TRANSITION FROM QUALITATIVE TO THE QUANTITATIVE APPROACH OF FORMATION OF DECISIONS ON INCREASE OF RELIABILITY OF OBJECTS OF ELECTRO POWER SYSTEMS

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ABSTRACT

The decision of problems of maintenance service arising at the organization and repair of the equipment and devices of electro power systems is resulted. To them concern: an estimation of the importance of a version of the attributes describing reliability and profitability of work; an estimation of parameters of individual reliability; an estimation of parameters of reliability of homogeneous groups (clusters). Methods, algorithms and programs of calculation of these estimations are developed. As the initial information statistical data of operation serve. These data are represented not as sample, of which general population, and as final population of multivariate data. The expediency of classification of these data on the set versions of attributes has or under condition of not casual character of a divergence of statistical functions of distribution of the initial data $F^*_\Sigma(X)$ constructed on all population and sample $F^*_v(X)$. As criterion of estimation it is accepted non-exceedance to an estimation of a parameter of reliability calculated on experimental data of sample $\Pi^*_э(X)$, and critical value of this parameter $\Pi_к$ for the set significance value (Errors I type). It is shown, that: decrease in number of versions of attributes has basic value for decrease in time of calculations; it is necessary to analyze not only character of a divergence of the average parameter of reliability Π^*_Σ and Π^*_v, but also Π^*_v various combinations of versions of an attribute; it would be erroneous to represent, that estimations of parameters of individual reliability are considered on statistical data of operation of the concrete equipment. It is simply not enough of them or not. Individuality is set by significant versions of attributes for this reason exist more than one unit of equipment and devices, parameters of which individual reliability are equal. These groups form cluster; Parameters of reliability clusters differ from parameters of individual reliability forming cluster the equipment and devices. Distinction is caused by that parameters of individual reliability are calculated on the set versions of attributes. At calculation parameters of reliability clusters are considered only versions of attributes for which $\Pi^*_э$ not casually differ not only from Π_Σ but also from all others Π^*_v.

INTRODUCTION

Increase of efficiency of the decision of operational problems in electro power systems (EPS) demands the objective account of reliability of the equipment and devices (objects). Traditionally this account is spent, basically, at a qualitative level (an operational experience of objects + intuition + high qualification of the personnel). Eventually:

– The share of objects, which service life exceeds settlement, became not less than 50 % and increases. Their technical condition worsens, opportunities decrease, demand special attention;
– Occurrence of new objects with other designs and principles of work, the control systems, an increasing variety of volume and norms of test and repair of objects, reduces the importance of the saved up operational experience and demands improvement of quality of preparation of experts, regular retraining of the personnel, improvement of professional skill;
– The automated control systems of operating modes of objects EPS, which service life, exceed settlement, consider change of power characteristics owing to ageing objects insufficiently and demand perfection. And the systems intended for the continuous control of a technical condition of objects, giving the unique information, unfortunately, not always form the decision on increase of reliability.

Thus, methods of the traditional account of reliability of objects demand perfection. One of the most significant directions in it is the increase in making information support of the personnel in the automated information systems of the analysis of a technical condition of objects [1]. Recommendations include:

– Ranking of objects on reliability and profitability (efficiency) of work;
– Instructions on « weak parts » the objects, the based reasons causing deterioration of a technical condition;
– Estimation of quality:
  • Managements of operating modes of objects;
  • Restoration of deterioration during scheduled repair;
  • Preservation during the compelled idle time and a number of others

In present clause, methods and the integrated algorithms of the decision of three interconnected problems providing information support noted above of the personnel are resulted.

1. Method and algorithm of an estimation of the importance of a version of an attribute

It is known, that at the analysis of refusals of objects EPS the big number of information attributes is considered and, first of all, because it is difficult to approve with confidence what of them will appear the most important and useful. Each of attributes is characterized by several versions (VA). On the basis of this information parameters and characteristics of reliability (PR) also pay off. However, at all this, the average estimations calculated, as a rule, and the variety of attributes and their versions at calculations PR practically not considered. These average quantitative estimations of reliability of work are used, first of all, for an illustration of application of methods of calculation PR, the decision of separate design problems. The choice of schemes of switching centers, an estimation of a reserve of capacity concern to such problems, etc.

