A Study on Electronic Ballast for Metal Halide Lamps with Adaptive Ignition

Gye-Hyun Jo*, Myoung-Suk Song* and Chong-Yeun Park*

Abstract - Metal halide lamps have been made suitable for use in outdoor illumination systems over many years. They are also widely used in application and commercial lighting due to their attracting properties such as good quality color, rendering and high efficiency. Over the past few years, a considerable number of studies have been conducted on the electronic ballast with hot restarting and resonance phenomenon. However, very few attempts have been made at the adaptive ignition method according to lamp state.

This paper proposes an electronic ballast for metal halide lamps with an igniter for adaptive ignition. The proposed electronic ballast can generate different ignition voltages according to the arc tube state. The experimental results showed that the proposed ballast circuit using adaptive igniter is suitable for 70W HQI lamps.

Keywords: adaptive igniter, lamp life, restarting final

1. Introduction

Metal halide lamps have been made suitable for use in outdoor illumination systems for a long time. They are now widely used in application and commercial lighting due to their attracting properties such as good quality color rendering and high efficiency. [1-5]

Metal halide lamps belong to the class of high pressure discharge lamps, in contrast to fluorescent lamps, which are classed as low pressure lamps. The main difference in the electrical characteristics between these two groups is that the required ignition voltage in the high pressure discharge lamps are sensitive to acoustic resonance. In the case of the cold lamps, ignition voltage must be up to several kV for breaking down the electrodes during the ignition period. However, the ignition voltage for restarting a hot lamp is higher than ten times that needed for a cold lamp. As a result, a high voltage of 20kV is usually required in the hot strike case and the take over current must supply the lamp during the hot re-strike period. [1, 2]

Metal halide lamps have a serious problem with acoustic resonance in the case of using high frequency electronic ballasts. Acoustic resonance causes various problems, such as arc instability, light output fluctuation, and color temperature variations. In the worst case, it may crack the arc tube.

Over the past few years, a considerable number of studies have been conducted on the electronic ballast with hot restarting. However, very few attempts have been made at the adaptive ignition method according to the lamp state.

This paper proposes an electronic ballast for metal halide lamps with an igniter for adaptive starting. The proposed electronic ballast can generate different ignition voltages according to the arc tube state. When the temperature of the arc tube is low, the ballast provides the lamp with about 2kV~3kV of ignition voltage by the igniter using the resonant tank. When the temperature of the arc tube is high, the ballast supplies the lamp with about 18kV of ignition voltage by using the external igniter with spark gap and high voltage transformer.

The proposed electronic ballast supplies a low frequency rectangular waveform to the lamp. Finally, the acoustic resonance does not occur during ballast operation. The experimental results showed that the proposed ballast circuit is suitable for 70W HQI lamps.

2. Circuit Configuration

Fig. 1 shows the proposed circuit configuration of the electronic ballast with the igniter for adaptive starting. The proposed ballast circuit consists of the PFC circuit based in the boost converter operating at discontinuous mode, a DC/DC converter based in the Buck Converter operating at a high frequency controlling the lamp current and power, a low frequency rectangular wave current inverter to drive the lamp based in the full bridge inverter, and an igniter. After the start-up and during the warm-up phase, the lamp current increases until it reaches the required value.

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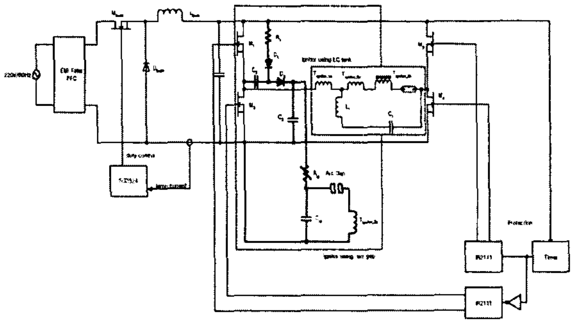

Fig. 1 The proposed electronic ballast

The adaptive igniter is classified into two parts. One is the internal igniter with the LC parallel resonance tank and the other is the external igniter with the voltage doubling rectifier, a spark gap and a step-up transformer.

