Influence of switching processes on effective operation modes of mixed load with complex waveform current supply

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Abstract. Currently, the development of effective modes of mixed-load with a complex waveform current supply is relevant. In the article by the example of the physical model of a low-voltage electrode water heater and an energy-saving lamp, the work of mixed load after switching in the network is investigated**.**
The purpose of the work is the processes research of heating in the electrode water heater and lighting characteristics of an energy-saving lamp with the complex waveform current supply. This was made to select the efficient mixed-load modes in a steady-state mode after commutation in the power node. This required the solution of scientific problems in the development of mixed-load research methods, obtaining regulatory characteristics, developing recommendations for the selection of effective operation modes necessary for the synthesis of the automatic control system algorithm.
The decision of the task allowed us to determine the influence of the electromagnetic component along with the temperature on the processes of water heating and lighting parameters of the lamp. It is proved that the mixed load in a steady-state mode after commutation works in an efficient mode.

1. Introduction

The efficiency of electrotechnological installations (ETI) is increased not only by mechanization and automation of the process. There are known developments of energy-saving technologies, for example, for induction heating of light alloys (aluminum, titanium) on the basis of electrothermal models of processes in the technological link. The application of the theoretical studies results allowed one to change the design of multilayer windings of induction heaters and reduce losses in the windings; reduce the energy consumption in the use of precision heating of long workpiece before processing pressure; develop an effective method of titanium crucibleless melting in a calm atmosphere [1-3] .

In electrotechnology, the increase efficiency of ETI is also possible during improvement of an electric mode due to use of the complex waveform current (CWC) with a constant component or without it in arc steelmaking furnaces of small capacity; electrolysis installations (with solutions, melts of electrolytes); resistance electric furnaces of direct and indirect heating (with dark and light infrared radiators, etc.). Their operation mode involves enabling, disabling and also changing the circuit parameters.

Currently, the development of effective technical means of water heating-low-voltage electrode water heaters used for heating water for individual processes in enterprises is relevant. An operating mode of water heater in the shop, the department is different in power and duration. Its power is realized from one of the substation transformer busbars together with the illumination load. In the node load is unavoidable switching processes, which can be dangerous for insulation, surge protection and multiple increase of the currents, for example, in the starting mode of the engine. The results of studies of transients researches in electric power systems (EPS) are presented in the works of domestic and foreign scientists: the decrease in the reliability of EPS during system fluctuations; the influence of periodical changing of the load and incorrect settings of the automatic controller of the synchronous generator as the causes of low-frequency oscillations and its detection by synchronized vector measurements [4]; transients in networks in different operation modes of the transformer neutral [5], improvement of methods of calculation of transients [6]. However, there are no the results of the research in the literature: whether the effective mode in ETI with the complex waveform current is supplied under mixed load in the power node in a steady state after switching in the network.

2. Used instruments

The following instruments were used for research: fiber optic spectrometer type AvaSpec-ULS2048-USB2, included - software AvaSoft-ALL. For measuring electrical parameters, the authors used the analyzer of electric energy quality - ANALYST 2060. To measure the temperature of water heating, the authors used a thermocouple included in the multimeter EM5512.

3. The experimental researches

In work the authors researched the heating process in an electrode water heater and lighting parameters in an energy-saving lamp during CWC supply (during the change of amplitude and frequency of the feeding voltage (current)) for the choice of effective modes in the steady-state mode after switching in a load node. To achieve the goal, scientific problems were solved: development of a method for studying mixed load in comparison with normal and new electric modes with a CWC supply, obtainment of control characteristics and selection of effective modes after switching in the network, and solution of the problem of developing a control algorithm and an automatic control device to maintain an effective mixed load mode.

Works [7-8] proved the feasibility of using the CWC for improving efficiency of dark infrared radiators "Nomacon", that is, by improving the electrical mode. The results of experiments on the influence of the electric mode on the operation of installations with dark IR radiators "Nomakon" type of IRS-203-0,1/230-2 power of 100 W 60x60 mm were presented. Experiments were performed for four different electrical modes.

