High Pressure Discharge Lamp — A Non-Liniar Circuit Element?

Harmonics Level. Network Electricity Losses Determined by Distorting Conditions

MIHAELA GUSA, CAMELIA BURLACU, MIRCEA COSTEA
Studies, Research and Engineering Group (GSCI)
Power Studies Center (CS)
1, Lacul Tei Blvd., 72301 Bucharest, Romania

ABSTRACT

Although electricity consumption for public lighting has a small weight compared to the industry one, all the developed countries keep an eye on public lighting systems which use top quality equipment.

Using high pressure discharge lamps with high efficiency can lead to important energy savings.

However, this kind of lamp is a non - linear circuit element with low power factor. More than that, the adherent electromagnetic ballasts worsen the circuit power factor. High harmonics can be injected into network.

This means that both power supply and consumer are affected, leading to energy savings diminution.

Even it is perfectly known that self ballasted high pressure mercury lamps (which will be called “blended lamps” in this paper) *do not have high efficacy*, so that, they are quite very rarely used in public lighting, we shall include them in our study, on the one hand, because they belong to the high pressure discharge lamps category, and, on the other hand, because they could be used for open spaces lighting, where the color rendering index must be improved.

The paper presents a harmonic levels studies for lamps produced by five manufacturers (1 - Romanian and 4 - other than Romanian) and used for public lighting.

The study is based on high precision laboratory measurements made by this paper authors.

For a concrete case, a comparative assessment of network electricity losses, caused by induced distorting conditions, is also presented.

INTRODUCTION

Nowadays, when efficient public lighting systems requires new and energy savings equipment (lamps, luminaires, fitting), it is obviously necessary to evaluate the impact his equipment has over the network. The authors should answer the question : is high pressure vapor lamp nonlinear element of circuit, having major negative impacts?

So, the authors are referring to the problems created, generally, by the nonlinear loads, meaning : low power factor and injection of high value harmonics into the network.

These possible implications determine negative consequences both over the electricity consumer and the utility: energy savings will decrease even if high energy efficient equipment is used.

Present paper presents the results of one authors’ study over same types of high pressure vapor lamps, in order to formulate an answer to the mentioned question.

TESTED EQUIPMENT. MEASUREMENTS AND RESULTS

For this study, the authors used the equipment presented in table 1.

The authors made measurements both over electric and photometric measures and over the harmonics distortion, as well.

The authors have estimated :

- the current harmonics level
- the current distortion coefficient
- the power factor without compensating condensator for all studied lamps.

The measurements have been made using the equipment called TRINET.

Since the measurements have been made only in the laboratory, the authors could not estimate the needed

Table 1

Studied Variant Number	Lamp Wattage rating	Lamp Manu-facturer	Ballast Wattage rating	Ballast Manu-facturer	Ignitor Wattage rating	Ignitor Manu-facturer
a). high pressure vapors mercury lamps						
1	80	# 1	80	# 1	-	-
2	125	# 1	125	# 1	-	-
3	250	# 1	250	# 1	-	-
4	400	# 1	400	# 1	-	-
5	125	# 2	125	# 3	-	-
6	250	# 4	250	# 3		
b). high pressure vapors sodium lamps						
7	70	# 1	70	# 1	70./.400	# 1
8	150	# 1	150	# 1	70./.400	# 1
9	250	# 1	250	# 1	70./.400	# 1
10	400	# 1	400	# 1	70./.400	# 1
11	250	# 2	250	# 3	250	# 2
12	150	# 4	150	# 3	70./.400	# 3
13	250	# 4	250	# 3	70./.400	# 3
c). blended lamps						
14	250	# 1	-	-	-	-
15	500	# 1	-	-	-	-
16	250	# 5	-	-	-	-

