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Prototype of electronic ballast to increase the radiation energy of discharge lamps

Abstract: *The article describes, a prototype of electronic ballast for discharge lamps operated at high frequency. Results of investigations into luminous flux values and luminous flux pulsation for a high pressure sodium lamp and metal-halide lamp, powered by electronic and traditional ballasts are presented.*

Streszczenie. *W artykule przestawiono opis prototypowego statecznika do lamp wyładowczych pracującego przy wysokiej częstotliwości. Zawarto wyniki badań wartości energii promieniowania świetlnego oraz pulsacji strumienia świetlnego dla wysokoprężnej lampy sodowej oraz lampy metalohalogenkowej zasilanych z opracowanego statecznika elektronicznego oraz klasycznego statecznika dławikowego.* ***(Prototyp statecznika elektronicznego umożliwiającego zwiększenie energii promieniowania świetlnego lamp wyładowczych).***

Słowa kluczowe: lampa wyładowcza, statecznik elektroniczny, energia promieniowania świetlnego.
Keywords: discharge lamp, electronic ballast, energy of light radiation.

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Introduction

Because of their high lighting efficiency, discharge lamps are at present the main light source used in road, industrial, agricultural, etc. lighting. The lamp consists of ceramic or quartz filament and the outer glass bulb which can be coated with a cover dissipating light and retaining the UV radiation.

Fig. 1. Arc inspection in filament of a discharge lamp

Fig. 2. View of the arc

Depending on lamp type, the filament is filled with different gas mixtures, as a result of electric discharges generate plasma prompting gas atoms to emit radiation. The lamps are characterized by light effectivity (36-61 lm/W for mercury lamps, 65-115 lm/W for metal-halide lamps, about 150 lm/W for high pressure sodium lamps, about 200 lm/W for low pressure sodium lamps) with the Color Rendering Index CRI= 10÷20 for low and high pressure sodium lamps, >90 for metal halide lamps, about 33 for mercury lamps and by long life time.

In order to ignite arc in a discharge lamp it is necessary to connect its terminals to a supply voltage source and then supply short ignition pulses with amplitudes of several kV. Ionization of gas occurs at that moment in the lamp filament and ignition of the arc channel, characterized by sudden increase in current taken by the lamp. This current must be limited by the lamp ballast system. Two types of ballasts are distinguished: the magnetic type one (classical) and the electronic one.

The magnetic type ballast

The magnetic type ballast is a reactor with high induction and low resistance, with a magnetic core. It prevents sudden changes in electric current intensity and limits the current at the moment of arc ignition in the lamp. Power losses in the ballast are related with wiring resistance, eddy currents and other sources of loses in the core.

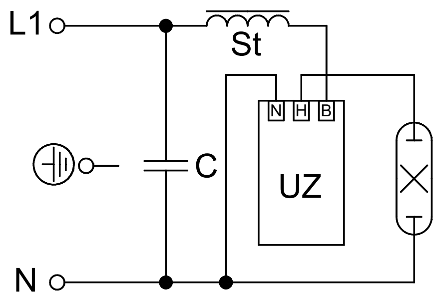

Fig. 3. Connection diagram for magnetic type ballasts [1].

The magnetic ballasts used in discharge lamps supply the light source with power direct from the power line. In the follow up an alternating current is flowing through the lamp with a frequency of f=50 Hz. It causes light flickering which has a direct effect on human feeling. Such a lighting for a longer time causes faster tiring, worse feeling, drowsiness and reduction in work effectivity.

In addition it constitutes a problem in the industry. Illuminating a part which rotates with the same frequency as pulsating lamp flux, creates an illusion that the part is at standstill (stroboscope effect) which may cause severe accidents . In the case of electronic ballasts this problem was eliminated by supplying the filament with high frequency power.

Description of the developed prototype of electronic ballast

The system of electronic ballast permits the discharge lamps to be supplied with a voltage of a frequency from some Hz to some hundred kHz. In [2], 3], [4] are described selected researches in discharge lamps power supply field. Fig. 4 shows the block diagram of the ballast.

It has an build in generator of high voltage pulses ionizing the gas in order to ignite the arc *UZ* and the input *PFC* system causing that the current taken from mains is of sinusoidal character with low current harmonics. The transistor bridge creating high frequency voltage supplies energy to the lamp through the *L* choke.

