Analysis of Electronics Control System of CFL Lamp

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Abstract

Energy saving has now become the major performance parameter for all the areas of engineering. Artificial lighting is one of the area where volume of energy consumption is very high. Various types of lamps are developed to get the energy efficient light output. Compact Fluorescent Lamp (CFL) is one of the lamp used in artificial lighting system. An electronic control system is required drive CFL. The objective of this paper is to give the working of electronic control system of CFL.

Keywords: Artificial light, Electronic control system, Power Electronics, CFL, Energy saving

I. INTRODUCTION

Over the years, the various advantages of Electronic ballasts over their counterparts along with advancements in the power electronics sector fuelling their cost-reduction has made them highly popular in domestic as well as industrial arenas[1]. The higher efficiency of fluorescent lamps supplied at high frequency provides significant energy savings when compared to incandescent lamps [2-3]. A typical application is the use of compact fluorescent lamps with the electronic ballast inside the lamp base, which can directly substitute for an incandescent lamp, reducing the energy consumption by a factor of 4 or 5 [4-5]. A half-bridge inverter is typically used in these energy-saving lamps, since it allows reduced size and cost [6-10]. The power of these lamps is normally below 25W. The average rated life of a CFL is between 8 and 15 times that of incandescent. CFLs typically have a rated lifespan of between 6,000 and 15,000 hours, whereas incandescent lamps are usually manufactured to have a lifespan of 750 hours or 1,000 hours [11-12]. Some incandescent bulbs with long lifetime ratings have been able to trade voltage for lifespan, slightly reducing light output to significantly improve the rated number of hours. The lifetime of any lamp depends on many factors including operating voltage, manufacturing defects, exposure to voltage spikes, mechanical shock, frequency of cycling on and off, lamp orientation and ambient operating temperature, among other factors. The life of a CFL is significantly shorter if it is only turned on for a few minutes at a time: In the case of a 5-minute on/off cycle the lifespan of a CFL can be up to 85% shorter, reducing its lifespan to “close to that of incandescent light bulbs”. The US Energy Star program suggests that fluorescent lamps be left on when leaving a room for less than 15 minutes to mitigate this problem.

Solid-state lighting has already filled a few specialist niches such as traffic lights and may compete with CFLs for house lighting as well. LED lamps presently have efficiencies of 30% with higher levels attainable. LEDs providing over 150lm/W have been demonstrated in laboratory tests, and expected lifetimes of around 50,000 hours are typical. The luminous efficacy of available LED fixtures does not typically exceed that of CFLs. Everyday operating temperatures are usually higher than those used to rate the LEDs, their driving circuitry loses some power, and, to reduce costs, LEDs are often driven at their brightest rather than their most efficient point.

The main objective of this paper to give an overview of electronic control system for CFL lamps.

II. ELECTRONIC CONTROL SYSTEM OR ELECTRONIC BALLAST

In a fluorescent lighting system, the ballast regulates the current to the lamps and provides sufficient voltage to start the lamps. Without a ballast to limit its current, a fluorescent lamp connected directly to a high voltage power source would rapidly and uncontrollably increase its current draw. Within a second the lamp would overheat and burn out. During lamp starting, the ballast must briefly supply high voltage to establish an arc between the two lamp electrodes. Once the arc is established, the ballast quickly reduces the voltage and regulates the electric current to produce a steady light output.

To achieve full rated light output and rated lamp life from a fluorescent lighting system, ballast’s output characteristics must precisely match the electrical requirements of the lamps it operates. The ballasts are designed to operate tubular fluorescent lamps or compact fluorescent lamps as the case may be, at a specific voltage and power. Thus, to find ballast compatible with a particular luminaire (light fixture), lamp type, power rating, and line voltage must be known.

