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Electrical measurements on LPS and HPM high-discharge lamps

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Abstract

Electrical characteristics of two high-discharge lamps (HPM and LPS) were characterized when biased with a series choke: steady state AC current and voltages across the lamp and the choke were determined. Measurements of the voltage phasors at the fundamental harmonic were used to evaluate the inductance and the dissipation in the choke and the lamps. The results are approximate because the current and voltage waveforms are not sinusoidal. The determined characteristics only approximately match the data sheets.

The two lamps are shown in Figures 1 and 2. The chokes are in-house matched to make the lamps operate properly. We are interested in confirming the data sheet specifications and to determine the inductance of the chokes used in stabilizing these lamps.

Figure 1 - Leybold 45115 High Pressure Mercury Lamp and in-house matched choke. Luminance 600 cd/cm², CCT ~ 6000 K, operating current ~ 1 A.

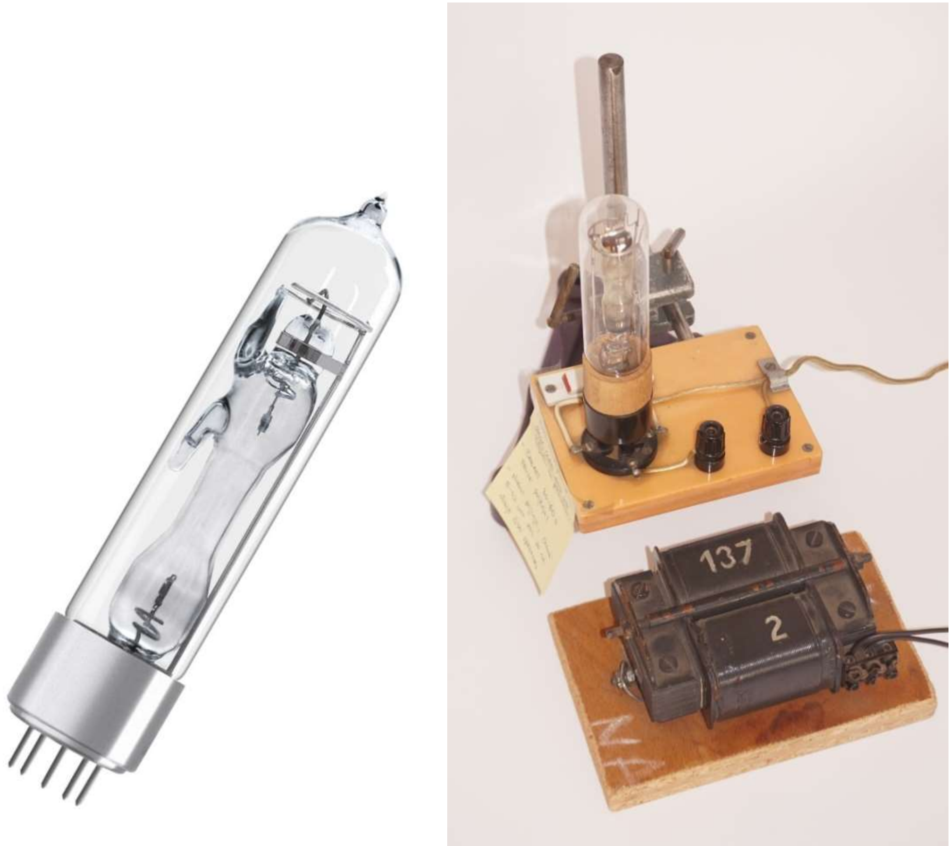

Figure 2 - OSRAM Na/10 Low-pressure sodium spectral lamp with choke and starter.

When powered, the current though the series combination of the lamp and the choke is close, but not exactly sinusoidal. The current is somewhat triangular waveform and hence the assuming that the current is sinusoidal (which we do later) will provide only approximate values for the power and operating conditions. For the purposes of this work, which is only based on curiosity, this is sufficient.

It is necessary to evaluate the phasors when the lamp is biased. The lamp was turned on and warmed up for several minutes. The steady state was established as the condition in which the current through the lamp stopped reducing and the voltage across the lamp stopped reducing.