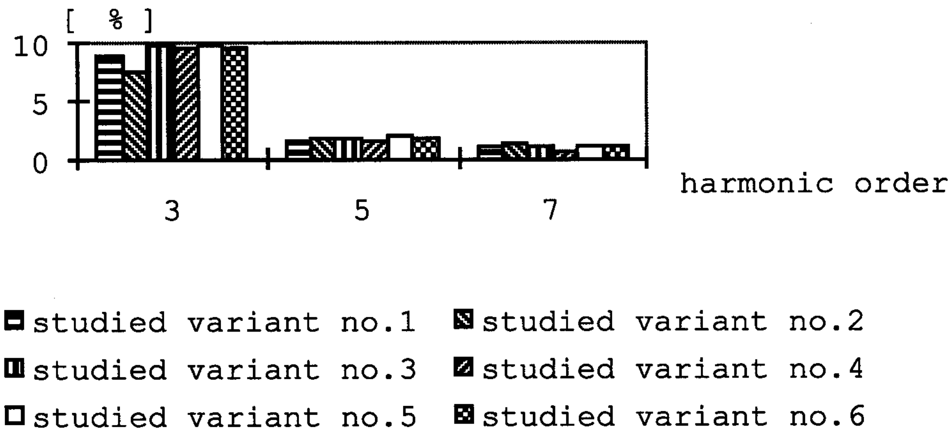

Figure 1. Measured values of the current odd harmonics levels for the studied high pressure vapor mercury lamps.

parameters for choosing the highest admitted values for current harmonics levels and for the current distortion coefficient :

- I_{SC} - short-circuit current in the consumer connection point at the network
- I_S - rate current, at fundamental frequency, for the connected load.

A. CURRENT HARMONICS LEVEL

The current waveform to the three types of lamps are presented too.

The *current harmonics level* is defined as the ratio between the effective value of the nth current harmonic (I_n) and the effective value of the fundamental (I_1):

$$\gamma_1 = \frac{I_n}{I_1} \times 100 \qquad [\%]$$

The authors have noticed that the 3rd current harmonics level of the blended lamps are more superior than those of the other types of lamps; they are between 20-26% depending on the wattage.

The 5th current harmonics levels of the blended lamps are closed to the 3rd current harmonics levels of the high pressure mercury/sodium lamps.

Comparatively, the results are shown in figures :

1. for the high pressure vapors mercury lamps
2. for the high pressure vapors sodium lamps
3. for the blended lamps.

B. DISTORTION COEFFICIENT OF THE CURRENT WAVEFORM

The *distortion coefficient* of the current waveform estimates of the total distortion and is defined as the ratio between the effective value of the distortion residue and the effective value of the fundamental, namely:

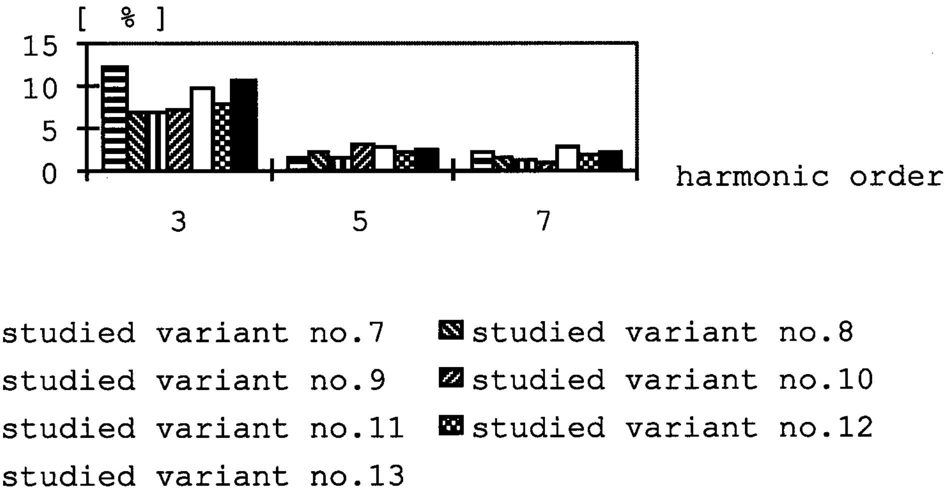

Figure. 2. Measured values of the current odd harmonics levels for the studied high pressure vapor sodium lamps.