The presented results of research were compared in two electrical modes: when a mixed load is connected to the power node and operating in the normal electrical mode with an alternating current supply of 50 Hz and during the CWC supply without a constant component, because the rectified current (its constant component) causes water electrolysis. In the normal mode, the mixed load power supply was carried out from a single-phase transformer 220/110 V with switching voltage without excitation A-X1, A-X3. In the second mode, a throttle was provided to regulate the form of the supply voltage (current). The physical model of the low-voltage electrode heater is a glass vessel with a non-consumable water volume of 500 ml. Two steel plate electrodes 18x90 mm^2 were installed in it. The experiments used the same organoleptic properties of water composition: drinking water. The initial temperature of the water in the experiments was 22 ^{o}C. The time of the experiment was 10-15 minutes. The energy saving lamp LUXURY with a power of 20 watts was selected as a light source.

4. The results of experiments

The results of experiments for the normal electric mode with alternating current of 50 Hz when operating in the load node of the energy-saving lamp and the subsequent connection of the electrode water heater are given in table 1.

Table 1. The results of experiments for the normal electric mode with alternating current of 50 Hz when operating in the load node of the energy-saving lamp and the subsequent connection of the electrode water heater

Electrical modes	Network power			Power factor
	Active, kW	Reactive, kVar	Full, kVA	
Normal mode: alternating current, 50 Hz (energy-saving lamp turned on)	0.020	0.089	0.091	0.22
Normal mode: alternating current, 50 Hz (mixed load turned on)	0.076	0.092	0.119	0.63

Figures 1-4 show the windows of radiation spectra, color diagrams, color temperature, luminous flux and photon output from the diffuser surface for an energy-saving lamp with a power of 20 W for the normal mode: a) the lamp is turned on; b) the mixed load.

The results of experiments with mixed load in the new electrical mode of the CWC supply are given in table 2: a) lamp is turned on; b) mixed load.

Figures 5 show the windows of color diagrams, color temperature, luminous flux and photon output from the diffuser surface for an energy-saving lamp with a power of 20 W for the new mode: the mixed load.

