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PROBLEMS OF HEAT LIGHT SOURCES USE

The article is exploring the prospects of increasing efficiently of traditional filament lamps, since their market share accordingly to prognosis of European lighting market is still significant up to 2020 year. On top of that some specific manufacturing areas have no other options as to use special bulb lamps. The reasons are simple: low production cost, simple setup and usage rules, and wide range of power outputs, from few to hundreds of kilowatts of power. At the same time these lamps has worse light output and shorter lifetime comparing to electrodeless or LED lamps.

There were attempts to solve this by creating halogen bulb lamps that increased light output up to 25 lm/W and lifetime up to thousands of hours. Currently there are more than 100 types of halogen lamps for different types of tasks: searchlight lamps, infrared heating, photo and TV lighting,automotive lamps, etc. There are ongoing researches are performed in order to further improve characteristics of these lamps, such as increasing light output and lifetime by improving halogen cycle, further improving geometry of reflection elements and work modes. They revealed that in the moment of flashing starting current amplitude may be higher than regular current in 10-15 times, which causes overheating of spiral material and even evaporation, which respectively leads to burning out.

So author believes that halogen lamps lifetime could be significantly extended by improving temperature modes of glow bodies in a moment of lighting as well as in regular glowing time. The article suggests to select parameters of electronic lighting schemes considering temperature modes of glow body of regular lighting bulb lamps.

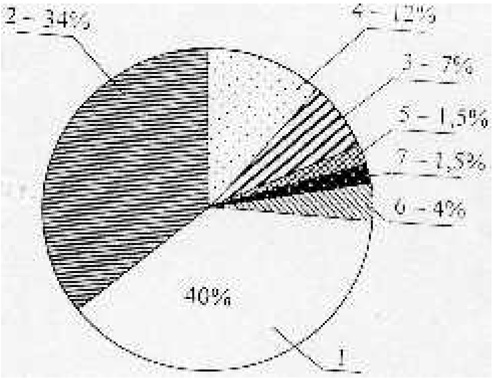
***Keywords**: Lighting bulb lamp, Heating lamp, energy-efficiently, improving lamp light output, temperature or light body, ignition-control system (ICS), non-shock lamp ignition.*

Introduction

The problem of increasing the efficiency of light energy generation is one of the priorities in energy and communal services. In spite of the growing volume of the discharge and LED light sources use, which account for up to 2/3 of the total produced light energy, incandescent lamps (LR) of general and special purpose for a long time will be used in various sectors of the national economy, and in some they do not have competition at all. This is due to the simplicity of construction, low cost of production, ease of use and a wide range of capacities - from units to hundreds of kilowatts. Moreover, measures are taken to increase their light output (for example, by locking infrared radiation in the bulb of the lamp by applying an interference coating, improving the halogen cycle, selecting optimal geometric parameters, etc.).. Picture 1 shows the projections [1] of the use of various light sources in the world in 2020.

Analysis of literary sources

As it is known, the essential disadvantage of such lamps is, first of all, relatively low light output, and a short life span. But the development of halogen filament lamps, which significantly increased light output (up to 25 lm / W) and brightness, service life (≈ 103 hours), allowed to solve these problems to a large extentIn our time, more than 100 types of halogen lamps have been created: for spotlight, infrared heating, film and photography, television, motor vehicles, etc. [2,3].



Pic. 1. - Forecasted evaluation of lighting structure in 2020; 1− L.R; 2− FL; 3 − ADL; 4− CLL; 5− MHL; 6− HPSL; 7− HLM.

The luminous efficiency of the tungsten spiral of LR can be increased by increasing its temperature, but at the same time the rate of tungsten evaporation increases sharply and, consequently, the service life of the lamp decreases One of the reasons for the intense sputtering of the tungsten spiral may be the mechanical separation of metal particles due to the rapid separation of gases absorbed by the metal at a sharp increase in temperature caused by the increase in the supply voltage [4]. In halogen filament lamps, the temperature of the spiral is close to the temperature of the melting of tungsten (3930 K), so the excess supply voltage of only 10% can lead to the melting of tungsten. So, when the low-voltage projection lamps are turned on in the feeding network, the short-term overheating of the helix is ≈ 80 ° C, so it is necessary to limit the supply voltage when the cold lamp is turned on. The dependence of the service life and the efficiency of the illumination on the volatility of the supply voltage value was investigated in [5] and for the determination of the duration of the lamp operation, such dependence was established.