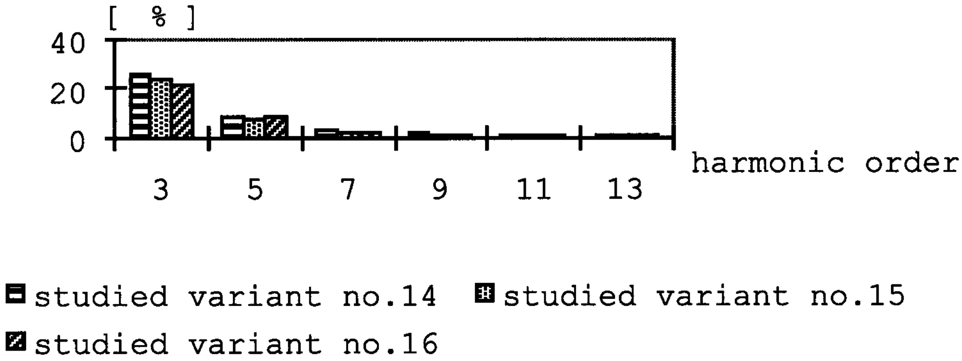

Figure 3. Measured values of the current odd harmonics levels for the studied blended lamps.

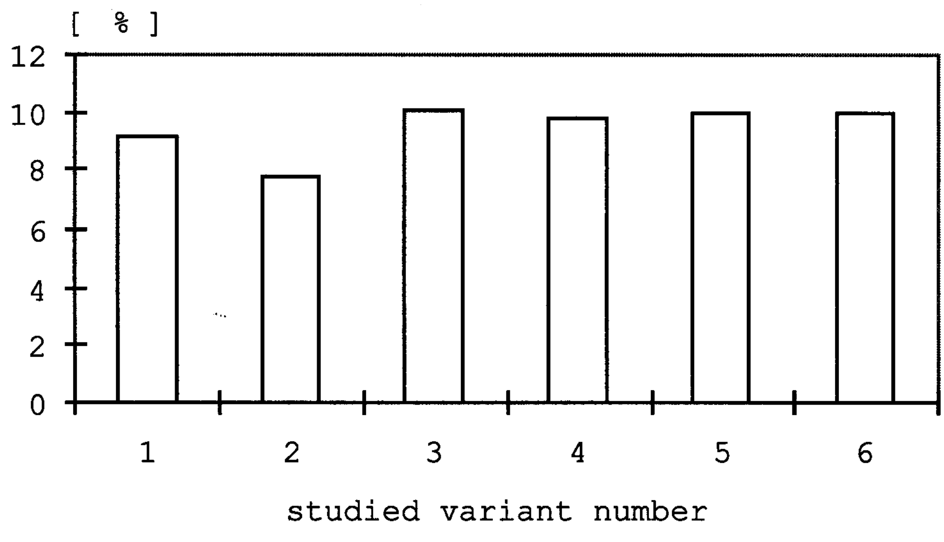

Figure 4. Measured values of the current waveform distortion for the studied high pressure vapor mercury lamps.

$$\delta_1 = \frac{\sqrt{\sum_{n=2} I_n^2}}{I_1} \times 100 \qquad \text{[\%]}$$

where : *n* - the harmonic order

Comparatively, the results are shown in figures :

4. for the high pressure vapors mercury lamps
5. for the high pressure vapors sodium lamps
6. for the blended lamps.

The authors have also remarked the high level of the current waveform distortion coefficient for the blended

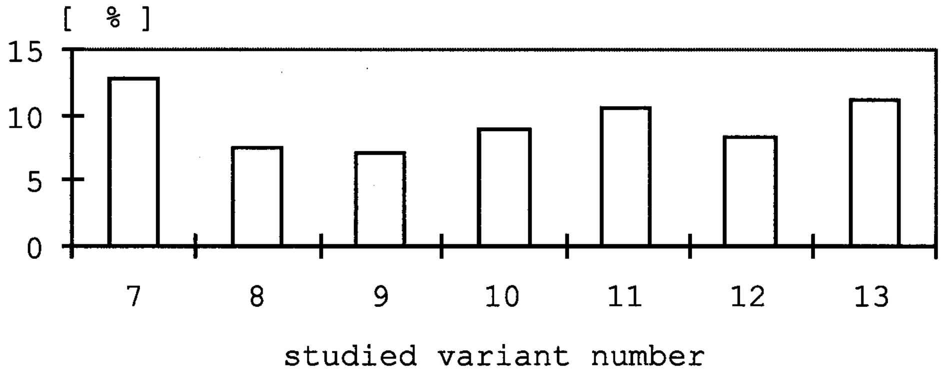

Figure 5. Measured values of the current waveform distortion for the studied high pressure vapor sodium lamps.

