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Analysis of the Forecast Models-Evaluation of Resources Object of Diagnosis Based on the Methods of Statistical Solutions

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***Abstract*—This paper analyzes some of the current models of planning the technical impact on technical systems. Consider the group of mathematical models of changes in the state of the diagnosis object based on statistical methods recognize signs of states of the objects of diagnosis, in particular, on the methods of statistical solutions. Models allow to diagnose the current state of the diagnosis object if one of the selected diagnostic parameter. The results obtained in this work indicate that for one and the same object at the same diagnosis source data, but at different computational methods can be obtained of strikingly different from each other.**

Keywords—mathematical models; resources, diagnostics, methods of statistical decisions, minimal risk method, the minimum number of erroneous decisions, maximum likelihood method, minimax, Neyman-Pearson method

I. INTRODUCTION

The results of the analysis of the reliability of the diagnosis of numerous objects indicate that in the course of long and intensive use, almost all indicators of reliability vary significantly and, furthermore, – worsen. As the impact of operational factors in the diagnosis objects originate, develop and accumulate damage, which, in turn, are the causes of the origin and development failures. Objects like "age". In contrast to this negative process should be put a positive process of timely and quality execution of maintenance work, maintenance work, sound operation.

II. MATERIALS AND METHODS

With the purpose of timely and quality execution of maintenance work, maintenance work of equipment pre-planned and carried out monitoring activities to assess the current condition of the diagnosis object. Especially it concerns the systems and complexes, which results in a failure to substantial material damage or adverse environmental consequences, which correlates with the substantial material damage. In order to minimize the risk of consequences of failures is necessary to plan and carry out control and diagnostic activities on the equipment on the criterion of "the more, the better."

However, carrying out the control and diagnostic procedures on the equipment due to the significant resource costs. This significant financial costs associated with carrying out inspections, the cost of consumables, as well as the high cost of time working professionals (resource consumption, measured in persons/Hr). Therefore, planning and implementation of control and diagnostic procedures on the equipment on the criterion of "the more, the better" is not economically efficient. This increases the cost of the whole operation of the equipment, making it uncompetitive on the market of devices of similar purpose. In order to reduce the cost of resources in the diagnostic work is necessary to plan and carry out the control and verification activities by the criterion of the equipment "the less the better."

Available contradiction can be resolved only by the choice on the scientific basis of rational (optimal) frequency and sound volume control and validation, and maintenance work. Select the frequency of rational and efficient amount of test and maintenance work can only be based on the systematic collection and in-depth analysis on the results of diagnostics data. For this purpose engineering practice widely used various technical state change model of the diagnosis object (OD). As examples of such models can be cited: Model preventive maintenance (PPR) (operation "on the assigned resource"), the service model of the current technical condition (operation "on-condition"), Models of failures (failure Parametric models) [1-6]

Currently, the practice of exploitation of the diagnosis objects are widely implemented methodology of risk-based approach to the planning of technical influences on the state of the main technological equipment. This algorithm predicting changes in the technical condition of the main equipment and calculation of the probability of failure, depending on the technical condition is designed for electric power facilities and is a methodological basis for the implementation of forecasting and warning systems for emergencies. The relevance of a risk-based approach is based including the fact that it allows you to do "without the use of complex mathematical calculations." Developed and actively implemented and other modern models. For example, the model through the use of an integrated evaluation of actual state - the state of the index [8-10].

We consider the work group dedicated to mathematical models for diagnosis of changes in the state of the object based on the statistical methods of recognizing the signs of states of the objects of diagnosis, in particular, on the methods of statistical solutions. The urgency of the implementation of these methods in engineering practice is based on the fact that the current level of development of science and technology makes it possible to equip any, and the more complex and expensive equipment, measurement sensors, computational intelligence systems and integrated diagnostic complexes, allowing to assess the current technical condition of the equipment and to predict the change in technical diagnosis object condition. At the present level of development of science and technology, the introduction into practice of statistical methods of recognition of signs of the States of objects of diagnosis is not constrained by the need to use complex mathematical calculations.

Let us consider the model changing states of the diagnosis object based on statistical methods for feature recognition, in particular, on the methods of statistical solutions. Methods of statistical solutions include: minimal risk method; minimum number of erroneous decisions method; method of maximum likelihood; Minimax method; Neyman-Pearson method.

In the works [5, 6] analyzed object model diagnosis resource estimates based on statistical features of pattern recognition methods states, in particular, to a method and minimum risk to the Neyman-Pearson method. Models allow to diagnose the current state of the diagnosis object if one of the selected diagnostic parameter. For the analysis of models based on statistical decision methods selected objectthe electric grid complex of the Russian Federation - a power transformer with fluid insulation. Produced diagnosing transformer oil by the number of iron impurity in the dielectric fluid (oil) of the transformer (parameter k).

