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The influence of power supply voltage on exploitive parameters of the selected lamps

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Abstract: In the paper some results of measurements of the selected properties of the selected types of lamps are presented and discussed. Investigations were performed for the classical incandescent bulb, the energy-saving fluorescent lamp and the LED lamp. All the considered lamps are characterised by the luminous flux of the same value. The influence of the supply voltage on such exploitive parameters as: supply current, luminance of the lighted surface, case temperature, coefficient of total harmonic distortion of the supply current and power factor is taken into account. On the basis of the obtained results of investigations, some suggestions connected with the power supply built-in in the considered lamps are formulated.

Keywords: Lighting sources, power LEDs, measurements

Vpliv napajalne napetosti na izkoriščene parametre izbranih svetil

Izvleček: V članku so predstavljeni rezultati nekaterih meritev izbranih parametrov določenih tipov svetil. Raziskave so narejene na klasičnih žarnicah, energijsko varčnih fluorescentnih sijalkah in LED sijalkah. Vsa svetila so karakterizirana pri enakih vrednostih svetlobnega toka. Obravnavani so vplivi napajalne napetosti na izbrane parametre kot so: napajalni tok, svetilnost osvetlene površine, temperatura ohišja, koeficient totalne harmonične distorzije napajalnega toka in močnostni faktor. Na osnovi pridobljenih reultatov so podane posamezni predlogi v povezavi z napajanjem vgrajenim v svetila.

Ključne besede: svetila, močnostne LED, meritve

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1 Introduction

Nowadays, many kinds of electric light sources such: incandescent bulbs, compact fluorescent lamps (CFL), sodium lamps, halogenous bulbs or LED lamps are available in the market. The values of exploitive parameters of the mentioned light sources differ from one other considerably, for instance in their prices [1, 2]. The incandescent bulbs are currently the most popular and are the cheapest. However, according to the legal regulations obligatory in the European Union and in Australia, classical bulbs should disappear from the market by the year 2016 [3, 4]. The similar legal regulations are obligatory in China and in the USA [3].

A basic defect of bulbs is low value of luminous efficiency. It causes that only several percent of the electrical energy received by the bulb from the line is exchanged into light. Furthermore, the life time of these light sources typically does not exceed 1000 h [5, 6]. On the other hand, equivalents of bulbs in the CFL form are considerably more expensive and contain mercury, which is harmful for health. They also need long time indispensable to obtain full light. Additionally, in practice it is not possible to control brightness of these lamps [7]. In turn, sodium lamps, because of the spectrum of the emitted light, differing indeed from the spectrum of the sun light are mostly used in street lighting [8].

The economical and ecological aspects decided that after the elaboration of white light emitting diodes (LEDs) in the last decade of 20th century, the ideas to use them for lighting appeared [9]. After a dozen or so years LED lamps constituting equivalents of popular bulbs are available in the market [2, 4, 5]. Additionally, the available LED lamps designed for street lighting are offered together with suitable casings [3, 10].

In many papers devoted to power LEDs, eg. [3, 11-17], the problems connected with the use of these semiconductor devices for lighting are described. To these problems belong: remove of heat generated in the considered devices (over 80% of the energy received from the power source is exchanged into heat [3, 7]), the fall of the luminous flux at the temperature increase [17, 18, 19] and during the exploitation, necessity to use special power supplies for LEDs [3, 4, 7, 20, 21] and the exponential decrease of life time with temperature [6, 12, 22]. On the other hand, solid-state light sources are not sensitive to the network voltage fluctuations and make possible the easy control of brightness [5]. Moreover, they have very rapid growth of the value of luminous efficiency of these devices, which attain at present already 100 lm/W [3] and also have long life time (theoretically to 100000 hours, in practice - 25000 hours) [12, 22].

In the paper [4], the results of measurements of low-wattage LED lamps within the range of their influence on the supply line and temperatures of their cases are shown. The results of measurement of temperature distribution on the surface of the investigated lamps and and time courses of the supplied current are presented. The cited paper drawsour attention to the fact that the power factor of the investigated lamps can be less even then 0.5, and the case temperature of the LED lamp can exceed 70°C.

