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ECONOMIC EVALUATION OF LOW-VOLTAGE DEVICES

Modern electrical products represent an extremely powerful industry and a dynamically developing market. Currently, there is a positive trend in the market, in particular for low-voltage devices, so an important aspect is to conduct a correct economic assessment of the efficiency of low-voltage devices. Literary sources are analyzed and it is revealed that, despite the significant amount of scientific research and publications, in scientific works on economic design, insufficient attention is paid to the study of real conditions and operating modes of products. Related works focus on developing numerical methods for solving the problem, and the usage conditions are usually taken as given. Data are presented on the actual use of the main parameters of automatic and push-button switches in the main conditions and modes of their use on the equipment of machine-building enterprises. Similar data were also obtained in metallurgy. In addition, a more in-depth study is required of the practical use of the main indicators of purpose and reliability, analysis of operating costs in specific conditions of use and features of economic assessment. The purpose of the study is to analyze issues of improving methods for economic evaluation of one of the most common types of electrical products - low voltage devices. Studies have been carried out on the actual use of indicators of purpose and durability, operating costs for scheduled and unscheduled repairs in real modes and operating conditions, losses due to failures. Improved indicators and criteria for economic evaluation are proposed. The possibilities of using both traditional economic assessment based on reduced costs, as well as economic assessment and criteria for choosing rational levels based on indicators more often used in modern conditions, including NPV, PI, IRR, PP, are considered. When solving the problem of economic justification for choosing a rational number of versions of devices, several main stages are identified. Among them is the choice of economic indicator and criterion.

Keywords: economic assessment, operating costs, operating modes, low voltage devices, repairs, failure losses

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ЕКОНОМІЧНА ОЦІНКА АПАРАТІВ НИЗЬКОЇ НАПРУГИ

Сучасні електротехнічні вироби являють собою надзвичайно потужну галузь і ринок, що динамічно розвивається. Нині на ринку, зокрема, низьковольтних апаратів спостерігається позитивна тенденція, тому важливим аспектом є проведення коректної економічної оцінки ефективності апаратів низької напруги. Проаналізовано літературні джерела та виявлено, що, незважаючи на суттєвий обсяг наукових досліджень і публікацій, у наукових працях з питань економічного проектування недостатньо уваги приділяється вивченню реальних умов і режимів експлуатації виробів. У відповідних роботах основна увага зосереджена на розробці чисельних методів розв'язання задачі, а «умови використання» зазвичай приймаються як дані. Наведені дані фактичного використання основних параметрів автоматичних і кнопкових вимикачів в головних умовах і режимах їх застосування на обладнанні машинобудівних підприємств. Аналогічні дані також одержані і в металургії. Крім того, потребує глибшого вивчення практичне використання основних показників призначення та надійності, аналіз експлуатаційних витрат у конкретних умовах використання та особливості економічної оцінки. Метою дослідження є аналіз питань щодо вдосконалення методів економічної оцінки одного з найпоширеніших видів електротехнічної продукції – апаратів низької напруги. Проведено дослідження фактичного використання показників призначення та довговічності, експлуатаційних витрат на планові та позапланові ремонти в реальних режимах та умовах експлуатації, втрат при відмовах. Запропоновано удосконалені показники та критерії економічної оцінки. Розглянуто можливості застосування як традиційної економічної оцінки на основі приведених витрат, так і економічної оцінки та критерію вибору раціональних рівнів на основі показників, які частіше використовуються в сучасних умовах, в тому числі NPV, PI, IRR, PP. При вирішенні задачі економічного обгрунтування вибору раціональної кількості виконань апаратів виділено кілька основних етапів. Серед них – вибір економічного показника і критерію.

Ключові слова: економічна оцінка, експлуатаційні витрати, режими роботи, апарати низької напруги, ремонти, втрати при відмовах

Introduction. Achieving high efficiency and quality in the production and operation of industrial products is an important task for both individual enterprises and the economy as a whole. In order to make a decision, it is necessary to correctly choose economic indicators and criteria, as well as to conduct a significant amount of research into the real use of products in specific conditions and modes of operation, to estimate costs during use, including maintenance and repairs related to reliability, costs during operation and others.