Parameters, as a rule, are necessary for the decision of operational problems PR compared objects, i.e. and characteristics of individual reliability (PIR). However, it would be erroneous to think, that estimations PIR spend on statistical data about refusals and restorations the concrete generator, the transformer or the switch. To experts well known, that such information simply is not present. And when we speak about PIR is available in view of PR which pays off for significant VA objects. Traditionally, classification of statistical data on the some VA is spent and does not represent any difficulty. For example, PR pay off for objects of a various class of a voltage, either a various design, or various service life. Occasionally PR pays off for two VA. For example, estimates PR linear switches with rated voltage of 110 kV. Thus, questions of expediency of classification of statistical data on these VA are not considered. Let's notice, that the concept "expediency" is indissolubly connected with concept "importance": classification of statistical data is inexpedient for insignificant VA.

Let's consider an essence of a solved problem. Let a result of gathering and processing of data on refusals and restoration of objects EPS we have some population of statistically data, formalized in the form of the empirical table. As this population depends on a lot of casual and not casual factors, it concerns to a class multivariate and final population of multivariate data (FPMD) is called. For FPMD about refusals of objects EPS absence of general population and, as consequence, inexpediency of application is characteristic at the analysis developed for sample of general population of well-known statistical methods. So, on FPMD it is required to estimate PR on some group VA.

VA are set or corresponding classifiers or are appointed. Thus, as a rule, number VA gets out subjectively (greatest possible) in conformity with aspiration to specify character of change PR. For quantitative scales of change of attributes as a first approximation, it is possible to start with optimum number VA that calculated under formula Starges:

$$K = 1+1,44\cdot \ln M \qquad (1)$$

where M – number of realizations τ, and K – the number of intervals, which length is defined under the formula:

$$h = (\tau_{max} - \tau_{min}) / K \tag{2}$$

τ_{max} and τ_{min} – accordingly, the greatest and least value of realizations τ.

In the illustrative purposes in table 1 recommended value for of some values of M.

Table 1. An illustration of dependence M=f (K)

Intervals of change of number of realizations of M of random variables τ	Number	
	VA	Combinations VA
11-23	5	30
24-46	6	62
74-91	7	126
92-183	8	254

We notice, that in conditions of a solved problem K optimum on number of random variables τ (Under condition of conformity of distribution F(τ) to the normal law of distribution), but, as a rule, essentially exceeds number significant VA.

In turn, laconic record of separate conditions of objects, for example, in dispatching schedules, often limits possible number of attributes and their versions. Having specified VA, having collected and having systematized in empirical table FPMD, we shall pass to an estimation of importance VA. The recommended method based on imitating modeling of casual character of estimations PR and application of substantive provisions of the theory of check of statistical hypotheses. As the account of casual character of estimations PR demands hundred, and more often thousand realizations, calculations carried out on the developed computer technology. This technology consists of following operations:

1. It is defined average PR on all FPMD. We shall designate it as Π^*_Σ

The note. It is obvious, that estimations PR calculated on significant VA should differ not casually as from Π^*_Σ, and among themselves. Hence, generally, it is necessary to speak not about significant attributes and their versions, and about significant combinations VA. The general number of combinations VA we shall designate it as K_S. It can be calculated under the formula:

$$K_S = \sum_{i=1}^{K-1} C_K^i = \sum_{i=1}^{K} \frac{K!}{i!(K-i)!} \tag{3}$$

For example, if K=3, then K_S =6 and possible versions of combinations will be 1; 2; 3; 1 and 2; 2 and 3; 1 and 3.

2. For each of K_S combinations VA sample of continuous random variables is defined τ;
3. Estimations PR for each of K_S samples pay off. We shall designate them as $\Pi^*_{V,i}$ with i=1, K_S;
4. Check of the assumption (hypothesis) H_1 about casual character of distinction $\Pi^*_{V,i}$ from Π^*_Σ for i=1, K_S is spent. The technique of such check is resulted in [2];
5. Combinations VA, PR are allocated, which not casually disperse with Π^*_Σ;
6. Groups VA with not casually differing PR are defined;
7. Ranking PR of these groups by way of increase in an Errors II types, i.e. reduction of capacity of criterion is spent. That, establishes significant combinations VA, classification FPMD on specified VA is spent.

