices. The cost of reactive components decreases with frequency up to 150 kHz, an upper frequency bound limited by electromagnetic interference (EMI) regulatory concerns.. Hence, in addition to meeting electrical requirements, the selection of semiconductor devices is a tradeoff between minimizing cost of reactive components (by increasing frequency) and switching device cost.

BASIC OPERATION :-

Fluorescence is the conversion of ultraviolet (UV) light to visible light. Electrons flow through the fluorescent lamp and collide with mercury atoms, causing photons of UV light to be released. The UV light is then converted into visible light as it passes through the phosphor coating on the inside of the glass tube.

This two-stage conversion process is much more efficient than incandescent lamp process, resulting in 25% of the total energy consumed used to generate light, lower lamp temperatures (40° C) and longer lifetime (10,000 hours). The lamp load itself is resistive, but the electronic ballast that is connected between the AC line voltage and the lamp for controlling the lamp current is a capacitive load.

The electronic ballast circuit block diagram (Figure 1) includes the AC line input voltage (typically 120 VAC/60 Hz), an EMI filter to block circuit-generated switching noise, a rectifier and smoothing capacitor, a control IC and half-bridge inverter for DC to AC conversion, and the resonant tank circuit to ignite and run the lamp. The additional circuit block required for dimming is also shown; it includes a feedback circuit for controlling the lamp current.

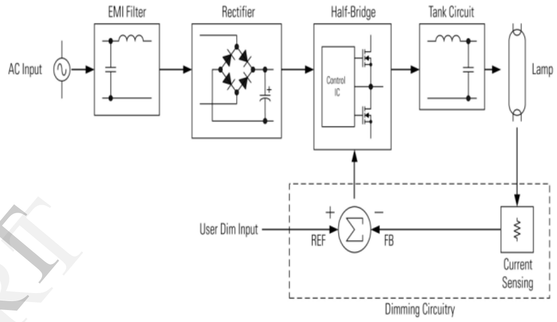

Figure 1:- CFL electronic ballast blockdiagram

The lamp requires a current to preheat the filaments, a high-voltage for ignition, and a high-frequency AC current during running. To fulfill these requirements, the electronic ballast circuit first performs a low-frequency AC-to-DC conversion at the input, followed by a high-frequeny DC-to-AC conversion at the output.

The AC mains voltage is full-wave rectified and then peak-charges a capacitor to produce a smooth DC bus voltage. The DC bus voltage is then converted into a high-frequency, 50% duty-cycle, AC square-wave voltage using a standard halfbridge switching circuit. The high-frequency AC square-wave voltage then drives the resonant tank circuit and becomes filtered to produce a sinusoidal current and voltage at the lamp.

During pre-ignition, the resonant tank is a series-LC circuit with a high Q-factor. After ignition and during running, the tank is a series-L, parallel-RC circuit, with a Q-factor somewhere between a high and low value, depending on the lampdimming level. When the CFL is first turned on, the control IC sweeps the half-bridge frequency from the maximum frequency down towards the resonance frequency of the high-Q ballast output stage. The lamp filaments are preheated as the frequency decreases and the lamp voltage and load current increase (Figure 2).

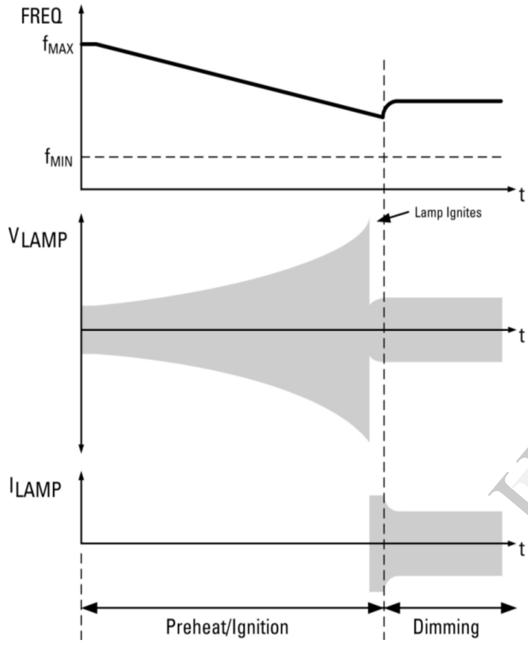

Figure 2:- CFL operation timing diagram

The frequency keeps decreasing until the lamp voltage exceeds the lamp ignition voltage threshold and the lamp ignites. Once the lamp ignites, the lamp current is controlled such that the lamp runs at the desired power and brightness level. To dim the fluorescent lamp, the frequency of the half-bridge is increased, causing the gain of the resonant tank circuit to decrease and therefore lamp current to decrease. A closed-loop feedback circuit is then used to measure the lamp current and regulate the current to the dimming reference level by continuously adjusting the half-bridge operating frequency.