Review of the recent literature and formulation of the research problem. The analysis of works devoted to the problems of economic assessment in the development of new technology [1, 2, 3, 4, 5, 6, 7, 8, 9, 10] shows that when two tasks are considered for its solution: a) the selection of rational technical and economic parameters of machines (economic design); b) improvement of the methodology for calculating economic efficiency. In scientific works on issues of economic design, insufficient attention is paid to the study of real conditions and modes of operation of products. In the methods devoted, for example, to the problem of optimizing parametric series, the main attention is paid to the development of calculation methods. Insufficient attention is paid to the study of the real use of the main indicators of purpose and reliability, analysis of operational costs in specific conditions of use, features of economic evaluation. These issues are considered in the article using the example of low-voltage contact devices. Modern electrical appliances are an extremely powerful industry and a dynamic market. Currently, there is a positive trend in the market of low-voltage devices. Taking into account the development of the electric power industry in terms of low-voltage devices, more and more various electrical devices for various purposes appear on the market, therefore the topic under consideration is quite relevant and modern.

The purpose of the study is to analyze issues related to the improvement of methods of economic evaluation of one of the most common types of electrical products - low voltage devices. The authors of this article have already explored this area [11, 12], but more widely, so here it is proposed to concentrate attention specifically on low-voltage devices.

Presentation of the main research material. It is known that each type of low voltage devices consists of a number of standard sizes. In this regard, the task of choosing rational parameters of low-voltage devices is to find rational parameters of economically justified numbers of options. That is, the problem formulated as the choice of rational parameters of low-voltage devices turns, as a rule, into the problem of determining the rational parameters of several variants of the same type of devices and determining the rational number of these variants. Moreover, in different devices of the same type, both one and several parameters can change. It is clear that this also changes the design of the device.

In the relevant works, the main attention is paid to the development of numerical methods for solving the problem, and the "conditions of use" are usually taken as given.

When solving the problem, it is necessary to find an economically rational number of options for low-voltage devices, also in relation to reliability indicators - non-failure operation, durability and maintainability.

When solving the problem of a feasibility study for choosing a rational number of options for low voltage devices, ten main stages can be distinguished:

1) establishing the nomenclature of the main parameters of low voltage devices and choosing the main parameters by which the rational number of options for devices is determined;

2) determination of quantitative values of the actual use of the main parameters of low-voltage devices on a large sample under operating conditions;

3) determination of the quantitative need for low voltage devices for specific parameters and their realistically possible range;

4) determination of the prospects for the use of the main parameters of the devices for a certain period of time;

5) determination of the costs for the manufacture of options for low-voltage devices, assemblies and elements, the design of which may change when specific parameters change;

6) determination of operating costs for realistically possible design options for low voltage apparatus;

7) analysis of changes in the costs of manufacturing possible options for low-voltage devices, depending on the volume of their production;

8) analysis of changes in operating costs with an increase and decrease in the number of options;

9) determination of the criterion for choosing the optimal number of options for devices;

10) selection of the optimal number of options for low voltage devices.

Let us dwell in more detail on the content of some of the above stages. The selected parameters should fully determine the design of low voltage devices. The nomenclature of the main characteristics largely depends on the type of apparatus. It is known that for the vast majority of devices, the main parameters that almost completely determine their design are: current, voltage, number of circuits, reliability indicators and switching capacity. The studies of the switching resistance of automatic switches and push-button switches in operation have shown that the existing designs of these devices have a significant margin for this parameter. In addition, other parameters - current, voltage, number of circuits and reliability indicators quite fully characterize the design of low voltage devices and mainly determine their cost. Therefore, these characteristics can be chosen as the main ones when solving the problem of choosing a rational number of variants of devices.

Determination of the quantitative need of low-voltage devices for specific parameters and their realistically possible range was carried out on a representative sample for the main operating modes and conditions. Thus, in particular, the quantitative needs for certain values of the parameters of automatic switches and push-button switches used in machine tool construction were determined. For instance, the following groups of circuit breakers in the power supply circuits of equipment of machine-building enterprises may be distinguished according to the required number of on-off cycles per year:

1) input from the busbar - 52-60;

2) input, based on the buslines assembly - 6-12;

3) inputs in the equipment scheme - from 310-415 to 725-830;

4) others in the machine diagram - 3-6.

