GOCE DELCEV UNIVERSITY, STIP, NORTH MACEDONIA
FACULTY OF ELECTRICAL ENGINEERING

ETIMA 2023

SECOND INTERNATIONAL CONFERENCE

27-29 SEPTEMBER, 2023

TECHNICAL SCIENCES APPLIED IN ECONOMY, EDUCATION AND INDUSTRY

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УНИВЕРЗИТЕТ „ГОЦЕ ДЕЛЧЕВ", ШТИП, СЕВЕРНА МАКЕДОНИЈА

FACULTY OF ELECTRICAL ENGINEERING,
GOCE DELCEV UNIVERSITY, STIP, NORTH MACEDONIA

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PREFACE

The Faculty of Electrical Engineering at University Goce Delcev (UGD), has organized the Second International Conference ***Electrical Engineering, Informatics, Machinery and Automation - Technical Sciences applied in Economy, Education and Industry-ETIMA*.**
ETIMA has a goal to gather the scientists, professors, experts, and professionals from the field of technical sciences in one place as a forum for exchanging the ideas, strengthening the multidisciplinary research and cooperation, and promoting the achievements of technology and its impact on every aspect of living. We hope that this conference will continue to be a venue for presenting the latest research results and developments on the field of technology.
Conference ETIMA was held as online conference. More than sixty colleagues contributed to this event, from five different countries with more than thirty papers.
We would like to express our gratitude to all the colleagues, who contributed to the success of ETIMA'23 by presenting the results of their current research and by launching the new ideas through many fruitful discussions.
We invite you and your colleague to attend ETIMA Conference in the future as well. One should believe that next time we will have opportunity to meet each other and exchange ideas, scientific knowledge and useful information as well as to involve as much as possible the young researchers into this scientific event.

The Organizing Committee of the Conference

ПРЕДГОВОР

Меѓународната конференција ***Електротехника, Технологија, Информатика, Машинство и Автоматика-технички науки во служба на економија, образование и индустрија-ЕТИМА*** е организирана од страна на Електротехничкиот факултет при Универзитетот „Гоце Делчев“.
ЕТИМА има за цел да ги собере на едно место научниците, професорите, експертите и професионалците од полето на техничките науки и да претставува форум за размена на идеи, да го зајакнува мултидисциплинарното истражување и соработка и да ги промовира технолошките достигнувања и нивното влијание врз секој аспект од живеењето. Се надеваме дека оваа конференција ќе продолжи да биде настан на кој ќе се презентираат најновите резултати од истражувањата и развојот на полето на технологијата.
Конференцијата ЕТИМА се одржа online и на неа дадоа свој придонес повеќе од шеесет автори од пет различни земји со повеќе од триесет труда.
Сакаме да ја искажеме нашата благодарност до сите колеги кои придонесоа за успехот на ЕТИМА'23 со презентирање на резултати од нивните тековни истражувања и со лансирање на нови идеи преку многу плодни дискусии.

Организационен одбор на конференцијата

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PHYSICAL LIMITATIONS OF DIMMING OF 400 W RATED HALIDE LAMPS (A CASE STUDY)

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Abstract

The aim of the expertise in this case study was to find out the cause of the malfunctioning of the lamps in the production hall. The light source was a halogen discharge lamp with a nominal power of 400 W. In accordance with the requirements of the investor, the lighting intensity regulation was installed in the premises of the production hall according to the daily light conditions. In conclusion, we explain the physical and chemical mechanism of the cause of failures of a halogen lamp with a nominal power of 400 W. Due to uncontrollable non-equilibrium states and changes in activation energy, the regulation of the discharge of halogen lamps with a nominal power of 400 W is inappropriate.

Key words

Halide lamps, dimming, regulation of light flux.

Introduction

The eighty-eight lamps were installed in the production hall. Over the course of 15 months, changes were noted on all fixtures. 46 lamps were completely non-functional and had to be completely replaced with new ones, light sources were replaced in 28 lamps, a choke or lighter had to be replaced in other lamps, and 2 lamps in the production hall remained non-functional even after repairs, because the lamps were not accessible. The objective of the expertise was to find out the cause of the failure of light sources and lamps in the production hall.

