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**ODESSA NATIONAL ACADEMY OF
FOOD TECHNOLOGIES**

International Competition of
Student Scientific Works

**BLACK SEA
SCIENCE 2020**
PROCEEDINGS



ODESSA, ONAFT 2020

Ministry of Education and Science of Ukraine
Odessa National Academy of Food Technologies

International Competition of Student Scientific Works

BLACK SEA SCIENCE 2020

Proceedings

Odessa, ONAFT 2020

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4. POWER ENGINEERING **AND ENERGY EFFICIENCY**

INVESTIGATION OF LED LIGHT SOURCES AND THEIR INFLUENCE ON THE POWER SUPPLY NETWORK

Authors: Dmitriy Lira¹, Aleksandr Baran²

Supervisor: Aleksandr Baran¹

¹*International Sakharov Environmental Institute of
Belarusian State University (Belarus)*

²*Slovakia State Technical University (Slovakia)*

Abstract. *This article presents the results of research of the operation of led strips and spotlights, they are a nonlinear load with harmonic components. High harmonics that occur when using led light sources lead to a significant increase in energy transfer losses, a decrease in the power factor, and can cause failures in the operation of start-protective equipment. When selecting start-protective devices for power lines, it is necessary to enter correction coefficients that take into account the non-linear nature of led technology.*

Keywords: *LED light sources, strip, spotlight, voltage, current, power factors.*

Introduction

The share of electricity consumption for electric lighting in total electricity consumption varies from country to country and ranges from 5 to 15% for the developed countries and up to 80% or more for the developing countries. In 2018 electricity consumption in the Republic of Belarus amounted to 38.8 billion kWh, with electric lighting accounting for about 19% of this amount [1]. In recent years many developed countries have begun to replace incandescent lamps and gas-discharge light sources to more modern energy-saving light sources. In Russia the rejection of incandescent lamps with a capacity of more than 100 W allowed to save 6030 MW, which is the capacity of the Sayano-Shushenskaya HES [2].

The most interesting and promising of the existing sources of optical radiation, are led light sources created on semiconductor devices with a p-n junction that emits incoherent light when an electric current is passed through it in the forward direction. They are a real alternative to incandescent and gas-discharge lamps that are widely used in Belarus at the present time.

The parameters of LEDs depend significantly on the amount of voltage applied to them and the current flowing through them. The most widely used models of LEDs are designed for a current of 10 to 20 mA. With an increase in the voltage applied to the led and the current flowing through it, the light output of the radiating p-n junction increases. Thus, by changing the applied voltage, you can adjust the amount of light flux of the source.

A number of factors contribute to the widespread use of led light sources, including:

- low power consumption, which is several times lower than that of fluorescent lamps, and almost by an order less than that of incandescent lamps;
- high luminous efficiency, which is up to 200 LM / W, which is higher than the luminous efficiency of incandescent lamps 6 ... 12 times, fluorescent lamps 1.5...2 times;

- long service life, which can reach some LEDs up to 30,000 hours;
- high resistance to mechanical damage;
- the absence of high electrical voltages and temperatures of all elements of the lamp;
- sufficiently high environmental safety and the absence of particularly dangerous compounds, such as mercury.

At the same time led sources have a fairly high cost, incompatibility with the existing supply voltage and special requirements for power sources, a gradual decrease in lighting characteristics with an increase in service life, a limited angle of light flux, features associated with the colour spectrum and light pulsation.

One of the most important features of led sources is that they are non-linear elements of the electrical network. The consequence of this is the appearance of harmonic components in the spectrum of electrical quantities of the supply network. Increasing the use of led sources in consideration of the above advantages, leads to a noticeable increase in the distortion of the harmonic signal of the supply network and the deterioration of the quality of electrical energy, and this affects the operation of electric motors, transformers and thermal electrical equipment.

The number and magnitude of the higher harmonics of led sources will largely be determined by the fact that many manufacturers, seeking to reduce the cost of their products, reducing its quality.

As a result, led light sources can be a source of higher harmonics, which will lead to exceeding the permissible standard values of current and voltage. As previously conducted studies have shown, led and gas-discharge light sources can have quite significant values of higher harmonics of the third order, as well as in some cases of the 9th and 15th order [3].