In turn, the paper [2] presents the results of measurements of electric, photometric and colorimetric parameters of the selected LED lamps being equivalents of classical bulbs. It is clear from the presented results of investigations that the declared by distributors of LED lamps values of their emitted luminous flux are smaller then of their classical equivalents. Additionally, it must be emphasised that LED lamps of the identical value of the nominal power can indeed differ from one other with regard to the value of the emitted luminous flux.

In the paper [5] exploitive proprieties of the selected types of LEDs are compared taking into account the influence of the supply voltage on the case temperature of the investigated lamps and the coefficient of the total harmonic distortion (THD) of the supply current. The results of measurements presented in the cited work showed that LED lamps offered by different producers indeed differed with regard to the value of the power factor (PF).

The investigation results presented in the cited papers refer to the light sources of different values of the exploitive parameters. In this paper the comparative results of measurements of characteristics of bulbs, CFLs and LED lamps are presented. The investigations were performed for lamps of different types of the close value of the emitted luminous flux.

2 Investigated lamps

Three lamps of the emitting luminous flux value equal to about 400 lm were arbitrarily selected: the LED lamp (OSRAM type PARATHOM CLASSIC A40 Warm White E27), the CFL (PHILIPS Eco Ambiance A A55 8W) and the classical bulb (OSRAM type CLAS A CL 40). The basic exploitive parameters of these lamps are collected in Table 1.

Table 1: Exploitive parameters of the investigated lamps [23, 24, 25]

Parameters	classical bulb	CFL	LED lamp
nominal power	40 W	8 W	8 W
nominal supply voltage	220-240 V	220-240 V	100-240 V
power factor	1	0.6	0.8
life time	1000 h	8000 h	25000 h
color rendering index	100	82	80
nominal luminous flux	415 lm	370 lm	345 lm
correlated color temperature	2700 K	2700 K	3000 K

As it is visible in Table 1, all the considered lamps can be used with the power supply from the line and they emit light of warm white colour. The essential differences refer to their life time (the longest for the LED lamp), the power factor (the biggest for the bulb) and luminous efficiency equal to the quotient of the emitted luminous flux through the nominal power (the best for the CFL).

3 Results

The proprieties of the lamps described in the previous section were examined in the measuring-set shown in Fig. 1. In this measuring-set the investigated lamp is supplied from the autotransformer. The RMS values of the supply voltage and current are measured by means of the voltmeter and the ampmeter. The current probe Tektronix TCPA300 together with the oscilloscope make possible determination of time courses and the spectrum of the supply current. The pyrometer Optex PT-3S measures the temperature in the warmest point of the casing of the lamp, while the illuminometer Sonopan L-100 equipped with the set to measure luminance allows measuring luminance of the lighted up area being found in the axis of the lamp within 75 cm below the stem of this lamp.

Using the presented measuring-set, the characteristics of the examined lamps illustrating the influence of the supply voltage on the supply current, the case temperature, the luminance of the lighted up area and the THD of the supply current were measured. The results of these measurements are shown in Figs.2-8.

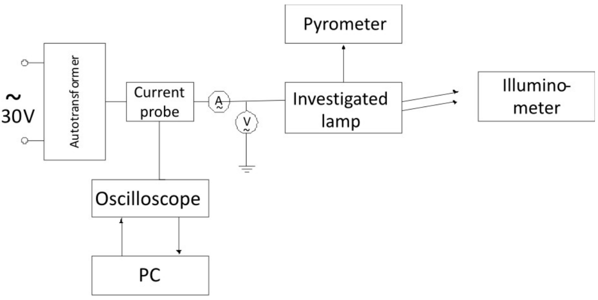

Figure 1: The block diagram of the measuring-set

Analyzing Figs. 2 and 3 one can see that the bulb begins to shine at the supply voltage equal to about 80 V and with an increase of this voltage the luminance of the lighted up area and the supply current increase visibly. In turn, the supply current of the CFL practically does not depend on the supply voltage, unless it exceeds the value 120 V. On the other hand, the luminance of the lighted up area by the CFL grows in the function of the supply voltage. The LED lamp is a light source the luminance of which practically does not depend on the supply voltage. In turn, the supply current of this lamp is a strongly decrescent function of this voltage. It is worth noticing that the luminance of the area lighted up by the bulb is the smallest, in spite of the greatest value of the luminous flux (see Table 1), of all the considered lamps. This is the result of the fact that the bulb emits radiation in the perigon, whereas the angle of emission of the remaining lamps is narrower.