1. Basic data

The lighting of the production hall was realized with lamps designed for high-pressure halogen discharge lamps. The rotationally symmetrical reflector of the lamp was aluminum with a lower cover made of tempered glass. The electrical accessory was a conventional electromagnetic ballast with an igniter. Electrical components - igniter, choke, compensating capacitor are located inside the lamp box on a galvanized sheet metal installation plate. The lamp box was plastic with one cable entry for the power cable. The internal wires have a twisted copper core and silicone insulation, ensuring heat resistance up to 130°C. The light source was a halogen discharge lamp with a nominal power of 400 W. The lamps were installed vertically on a support structure at a height of 7 m above the floor. According to the investor's requirements, regulation of the intensity of artificial lighting according to daylight conditions was installed in the premises of the production hall. The lighting intensity was measured using 6 sensors in the production hall. The power unit of the regulator was controlled by programmed lighting control schedules and superimposed the modulating voltage on the mains voltage AC 230 V, which is used to power the regulators and lamps. Based on the received control signals, the controller was supposed to smoothly regulate the power of the connected lamp.

2. Experimental

The subject of the experiment was to simulate the operating electrical conditions in the lamp with the aim of identifying the influence of the regulator connection on the current and voltage on the discharge lamps. The experimental sets were designed in a combination of a lamp with and without a regulator and powered by a stabilized voltage source CHROMA model 61505, first with a voltage of 230 V and then with a limit increased voltage of 253 V. The values and courses of the output voltage and current were recorded by an ELCOM network analyzer type ENA500. The analyzer records waveforms simultaneously, time-synchronized. From the measured values and oscilloscope waveforms, current and voltage deformation waveforms were evaluated. Due to measurement safety and high ignition voltage values, the voltage on the discharge lamp was measured only after the discharge was ignited. After the onset and stabilization of the discharge (after about 15 min), the time courses of voltages and currents were recorded. The effective values of voltages and currents were recorded at 200 ms intervals. The boundary conditions of the measurement - temperature and humidity in the room varied between 24°C and 26°C and 52% and 55% during the experiment. The experimental sets were 24 combinations of specific components that were used in the production hall. Fig. 1 shows the discharge lamps on which the measurements were carried out. Fig. 2 shows a change in the color of the cover of choke due to increased temperature

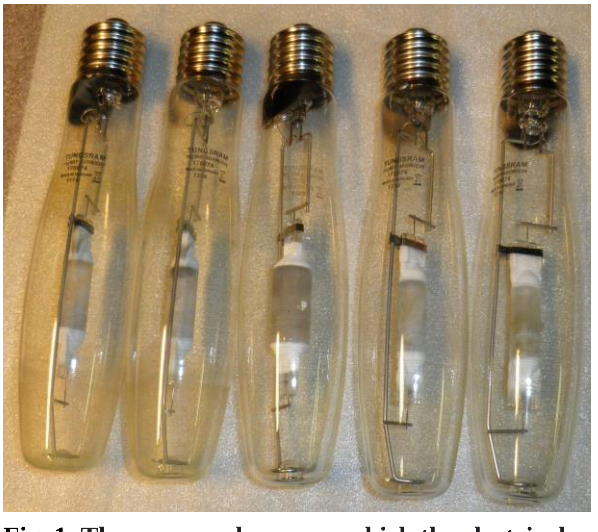


Fig. 1 The mercury lamps on which the electrical parameters were monitored.

Fig. 2 A choke showing a change in the color of the cover due to increased temperature

3. Results

We present only selected results from the experiments. In the Note 1, the measured quantities are described in more detail. The measured values of voltages and currents after stabilization on the lamp and the discharge lamp are shown in the table 1 and table 2. The manufacturer's permitted values of voltage and current on the observed discharge lamps are shown in table 3.

Note 1: Name of the measured quantity and description

Supply voltage: 50 Hz sinusoidal AC voltage set on the power supply (230 V, 253 V) and measured by the analyzer at the same time
Voltage on the lamp: Voltage measured on the terminals of the lamp

Current flowing through the lamp: Current measured by current clamps placed in front of the lamp
Voltage on the discharge lamp: Voltage measured at the discharge lamp leads
Current flowing through the discharge lamp: Current measured by current clamps placed in front of the discharge lamp
Current flowing through the regulator: Current flowing from the power supply to the regulator, measured by current clamps located in front of the regulator

