ANALYSIS OF THE LCC RESONANT FILTER USED IN FLUORESCENT SYSTEMS CONSIDERING THE FILAMENTS

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***Abstract* – In this work is an analyzed LCC resonant filter used in electronic ballast through the phase angle between the input filter current from the input filter voltage considering the lamp model and its filaments. The proposed analysis allows evaluating the total power in the lamp, the filaments power, and discharge column power separately. This paper presents the sensibility to total power, filaments power, and discharge column power from the resonant filter components values. The work allows evaluating the lamp behavior from a previously designed filter.**

KEYWORDS

Fluorescent lamp model, electronic ballast, filaments, dimming.

I. INTRODUCTION

Nowadays, a great amount of the electric energy used worldwide is consumed as artificial lighting, and any improvement in the efficiency of illuminating systems is desirable. The converters used in electronic ballast generally generate a square waveform, which through resonant filter contents the necessaries conditions of the fluorescent lamp operation.

The electronic ballast design depends almost totally of the filter design guarantying the success of fluorescent lamps performance. The filaments power must be considered in the design [1]. The filaments power is important for adequate electrode temperature. The failure of fluorescent lamps is caused mainly by the loss of the electron emissive coating of the lamp electrodes, and electrode temperature directly determines the rate of loss of this emissive coating. Electrode temperature below 700ºC or above 1000º C can reduce lamp life by increasing the rate of loss of the emissive coating on the electrode. Thus, The ballast must provide appropriate electrode heating during lamp starting and operation to reduce the damage to lamp electrodes and maintain a long lamp life [2].

This paper is organized as follows: section II presents the evaluated procedure and section III presents some conclusions drown based on evaluated procedure.

II. EVALUATE PROCEDURE

In this section, the evaluating procedure is developed. The Procedure is based on phase angle from the input filter voltage to the resonant input filter current. The design method uses the phase angle with the following approximations:

- Fundamental approximation;
- The fluorescent lamp is represented by an equivalent model;
- The filters components are ideal.

The development of the analysis follows the procedure below:

Step 1: Determination of the input impedance of the resonant filter and the lamp;

Step 2: Consider the input voltage as reference (zero angle), thus finding the angle of the input current;

Step 3: The lamp power may be obtained through the real power of the resonant circuit;

Step 4: The filter components design equations are determined through phase angle;

Step 5: The total lamp power, filament power and discharge column power as function of phase angle are plotting;

Step 6: The power sensitivity analysis is made.

Figure .1 shows the filter lamp equivalent circuit. The filter components are represented by series inductor Ls, series capacitor Cs and parallel capacitor Cp. The Lamp is modeled through resistance RL that represents the column discharge and resistances R1 and R2 that represent the filaments.

The equivalent circuit input impedance is

$$Z = \frac{ZA + j \cdot ZB}{ZC} \tag{1}$$

where

$$ZA = 2 \cdot R1 \cdot Cs \cdot \omega \left[X1^2 + 1 \right] + RL \cdot Cs \cdot \omega \cdot \left[2 \cdot R2 \cdot Cp \cdot \omega \cdot X1 + 1 \right]$$

$$ZB = \left(Ls \cdot Cs \cdot \omega^2 - 1 \right) \cdot \left[X1^2 + 1 \right] + RL \cdot Cs \cdot \omega \cdot \left[2 \cdot R2 \cdot Cp \cdot \omega - X1 \right]$$

$$ZC = Cs \cdot \omega \cdot \left[X1^2 + 1 \right]$$

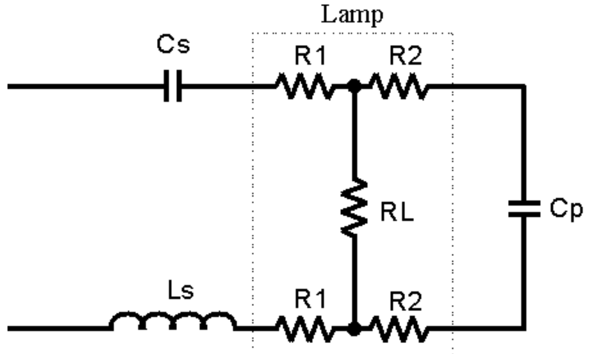


Figure 1 – Filter and fluorescent lamp equivalent circuit.