The internal igniter consists of an LC parallel resonance tank. The low frequency rectangular wave voltage consists of fundamental voltage and harmonics. If the harmonic frequency is equal to the LC parallel resonant frequency, the high voltage will be induced to the arc tube.

The external igniter is composed of a voltage doubling rectifier, a spark gap and a step-up transformer. The secondary of the ignition transformer is connected in series with the metal halide lamp. The igniter is operated when the voltage of c_{ig} reaches the level required to breakdown the spark gap. The energy is transferred into c_{ig} through the step-up transformer. Then, the ignition voltage is applied to the transformer, inducing the impact voltage on the secondary winding. This voltage is applied on the secondary of the transformer inducing the impact voltage pulse superimposed on the inverter output for hot restarting.

Fig. 2 shows that the intensity of illumination of the arc tube and the arc tube temperature of the outer wall has changed. The intensity of illumination rises for 150sec and the arc tube of the outer wall temperature rises for 300sec and is maintained so that it is regular.

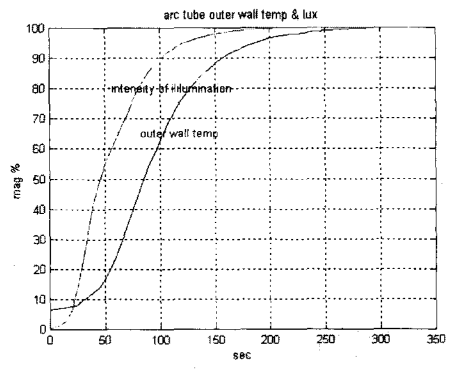

Fig. 2 The arc tube temperature and illumination rising characteristics

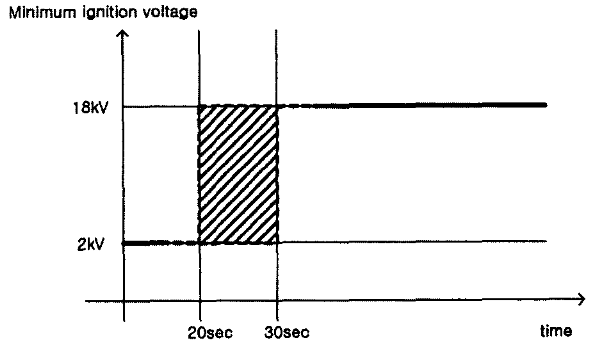

Fig. 3 The relation of required ignition voltage and lighting hour

Fig. 3 shows the experimental result concerning the relation between minimum ignition voltage and the lighting hour in the laboratory on normal temperature. The arc tube requires about 18kV of ignition voltage after the lamp restarting turns on between 20sec and 30sec.

3. Adaptive Igniter

The proposed adaptive igniter is classified into two parts. One is the internal igniter with an LC parallel resonant tank. The other is the external igniter with a voltage doubling rectifier and spark gap. Fig. 4 shows the ignition sequence of the proposed electronic ballast with adaptive igniter. When the lamp temperature is cold or the lamp first turns on, an ignition voltage of about 2kV~3kV is required using the LC resonance tank. However, if the lamp temperature is hot or if the lamp is of the hot restarting type, several kV ignition voltages are not enough to ignite it. The external igniter generates about 18kV after it goes on the second time.

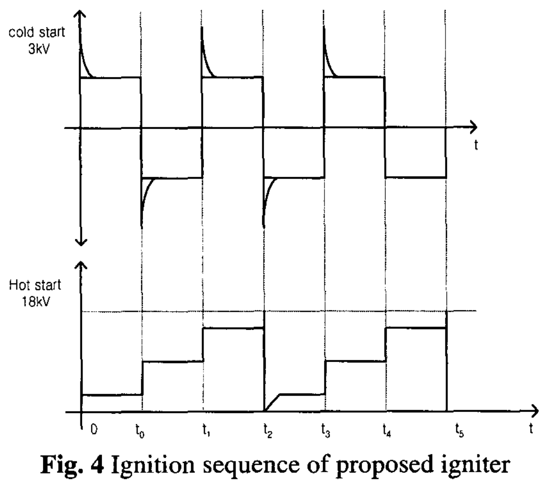

Fig. 4 Ignition sequence of proposed igniter

Fig. 5 shows the internal igniter composed of an LC parallel resonant tank.