Table 1: Measurement without voltage regulator

Measurement number	Supply voltage [V]	Voltage on the lamp [V]	Current flowing through the lamp [A]	Voltage on the discharge lamp [V]	Current flowing through the discharge lamp [A]
1	230	230.2	2.051	136.8	3.626
2	253	253.3	2.232	148.3	4.099
5	230	230.1	2.016	127.3	3.862
6	253	253.1	2.205	137.5	4.351
7	253	253.1	2.233	148.4	4.078
8	230	230.1	2.053	137.3	3.598

Table 2: Measurement with a voltage regulator

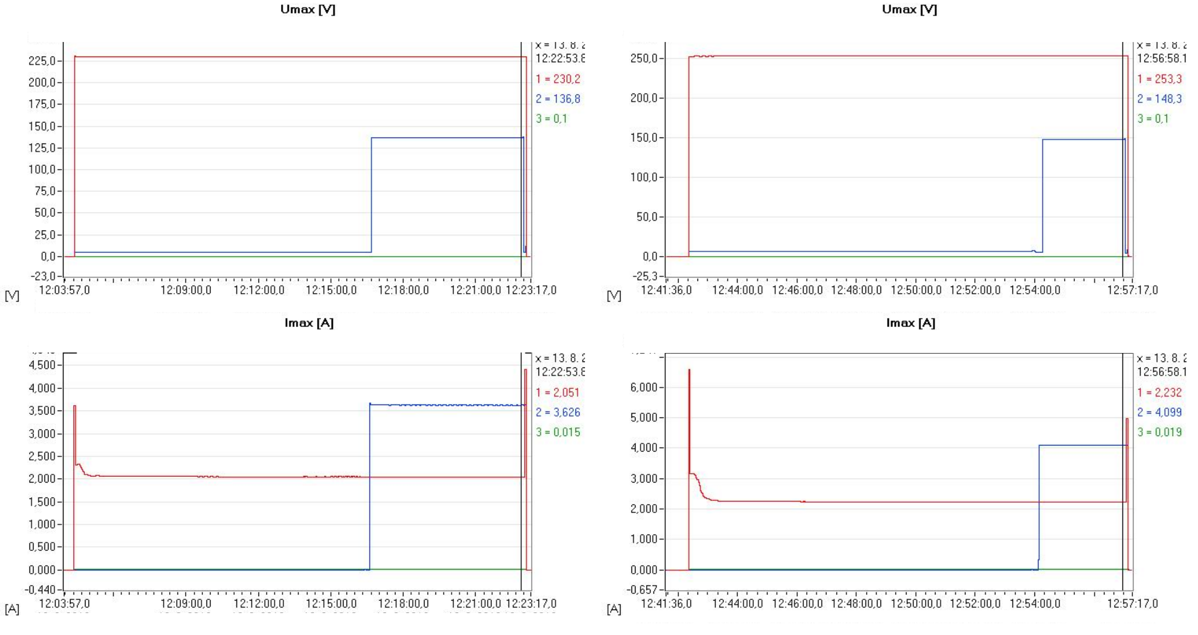
Measurement number	Supply voltage [V]	Current flowing through the regulator [A]	Voltage on the lamp [V]	Current flowing through the lamp [A]	Voltage on the discharge lamp [V]	Current flowing through the discharge lamp [A]
3	230	2.071	229	2.011	136.9	3.609
4	253	2.254	252	2.19	147.8	4.096
9	230	2.077	229	2.022	136.1	3.641
10	253	2.252	251.9	2.196	147.7	4.099
11	230	2.034	229	2.013	126.5	3.849
16	253	2.204	252	2.182	137.1	4.321

Table 3: Manufacturer's permitted values of voltage and current on measured discharge lamps

Measurement number	Voltage on the discharge lamp [V]	Current flowing through the discharge lamp [A]
1 - 8	120	4.0
9 - 11 and 16	130 *	3.5
* **Note 2:** The manufacturer allows a parameter tolerance of 118±12V, therefore a limit value of 130V is calculated here.		