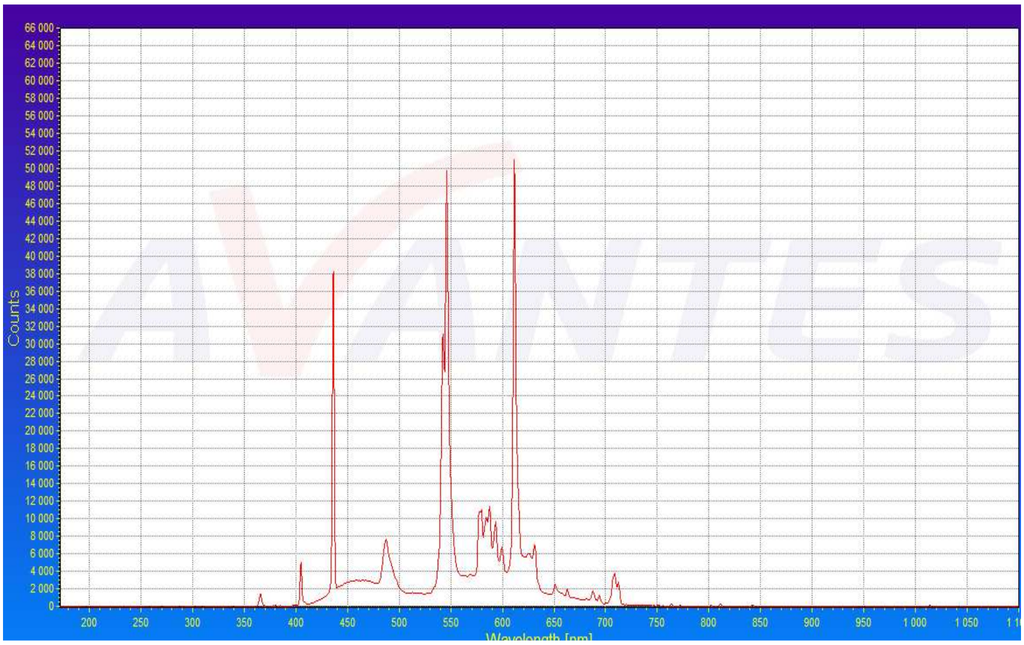

Figure 1. The window of the radiation spectrum of energy saving lamp 20 W LUXRAY for the normal mode: the intensity of radiation at a wavelength of 430 nm – 38000, 550 nm - 50000, 620 nm – 51000 (only the lamp is turned on)

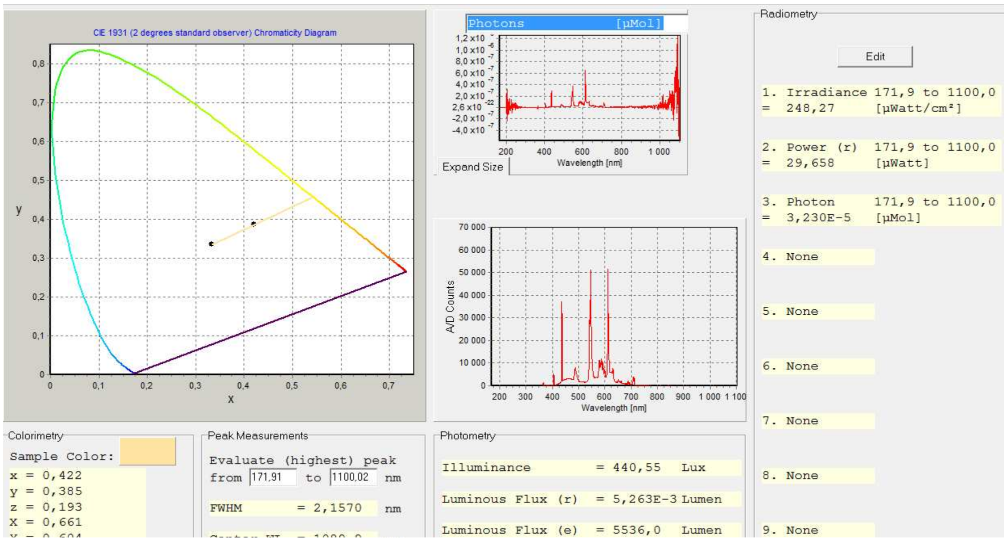

Figure 2. The color chart window of a LUXRAY energy saving lamp of 20 W for the normal mode: the color temperature – 3127.5 K, the luminous flux – 5506.8 lm, the photons output from the surface of the diffuser is 3.23 e-5µMol (only the lamp is turned on)