DESCRIPTION& CHARACTERISTICS OF PROPOSED BALLAST CIRCUIT :-

To design a low-cost and small-size high-powerfactor electronic ballast circuit for CFLs, the design objective is to reduce the number of active components (i.e., diode and MOSFET) in the power circuit. A typical electronic ballast configuration consisting of a high power factor converter stage and a resonant inverter is shown in Fig. 3. AC input of 220V 60Hz is fed to the converter and then rectified output is fed to series resonsntinverter based on MOSFET & IGBT's.

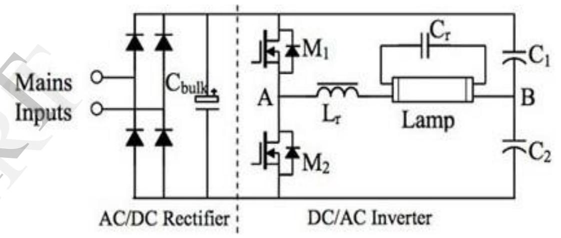

Figure 3:- simplified model of proposed ballast

$L_r$and C_r makesthe resonant circuit across the CFL load.

Characteristics of Resonant Circuit:-

The basic characteristics that define theresonant circuit are provided in this section. The cornerfrequency (*fo*) and the quality factor (*Q*) are defined as (1) and (2), respectively

$$f=\frac{1}{2\pi\sqrt{Lr\ Cr}} \quad (1)$$

$$Q=\frac{\omega o\ Lr}{R\ lamp} \quad (2)$$

$$Z_o=\frac{\sqrt{Lr}}{\sqrt{Cr}}=QR_{lamp} \quad (3)$$

The resonant inverter stage employs a singleinput inductor (L_1) current-source resonant inverter thatconsists of a resonant inductor (*Lr*) and a parallelcapacitor (*Cr*) to form the corner frequency, as given in(1). The parallel inductor is the starting inductorthat provides sufficient high voltage to ignite the lamp.It also helps to reduce the circulating current in theresonant tank by providing more current to flow to thelamp at the desired switching frequency. Equation (2)gives the equation for the *Q*-factor of the proposedresonant circuit. By selecting high-enough *Q*value in theresonant circuit, close-to-sinusoidal waveforms areachieved at the output, and fundamental approximationcan be applied. The characteristics impedance (*Zo*)of the resonant circuit is also defined, as in (3), to relate the quality factor and the lamp resistance. Before the lamp is ignited, the lamp resistance is infiniteand the output of the resonant circuit can be modeled as an open circuit.

SIMULATION AND RESULT:-

The CFL ballast parameters are given below

V_s	R_1	L_1	C	L_r	$\mathbf{C_r}$
220v	2.2Ω	330µH	47µF	760µH	15nF

Table 1:- Ballast parameter

CFL BALLAST WITH MOSFET:-

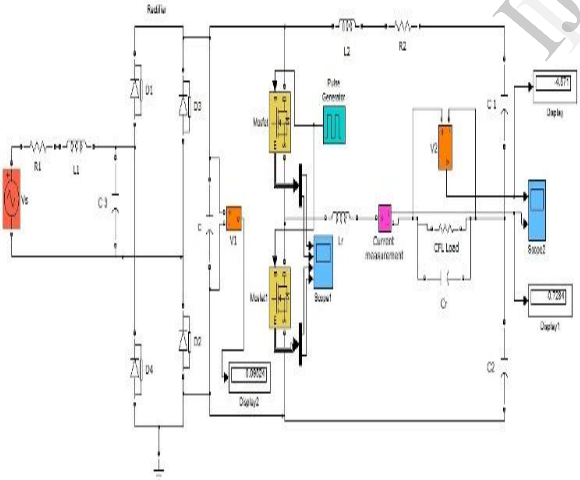

Figure 4:- proposed ballast

Now Vs, Ic, Vc, V_{load},I_{load}, I_{cr}has been traced for MOSFET & IGBT based CFL ballast (Fig 5 & 6) respectively.