The return of mains harmonic components of voltage and current led light sources leads to a number of negative consequences they are measurement error of electricity, additional power losses in networks and transformers, excessive strain on wire and insulation of the mains, the problems of compensation of the reactive component of electrical power, interference for the transmission of electromagnetic signals.

Non-linear characteristics of led devices are not taken into account in the existing methods of calculations of electric networks and the choice of start protective devices, although the value of such current deviations can be up to 63%, and additional power losses can be up to 30% [1, 4-8]. This is confirmed by the authors experience during the study of the use of led light sources on various objects.

Today automatic switches with an electromagnetic release are used, in order as a rule, to protect lighting networks from short-circuit currents. They are selected according to the rated voltage, the rated current, the maximum cut-off current, the current of the setpoint operation (cut-off). When selecting the setpoint (cut-off) current, the following conditions must be met:

$$I_{cut-off} \geq k_{m.d}.I_{c.c.max}; \quad (1)$$

$$I_{cut-off} \geq k_{a.m}.I_{r.m.r.}, \quad (2)$$

$k_{m.d}$.- reliability coefficient of maximum disconnectors with reverse current-dependent characteristic;

$k_{a.m.}$ - multiplicity of the actuation current of the maximum instantaneous release in relation to the rated current of the release;

$I_{c.c.max}$ - maximum short-circuit current at the location of the switch, A;

$I_{r.m.r.}$ - rated current of the maximum release, A.

Taking into account the fact that the share of electricity for lighting in the total consumption of electricity for many consumers is about 20-30 %, it is important to understand the consequences of switching to led light sources and the associated negative impact of harmonic components on the power supply system.

Research methods

The active power of led light sources can differ significantly from the product of the actual values of voltage, current and power factor, since the curves of instantaneous values of these values are significantly different from sinusoids, and, therefore, to calculate the true value of the discharge power in the interelectrode gap, it is necessary to decompose the current and voltage curves into harmonic components. To characterize this process, except for the power factor determined by the formula:

$$\cos \varphi = \frac{P}{UI}, \quad (3)$$

the term harmonic signal distortion coefficient is used:

$$k_d = \frac{\sqrt{U_2^2 + U_3^2 + U_4^2 + \dots + U_n^2}}{U_1}, \quad (4)$$

P -active power, W;

U - current voltage value, V;

I - current value, A;

U_n -voltage of higher harmonics, V;

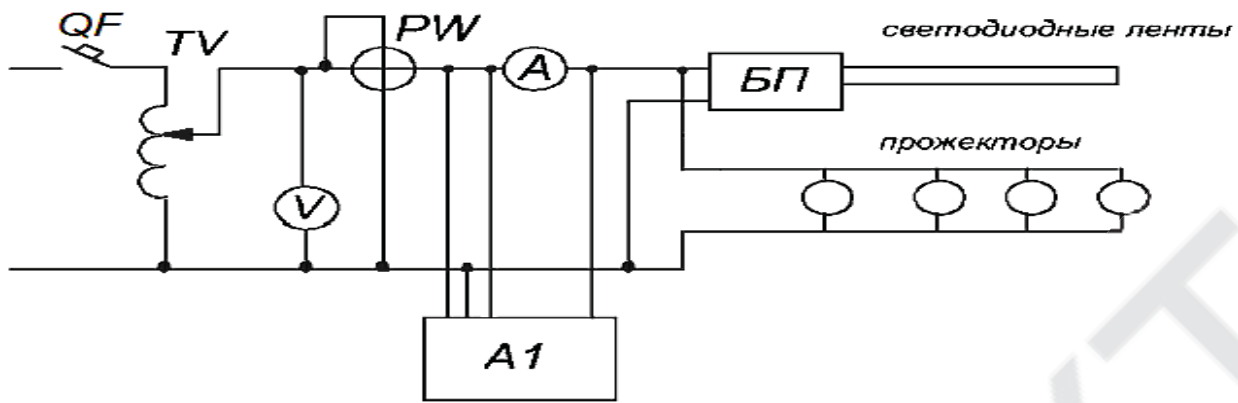
U_1 - voltage of the first harmonic, V.