A fluorescent lamp consists of a cylindrical glass tube, coated on the inside with fluorescent phosphors. Each fluorescent tube contains a minute dose of either mercury or amalgam and a mixture of inert gases, such as argon and krypton or neon and argon. At either end of the tube are electrodes (cathodes) which pass an electrical charge from one end to the other, exciting ions in the process. As these ions pass down the tube, they collide with particles of mercury and produce ultraviolet radiation. This in turn radiates onto the phosphor coating which produces visible white light. Colour temperature and colour rendering can be determined by the phosphor mix coating on the inside of the tube, Fig. 1.
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A. Main Power
This block actually contains EMI filter. EMI can be in form of conducted EMI, which means the noise travels along electrical conductors, wires, printed-circuit traces, or it can be in the form of radiated EMI. Radiated are those who travel through air or free space.

B. Power factor correction rectifier
This block does power factor correction. Power factor correction circuit is also called as Valley fill circuit. There can be losses due to the introduction of power factor. Power factor correction can be done by increasing the charge time of capacitors. In ballast we mainly use this method only, i.e. by increasing the charge time of capacitors. Rectifier is used to convert AC into DC. Actually ballast is nothing but an AC to AC converter. This is done in two parts. First we are converting AC into DC and then again from DC to AC. The only change is in the frequency.

C. Inverter
In this we are converting DC again to AC. However the frequency is increased by switching the two transistors Fig. 2.

III. CONTROL CIRCUIT OF ELECTRONIC BALLAST FOR CFL LAMPS
A discharge fluorescent lamp normally exhibits negative resistance characteristics in its operation region. Therefore, it can be roughly operated under open-loop control. If it is directly connected to a voltage source high enough to produce ionization, the discharge will cause overcurrent. Hence, it requires a current-limiting device, the ballast. Filaments could be employed, but the ballast efficiency is seriously degraded. Traditionally, leakage transformers or choke coils are utilized as ballasts. However, their size and weight are considerable and efficiency still deserves improvement.

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Fig. 3(a) shows the circuit scheme of a half-bridge inverter. Under inductive loads, it features the function of zero voltage-switching and clamped-voltage (ZVS-CV). Namely, the reverse-recovery problem of freewheeling diodes can be avoided and the turn-off loss of transistors can be reduced by two transition capacitors [6]. Basically, two transition capacitors are in parallel when both transistors are off. They can be merged into one capacitor and placed in parallel to either one of the transistors. Similarly, two dc capacitors are in parallel when one switch conducts; they also can be merged into one capacitor and connected to either rail of the dc bus. Fig. 3(b) shows the circuit alternatives with dot lines. To obtain the ZVS operation, the series-parallel resonant network should be inductive in nature. Also, the switching frequency of the half-bridge inverter should be higher than the resonant frequency that forms the boundary between capacitive and inductive loads.

A. Principle of Operation
The operation of an electronic ballast follows 3 stages: preheat, ignition and run modes.

1) Preheat
During preheat, the lamp filaments must be preheated at the right emission temperature to guarantee a long lamp life (5,000-300,000 number or starts). High starting frequency is applied to avoid stress on the lamp filaments at start-up. The preheat phase also facilitates the beginning of discharge inside the lamp by sweeping the frequency from a very high value towards the resonant frequency until the lamp is ignited. The voltage across the lamp increases as we move towards the resonant peak.

2) Ignition
In the off state the effective resistance of the lamp is very high (of the order of a few hundred kΩ) and the lamp thus behaves as open circuit. During Ignition, the frequency will ramp down through resonance and the voltage across the lamp will increase causing the ignition of the lamp. The parallel capacitance in the resonant LCC network helps in the voltage build-up. The lamp specs specify a “Maximum Ignition Voltage” that is the voltage needed across the lamp to ignite the lamp in the worst case (lamp cold).

3) Run Mode
During run mode, the voltage and the current across the lamp must guarantee the nominal current, voltage and power of the lamp. The lamp resistance shifts to a

![Fig. 4: Gain curve of the lamp voltage over Vin as a function of the switching frequency][6]

Small value on the account of establishment of discharge inside the lamp. The operating frequency is thus made lower or higher than the resonant frequency to avoid high voltage across the lamp and eventual burnout.

The control circuit should be capable of driving the inverter in all the three phases.

IV. CONCLUSION
The main objective of the paper is to give an overview of electronic control system (electronics ballast) for CFL Lamps. The operation of electronic ballast is divided in 3 modes and the electronic ballast should be capable of working in all the three modes of operation.

REFERENCES