MULTIMETER OUTPUT FOR MOSFET BASED INVERTER:-

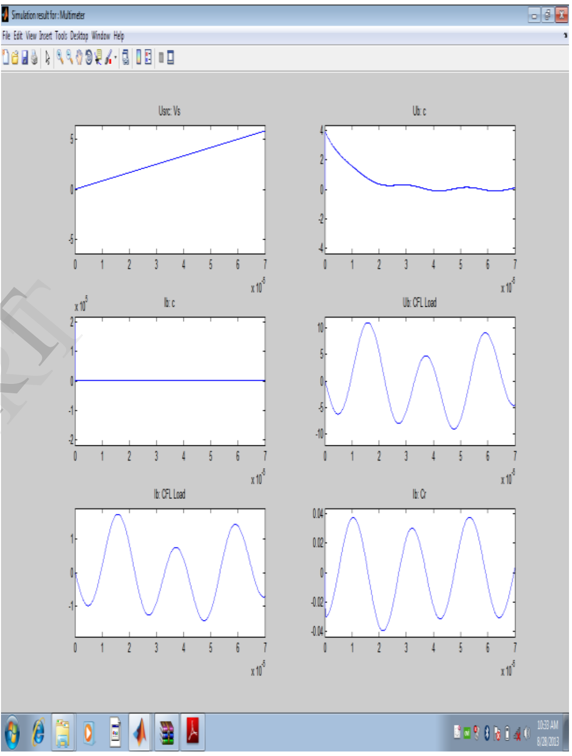

Figure 5

MULTIMETER OUTPUT FOR IGBT BASED INVERTER:-

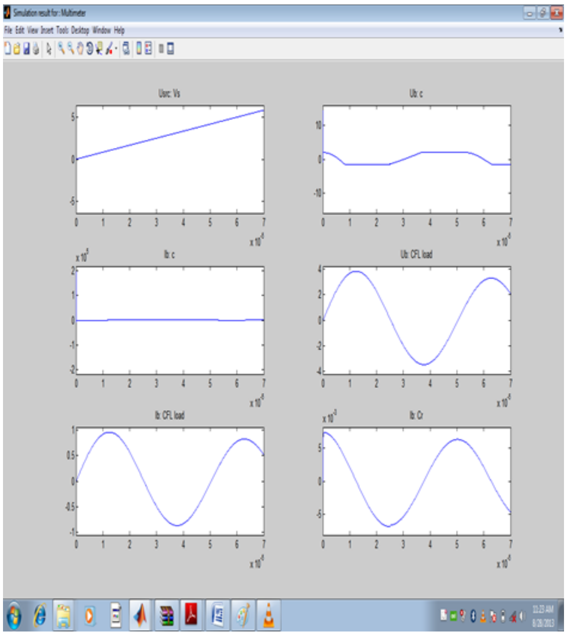

Figure-6

Parameter	MOSFET based	IGBT based
Vs	220V	220V
Input frequency	60Hz	60Hz
Vc	0.09524V	0.6374V
I_{load}	0.7284A	0.7478A
V_{load}	4.571V	2.973V
Output frequency	40KHz	25KHz

Table 2:- simulation result

COMPARSION OF IGBT WITH MOSFET

1. With rise in temperature, the increase in on-state resistance in MOSFET is much pronounced than it is in IGBT. So, on-state voltage drop is more dominant in MOSFET with rise in temperature.

2. With rise in voltage rating, the increment in on-state voltage drop is more dominant in MOSFET than in IGBT. This means IGBTs can be designed for higher voltage ratings than MOSFETs.

3. MOSFET are more suitable for higher frequency operation whereas IGBT are more suitable for higher voltage & current operation because at higher voltage rating MOSFET has more conduction losses.

4. In MOSFET turn-off process is initiated soon after the removal of gate pulse and its turn-off is complete whereas IGBT turn-off time consists of three intervals viz.

5. delay time, initial fall time & final fall time and overall turn-off time is about 0.25 to 20µs.

CONCLUSION & FUTURE SCOPE :-

In this paper, the simulation of CFL ballast circuit is performed using MATLAB with MOSFET and IGBT as a switching device and the corresponding output voltage and current has been traced. From the *Table 2* we see that output frequency in case of MOSFET based inverter is more than that of IGBT. This high operating frequency avoid light flickering. By selecting high Q factor in the resonant circuit close-to-sinusoidal waveform has been achieved. Improving efficiency and reducing switching losses, cost as well as harmonics is a major challenge due to practical limitation of different switching devices. Consideration of maximum permissible junction temp for different devices is a good choice for future research to determine reliability of an electronic ballast.

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