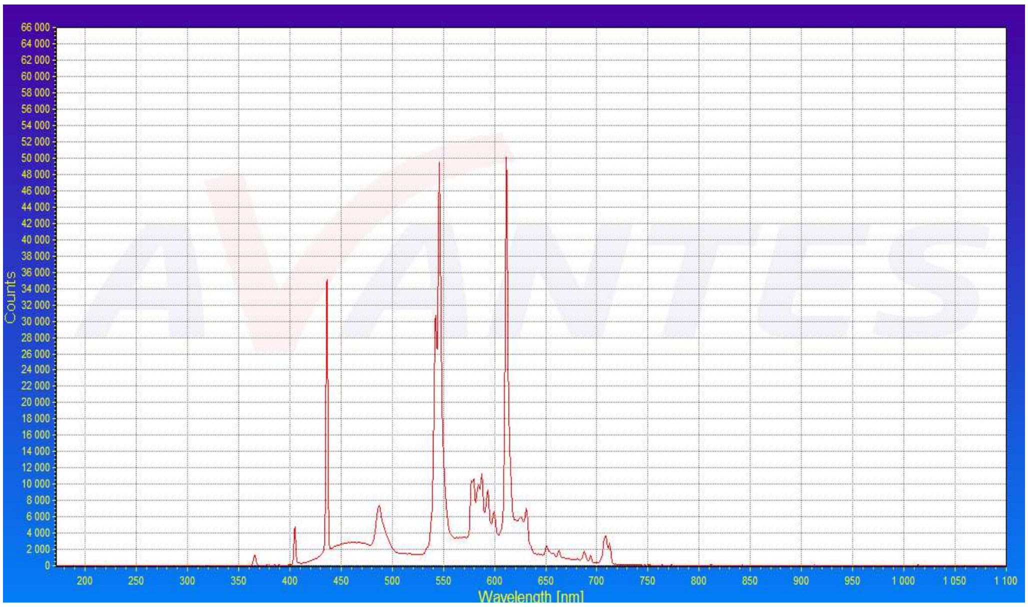

Figure 3. The window of the radiation spectrum of the energy saving lamp 20 W LUXRAY for the normal mode: the intensity of radiation at a wavelength of 430 nm – 35000; 550 nm – 50000; 620 nm – 50000 (the lamp and the water heater are turned on)

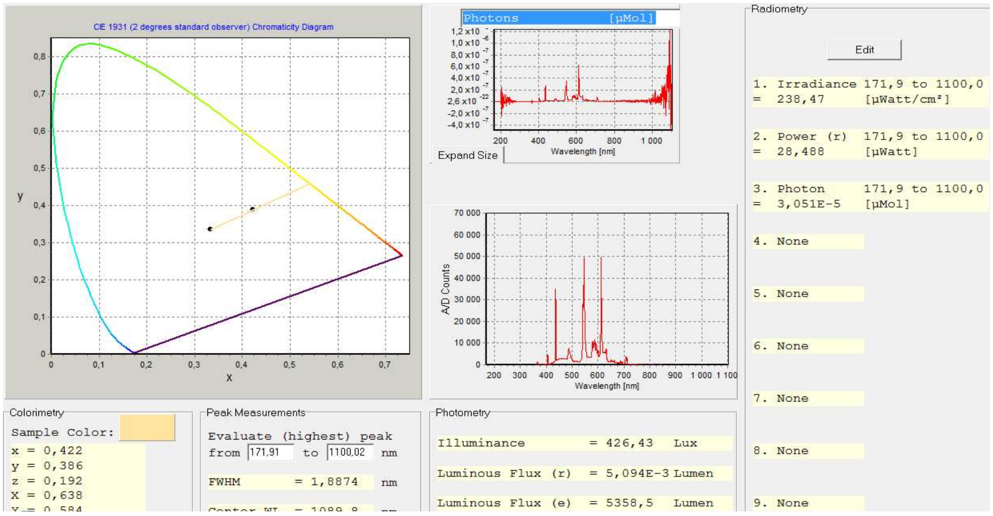

Figure 4. The color chart window of a LUXRAY energy saving lamp of 20 W for the normal mode: the color temperature – 3116.9 K, the luminous flux – 5286.6 lm, the photons output from the surface of the diffuser of 3.051 e-5µMol (the lamp and the water heater are turned on)

Table 2. The results of experiments for the new electric mode with the complex waveform current supply when operating in the load node of the energy-saving lamp and the subsequent connection of the electrode water heater

Electrical modes	Network power			Power factor
	Active, kW	Reactive, kVar	Full, kVA	
New mode: Complex waveform current without constant component (energy-saving lamp turned on)	0.013	0.016	0.021	0.619
New mode: Complex waveform current without constant component (mixed load turned on)	0.089	0.019	0.091	0.97