Accepted designations:

– D_1 – up state of the transformer;

– D_2 – a defect in a transformer.

The task is to determine the boundary value of parameter k_0 k such that: the $k<k_0$ $k\in D_1$ (Transformer recognized serviceable); at $k>k_0$ $k\in D_2$ (Transformer is found to be defective should decide to terminate the operation of the transformer).

<u>Model changes in the diagnosis of the state of the object, based on the minimal risk method.</u>

In assessing the state of the object of diagnosis of minimal risk is determined by the density of the distribution function <u>likelihood</u> diagnostic parameter k: $f(k/D_1)$ – at proper (D_1) and $f(k/D_2)$ – in case of faulty (D_2) states transformer. In addition, defined: false alarm probability $P(H_{21})$ – the probability that a defective OD recognizes defective; the probability of missing a defect $P(H_{12})$ – the probability that the defective OD recognized serviceable; the probability of erroneous decisions (medium risk) R – defined as the sum of possible events:

$$R = C_{21}\cdot P(D_1)\cdot \int_{k0}^{\infty} f(k/D_1)\cdot dk + C_{12}\cdot P(D_2)\cdot \int_{-\infty}^{k0} f(k/D_2)\cdot dk, \quad (1)$$

where C_{21} – financial (or other) valuation of false alarms;

C_{12} – the valuation of the defect skipping;

$P(D_1)$, $P(D_2)$ – a priori probability of the diagnosis and D_1 respectively D_2 (assumed to be known on the basis of the preliminary statistical data).

Fig. 1 shows the results of the calculation of density values likelihood diagnostic parameter k for years of use for 5 years: – $f(k/D_1)$ with intact D_1 and $f(k/D_2)$ – fault D_2 states transformer.

<u>Model diagnosis object state changes, a method based on the minimum number of erroneous decisions.</u>

The method is a special case of minimal risk method discussed above. These methods are equivalent, if the cost of false alarms and the cost C_{21} C_{12} defect passes the same.

In assessing the diagnosis object condition by a minimum number of erroneous decisions are similarly defined density distribution function likelihood diagnostic parameter k – $f(k/D_1)$ and $f(k/D_2)$, the probability of false alarm $P(H_{21})$, the probability of missing a defect $P(H_{12})$, the probability of erroneous decisions (medium risk) R.

<u>Model changes in the diagnosis of the state of the object based on the method of maximum likelihood.</u>

The method is also a special case of minimal risk method discussed above.

The decision rule on the status of the transformer ("decision rule") is as follows:

– decision $k\in D_1$ ("OK transformer") was adopted on condition that:

$$\frac{f(k/D_1)}{f(k/D_2)} > 1; \quad (2)$$

– decision $k\in D_2$ ("Faulty transformer") was adopted on condition that:

$$\frac{f(k/D_1)}{f(k/D_2)} < 1. \quad (3)$$

The boundary value of k0 is the condition:

$$f(k_0/D_1) = f(k_0/D_2). \quad (4)$$

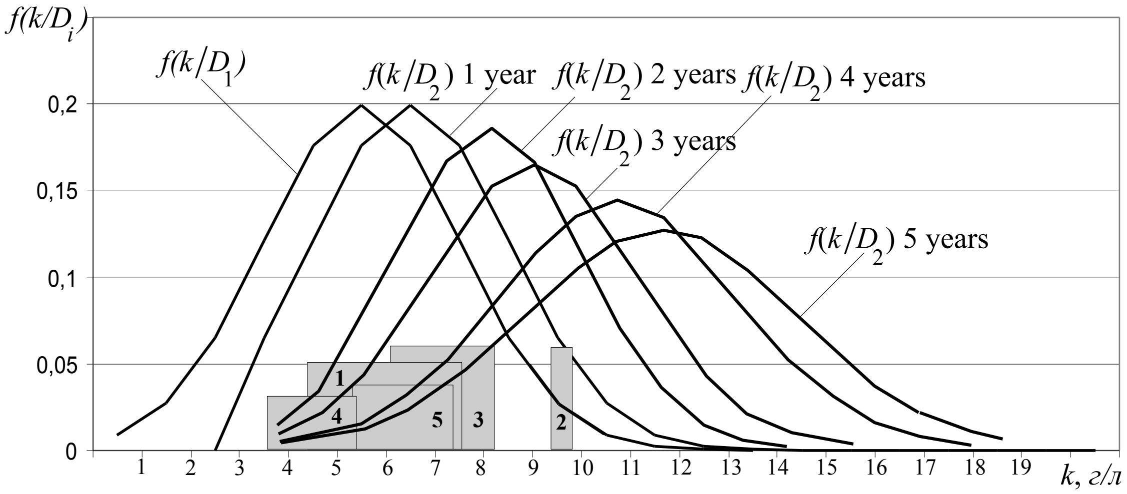

Fig 1 Changes in density likelihood diagnostic the parameter k with intact D_1 and D_2 defective operating conditions transformer years designated area of change numbers k_0 values calculated: 1 – by minimal risk; 2 – by the minimum number of wrong decisions; 3 – maximum likelihood method; 4 – minimax method; 5 – by Neyman-Pearson

Model changes in the diagnosis of the state of the object based on the method of minimax method.