The aim of measurements No. 1 and No. 2 without a voltage regulator was to capture the effect of the increased supply voltage of 253 V on the current flowing through the lamp and the discharge lamp and on the voltage on the discharge lamp. Voltage 253 V represents the upper limit normative value of voltage 230 V ± 10%. From the waveforms in fig. 3 it can be seen that the increased supply voltage causes an increased voltage on the discharge lamp and an increase in the current flowing through the choke and the discharge lamp and a change in the current flowing through the compensating capacitor. From measurements No. 1 and No. 2, it can be seen that at the limit value of the supply voltage of 253 V, the nominal value of the discharge lamp current as well as the voltage given by the manufacturer were exceeded. Here it should be pointed out that even with a voltage of 230 V, the voltage measured on the discharge lamp was 136.8 V compared to the manufacturer's recommended value of 120 V. However, the increase in supply voltage does not have a deforming effect on the course of voltage and current and the content of higher harmonics.

The aim of measurements No. 3 and No. 4 was to analyze the influence of the regulator, as an electrical component, on the electrical characteristics of the lamp and the discharge lamp and to compare it with the results without the voltage regulator (that is, with measurements No. 1 and No. 2). The system of the lamp with the regulator was monitored at a nominal voltage of 230 V and at an increased voltage of 253 V. During the measurement at the nominal voltage, the behavior of the lamp during repeated start-ups, which can be caused by power supply voltage failures, was also monitored. From the waveforms in fig. 4, it is clear that after the ignition of the discharge, a change in the effective value of the voltage on the lamp occurs even during stabilization (see the curves highlighted in the circle). It can be seen from the voltage and current curves that the controller disconnects the power supply to the lamp if the discharge fails to ignite. The same can happen with an insufficiently cooled discharge lamp.

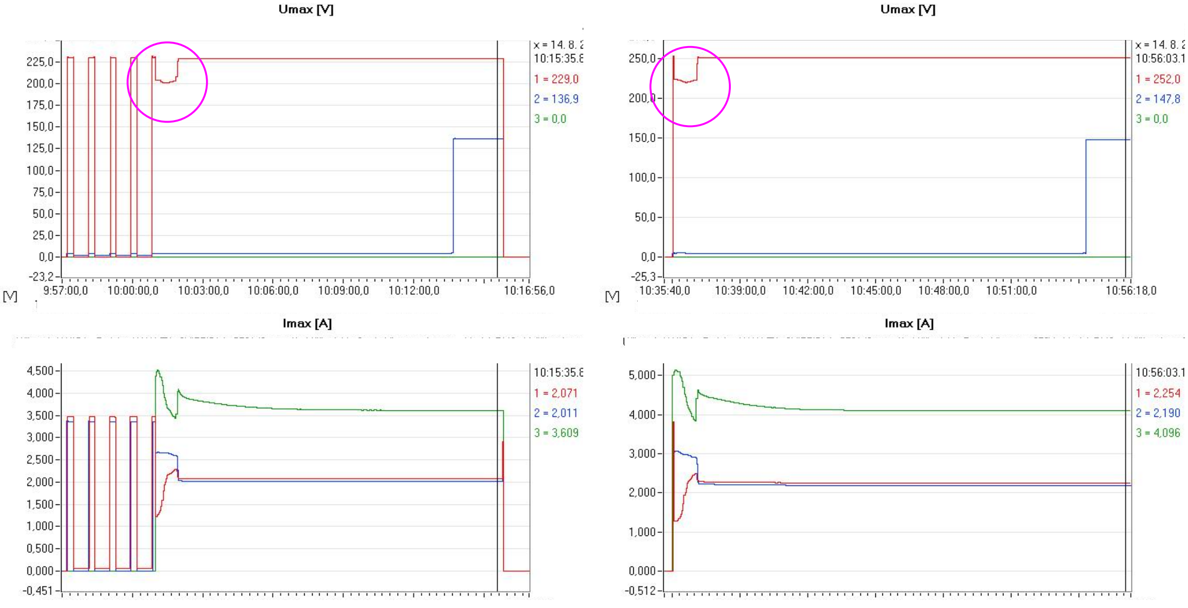


1 AC 230 V   2 AC 253 V

Fig. 3 **Measurement without voltage regulator. Course of voltage and currents during measurement No. 1 (left) and measurement No. 2 (right). The red curve is the measurement on the terminals of the lamp. The blue curve is the measurement at the terminals of the discharge lamp.**

By analyzing the time course of voltages and currents during laboratory operation with the regulator, after igniting the discharge, it was found that the voltage at the terminals of the lamp is deformed and voltage-free pauses occur, as can be seen from fig. 5. On the discharge lamp (e.g. fig. 5 green waveform) the harmonic current waveform is preserved, but a phase shift with respect to the voltage waveform is visible. When the igniter is in the open state, then the choke and the compensation capacitor act as a low-pass filter, which causes the current through the lamp to approach the harmonic curve even when the voltage is inharmonic, but this LC element always has a phase shift, just like any passive filter. Behind the regulator, the shape of the voltage wave on the lamp is changed, which is also reflected in the change in the current curves (fig. 6). The applied regulation manifests itself in the course of the current by rapid step changes.