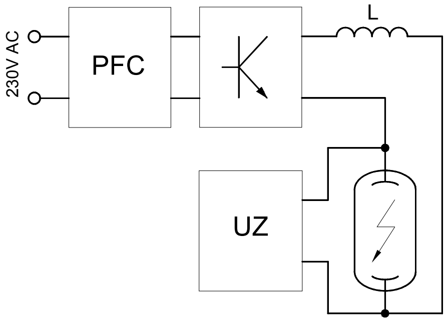

Fig. 4. The block schematic diagram of the developed ballast

After performing the Fourier analysis the content of harmonics (THD) in the current taken from the mains for the developed electronic ballast amounted to *THD*=9.7 %.

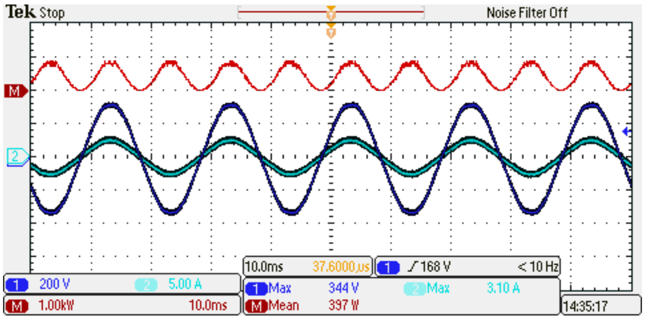

Fig. 5. Exemplary waveforms of voltage, current and power taken from the power grid using the PFC system

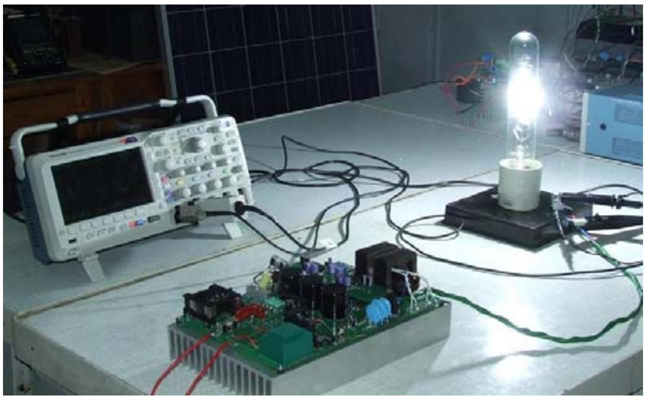

Fig. 7. View of the developed electronic ballast together with discharge lamp

Fig. 8. View of the filament and of the high voltage pulse ionizing gas before ignition

Efficiency of the electronic ballast

Table 1 shows a comparison of basic parameters of the induction type and electronic ballasts which despite of many used elements allows to achieve an efficiency which is comparable to the magnetic ballast.

Table 1. Comparison of selected parameters of 400 W ballasts

Parameter	magnetic	electronic
Efficiency	90.7 %	92 %
Content of harmonics in the supply current (THD)	22.7 %	9.7 %

Measurements of light radiation energy

Measurements of light radiation energy were performed using the PHOTO-RESEARCH digital spectroradiometer type PR680.

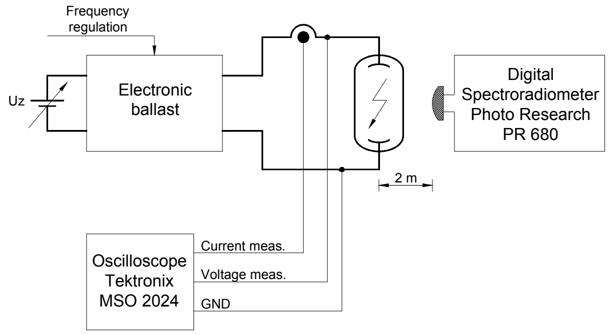

Fig. 9. Schematic diagram of the test stand for measuring light radiation energy

The distance between the light source and the spectroradiometer was 2 meters, hence all values of light radiation energy were determined for this distance.