The AC current was measured using a multimeter that states it measures *rms* values. The power supply voltage (house 220V~) voltage was measured using the same multimeter, but the relationship between the phasor was only measured for the fundamental harmonic (50 Hz) using an oscilloscope with a Fourier transform capability.

The phasor diagram modeling the circuit is shown in Figure 1.

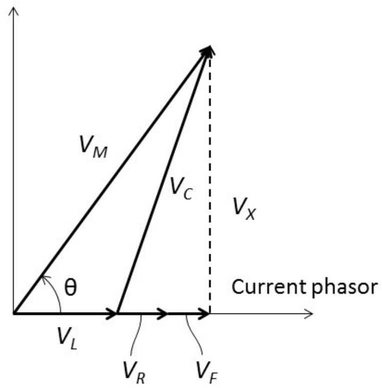

Figure 3 - Phasor diagram showing voltages of interest: the sinusoidal (50Hz) component of the wall power 220V (V_M), the voltage across the lamp (V_L) and the choke (V_C). The voltage across the lamp is approximately proportional to the current [1] as are voltages V_R, which represent the ohmic losses of the choke, and V_F voltage representing the ferrite losses. The voltage V_C across the choke is given by the sum $V_R + V_F$ and the orthogonal voltage across the inductor V_X. The amplitudes of the fundamental harmonics of the voltages V_C, V_M, and V_L are measured to obtain the angle θ and with it the power losses on the lamp and the choke. The angle θ and the inductance of the choke are given respectively with,

$$\cos\theta = \frac{V_M^2 + V_L^2 - V_C^2}{2V_L V_M} \qquad \omega L = \frac{V_M \sin\theta}{I_{rms}} \tag{1}$$

The power dissipated on the lamp, the choke, P_R, and P_F are given by

$$P_L = V_D I_{rms} \quad P_C = \left(V_M \cos\theta - V_D\right) I_{rms} \qquad P_R = R \cdot I_{rms}^2 \quad P_X = P_C - P_R \tag{2}$$

The fundamental harmonics of these voltages are obtained by measuring their real-time waveforms and taking the Fourier transform (in the oscilloscope). A voltage divider was used to accomplish this measurements is of critical importance to ensure that the neutral terminal of the wall-plug power is also the ground terminal on the oscilloscope. This mandated separate measurements of the lamp voltage, shown in Figure 2, and the choke voltage, shown in Figure 3. The amplitude of the main power V_M was determined using the same voltage divider, shown in Figure 4.

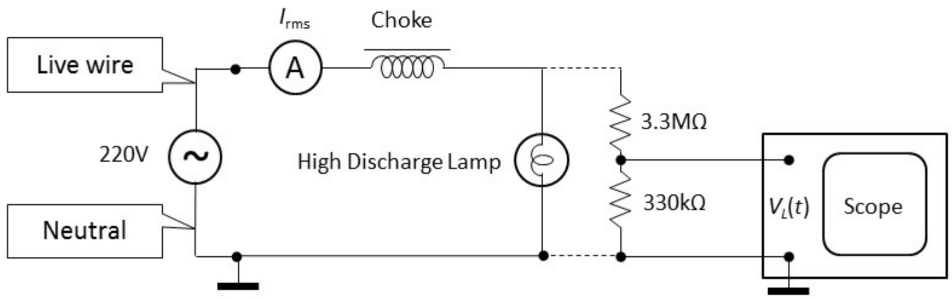

Figure 2 - Measurement of the lamp voltage fundamental harmonic. Voltage divider is used to reduce the voltage seen by the oscilloscope and for this purpose one must track the live and neutral lines.

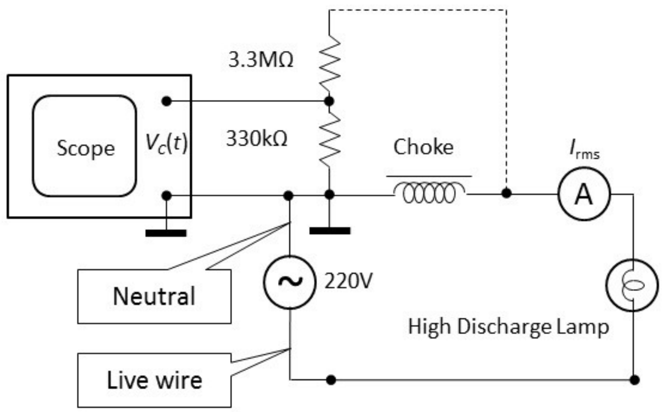

Figure 3 - Measurement of the choke voltage. Voltage divider is used to reduce the voltage seen by the oscilloscope and for this purpose one must track the live and neutral lines.