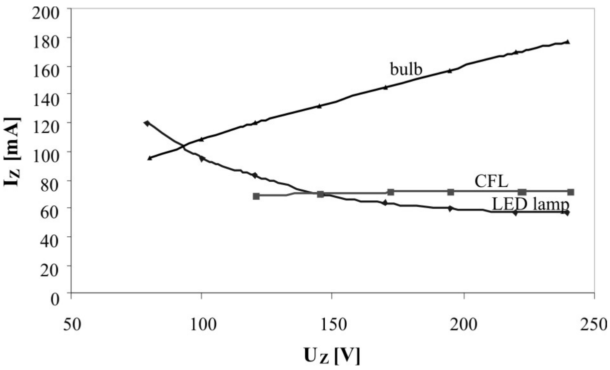

Figure 2: Measured dependences of the supply current on the supply voltage

The inequality of the area lighting obtained with the use of the considered lamps was analyzed. It turned out that for all the considered lamps the inequality of luminance distribution in the middle and on the circle of the ray of 10 cm did not exceed a dozen or so percent.

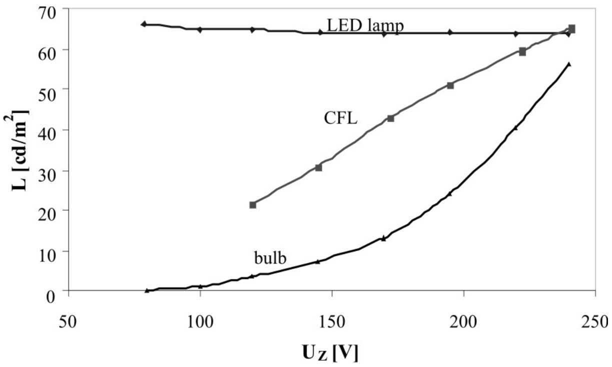

Figure 3: Measured dependences of the luminance on the supply voltage

The presented in Fig. 4, the dependences of the temperature of the lamp on the supply voltage show that all the investigated lamps strongly self-heat during the operation, even to over 130°C. The temperature of the bulb and the CFL is an increasing function of the supply voltage, while the temperature of the LED lamp is practically independent of this voltage.

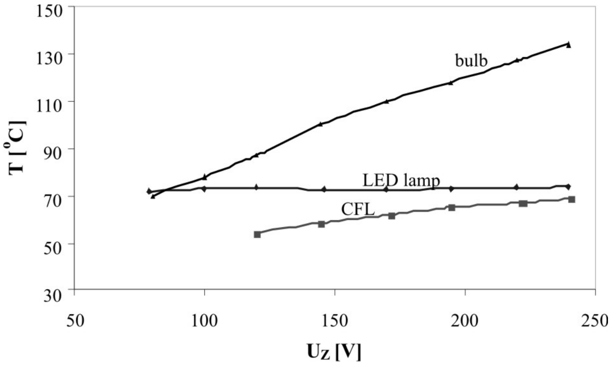

Figure 4: Measured dependences of the lamps temperatures on the supply voltage

The temperature of the case of the LED lamp is considerably lower and it does not exceed 72°C. The dependence of this temperature on the supply voltage shows the weak increasing tendency, which results from the fact that practically no changes of luminance of the area lighted up by these elements with the changes of the supply voltage are observed. Now then, the increase of their temperature is due mostly to an increase of power losses in the power supply system of the shining elements of the lamp.

From the point of view of the quality of electrical energy in the line, it is important that the supply current of each device, e.g. lamps, should have the sinusoidal time course. In Fig. 5 the time courses of the supply current of the examined lamps measured at the supply voltage U_Z = 220 V are shown.