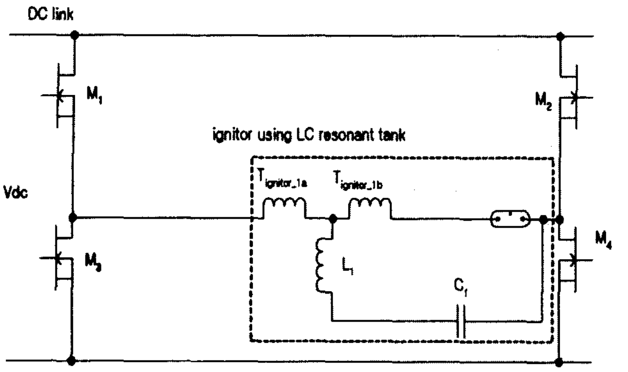

Fig. 5 The internal igniter using an LC resonant tank

Fig. 6 shows the equivalent circuit before the lamp turns on. Prior to a lamp turning on, its impedance is very high. Therefore, Tigniter_1b impedance can be omitted as compared with lamp impedance. C1 impedance is much higher than L1 impedance. Therefore, L1 impedance can be omitted too. The L1, Tigniter_1a tank acts as a band pass filter for the input voltage.

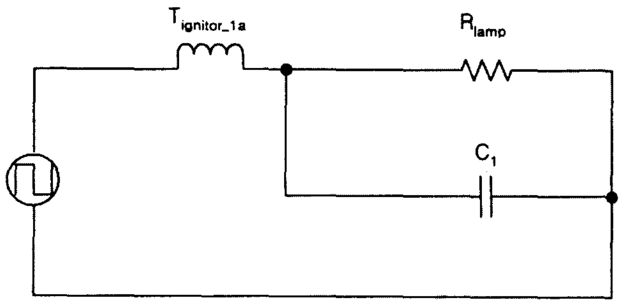

Fig. 6 Simplified circuit using fundamental approximation for analysis

The input rectangular voltage wave to the resonant tank can be expressed as follows:

$$V_{lamp} = \sum_{n=1,3,5,..}^{\infty} \frac{4V_{lamp}}{n\pi} \sin nwt \tag{1}$$

As long as the lamp impedance is high enough prior to ignition, the approximation is justified for the circuit analysis at fundamental frequency. Thus, the circuit is described by parallel parameters.

$$w_o = 2\pi f_o = \frac{1}{\sqrt{L_{Tigniter\_1a} C_1}} \tag{2}$$

$$Q = \frac{Rlamp}{W_O L} \tag{3}$$

The voltage gain of the Tigniter_1a and C1 tank is calculated as follows:

$$|G(jw)| = \left|\frac{V_o(jw)}{V_{input}(jw)}\right| = \left|\frac{1}{1 - w^2 LC + j\frac{wL}{R}}\right| = \frac{1}{\left[1 - (\frac{w}{w_0})^2\right] + \left[(\frac{w}{w_o}Q)^2\right]} \tag{4}$$

Fig. 7 shows a voltage transfer function of $\frac{w}{w_O}$ before ignition. Because the lamp impedance is high enough before ignition, the voltage gain is increased as long as Q is high. Based on the simplified circuit, the ignition sequence is analyzed to determine the maximum voltage applied to the lamp.

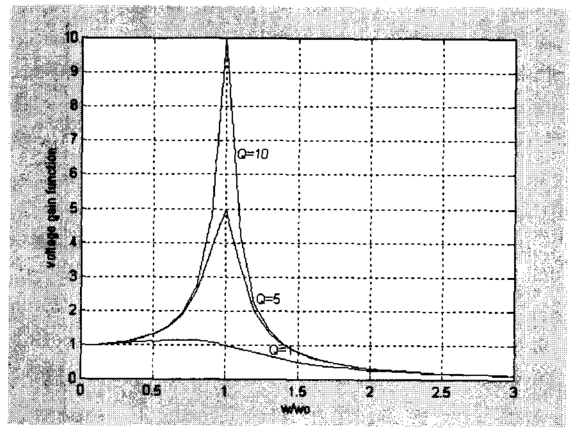

Fig. 7 Voltage transfer function of w/wo

Fig. 8 shows the external igniter using a voltage doubling rectifier, a spark gap and a step-up transformer. FET M1, M3 and FET M2, M4 is alternatively operating. For C2 voltage reach of the spark gap turn on voltage, very high voltage is induced between the arc tubes.