The number of on-off cycles for the third group is given taking into account the actual coefficients of variability. In practice, smaller values are more common (in a ratio of approximately 4:1).

Studies of push-button switches in the circuits of metal-cutting machines have shown that both one and two circuits are used. Moreover, 73.19% of all buttons are used in the single-circuit version. The total number of buttons used on the analyzed machines is determined in accordance with the data on their quantitative use in the diagrams of specific models and the data on the release of the machines of these models. The need for push-button switches in the single-circuit version is determined at 1.15 million pieces.

To determine the prospects for using this parameter, a corresponding analysis of machine schemes of different years of production was carried out. With a significant increase in the use of push-button switches, the specifics of their use in single-circuit and double-circuit execution do not change much. Moreover, recently, due to the need to save copper mounting wire, the number of used push-button switch circuits has been deliberately reduced (especially in universal machines, which are produced in large series). Thus, the obtained data can be used in practice with sufficient reliability. At the same time, due to the shortage of push-button switches, there will be no significant changes in the serial production of those elements that will be removed from the design. These are, first of all, the contacts of push-button switches, which consist of scarce brass and silver.

In this case, operating costs for possible options will not change significantly. In connection with the removal of the contact in the push-button switches of the single-circuit version, we can even expect some reduction of these costs. However, this factor can be ignored in this case. It is obvious that the task here comes down to the analysis of costs for the production of push-button switches according to two possible options. Such an analysis is facilitated by the fact that the vast majority of push-button switches are manufactured by one company.

In the single-circuit version of the push-button switches, the number of bimetallic contacts and the number of brass parts are halved. The consumption of plastics is reduced by 30% and the number of fasteners for wires that supply current is reduced by two.

More significant results can be obtained by choosing a rational number of options for push-button switches in relation to their other main parameters, for which it is necessary to study the nature of changes in the significant characteristics of the devices depending on these parameters.

Similarly, the selection of a rational number of auxiliary contacts of magnetic starters can be made on the basis of data.

The study of maintenance and repairs of low-voltage devices, in particular, in mechanical engineering, shows that the unsatisfactory state in this area is caused, first of all, by the insufficient level of reliability of devices in specific operating conditions. This situation is caused, in our opinion, by the fact that currently the levels of reliability indicators of low-voltage devices are set, in particular, without sufficient economic justification. The lack of an economic assessment of the insufficiently reliable operation of devices leads to the fact that for a large part of low-voltage devices in technical conditions there is no very important indicator of reliability - failure-free operation, which primarily determines the costs of their operation. In turn, the absence of the no-failure indicator itself or the economic justification of its level allows manufacturing companies not to confirm it.

The costs of planned maintenance and repairs are described by the formulas given in the previously developed normative reference materials, as well as the calculation of the optimal interval between current repairs.

Push-button switches are used in control circuits, mainly to turn on (off) one, or even 2-3 or more electromagnetic devices. Thus, the current passing through the push-button switches is determined by the characteristics of the coils of low-voltage switching devices and their number. As the analysis of electrical circuits showed, pushbutton switches can be divided into two groups according to the magnitude of the flowing current:

1. Pushbutton switches with a cylindrical pusher used to turn on (off) one or more devices. The analysis showed that such pushbutton switches make up about 86% of their total number.

2. Pushbutton switches with a mushroom-shaped pusher for emergency shutdown of circuits, usually having from 2-3 to 10 or more devices.

Currents of the pushbutton switches were determined by the currents of the coils that were turned on (off) by them, in accordance with the data available in the reference information, for example, the current was determined by direct measurements in the control circuits.

Data analysis shows that more than 73% of pushbutton switches are used in circuits with current up to 0.3 A, and about 90% - up to 1A. Even rough estimates (taking into account the fact that push-button switches are only needed to be under current in a certain circuit, then break this circuit or vice versa) show that the dimensions of a significant part of push-button switches can be reduced. Moreover, about 50% of push-button switches are used only for turning on, that is, the current passes only when the device is turned on (up to 0.3 sec.).