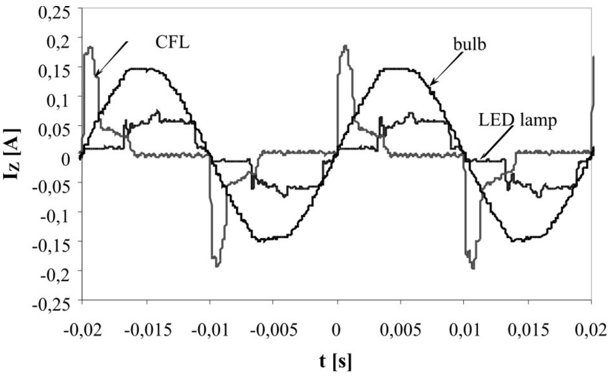

Figure 5: Measured time courses of the supply current of the lamps at the supply voltage U_Z = 220 V

From the point of view of the electric energy-network, the shape of the supply current of the investigated devices is of essential significance. Usually, the influence of the devices of the great power, e.g. industrial electric installations or large electric machines on the electric energy-network is considered [26]. Yet, a large number of diffuse low-power devices can also influence the quality of electrical energy significantly. Taking into account the fact that up to 30% of the used up electrical energy is used for lighting [6], the influence of lamps on the electric energy-network seems to be essential.

As one can observe, only the supply current of bulbs has the shape close to the sinusoid, and the remaining lamps receive the deformed current. To evaluate the degree of deformation of the supply current, the spectrum of the measured courses with the use of the fast Fourier transformation (FFT) is used. This spectrum, for all the examined lamps, is shown in Fig.6.

From Fig. 6 it is visible that for each of the considered lamps only the odd spectral stripes are visible. In the spectrum of the bulb current, practically only the stripe of the frequency about 50 Hz is visible. In turn, for the lamp LED the essential level of stripes are the stripes up to the ninth inclusively. The most strongly distorted is the supply current of the CFL, in which the spectrum harmonics up to 47th are visible.

Of course, the level of distorsions of the supply current of the lamp is relative to the supply voltage. In Fig.7 the dependence of the THD of this current of the examined lamps on the supply voltage is illustrated. As one can observe, the THD value is the least for the bulb, while the greatest for the CFL. The dependence THD(U_Z) for the CFL is a monotonically growing function, and the maximum value of this parameter exceeds 0.76. The LED lamp to a much smaller degree worsens the quality of the electrical energy, because for it the THD value does not exceed 0.4. For the LED lamp the THD attains the minimum at the supply voltage equal 120 V. This means that these lamps would influence less harmfully the electric energy-network, if there were supplied by the step-down transformer.

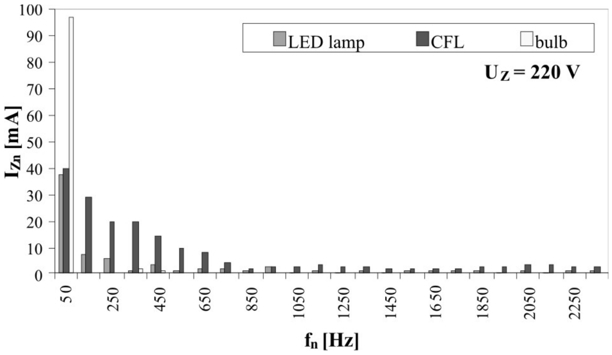

Figure 6: Measured spectrum of the supply current of the lamps at the supply voltage U_Z = 220 V

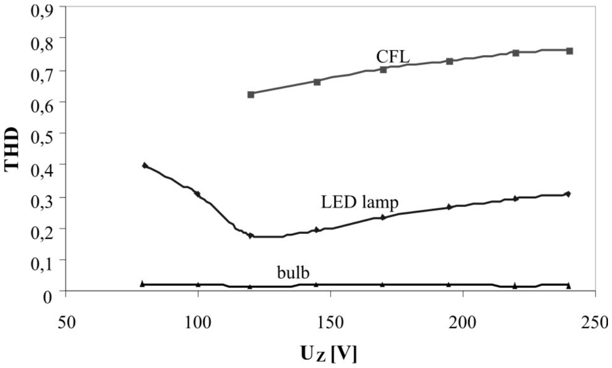

Figure 7: Measured dependences of the THD on the supply voltage

The considered lamps are dedicated to the operation at the nominal voltage of the electric energy-network. In such conditions the measurements of the active and apparent powers consumed by these devices and the power factor PF (equal to the quotient of the active and apparent powers) with the use of the instrument Voltcraft Energy Logger 4000F were performed. The obtained values of the power factor for the considered lamps are shown in Fig.8 in the form of the bar chart. Additionally, in this figure the values of the PF obtained from the equation, being the transformation of the dependence from the paper [26] were presented. This equation is of the form