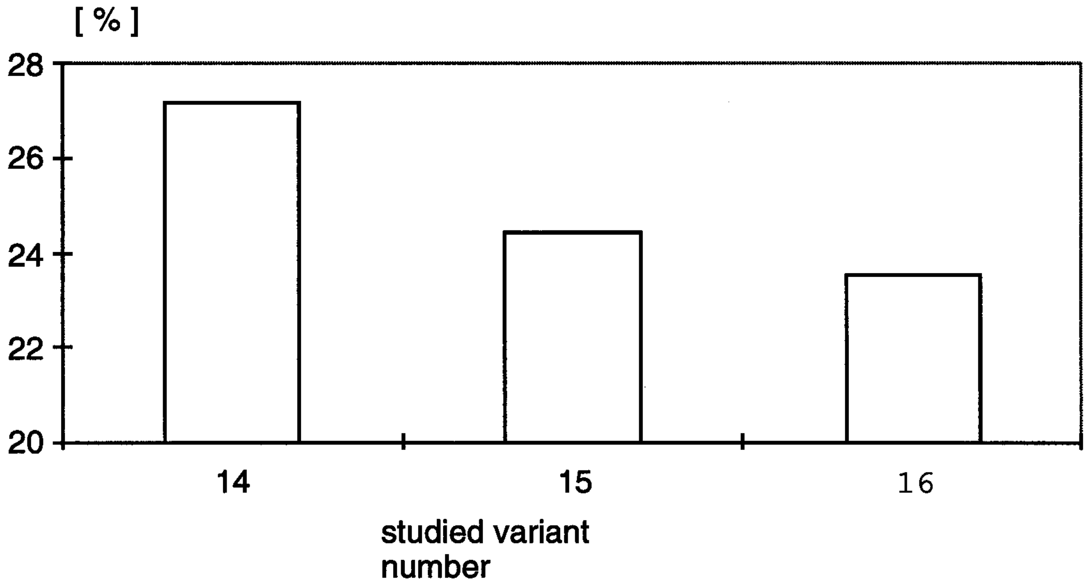

Figure 6. Measured values of the current waveform distortion for the studied blended lamps.

lamps, compared to that of the other types of lamps. They are between 23 % and 27 %, depending on the wattage.

C. POWER FACTOR (*without compensating condensator*)
The *power factor* is defined as the ratio between the active power, P_a - in W - consumed by the load and the apparent power - in VA - absorbed from the network :

$$k = \frac{P_a}{U \times I} \qquad [\,-\,]$$

The comparative results of the power factor measurements, in a circuit without compensating condensator, are shown in figures:

7. for the high pressure vapors mercury lamps
8. for the high pressure vapors sodium lamps
9. for the blended lamps.

The high levers of the blended lamps power factors (very closed to 1) are explained by the lack of the electromagnetic ballast, whose role is taken over by the wolfram filament. This is set in series with the mercury vapors discharge tube.

LOSS OF ENERGY CAUSED BY THE DISTORTION HARMONICS

The loss of power, P_e, caused by the distortion harmonics is calculated with the well-known relation :

$$P_e = \sum_n (2 \times L \times R_{nl} \times I_n^2) \qquad [\,W\,]$$

where :

R_{nl} - cable electric resistance per km at the n^{th} current harmonic passage

$$\left[\frac{\Omega}{km}\right]$$

L - line length [km]
I_n - effective value of the n^{th} current harmonic [A]

So, cable electric resistance, per km, is a function of the current harmonic order. Generally speaking, the alternative current (a.c.) resistance of the cable conductors raises compared to that from the direct current (d.c.), especially because of the surface and the approach effects, namely :

