$$I_0 = \frac{\left(\overline{I}_{xx} + \overline{I}_p\right)}{2} \ . \tag{9}$$

Полученное выражение (9) позволяет выбрать пороговое значение компаратора для практических случаев, связанных с изменяющимся значением порога срабатывания, в зависимости от величины напряжения, подаваемого для питания светофорной лампы, т. е. адаптивных систем контроля.

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LIMIT OF CONTROL ACTUATION IN SWITCHING AND CONTROL UNITS OF DOUBLE-FILAMENT BULBS OF LIGHT RAIL SIGNALLING SYSTEM (PKU-M)

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ABSTRACT

The article deals with methods of determination of limit values of actuation of control block unit in microelectronic switching and controlling devices of color light signals. The author describes techniques to determine value of voltage or current that actuates comparator in threshold device of the circuit of digital processing of the signals in the units of control of light signals system's bulbs. Method of statistical decision-making on the basis of average risk criterion is used to obtain calculated formulas. The set of proposed methods can be used at manufacturing plants to adjust manufactured devices.

ENGLISH SUMMARY

Background. *Microelectronic switching and control units (Russian abbreviation – PKU) are used in devices of rail color light signaling of the systems of automatic block signaling and electric centralization. They are widely used especially for centralized systems of control of color light signals as they permit to reduce cable use and considerably limit volume of mounting work.*

Objectives. *While using switching and control units for switching and controlling of conditions of double-filament bulbs in light signals (pic. 1) it is necessary to determine the value of voltage or the value of current, leading to actuation of threshold comparator, which is a part of a circuit of digital processing of the signals of control units.*

Methods. *Determining of the threshold of actuation of comparator I_0 is reduced to the known problem of statistical decision-making. It is necessary to determine how an unknown value of attribute f (I) should be classified.*

Results. *Fault-free or faulty state of filament of a bulb of a light signal is determined by the comparator which is connected to resistor R (pic. 1), through which the current flows and its value changes depending on the fact whether the filament is connected to signal transformer or is not. When the filament is disconnected, the current, flowing through resistor, is determined by input resistance of a cable line and by off-load resistance of signal transformer CT. The value of operating current I_p flowing through resistor R is a random value which depends on a set of random parameters of electric circuit. There are purely random values, resistance of filament of a bulb, basic parameters of a cable line, parameters of signal transformers, other factors caused by operation features of light signaling.*

So the bulb's operating current and off-load current, when the bulb is disconnected, flowing through resistor R, are functions of important number of random arguments, comparable by their dispersion. In that case it is possible to expect that random values (operative current I_p and off-load current I_{xx}) are distributed according to normal law of distribution:

$$f(I_p) = \frac{1}{\sigma_p \cdot \sqrt{2\pi}} \cdot e^{\frac{-(I_p - U_p \cdot \overline{g})^2}{2 \cdot \sigma_p^2}} \tag{1}$$

$$f(I_{xx}) = \frac{1}{\sigma_{xx} \cdot \sqrt{2\pi}} \cdot e^{\frac{-\left(I_{xx} - U_н \cdot \overline{g}_{xx}\right)^2}{2 \cdot \sigma_{xx}^2}} \tag{2}$$

Expressions (1) and (2) are functions of density of distribution of random values of I_p and of I_{xx}, and g_p и g_{xx} show conductivity of resistance of transfer between power input and light signal bulb and input resistance of signal transformer in off-load mode. In both cases a resistance of a cable line between in-office and outside devices is taken into account when total resistance of transfer is counted.

There are two modes of operation of light signals within centralized control of signaling system. $U_н$ has a day mode with nominal alternative current $U_н$=220 V, and night mode with $U_н$=180 V. When the value of threshold of comparator actuation is determined, one come across another problem related to determining this value under the conditions of statistical decision-making with known density of distribution of stochastic values f (I_p) and f (I_{xx}). Statistical decision-making under changing mode of light signals' operation (day and night) may cause errors of first and second kind. It is explained by the fact that values I_{xx} under day mode can coincide with operative current values under night mode I_p.

The area of cross-cut of functions of density of distribution (pic. 2) of f (I_{xx}) and f (I_p) depends on the values of dispersion of random values; of resistance of a bulb in light signal; of a resistance of off-load mode of transformer etc.