$$T_д/T_н = (U_н/U_д)^n, \qquad (1)$$

where Td, Tn - the actual and nominal terms of service; Un, Ud - active and rated voltage of supply; n is an indicator that depends on the characteristics of the lamp design and is about ≈14, which indicates a strong dependence of the service life of the LR on the excess of the supply voltage. An equally important factor that also significantly affects the service life of the discharge lamps is the abnormal startup of such light sources. Investigation of the triggering modes of incandescent lamps conducted with serial lamps of different power states [6] that at the moment of activation of the starting current amplitude can exceed the value of the operating current by 10 ÷ 15 times, and therefore the magnitude of the electrodynamic force acting on the spiral of the lamp may exceed 100 ÷ 225 times the nominal value, therefore, is also one of the main causes of the failure of the lamps.

To prevent this negative processes, numerous electronic circuit diagrams of shock-free start-up of incandescent lamps [7] have been proposed, which reduce the starter current amplitude and electrodynamic forces on the spiral, which are proportional to the square of the current [6], ensuring a slow heating of the lamp.

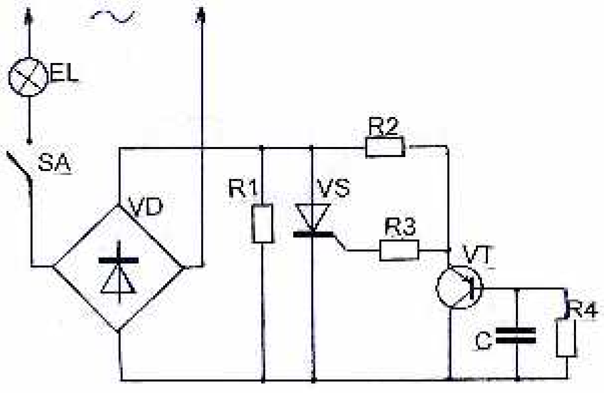
Formulation of the problem

An important modern requirement for energy saving is the possibility of regulating the lighting conditions necessary for specific working conditions, which is one effective method for increasing the energy efficiency of lighting installations (OCs), which consume up to 20% of all electricity produced in Ukraine. It complies with the requirements for comprehensive energy conservation, in particular, Directive 2002/91 EU of the European Parliament on the minimum allowable energy efficiency criteria of the OS and allows saving up to 50% of electricity consumption. Thus, for efficient operation of incandescent lamps, the starters should realize three main functions: to carry out a shockless lamp start, to limit the working current to the optimal value for this lamp, to create an opportunity to adjust the intensity of the light flux and, moreover, to be as energy efficient as possible. Therefore, the task of this study was:

- to analyze the current state of power systems of warm light sources for the subject of their compliance with the requirements of electromagnetic compatibility;
- to investigate the work of typical schemes of shock-free switching on of incandescent lamps and their conformity to optimal conditions of operation of such light sources;
- on the basis of the conducted researches to determine the directions of improvement of electric schemes of power supply of heat sources of light to ensure maximum energy efficiency and service life of such lamps.

The main part

We will conduct a study of the operation of the incandescent lamp on the basis of a typical scheme of shock-free lamp activation (Pic. 2) in order to determine its efficiency and compliance with the requirements stated above to ensure optimal operating conditions.



Pic. 2. Scheme of shock-free activation of LR

In this scheme, after switching on the supply voltage, the limit of the inrush current of the lamp is provided by the ballast resistor R1 and simultaneously, through the resistor R2, the capacitor C starts charging until the transistor VT is turned on. After that the thyristor VS is switched on, resulting in the shunting of the resistor R1 and the nominal supply voltage is fed to the lamp. Resistor R3 promotes rapid discharge of capacitor C and preparation of the circuit for re-inclusion of the lamp. In this case, the voltage drop in the circuit does not exceed 5.5 V, which is less than 3% of the supply voltage, and the duration of the supply delay is determined by the parameters of the RC-chain and does not depend on the power of the lamp and the voltage of the network.