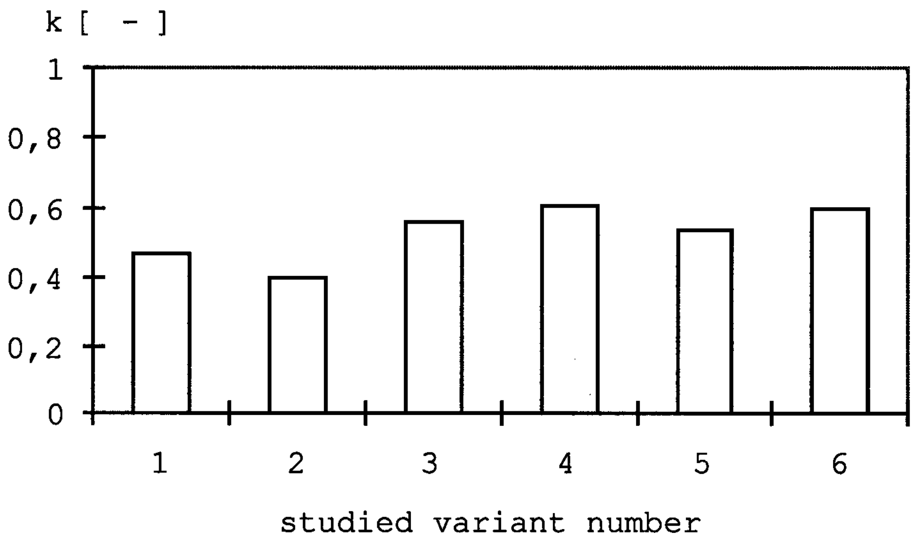

Figure 7. Measured values of the power factor for the studied high pressure vapor mercury lamps.

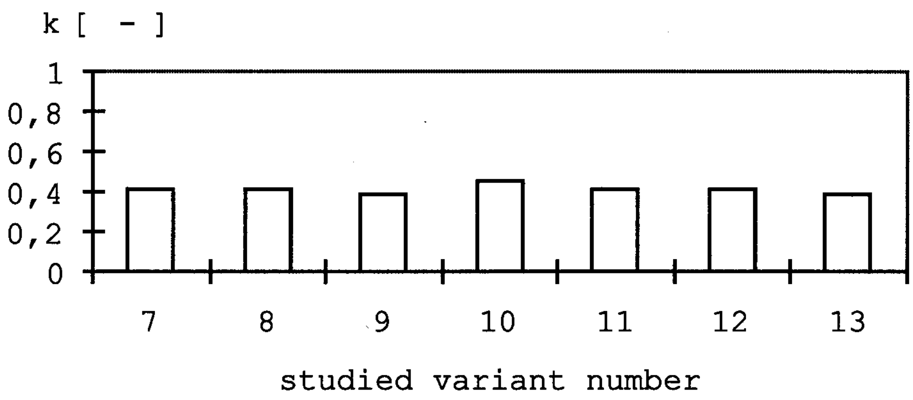

Figure 8. Measured values of the power factor for the studied high pressure vapor sodium lamps.

$$\frac{R_{ca}}{R_{cc}} = 1 + y_s + y_a$$

where :

y_s and y_a are coefficients for the surface effect and approach effect, respectively.

Depending on the frequency, the cable section and construction the technical literature mentions the semiempirical relations to calculate this important parameter (/ 2 /).

For instance, we considered a monophasic network that supplies 20 lamps, placed at 20 m each other. The used cable is aluminum 3 x 50 + 25, with :

$$\frac{d}{s} = 1.63 \quad \text{and} \quad R_{dc} = 0.567 \frac{\Omega}{km}$$

where :

d - exterior diameter of the conductors

s - distance between the conductors' axes.

The authors have considered the following cases :

- high pressure vapors mercury lamps
- high pressure vapors sodium lamps
- blended lamps.

The power losses were calculated using a simple software and the comparatively results are shown in figure 10.

The power losses in the network calculated for the studied lamps are, generally, low, with some variation depending on the wattage and type.

The blended lamps have power losses superior than those belonging to the other type of lamps. The differences are up to the values of the current absorbed from the network by each of lamp.