The distortion coefficient of the harmonic signal depends on the quality of the mains voltage and is not constant for these optical radiation sources. GOST 32144-2013 [9] allows a deviation of the voltage at the consumer $\pm 10\%$ of the nominal for 100% of the time interval of one week, i.e., a change in the network phase voltage is allowed in the range from 198 V to 242 V, which entails changes in the current and power of the led light source.

For each led, there are valid supply voltage values U_{min} and U_{max} . When the voltage is applied above the U_{max} values, an electrical breakdown occurs, as a result of which the led fails. At a voltage below U_{min} , the led does not generate visible radiation. The range of supply voltages between both U_{min} and U_{max} is called the "working" zone (the allowable range of voltage variation).

For a more detailed study of these phenomena at the Department of energy-efficient technologies of the ISEI state University named by A.D. Sakharov BSU developed and manufactured a test table (picture 1), which allows you to record not only the integral characteristics of the measured values, but also to observe them in dynamics.

The research was carried out in the range of "working" voltage from 100 to 260 V, i.e. from the moment of ignition to the permissible overvoltage. The voltage and current waveforms were examined with a two-beam Hantek DSO 5062B oscilloscope.



Picture 1. Schematic diagram of the test stand: QF-circuit breaker; TV-voltage regulator; PW-wattmeter; A-ammeter; V-voltmeter; BP-led strip power supply AC input 180-264 V; A1-Hantek DSO5062B oscilloscope.

Research result

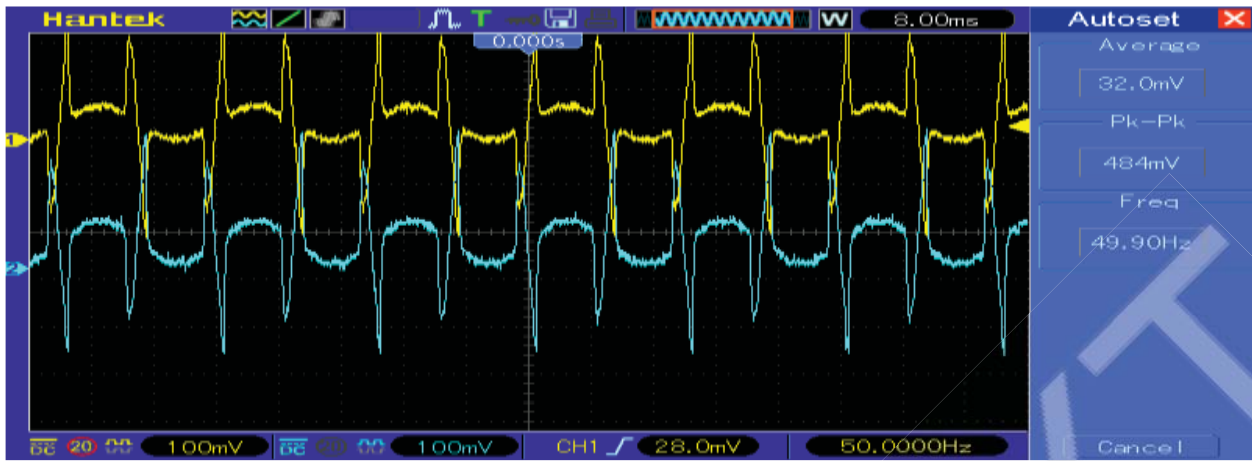
The received waveforms of the voltages at the sources with led tape and projectors are represented respectively in Pic. 2 and 3. The oscillograms showed the presence of harmonics in the voltage passing through the led source, which significantly distort the shape of the sinusoidal signal of these values. However, lamp power is not equal to the product of effective values of voltage and current as curves the instantaneous values of these quantities differ substantially from sinusoids, and consequently to calculate the true value of the discharge power in a p–n junction of the led must be expanded curves of current and voltage harmonic components. Therefore, the term "distortion coefficient" is used».