The transistor *VT* during the start-up ($0 \le t \le t_{вк}$) saturated and dependencies for the currents of the lamp $i_л$ and transistor i_k, voltage collector-emitter of transistor $u_{k\text{е}}$, of instantaneous lamp power $p_л$ i transistor p_m have the following look:

$$i_л = i_k = \frac{E - U_{ке}}{R_1 + R_л}, \quad u_л = R_л\, i_л, \; p_m = i_k \cdot U_{\text{ке}},$$

$$U_{ло} = R_{ло}I_{ло},$$

$$P_m = \frac{U_{ке}(E-U_{ке})}{R_б + R_{лср}},\ p_л = i_л \cdot u_л,\ P_б = R_б\left(\frac{E-U_{ке}}{R_б+R_{лср}}\right)^2,$$

$$I_{ло} = \frac{E-U_{ке}}{R_б + R_{ло}}, \qquad (2)$$

here $P_б$ – is average transistor voltage; $I_{ло}$ – is starting current amplitude; $R_л = R_{ло}(1+\alpha\theta)$ – resistance of the LR spiral; $R_{ло}$– resistance of the spiral at ambient temperature T^o; α – temperature coefficient of spiral resistance; $\theta = T_o - T_{осер}$ – excess of spiral temperature T_o above ambient temperature $T_{осер}$. Average power, which is allocated in the transistor during the start of the LR

$$P_{mc} = \frac{1}{t_{вк}}\int_0^{t_{вк}} p_m dt = \frac{E^2}{R_{лср}}\left[1 + \frac{2}{2t_{вк}}(e^{-t_{вк}/2} - 1)(3 - e^{-t_{вк}/2})\right], \quad (3)$$

where$R_{ср} = R_o[1 + (\alpha/2)\theta]$ – average (during start-up) the resistance of the spiral lamp. To determine the parameters of the control unit elements, it is necessary to focus on the optimum temperature of the RL spiral, which it must provide. Assuming that the heat transfer from the spiral to the volume of the bulb lamp occurs mainly by radiation, then without taking into account the heat transfer in the places of the mounting of the helix, the equation of thermal balance has the form [3]

$$p_л\, dt = \varepsilon\sigma S_{ox}[(T^o)^4 - (T^o_{нв})^4]dt + \kappa_c\, dT^o, \qquad (4)$$

where ε – is coefficient of thermal radiation of a spiral ($\varepsilon < 1$);

$\sigma = 5{,}67\cdot10^{-7}$ – constant Stefan-Boltzmann, Wt $^{-2}(^oK)^{-2}$;

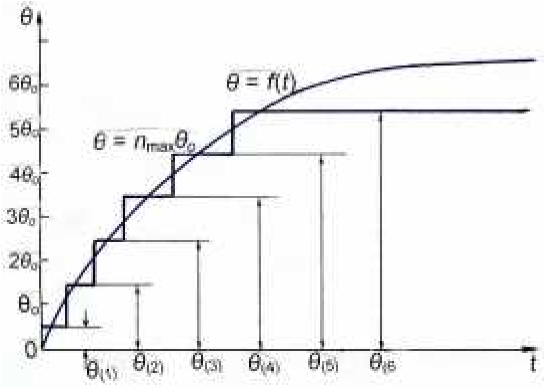
S_{ox} – Area of cooling surface of the spiral, m2; ks - heat capacity of the helix, Wt (s) -1.

This equation can lead to a simpler form

$$\frac{d\bar{}}{dt} + \frac{\bar{}}{{}^2{}_m} = V, \qquad (5)$$

where $\tau_m = \kappa_c / \{\varepsilon\ \sigma\ S_{ox}(\theta + 2T^o_{ср})\ [\theta(\theta + 2\ T^o_{ср}) + 2(T^o_{ср})^2]\} \approx \kappa_c / (\varepsilon\ \sigma\ S_{ox}\theta^4)$;

$\theta = T^o - T^o_{ср};\ V = p_л / \kappa_c$



Pic. 3. Piece-linear approximation of the curve θ = f (t) for the helix heating of LR

The analytical expression of the solution of this nonlinear equation will be obtained by the method of piecewise linear approximation of the dependence θ = f (t) by the "step" function (pic. 3). In this case, the curve θ = f (t) along the ordinate axis θ is broken up into n segments of the same value θo, within each of them, the resistance of RL Rl (n) and the thermal "constant" time of the helix τt (n) are unchanged:

$$R_{л(n)} = R_{ло}(1 + \alpha\theta_{(n)}) = const,$$

$$\tau_{T(n)} = \kappa_c / (\varepsilon\ \sigma\ S_{ox}\theta^4_{(n)}) = const, \qquad (6)$$

where $\theta_{(n)} = (n - 1/2)\theta_o$ – excess of the temperature of the spiral Then the environment Tosr in the mid-n-th segment θ. excess of the temperature of the environment spiral in the n-th segment θ.

$$\frac{d\bar{}}{dt} + \frac{\bar{}}{{}^2{}_{m(n)}} = V_{(n)}, \qquad (7)$$

where $V_{(n)} = p_{л(n)} / \kappa_c$; $p_{л(n)}$ – the instantaneous power of LR within the nth segment θ.