Despite the very large number of applications of individual pushbutton switches that are embedded in control circuits, for machine tools, for example, two main groups can be distinguished in relation to the required resource:

1. Pushbutton switches, the number of on-off cycles of which practically does not depend on the number of manufactured parts or on the number of operations (for machines operating in serial and small-scale production) and is a random variable that varies from 1 to 10 per shift. This includes almost all pushbutton switches of group 2, which are highlighted in the analysis of currents, all buttons of automatic machines and machines operating in automatic lines, and some buttons in modular machines, semi-automatic machines and universal machines. These pushbuttons perform mainly debugging and other auxiliary functions, such as testing signal lamp circuits.

2. Pushbutton switches, the number of on-off cycles of which is proportional to the number of parts produced or the number of operations performed and changed, from several per shift for heavy machines to 3200 per shift for some modular machines. For press-forging equipment, according to observations, the number of on-off cycles reaches in some cases up to 6000 per shift. But in general, the share of push-button switches operating in such modes is insignificant.

Methodological developments and regulatory materials are used to determine the cost of manufacturing options for low-voltage devices, assemblies and structural elements that can change when specific parameters change.

Operating costs were determined in accordance with the methodological recommendations in force in the relevant industry. Relevant research was carried out in mechanical engineering and metallurgy. There were costs for inspections, current, medium and unscheduled repairs in the main operating conditions and modes. When determining the losses associated with equipment downtime as a result of failures of low-voltage devices, it is necessary to consider, in particular, the overspending of semi-fixed costs in the unit cost of production, losses from underdepreciation of the main technical equipment not included in semi-fixed costs. That is, the amount of losses due to downtime can be determined from the expression:

$$Ld = \Delta FC + \Delta UD + \Delta I \quad (1)$$

where: ΔFC – semi-fixed costs; ΔUD – amount of underdepreciation of the main technical equipment; ΔI – additional capital investments as a result of an hour of equipment downtime.

In turn:

$$\Delta FC = Ct \cdot \alpha 1 \cdot \Delta \Pi \quad (2)$$

where: Ct - the total cost of a unit of manufactured products; $\alpha 1$ - the share of fixed costs in the total cost of production; ΔΠ = 1/ Fact - reduction of production volume as a result of equipment downtime for an hour.

$$\Delta UD = \frac{D_{eq} + D_b}{F_{act}} \quad (3)$$

where: Deq + Db - the sum of annual depreciation charges for technological equipment and buildings; Fact is the actual fund of equipment operation time.

ΔCI is determined depending on the place of operation of low voltage devices.

As a criterion for choosing a rational number of options for low-voltage devices, you can use the "adjusted costs" indicator, which reflects the change in the necessary costs for production and operation by technology options.

The list of restrictions is set in each specific case separately. Technical limitations depend on the particular low voltage apparatus. Such restrictions may, for example, be: extreme temperature rises of the coil winding; minimum traction force; maximum linear dimensions of the magnetic system and coil, etc.

The mathematical solution of the problem posed depends on the specific number of basic parameters used and the relationship between them, the restrictions imposed. The choice of method depends on the difficulty of the task.

Both previously and now, for example in [13, 14, 15], indicators based on the reduced costs are used. In modern conditions, for economic evaluation, monetary characteristics of cash flow are more used, first of all, the main ones: NPV, PI, IRR, PP. Most often, the net present value (NPV) is used. The calculation of NPV depends on the characteristics of obtaining results and investing. In the most general case, when results and costs are received and implemented simultaneously, the indicator is found as follows:

$$NPV = \sum_{i=1}^{i=n} \frac{CF_i}{(1+r_i)^i} - \sum_{j=1}^{j=m} \frac{I_j}{(1+r_j)^j} \quad (4)$$

where: CFi - incoming cash flow ("cash flow"); i – index of the year in which the cash flow is received; n – number of years in which receipts are received; I – amount of investments in the j-th year; rj – discount rate in the jth year; m – number of years during which the investment is carried out.

The value of the discount rate r can be taken at the level of the average bank interest.

Cash flow in the most cases is calculated as follows:

$$CFi = Pi + Di \quad (5)$$

where: Pi – profit in the i-th year; Di - depreciation in the i-th year.

The best option will be the one that provides the maximum NPV value.

Conclusions and prospects for further research. The object of further research may be an economic assessment of the possibilities for improving the range of devices for various modes and operating conditions, taking into account modern opportunities for access to previously scarce materials. It is promising to develop a methodology for evaluating the economic effect of these products on the basis of modern financial indicators, taking into account the received materials.

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