$$k_a = \frac{P}{UI} \quad (5)$$

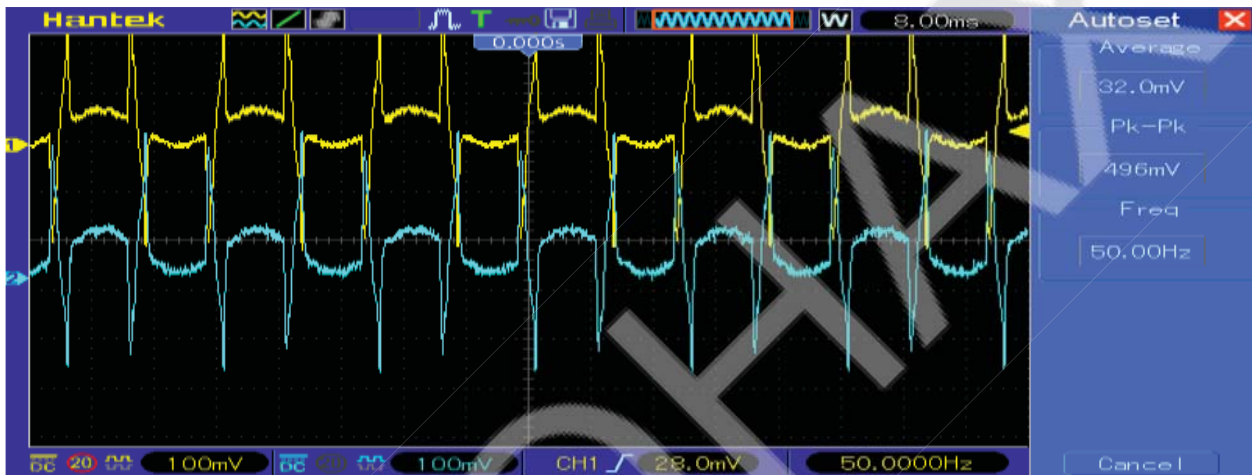
The operation of led light sources in the AC network is somewhat different from the operation in the DC network and makes its own additional requirements for optimizing the circuits of their power sources. During operation in the AC network the processes of occurrence and termination of electric discharge in the source are resumed each half-period of a sinusoidal change in the voltage of the supply network, while the source parameters (voltage, current and radiation flow) are constantly changing.

The volt-ampere characteristic of the led is nonlinear, and each voltage value corresponds to its own value of the current flowing through the led. The increase of voltage, the results in increase of the current value and the increase of the radiated light flux (luminosity), since the light flux changes, therefore, and is regulated when the voltage changes.

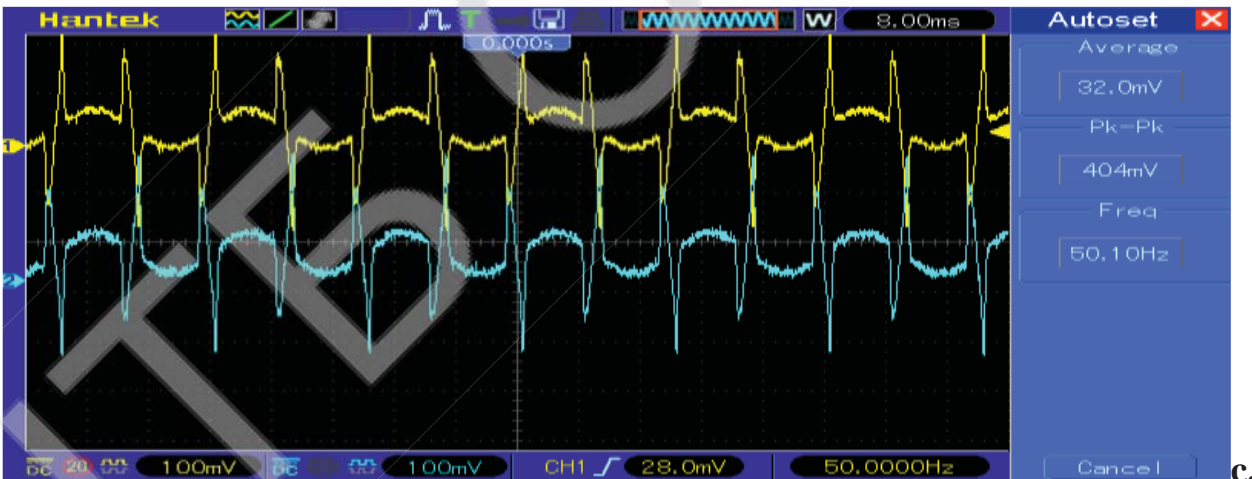
The current and active power values were obtained using the stand's measuring instruments, and the total power, power factor were calculated on the studied led light sources at different values of the input voltage in the accepted "working" range. The results of the research are presented in table 1 and 2.



a.