$$PF = \frac{1}{\sqrt{1+THD^2}} \cdot \cos\varphi \tag{1}$$

where φ denotes the phase shift between the supply current and the line voltage.

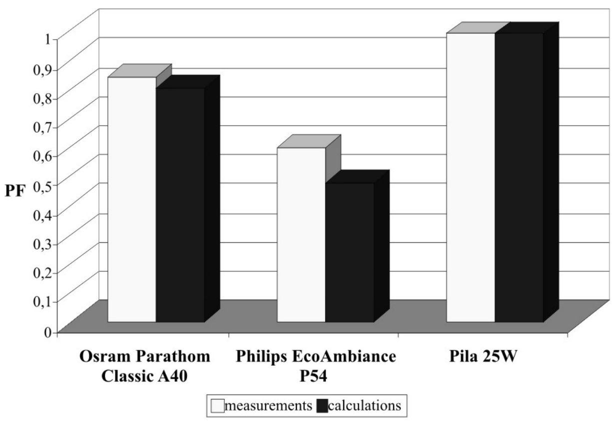

Figure 8: Measured and calculated values of the power factor of investigated lamps

The values of the power factor obtained from the measurements and values calculated from the equation (1) as well as the value of the THD calculated with the spectral stripes of the supply current are in agreement only for the bulb, whereas for the LED lamp and the CFL the essential differences between these values are observed. These differences result probably from the simplified manner of the measurements of the power factor in the device Voltcraft Energy Logger 4000F, which is based on the measurements of the phase shift between time courses of the supply current and the line voltage. This manner is correct only for lineal circuits [26]. Such a manner assures the reliable results, when these signals are not strongly deformed, which is not the case in the considered situation. It is worth noticing that the value of the power factor of the investigated LED lamp is comparatively high and negligibly exceeds 0.8, while for the CFL, the PF amounts to only 0.55. This means that the examined lamps unfavourably influence the quality of the electrical energy.

4 Conclusions

In the paper, the results of measurements of characteristics of the selected lamps were presented. From the presented results of the investigations one can draw the conclusion that at the nominal value of the supply voltage, the LED lamp consumes from the line the current of the least value. Because of the built-in swiching converter, the LED lamp assures the nominal luminous flux already at the supply voltage equal to 80 V. The power supplies built-in into the LED lamp and the CFL cause that the current consumed from the line by these lamps has not the sinusoidal course characteristic, like for the bulb. From among the examined lamps, the most negative influence on the electric energy-network has the CFL for which the THD exceeds even 0.76. As the result of heat generation in electronic circuits built-in in the CFLs and LED lamps the case temperature of these devices is high - it exceeds even 70°C.

Analyzing the spectrum of the supply current of the examined lamps, one can state that the reliable estimation of the value of the power factor of the examined lamps requires taking into account even 50 harmonics of the line frequency. Therefore, simple instruments used to measure the power factor can give the excessive value of this parameter. The high value of the THD of CFLs and the content of harmful mercury in these lamps should soon cause elimination of these lamps from the market. The LED lamps are already more and more spread and take their place. The use of LED lamps on mass-scale should bring down the inprice and make it possible to introduce, the power factor correction circuits (PFC) in the power supplies used in these lamps. The integrated circuits dedicated for this end are already offered by many producers.

It is worth noticing that luminous efficiency of LED lamps depends not only on luminous efficiency of the used LEDs, but also on watt-hour efficiency of the power supply applied in the lamp. For example, the luminous efficiency of the LED lamp examined in this paper amounts to only 43 lm/W, while the luminous efficiency of power LEDs already some years ago exceeded 100 lm/W [3].

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