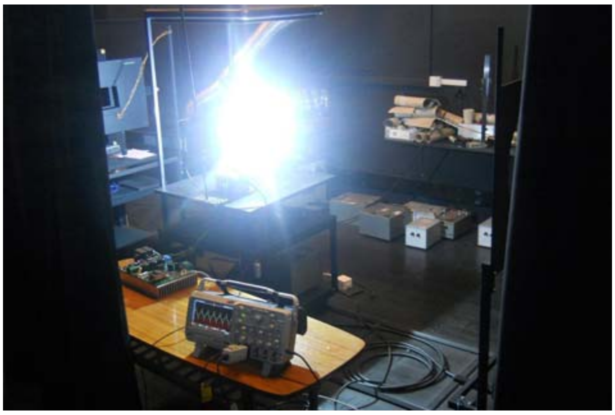

Fig.10. View of the developed electronic ballast at measuring test stand in the photometric laboratory

The Tektronix oscilloscope type MSO2024, current probe type TCP0030, 30 A_{rms} (50 A_{peak}) with bandwidth of 120MHz and a voltage probe type P5100, x100, 2,5 kV_{peak} and a bandwidth of 250 MHz were used for electric measurements. Power supplied to the lamp was calculated directly in the oscilloscope.

Fig. 11 shows the waveforms of the light radiation energy as a function of power supplied to the lamp. The researches were performed for frequency of the supply voltage f=100 kHz from electronic ballast and f=50 Hz from magnetic type ballast. The ΔE is an increase in light radiation energy at supplying the lamp with the rated apparent power Sn=400 VA for both frequencies is shown in the figure.

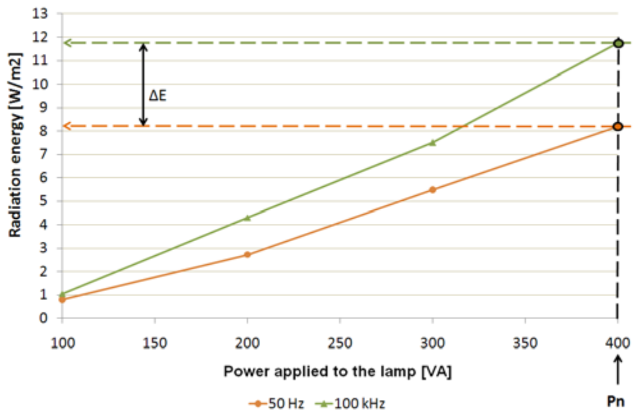

Fig. 11. Measurements of light radiation energy of a high pressure sodium lamp with a rated apparent power Sn=400 VA

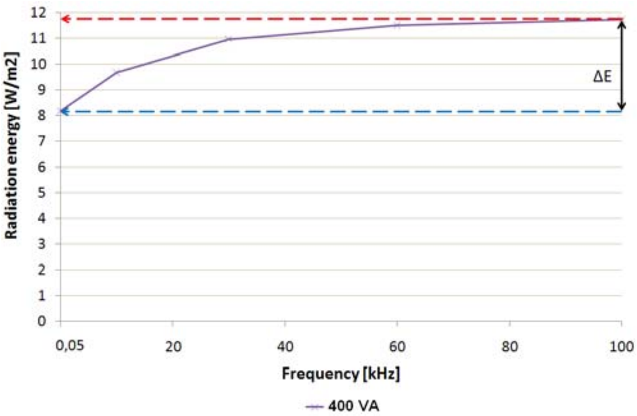

Fig. 12. Measurements of light radiation energy of a high pressure sodium lamp with rated apparent power of Sn=400 VA

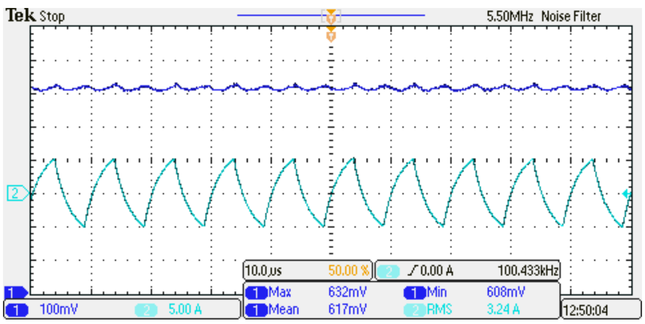

Fig. 12. Waveforms of voltage from the photo detector (channel 1) and of the metal-halide lamp supply current (channel 2). Measurements were performed for Sn=400 VA and f=100 kHz