COMMENTS AND RESULTS

The study results lead to the same conclusions concerning the public lighting equipment running, namely :

- high pressure vapors lamps used in public lighting could have high values for the current harmonics – especially the blended ones – but, because of the very small value for the absorbed currents, they do not determine important losses in the network;
- the power factor of the high pressure vapors lamps having auxiliary equipment could be corrected to the right values relatively easily, by mounting the compensating condensators. The experimental results show that the current increase due to the running with low power factor does not determine an unacceptable increase of the energy losses.

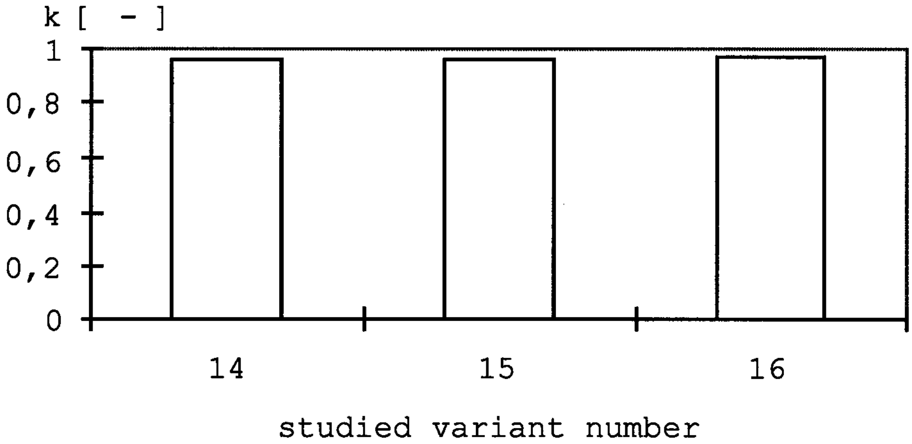

Figure 9. Measured values of the power factor for the studied blended lamps.

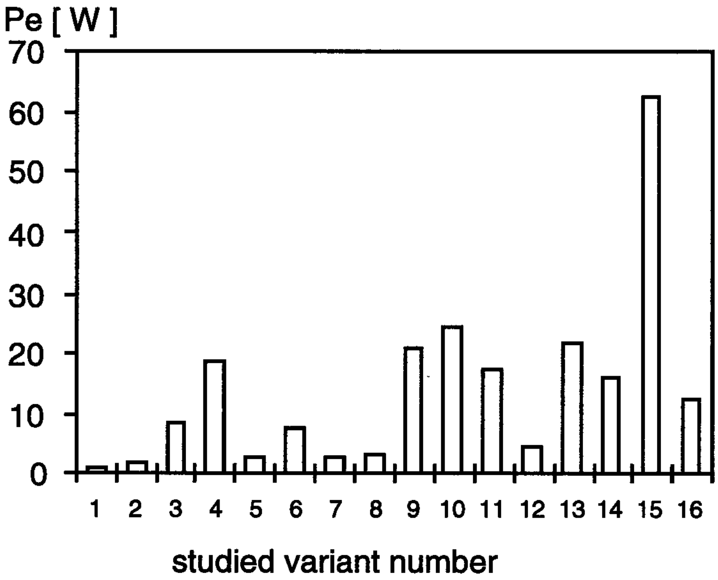

Figure 10. Calculated power losses for the studied lamps.

So, the authors appreciate that high pressure vapors mercury / sodium lamps, running together with the auxiliary equipment, do not represent non-linear loads with important negative effects over the network.

The new types of lamps running with electronic ballasts – generally used for interior lighting – compact fluorescent lamps, must be similarly studied, especially in conditions where many other non-linear loads are used on a large scale.

The Utilities must pay attention to the efficient use of the energetic system. That means that the loads must have power factors as high and harmonic distortion coefficient as low as possible. ●

REFERENCES

1. Romanian Electricity Authority (RENEL), PE 143 / 94 : Regulation concerning the limitation of the ansimmetrical and distortion regime in the electric network, 1994

2. M. Bercovici, A. Arie, Al. Poeata, Electric network - Electric calculation, 1980

3. RENEL - Studies, Research and Engineering Group (GSCI), Measurements concerning the mutual influences between some electricity and luminotechnics parameters, 1996

4. Right Light One, Proceedings, 1991

Education and Information