$$ZA = 2 \cdot R1 \cdot Cs \cdot \omega \left[X1^2 + 1 \right] + RL \cdot Cs \cdot \omega \cdot \left[2 \cdot R2 \cdot Cp \cdot \omega \cdot X1 + 1 \right]$$

$$ZB = \left(Ls \cdot Cs \cdot \omega^2 - 1 \right) \cdot \left[X1^2 + 1 \right] + RL \cdot Cs \cdot \omega \cdot \left[2 \cdot R2 \cdot Cp \cdot \omega - X1 \right]$$

$$ZC = Cs \cdot \omega \cdot \left[X1^2 + 1 \right]$$

$$X1 = Cp \cdot \omega \cdot RL + 2 \cdot R2 \cdot Cp \cdot \omega$$

ω : angular frequency.

The phase angle is given by

$$\phi = -\arctan\left(\frac{ZB}{ZA} \right) \tag{2}$$

The total lamp power is defined by

$$P = Vac^2 \cdot \frac{ZC \cdot ZA}{ZA^2 + ZB^2}, \tag{3}$$

Being Vac = RMS value of a fundamental square wave input voltage.

The filter components are equated by (4) and (5).

Parallel capacitor is defined by

$$Cp(\phi) = \sqrt{\frac{Vac^2 - (RL + 2 \cdot R1) \cdot P \cdot (\sec(-\phi))^2}{\omega^2 \cdot \left\{ \left[2 \cdot R1 \cdot (RL + 2 \cdot R2)^2 + 2 \cdot RL \cdot R2 \cdot (RL + 2 \cdot R2) \right] \cdot P \cdot (\sec(-\phi))^2 - Vac^2 \cdot (RL + 2 \cdot R2)^2 \right\}}}, \tag{4}$$

and resonant inductor is

$$Ls(\phi, Cs) = -\frac{1}{Cs \cdot \omega^2} \cdot \left[\frac{\tan(-\phi) \cdot [X2] - RL \cdot Cs \cdot \omega \cdot (2 \cdot R2 \cdot Cp(\phi) \cdot \omega - L1)}{X1^2 + 1} + 1 \right]. \tag{5}$$

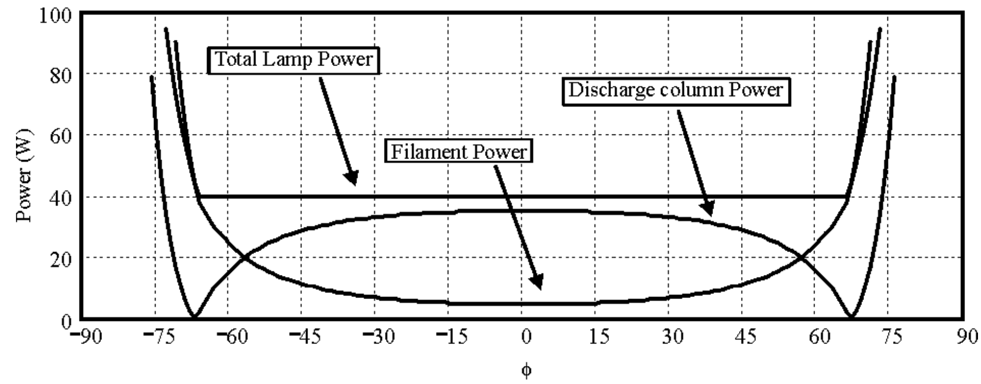
where

$$X2 = 2 \cdot R1 \cdot Cs \cdot \omega \cdot \left(L1^2 + 1 \right) + RL \cdot Cs \cdot \omega \cdot (2 \cdot R2 \cdot Cp(\phi) \cdot \omega \cdot L1 + 1)$$