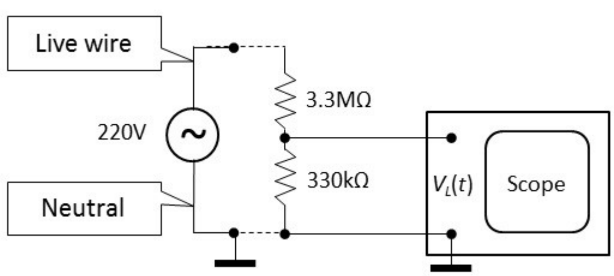

Figure 4 - Measurement of the main power voltage. Voltage divider is used to reduce the voltage seen by the oscilloscope and for this purpose one must track the live and neutral lines.

The waveform the voltage on the HPM and LPS lamps are shown in Figures 5 and 6, respectively.

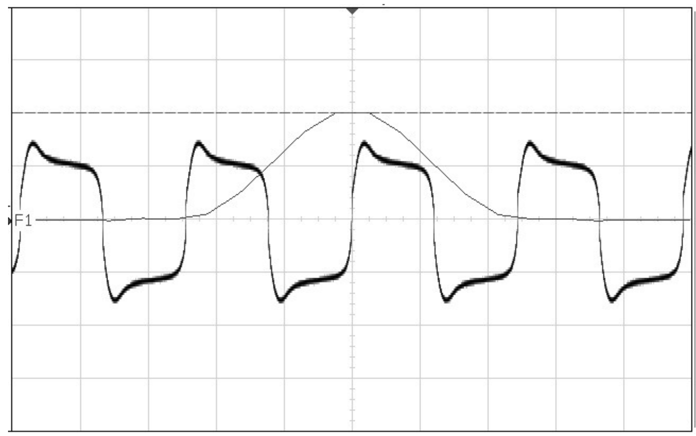

Figure 5 - HPM voltage waveform (units are arbitrary): periodicity is 50 Hz, while the amplitude was scaled using the voltage divider.

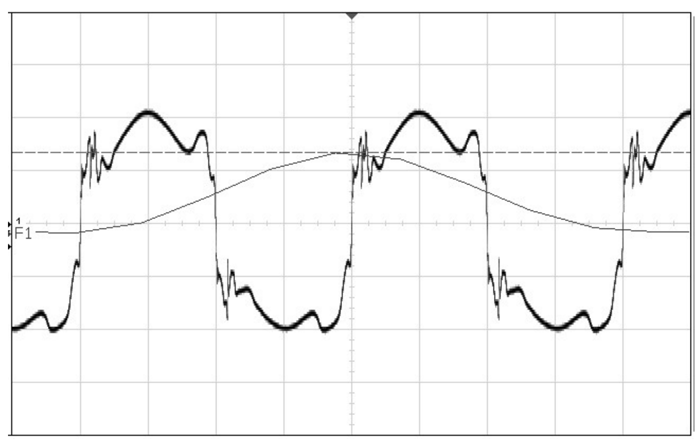

Figure 6 - LPS voltage waveform (units are arbitrary)): periodicity is 50 Hz, while the amplitude was scaled using the voltage divider.

Figure 7 - Test setup with oscilloscope and the two lamps

Lamp	I_{rms}	Choke	Lamp	Choke	Total
HPM	0.77 A	L = 0.64 H R = 10.5 Ω	90.2 W 120 V_{rms}	P_C = 44.9 W P_R = 6.20 W P_F = 39.7 W	135.1 W $\theta \approx 41°$
LPS	1.46 A	L = 0.50 H R = 10.0 Ω	25.7 W 17 V_{rms}	P_C = 31.5 W P_R = 21.2 W P_F = 10.3 W	57.1 W $\theta \approx 80°$

Table 1 – Approximate operating conditions of the spectral lamps used for calibrating the spectrometer