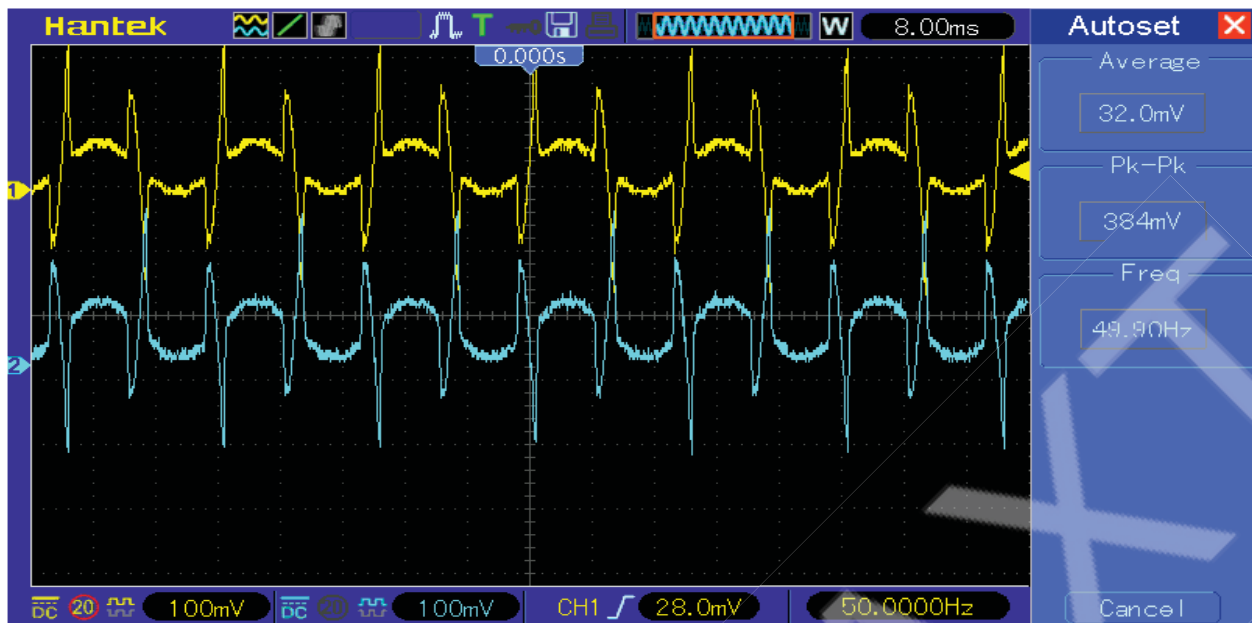


b.



c.

Picture 2. Oscillogram of voltage (1) and current (2) during operation of LED strips at voltage: a - 200 V; b - 225 V; in - 250 V



Picture 3. Oscillogram of voltage (1) and current (2) during operation of SDO06 led spotlights