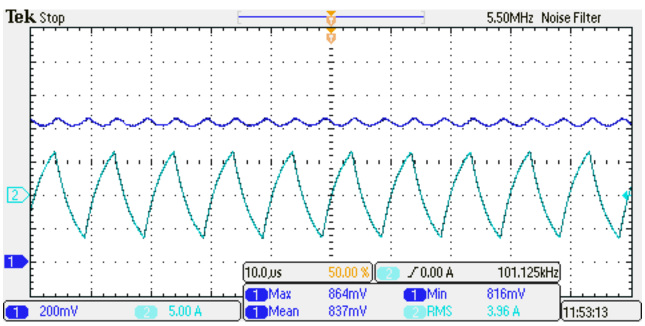

Fig. 13. Waveforms of voltage from the photo detector (channel 1) and of the high pressure sodium lamp supply current (channel 2). Measurements were performed for Sn=400 VA and f=100 kHz

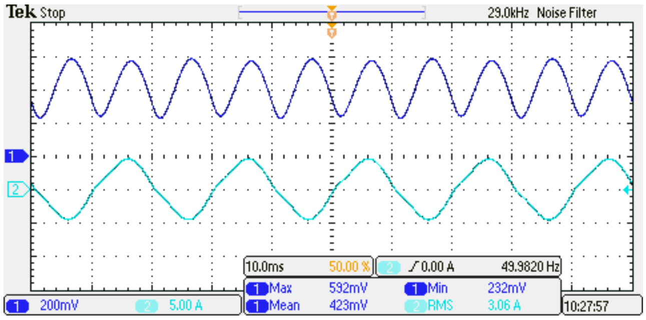

Fig. 14. Waveforms of voltage from the photo detector (channel 1) and of the metal-halide lamp supply current (channel 2). Measurements for Sn=400 VA and f=50 Hz

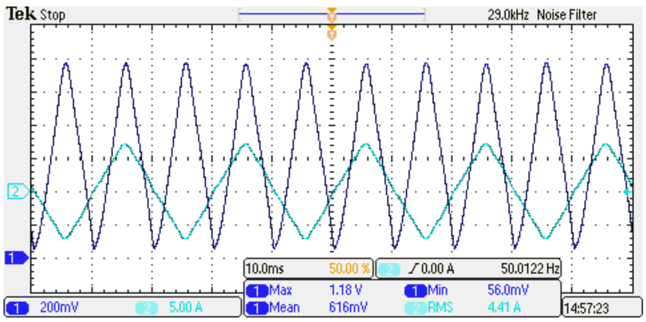

Fig. 15. Waveforms of voltage from the photo detector (channel 1) and of the high pressure sodium lamp supply current (channel 2). Measurements were performed for Sn=400 VA and f=50 Hz

Fig. 12 shows waveforms of light radiation energy as a function of frequency of the lamp supply voltage. The researches were performed for the rated apparent power supplying the lamp of Sn=400 VA. A measurement for frequency of f=50 Hz was made at supplying the lamp with power from a magnetic type ballast.

Measurements of light flux pulsation

Researches of light flux pulsation were performed for two types of discharge lamps: a high pressure sodium lamp and a metal-halide lamp. The power supplied to the lamp was Sn=400 VA. The tested lamps were supplied with power from a transistor bridge, the switching frequency of which was f=100 kHz. To compare the results, identical measurements were performed at supplying the lamp from a magnetic type ballast dedicated for such type of light sources. Measurements of light flux pulsation were performed measuring the time variation of the voltage across the output of a high speed photo detector.

The distance between the light source and the photo detector was 2 meters, hence all measurements of light flux pulsation were determined for this distance.
The schematic block diagram for the light flux pulsation is shown in Fig. 17. Calculations of the pulsation value [5] were made according to formula (1) and they were shown in Table 2.

$$w = ((z_{max} - z_{min}) / z_{max}) \cdot 100\ \% \qquad (1)$$

Description:

w - pulsation of the light flux
z_{max} - the maximum value of the photometric parameter
z_{min} - the minimum value of the photometric parameter