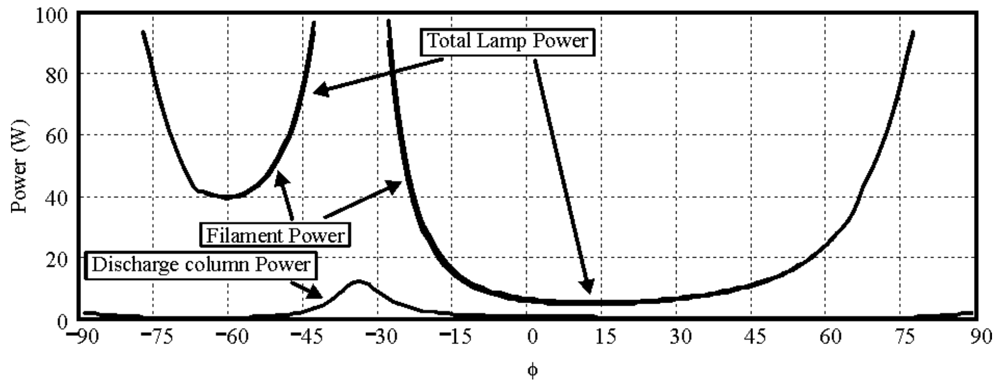
The value of the capacitor Cs is determined using a typical value to provide a lamp current without dc level.

Figure 2 shows the total lamp power, filament power and discharge column power as function of phase.

The lamp power sensitivity is made to evaluate which filter component has more influence in the filament power, discharge column power and total power. Figure 3 shows the sensitivity power for each component. Figures 3 (a) and (b) show the sensitivity of the lamp power from inductance Ls and capacitor Cs, respectively.

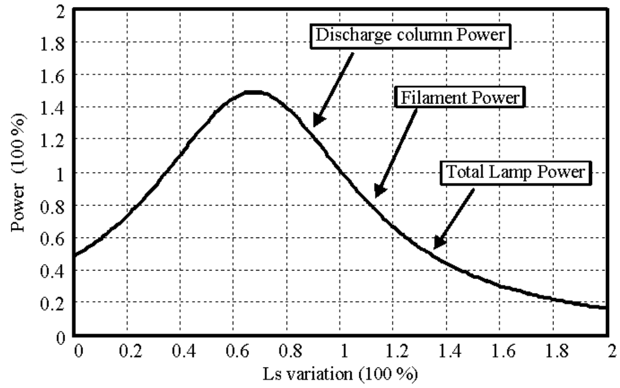


(a)

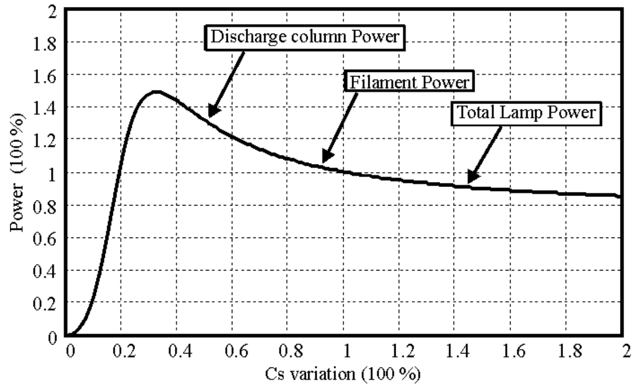


(b)

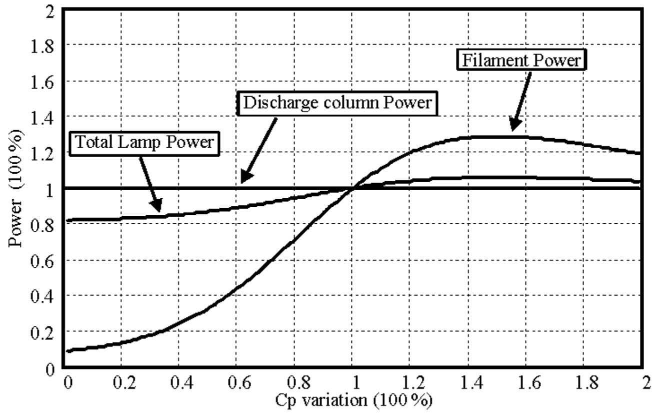
Figure 2 – Power in the Lamp as function of phase angle: (a) steady-state, (b) starting.



(a)



(b)



(c)

Figure 3: Power Sensitivity (a) series inductor, (b) series capacitor and (c) parallel capacitor.

It can be seen that the rate between filaments and discharge column power remains constant. In other hand, Fig.3 (c) shows that this rate changes significantly.

III. CONCLUSIONS

This work evaluates the lamp power as function of input current phase angle and power sensitivity. This analysis allows identifying the component that changes the rate between discharge column power and filament power. A difference between obtained and expected results has been observed because lamp model is not dependent of power.
However, these results indicate the way to obtain a complete analysis. The worth of this analysis is to determine the best filter parameters to increase the lamp life.

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