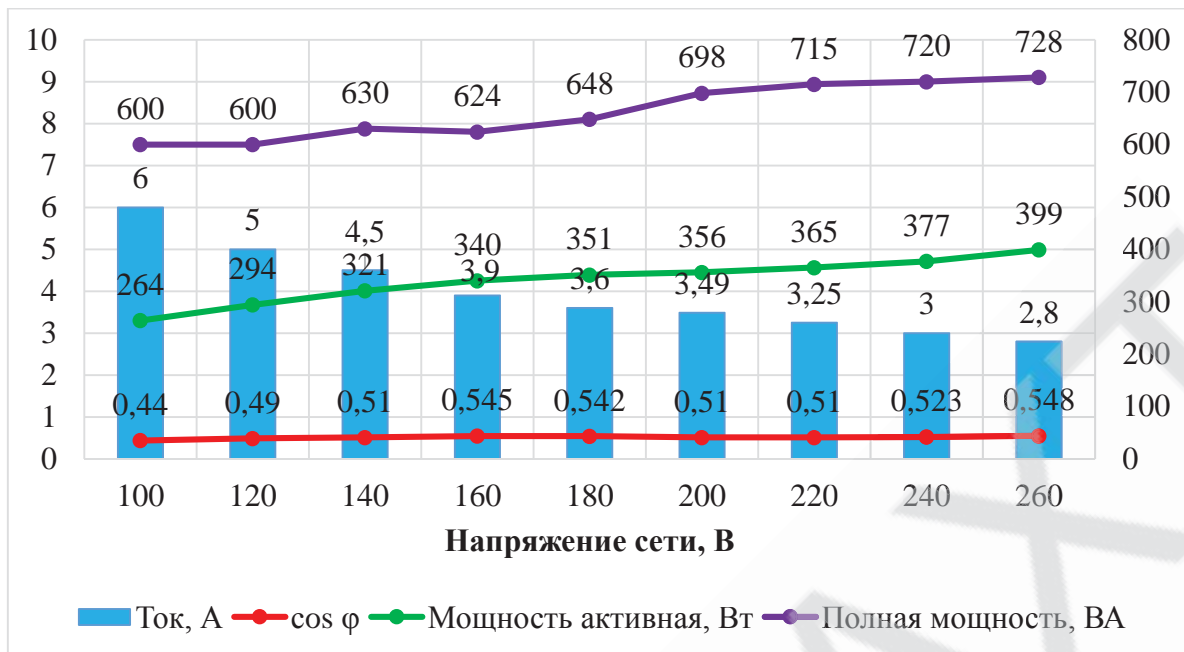
Table 1 – Research results of LED strips LED Strip 5050SND l = 5 m, 6 pcs., 2 blocks x 300 W

Network voltage, V	Current, A	Active power, W	Full power, VA	cos φ
100	6,0	264	600	0,440
120	5,0	294	600	0,490
140	4,5	321	630	0,510
160	3,9	340	624	0,545
180	3,6	351	648	0,542
200	3,5	356	698	0,510
220	3,25	365	715	0,510
240	3,0	377	720	0,523
260	2,8	399	728	0,548

Table 2 – The research results of LED spotlights SDO - 06

Network voltage, V	Current, A	Active power, W	Full power, VA	cos φ
100	3,10	266	310	0,850
120	2,93	295	352	0,839
140	2,74	321	384	0,837
160	2,56	340	410	0,830
180	2,40	352	432	0,772
200	2,28	356	456	0,781
220	2,20	365	484	0,754
240	2,11	377	506	0,740
260	2,03	399	528	0,750

Based on the results obtained, graphs of the dependence of current, active, full power and power factor for the studied voltage values were constructed, which are shown in picture 4 for a source with led strip and in picture 5 for led spotlights.



Picture 4. Dependence of current, active and apparent power, power factor of LED Strip 5050SND LED strip on supply voltage.

The analysis of the obtained results shows that the change in the mains voltage in the range allowed by the current standard from 198 V to 242 V on led light sources leads to a decrease in current by 17% and an increase in active power by 8 %, and the total power on average by 12 %. In this case, the power factor will have sufficiently low values and be in the specified voltage range for the investigated source on the led strip 0.51-0.55, and for led spotlights-0.74-0.78.