The model is applied to a situation where no preliminary statistical information on probabilities of diagnoses transformer – D_1 and D_2. (Probability values $P(D_1)$ and $P(D_2)$ not initially known).

We consider the "worst case", ie least favorable diagnosis priori probability values – $P(D_1)$ and $P(D_2)$, which lead to the greatest value of the probability of erroneous decision (maximum) risk R.

Method for risk value R depends on the boundary value k_0 and a priori probability of diagnosis – $P(D_1)$. In this case, the probability of the opposite diagnosis D_2: $P(D_2) = 1 – P(D_1)$.

III. Result and Discussion

Based on the models changing states of the diagnosis object, based on statistical features of pattern recognition methods, calculations were performed to assess the limit value the amount of iron impurity in the transformer oil (parameter k_0) (Fig. 1). Furthermore, the methods listed values were determined erroneous solutions (medium risk) R manual data N (Fig. 2).

Analysis of the data shows that for the same object of diagnosis using the same initial data, but different calculation methods (models changes states OD) may be obtained of strikingly different from each other. For instance, for the considered OD - power transformer were obtained editing area boundary values k_0 operation data calculated statistical methods of making. The analysis shows (Fig. 1) that in calculating the boundary values of minimum risk k_0 method (area 1), the method of maximum likelihood (area 3) and the Neyman-Pearson method (area 5). The results show good agreement. Calculations k_0 values by the minimum number of erroneous decisions (area 2) and the minimax method (area 4) give dramatically different results.

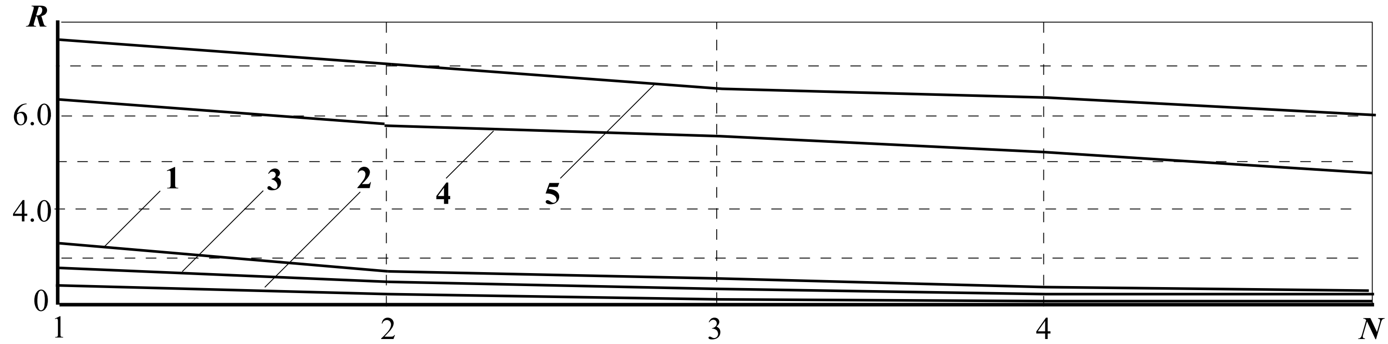

Fig 2 Medium risk values R operating years
The numerals indicate the values change graphics R, calculated: 1 – by minimal risk method; 2 – by the minimum number of erroneous decisions method; 3 – maximum likelihood method; 4 – minimax method; 5 – by Neyman-Pearson method

IV. CONCLUSION

Analysis evaluation erroneous solutions (medium risk) R calculated with statistical methods (Fig. 2) shows weighty contrast results obtained minimax methods (curve 4) and the Neyman-Pearson (curve 5). The risk setting the wrong diagnosis of the state of the power transformer is very large. Medium Risk defined minimum risk methods (curve 1), the minimum number of erroneous decisions (curve 2) and maximum likelihood (curve 3) show good reproducibility. Thus quantitative estimates of average risk is small. It speaks about the reliability of the decision on the technical condition of the object of diagnosis. Reducing the average risk value below the threshold value of the received $R_{\max}^{\partial on}$. It allows you to emphasize evidence-based diagnosis of the operational phase of the object (the number of years in operation), when the number of measured diagnostic features for a reliable assessment of the actual technical condition of the equipment can be reduced to a minimum at the same level of reliability of the diagnosis.

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