In the stable operation of the lamp, the influence of the regulator on the power supply of the lamp, the content and deformation of the harmonics is small and the voltage drop on the regulator is minimal. But even during the stable stage of operation of the lamp, increased effective values of the voltage on the discharge lamp were recorded, and at the limit value of the supply voltage, the maximum values of the current as well as the discharge lamp voltage set by the manufacturer were exceeded.



3 AC 230 V

4 AC 253 V

Fig. 4 Measurement with a voltage regulator. The course of voltage and current during measurement No. 3 (left) and measurement No. 4 (right). The red voltage curve is measured at the terminals of the lamp. The blue voltage curve is sensed at the terminals of the discharge lamp. The red course of the current is sensed at the input of the regulator. The blue current flow is on the current terminals of the lamp. The green circuit is on the current terminals of the discharge lamp.

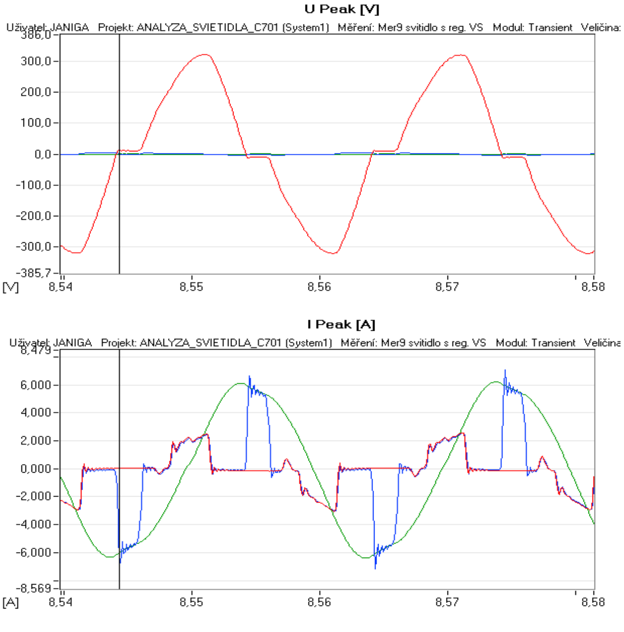


Fig. 5 Time course of voltages and currents during laboratory operation with a regulator at a supply voltage of 230 V. The red voltage curve is measured at the terminals of the lamp. The red course of the current is sensed on the current terminals of the regulator. The blue course of the current is sensed on the

current terminals of the lamp. The green current is sensed on the current terminals of the discharge lamp. The time t(s) is recorded on the x-axis.

Fig. 6 Time course of voltages and currents capturing the ignition of the discharge and the deformation of the voltage and current on the discharge lamp at the limit value of the supply voltage of 253 V. The red voltage curve is measured at the terminals of the lamp. The green current flow is the current at the current terminals of the lamp. The blue current flow is on the current terminals of the discharge lamp. The time t(s) is recorded on the x-axis.

Conclusion

The objective of the expertise was to find out the cause of the failure of light sources and lamps in the production hall. After the measurements and analysis of the electrical installation, we came to the following conclusions:

1) The light source was in the wrong position. The installed lamps were used in accordance with the manufacturer's specification in the basic characteristics, i.e. as a lamp for halogen discharge lamps with a nominal power of 400 W. However, according to the manufacturer's information in the product type and catalog sheet, the installed light sources should be placed in a horizontal position at an angle of ± 45°, not in a vertical position as it was in the installation.