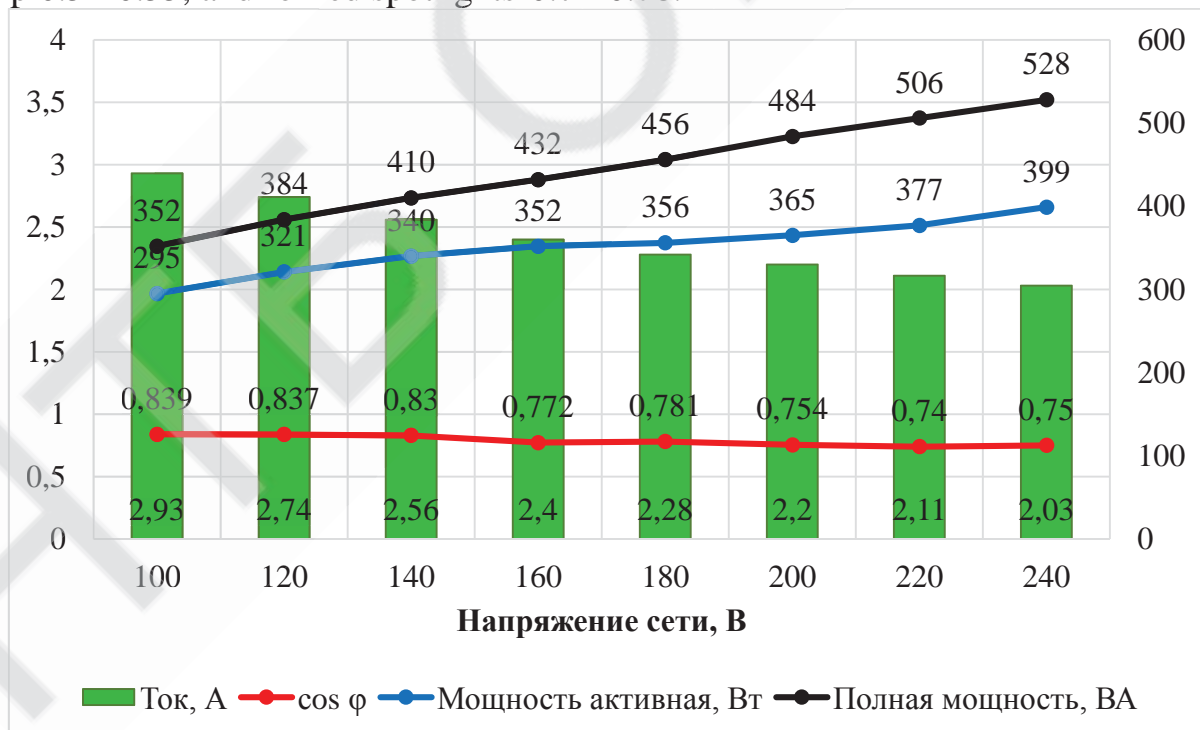


Figure 5. Dependence of current, active and apparent power, power factor of LED spotlights SDO-06 on supply voltage.

To increase the power factor of the supply network with a static lighting load, it is possible to use passive filter-compensating devices.

The use of reactive power compensation devices allows:

- maintain the required power factor of electrical installations;
- improve the quality of electricity directly in the power supply networks;
- reduce power consumption for lighting up to 45-49% for led strips and 22-26% for led spotlights;
- reduce energy and power losses in the power supply system (overhead lines, transformers);
- reduce the load of the elements of the supply or distribution network, increase their service life.

Reactive power compensation in the lighting system it can be individual when compensating capacitors are installed at each lamp or power supply unit of the led strip, and group when they are installed on group lines, in the power supply network or on the buses of a substation. The choice of a method of compensation for reactive power is determined by the feasibility study.

The power of the compensating unit Q , kVAr, required to increase the power factor of the network, is defined as:

$$Q = P_{calc}(tg\varphi_1 - tg\varphi_2), \quad (6)$$

P_{calc} - total rated power of the lighting system taking into account the demand and loss factors in the power supply, kW;

$tg\varphi_1, tg\varphi_2$ - phase shift angles before and after compensation, respectively.

Conclusion

Led light sources are non-linear loads with a capacitive nature.

The widespread introduction of led lamps may be accompanied by problems associated with maintaining the standard values of electricity quality indicators, because their operation leads to the appearance of higher current and voltage harmonics in the power supply networks. Real instantaneous and active currents differ significantly from those of the first harmonic.

High harmonics that occur when using led light sources lead to an increase in losses during transmission and consumption of energy by other consumers up to 30 % and can cause failures in the operation of start-up protection equipment.

The results of the research can be the following recommendations:

- when selecting start-up protection devices and supply lines, it is necessary to introduce corrective coefficients that take into account the nonlinear nature of the load and the associated increase in instantaneous current values. The specification of the coefficients requires further research.

- to reduce the current harmonics and increase the power factor, it is advisable to use active correction in circuits with led light sources using special power factor correctors.

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