As was mentioned above, determining of the threshold of actuation of comparator I_0 is reduced to the known problem of statistical decision-making, where it is necessary to determine how an unknown value of attribute f (I) should be classified.

According to the terminology of statistical-decision theory error of the first kind (false alert) can be determined by expression (3). The error of the

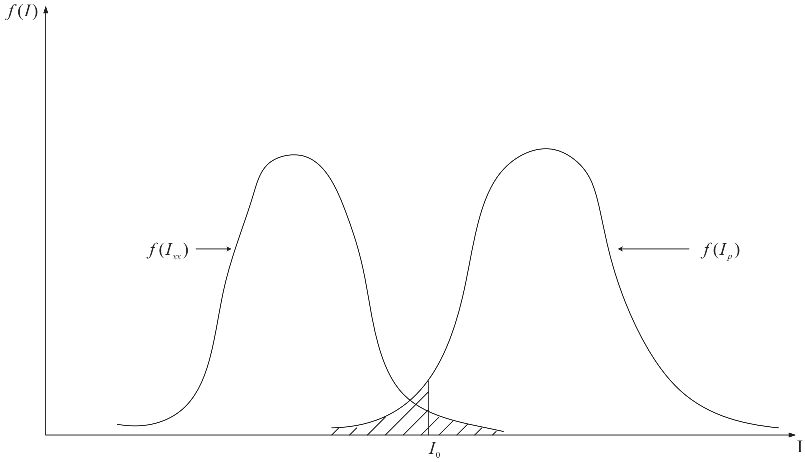

Рис. 2 / Pic.2.

$$I_0 = \frac{\sigma_p^{\,2} \cdot \overline{I}_{xx} - \sigma_{xx}^{\,2} \cdot \overline{I}_p \pm \sigma_{xx} \cdot \sigma_p \cdot \sqrt{\left(\overline{I}_p - \overline{I}_{xx}\right)^2 + \left(\sigma_p^{\,2} - \sigma_{xx}^{\,2}\right) \cdot \ln \lambda_0 \cdot \left(\frac{\sigma_p^{\,2}}{\sigma_{xx}^{\,2}}\right)}}{\sigma_p^{\,2} - \sigma_{xx}^{\,2}} \quad (7)$$

second kind (probability to miss the objective) can be determined by expression (4).

The guidelines for selecting threshold value I_0, should take into consideration losses caused by errors of first and second kind, as well as losses of correct solutions, if there are any. The mentioned losses constitute a payoff matrix (5).

Average risk related to correct selection of threshold, considering for errors of first and second kind, is composed by (6).

To determine minimum risk R it is necessary to take derivative value $\frac{dR}{dI_0} = 0$ (set equal to 0). After some transformations we'll receive equation (7) for threshold value of I_0(7), where $\overline{I}_{xx}$, $\overline{I}_p$ are values of assessment of mathematical expectations of respectively off-load current and operative current; λ_0 is likelihood factor, determined through expression:

$$\lambda_0 = \frac{P(I_{xx}) \cdot (C_{12} - C_{11})}{P(I_p) \cdot (C_{21} - C_{22})} \quad (8)$$

The calculated values permit to select the threshold value of comparator taking into account minimum value of average risk.

Particularly, if the losses caused by correct decisions are assumed to be equal to zero $C_{11} = C_{22} = 0$; losses caused by errors of first and second kind are assumed to be equal between both errors $C_{12} = C_{21}$, and $P(I_{xx}) = P(I_p)$, $\sigma_{xx}=\sigma_p$, then the value of threshold value can be calculated on the basis of expression:

$$I_0 = \frac{\left(\overline{I}_{xx} + \overline{I}_p\right)}{2} \quad (9)$$

Conclusions. *The received expression (9) permits to select threshold value of comparator for practical cases, related to changing value of threshold of acuation depending on the value of voltage for bulb feeding, that is to say, depending on adaptive control systems.*

Key words: switching device, signal transformer, double-filament bulb, light signal, control device, AC 220 V input, individual fuse, operative current of a bulb, mathematical expectance, dispersion, risks, root-mean-square deviation.

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