5. Analysis of the results

To analyze the results in the water heaters, a hypothesis was adopted that in the new electric mode when using CWC with no constant component, when the frequency of the water molecules vibration coincides with the frequency of the external driving force, the amplitude of fluctuations and displacement and the mobility of water molecules increases. When using a current of complex shape, the kinetic energy of molecules and the number of collisions increases, which causes an increase in the rate of rise of temperature. When providing the same rate of temperature rise in the compared modes, the transformer in the new mode can operate at a lower stage. And for light sources, the possibility of improving energy performance is experimentally and theoretically proved [7-8]. It was determined that power factor for a mixed load increased from 0.63 to 0.97 (table 1 and table 2). The output of photons from the diffuser surface increased (Figure 5) at the same color temperature value 3116.9 K (Figure 4) and 3115.2 K (Figure 5). The data analysis of table 1 and table 2 showed that the disconnection of the heater or the lamp does not change the efficient mode parameters of operation of the each power consumers with CWC supply. Only the absolute values of power and power factor change during the switches and the load continues to operate in the efficient electrical mode.

6. Conclusion

By the example of the low-temperature electrode of the water heater and the energy-saving lamp, it was determined that the operation efficiency improves in the power node with mixed load in the mode with the power supply in the steady state after switching on the network. For the water heater, the electromagnetic component along with the temperature affects the mobility of charged particles in the water. It increases the efficiency of the heating process. The output of photons from the diffuser surface indicates that the electromagnetic component in the lamp also activates the processes along with the temperature component. For the studied mixed load, this is manifested in an increase of the power factor in the power node: the increase in the power factor from 0.63 (normal mode) to 0.97 (new mode). In the steady-state mode, after switching in the network, the effective mode of the electrode water heater (at the same temperature rise speed) and the color temperature in the energy-saving lamp are saved.

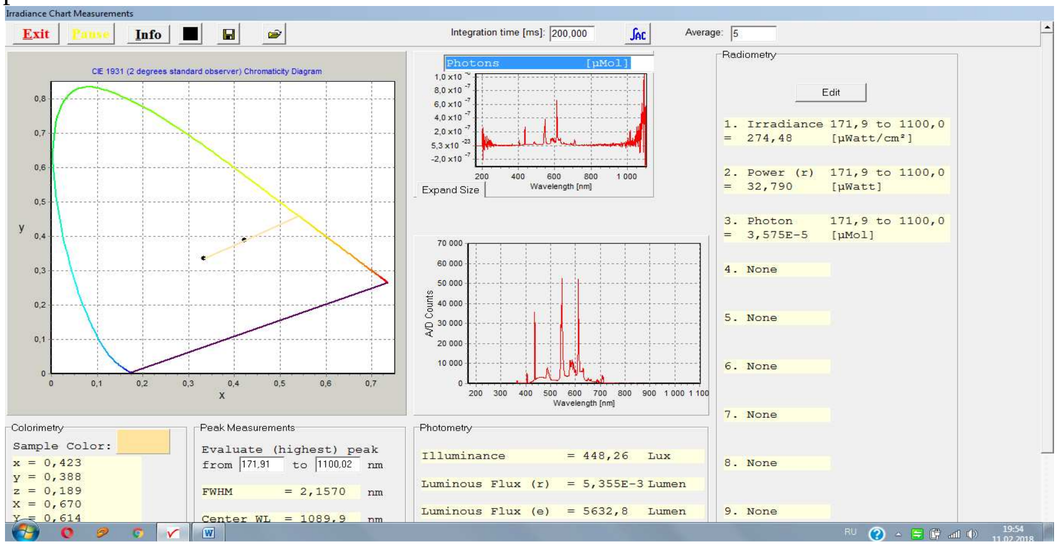

Figure 5. The color chart window of a LUXRAY energy saving lamp of 20 W for the new mode: the color temperature – 3115.2 K, the luminous flux – 5603.3 lm, the photons output from the surface of the diffuser 3.575 e-5µMol

References

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