2) The discharge in the torch of the discharge lamp is ignited by an external high-voltage pulse with an amplitude of up to 5 kV. The discharge first takes place in mercury vapor and inert gas. By discharge, the halides formed by polar covalent to covalent bonds break down into starting substances: metal atoms and halogen atoms or their ions. The chemical reaction initiated by the ignition voltage leads to the formation of substances formed by the decomposition of the metal halide in one part of the burner, while the reverse reaction will also take place in another part of the burner , formation of a metal halide. In the discharge lamp, a concentration gradient of metal and halogen atoms is created in the axial and radial direction, their subsequent diffusion to the walls of the burner with a lower temperature occurs, where the original metal halides are formed again. The metal halide formation reaction is already taking place spontaneously. When a metal is directly combined with a halogen, a lot of energy is released and either it is converted into heat and the reaction proceeds slowly, or there can be a rapid release of energy and the reaction is explosive in nature. Therefore, a stable state of discharge (back reaction) is reached only after a certain time. In order for the event to take place in the necessary balance, the burner and the electrodes must be in such a spatial orientation that keeps the ignition and the existence of the discharge in a stable state, and at the same time part of the discharge must allow heat to be dissipated. These are two essential reasons for the discharge lamp to be in the prescribed mounting position.

3) The voltage and current curves were changed by the regulator. A common feature of all performed laboratory voltage and current measurements on discharge lamps, both at the nominal voltage value of 230 V and at the limit value of the supply voltage of 253 V, is the exceeding of the voltage and current values specified by the manufacturers. By analyzing the time courses of voltages and currents during the laboratory operation of the lamp with a regulator, it was found that the voltage at the lamp terminals is deformed and voltage-free pauses occur. Behind the regulator, a changed shape of the voltage wave on the lamp and an increase in steep current jumps were observed.

4) Rapid sudden changes (of current or voltage) will be manifested by transient events in the discharge lamp, also on the choke and capacitor. Their obvious external manifestation is the heating of the choke (also the capacitor) and, of course, the cable line, contacts, which was visible on the components from operation. Heat losses in the choke were also manifested on the outer shell of the choke. (Increased voltage, even if the choke manufacturer guarantees its operation only at 230 V, should not cause the choke to be destroyed, but accelerates the degradation of its insulation.) Jump changes, voltage and current fluctuations shorten the life of the discharge lamp.

5) Halide lamps are used wherever high demands are placed on color fidelity, which is their dominant advantage. An unexpected change in the state of the discharge due to a change in voltage will change the color presentation, that is, the unique property for which halide lamps are used in the lighting system. The physical cause of the change in the spectral behavior of halide lamps under the influence of a change in supply voltage is a change in the energy state of dissociated metal and halogen particles, which results in undefinable changes in the emitted spectrum of the light source.

6) The disadvantage of halogen lamps is the slow start-up to a stable light flux (approx. 4 min), the delay between switching off and the possibility of re-switching on (i.e. the impossibility of immediate ignition of warm lamps, the cooling time is approx. 15 minutes), therefore the possibility of dimming them is limited.
7) In the case of a regulated reaction (regulated discharge), the speed of ongoing reactions changes, but also the type of reactions. The reaction rate of metal halide formation is higher

than the reaction rate of its decay. Every change in electrical voltage and fluctuation of voltage on the electrodes changes the activation energy, i.e. the speed of the metal halide formation or decay reaction and thus affects the type of reaction mechanism of the ongoing reactions.

8) By changing the voltage (regulation) and current density, the balance of the ongoing reactions will change. If the discharge lacks an energetic component of radiation (e.g. UV), which initiates a reaction leading to the formation of a metal halide, only the oxidation-reduction reaction prevails, which generates heat in the discharge and causes a reaction with the burner material as well. Due to the exothermic nature (release of heat during the reaction) of the formation of the metal halide, it is necessary to let the discharge lamp cool down after turning it off in order to restore the metal halide on the electrode. Therefore, the extinguishing and re-igniting of the discharge requires a time interval.

Due to the uncontrollable non-equilibrium conditions, speed and type of reaction occurring due to the change in activation energy, the regulation of the discharge of halide lamps with a nominal power of 400 W is inappropriate.

In the technical characteristics of the discharge lamps, information about the possibility/impossibility of dimming the discharge lamp is usually indicated by the manufacturer. Frequency modulation of the supply voltage for lamps with an electronic ballast is real and implemented in lighting systems with halide lamps with a rated power of up to 250 W [1], [2]. Halide lamps (with a rated power of up to 250 W) designed by manufacturers for dimming, have a modified internal structure, geometrically (elongated) or material (ceramic) adapted burner and electrodes. Despite the advantages of the color excellence of halide lamps, lighting is currently oriented towards LED technologies. According to our experience, lighting with halide lamps is now only used in special requirements.

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