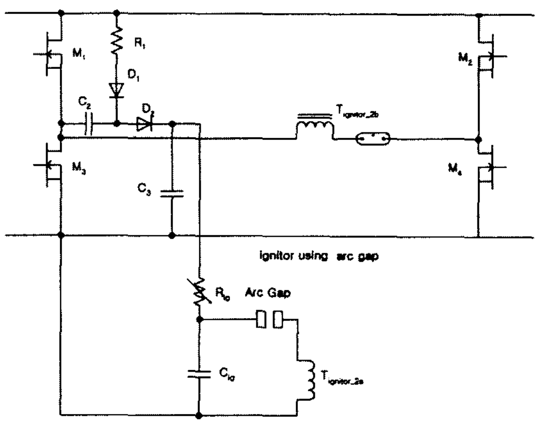

Fig. 8 Igniter circuit using arc gap

4. Experimental Results

The breakdown voltage of the metal halide lamp is shown in

Fig. 9 illustrating that the impact peak voltage is 18kV.

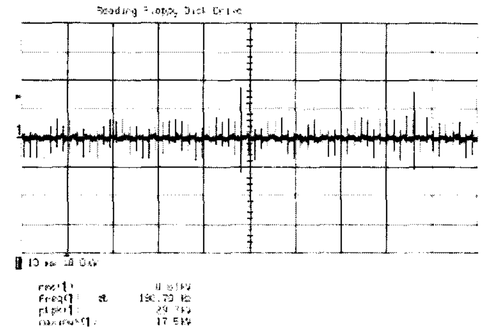

Fig. 9 Measured output voltage waveform of igniter [10ms/div, 10kv/div]

Fig. 10 shows the voltage waveform on C3. The voltage is built up step by step. When it reaches about 600V, the spark gap breaks down to generate an ignition voltage on the arc tube.

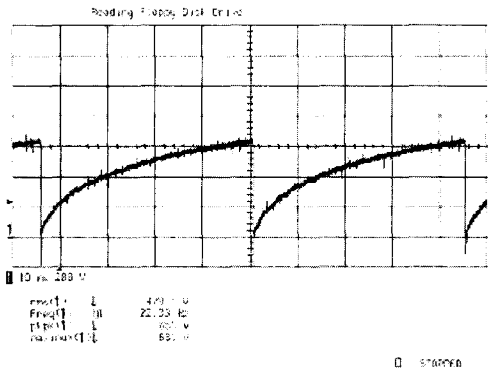

Fig. 10 Measured voltage waveform of Cig[10ms/div, 200V/div]

Fig. 11 and Fig. 12 show the ignition voltage when the lamp is removed. Fig. 11 indicates that the peak voltage of the internal igniter using an LC parallel resonant tank is higher than 2kV. It is a sufficiently high voltage to ignite a cold lamp. Fig. 12 depicts the peak voltage of the external igniter using a spark gap that is higher than 20kV.

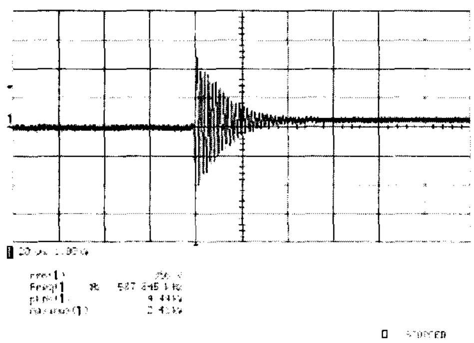

Fig. 11 Measured ignition voltage waveform of LC resonant tank. [20us/div,1kV/div]