The solution of the equation (6) with the initial condition θ (n) (0) = (n-1) θo allows us to obtain a dependence for increasing the temperature θ on the n-th segment

$$\theta = \theta_{в(n)} + [\theta_{(n)}(0) - \theta_{в(n)}]\ e^{-t/\tau T(n)}, \qquad (8)$$

where θv (n) = pL (n) τT (n) / kc is a constant temperature increase over the nth segment θ.

The time over which the temperature θ on the nth segment increases by the value of θo is determined from the expression $t_{0(n)} = \tau_{T(n)} Ln \frac{\bar{}_{в(n)} - \bar{}_{(n)}(0)}{\bar{}_{в(n)} - n\bar{}_0}$ (9)

If on any segment θ the growth condition θ on the value of θo does not appear to be fulfilled, this will mean the exit to the saturation region of the curve θ = f (t), and the previous section θ will be considered the last. The time tmax, for which θ reaches a stable value θst = tmaxθo, is determined by adding the duration of the intervals of time $t_{o(n)}$

$$t_{max} = \sum_{n=1}^{n(\max)} t_{o(n)} \qquad (10)$$

The estimation of the scheme parameters for a shock-free activation of the LR for a lamp of 60 W, according to the above ratios, is carried out under the condition of providing the nominal temperature of the spiral, gives the following values: the operating current of the lamp at nominal voltage of power is 0.273 A; the resistance of the spiral in the warmed state is 807 ohms, and in the warm-up mode it is 593 ohms. The resistance of the ballast resistor R1 = 565 ohms; The current preheating of the helix is 0.19 A, which is 70% of the nominal. The voltage drop across the ballast resistor R1 will be 107.35 V, and the power dissipated in it reaches 20.4 Watts. The shock current at the moment of the lamp is 0.335 A, which is equal to 129% from the working.

Conclusions

Thus, the proposed calculation technique allows one to determine, with sufficient accuracy, the parameters of the control circuit for the LR of any power in terms of providing optimum temperature regimes of the helix and, thus, achieving the maximum efficiency and maximum service life of such light sources. The conducted analysis shows that the given typical control circuit of the start-up device effectively provides only one function - limiting the starting current while the remaining two remain not fully implemented (first of all, it is a question of the need to create a simple and reliable limiting system for the limit value of current with prolonged over-voltage of the feeding network) and therefore further searches for ways to improve such devices are needed.

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ПРОБЛЕМИ ВИКОРИСТАННЯ ТЕПЛОВИХ ДЖЕРЕЛ СВІТЛА

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В роботі наведено аналіз проблем підвищення ефективного використання теплових джерел світла – ламп розжарювання, доля світлової енергії, яких в загальному балансі освітлення є досить значною. Розглянуті питання підвищення строку служби цих ламп шляхом створення оптимальних температурних режимів в момент їх ввімкнення та в процесі тривалої роботи. Пропонується розрахунок параметрів електричних кіл живлення цих ламп здійснювати шляхом прив'язки їх до миттєвих значень температури спіралі.

***Ключові слова**: теплове джерело світла, енергоефективність, світлова віддача, електричні кола, безударне ввімкнення лампи, температура вольфрамової спіралі, пускорегулюючий пристрій.*

ПРОБЛЕМЫ ИСПОЛЬЗОВАНИЯ ТЕПЛОВЫХ ИСТОЧНИКОВ СВЕТА

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В работе приведен анализ проблем повышения эффективности использования тепловых источников света- ламп накаливания, доля световой энергии которых в общем балансе освещения согласно прогноза европейского светотехнического рынка на 2020 год остаётся всё ещё достаточно большой. Однако существенным недостатком таких ламп является низкая по сравнению с розрядними лампами светоотдача и относительно малый срок службы. В настоящее время создано более 100 типів галогенних ламп: для прожекторного освещення, інфракрасного нагрева, кіно- і фотосёмок, телевидения, автотранспорта и др.

В данной статье рассмотрены вопросы, связанные с возможностью повышения срока службы таких источников света путём создания оптимальных температурных режимов тел накала как в момент их включения, так в установившемся режиме. Предлагается выбор параметров электронных схем зажигания таких источников света осуществлять исходя из теплового расчёта режима спирали лампы накаливания.

***Ключевые слова**: тепловой источник света, энергоэффективность, световая отдача, электрические цепи, безударное включение лампы, температура вольфрамовой спирали, пускорегулирующее устройство.*