Table 2. Comparison of light flux pulsation values

Frequency of the voltage supplying the discharge lamp	f=50 Hz	f=100 kHz
Value of light pulsation for the high pressure sodium lamp	95,2 %	5,5 %
Value of light pulsation for the metal-halide lamp	60,8 %	3,8 %

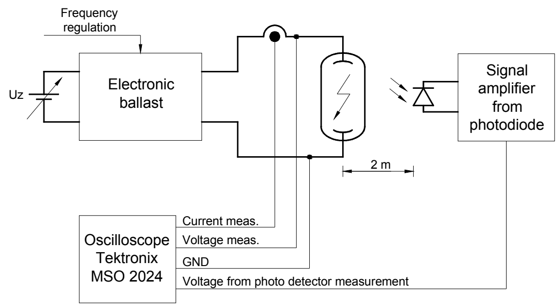

Fig. 16. Block diagram of the light pulsation test stand

Measurements of spectrum characteristics

Measurements of spectrum characteristics were performed using a digital spectroradiometer PHOTO RESEARCH type: PR-680.

The power supplied to the lamps amounted to Pn=400 W, it was a rated power. The distance between light source and the spectroradiometer was 2 meters.

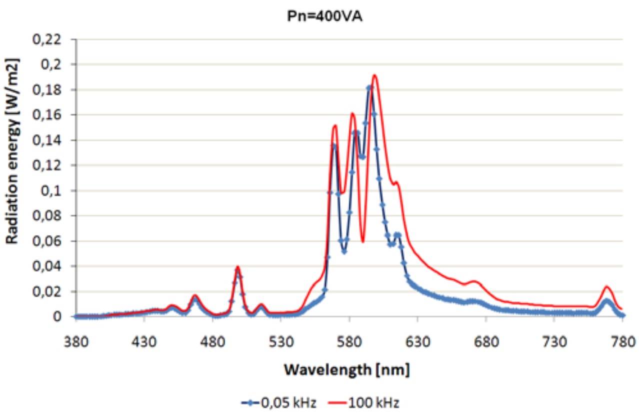

Fig. 17. Spectrum characteristics of a high pressure sodium lamp supplied with rated apparent power of Sn=400 VA

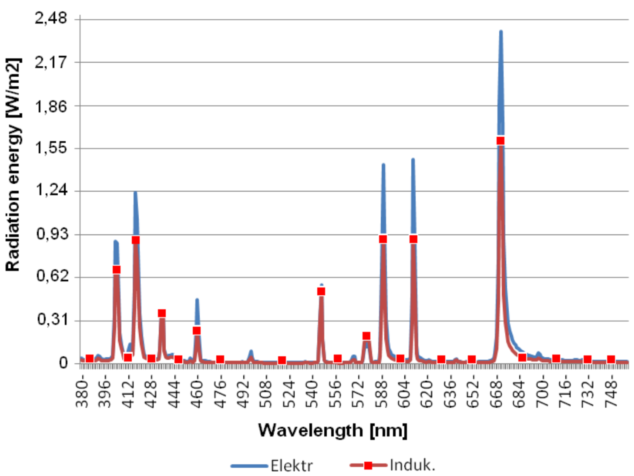

Fig. 19. Spectrum characteristics of a metal-halide lamp supplied with the rated apparent power of Sn=400 VA [6]

Tested lamps were supplied with power from an electronic ballast, the operation frequency was f=100 kHz. In order to compare the results measurements were also made supplying the lamp with power from a magnetic type ballast supplied by the mains frequency voltage. The measurement results are shown in Figs. 18 and 19.

Conclusions

Applying electronic ballasts operating at high frequency instead of magnetic type ballasts supplying a lamp with a voltage of mains frequency permits to improve the light parameters of discharge lamps. According to preformed researches it can be seen that for the lamp with a rated apparent power of Sn= 400 VA the value of radiation energy increases by ΔE=43,3% for high pressure sodium lamps and ΔE=13% for metal-halide lamps (in this case lamp used in researches were dedicated for vegetables lightning inside greenhouses). Pulsations of emitted light flux are distinctly reduced when supplying the lamps with a high frequency voltage. Applying a PFC system (Power Factor Correction) in design of the developed ballast permits to take sinusoidal supply current in phase with the mains voltage. Such a design enables to achieve a low level of interferences introduced into the power grid and does not have any negative effect on operation of other equipment connected to the same supply line.

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