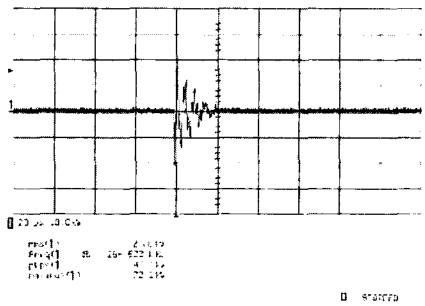

Fig. 12 Measured ignition voltage waveform of external igniter [20us/div,10kV/div]

Fig. 13 shows the waveform of the lamp voltage and current during cold starting. Once breakdown occurs, the lamp voltage is decreased slowly and the lamp current is increased. Fig. 14 shows the waveform of the lamp voltage and current during the hot restarting state. From these figures, the transition time from start-up to stable arc discharging needs to be 40sec for cold starting. Hot restarting does not have a transient time from start-up to stable arc discharging.

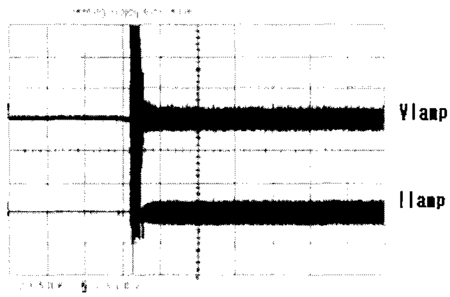

Fig. 13 Waveform for cold starting[100V/div,5A/div,2s/div]

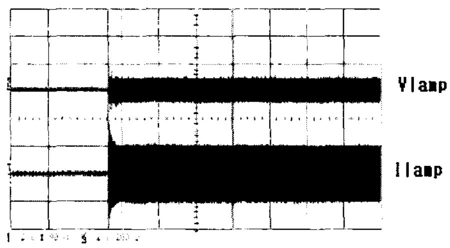

Fig. 14 Waveform for hot restarting[100V/div,5A/div,2s/div]

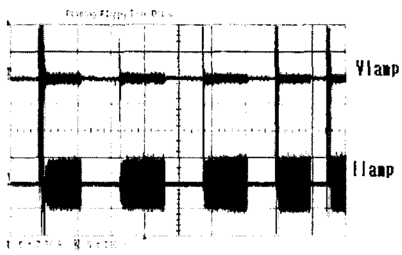

Fig. 15 Waveform of transient characteristics for hot restarting

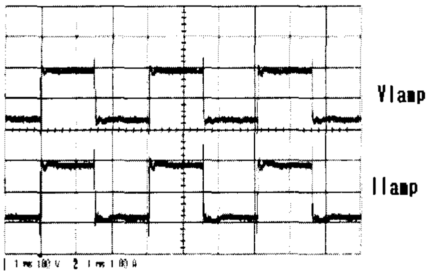

Fig. 16 Waveforms of the lamp voltage and current [100V/div, 1A/div,1ms/div]

Fig. 15 shows the switching transient characteristics for hot restarting. It also shows the lamp voltage and current waveform according to the on/off aging test.

Fig. 16 shows lamp voltage and current waveform during steady state operation.

5. Conclusion

This paper proposed an electronic ballast with a new ignition circuit for metal halide lamps. The cold HID lamp ignited at about 2kV~3kV. But, for hot lamp ignition or restarting, the ignition voltage was increased to about ten times more than the cold lamp. The adaptive igniter generated different ignition voltages according to the lamp temperature. There are two types of adaptive igniters. One is the internal igniter with an LC parallel resonance tank. The other is the external igniter with a voltage doubling rectifier, spark gap and step-up transformer.

The proposed electronic ballast operates at a constant low frequency. The acoustic resonance problems can be avoided. The prototype ballast consists of the PFC part, a step-down converter, a full bridge inverter and an adaptive igniter. A prototype circuit was built for experimental tests. Experimental results indicated that the electronic ballast is satisfactory for restarting characteristics and HQI 70W lamps manufactured by OSRAM. The proposed ballast with the adaptive igniter seems to assure an increase in lamp life to a greater extent than the normal igniter.

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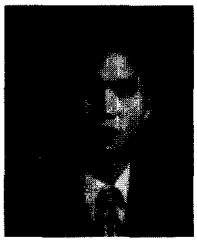

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