Practical realization of this method has shown that the big number of possible combinations VA brings bulkiness in carrying out of calculations and demands is inadmissible big time of the count. So, at the automated analysis of regularity of change of average duration of idle time in emergency repair of power units 300 MVt on gas-and-oil fuel on months of year when number VA К=12, number of combinations VA K_S=4094, and speed of the analysis of expediency of classification it is equal 10 combinations in minute, time of calculations, even at reduction of number of realizations N in 25 times, it has appeared unacceptable. However these calculations have allowed establishing:

1. *Combinations VA including insignificant VA are insignificant*. So, according to table 1 if from eight VA only three are *insignificant*, size K_S decreases in 8,5 times;

2. *The number of significant combinations VA does not exceed number of insignificant combinations VA. Hence the estimation of expediency of classification FPMD on set VA is necessary for spending by search of significant combinations VA;*

3. *With increase in absolute size of relative deviation PR $\Pi^*_{V,i}$ from Π^*_Σ with i=1,K_S an Errors I type (α) result of comparison $\Pi^*_{V,i}$ also Π^*_Σ decreases, and an Errors II type (β) – increases. This conclusion defines a way of ranging PR samples which are supposed to be compared with Π^*_Σ;*

4. *Settlement it is necessary to consider such combinations VA for which relative deviations PR of VA having an identical sign.* So if for the some j1[th] significant VA, PR is equal $\Pi^*_{V,j1}$, and for j2[th] significant VA, PR is equal $\Pi^*_{V,j2}$, association j1 and j2 is possible, if $\delta\Pi_{V,j2} = (\Pi^*_\Sigma - \Pi^*_{V,j2})/\Pi^*_\Sigma$ $\delta\Pi_{V,j1} = (\Pi^*_\Sigma - \Pi^*_{V,j1})/\Pi^*_\Sigma$ coincide;

5. *The algorithm considered above allows dividing VA into three groups. First group VA has PR equals Π^*_Σ, the second group VA has PR equals $\Pi^*_V > \Pi^*_\Sigma$, and the third group VA has PR $\Pi^*_V < \Pi^*_\Sigma$.*

In view of these results, following transformations of a method of an estimation of importance VA recommended:

1. For each of set K of VA is defined sample of continuous random variables τ (See prg.2 algorithm);

2. Estimations PR for each of K sample (see prg.3 algorithm) pay off. Relative changes of each of i=1,K estimations PR under the formula $\delta\Pi^*_{V,i} = \left|(\Pi^*_\Sigma - \Pi^*_{V,i})\right|/\Pi^*_\Sigma$ are defined. Ranking of absolute values $\delta\Pi^*_{V,i}$ with i=1,K by way of their decrease is spent. The greatest (first) value of absolute sizes $\delta\Pi^*_{V,max}$ is allocated;

3. Check of the assumption (hypothesis H_1) about casual character of distinction $\Pi^*_{V,max}$ from Π^*_Σ (see prg.4 algorithm) is spent. The method of comparison Π^*_Σ also Π^*_V depends on type PR. If, for example, Π* there is a model of distribution of a random variable of duration of idle time in emergency repair statistical functions of distribution (s.f.d.) FPMD $F^*_\Sigma(\tau_{ав})$ and s.f.d. samples $F^*_V(\tau_{ав})$ according to [6] are compared. If the observable divergence Π^*_Σ and Π^*_V is casual, a divergence with Π^*_Σ PR, calculated for the others VA also will be casual. In other words, classification FPMD on considered VA is inexpedient. Otherwise, when $\Pi^*_{V,max}$ not casually differs from Π^*_Σ, we pass to PR the following in variation number VA and we check character of its

divergence with Π^*_Σ. This process proceeds until a divergence Π^*_Σ and Π^*_V it will not appear casual.

4. Three group' samples from FPMD are formed. Into the first group enter VA, estimations PR, which casually differs from Π^*_Σ. We shall designate number of VA of first group as K1. These K1 VA withdrawn from full list VA, as insignificant VA. Into second group enter VA, estimations PR, which it is not casual more Π^*_Σ. If number VA of the second group К2 more than one that, as simplification, PR this group are calculated as an average arithmetic estimations PR of VA of the second group. With this estimation PR it is compared integrated VA. For example, if the second group included objects with rated voltage 110 and 220 kV, then integrated VA will be (110 – 220) kV. For VA the third К3 groups PR, $\Pi^*_{V,III}$ it is calculated as an average arithmetic samples random variables τ_{em} for which, $\Pi^*_\Sigma > \Pi^*_{V,i}$, instead of Π^*_V casually differs from Π^*_Σ. PR of $\Pi^*_{V,III}$ also it is compared integrated VA.

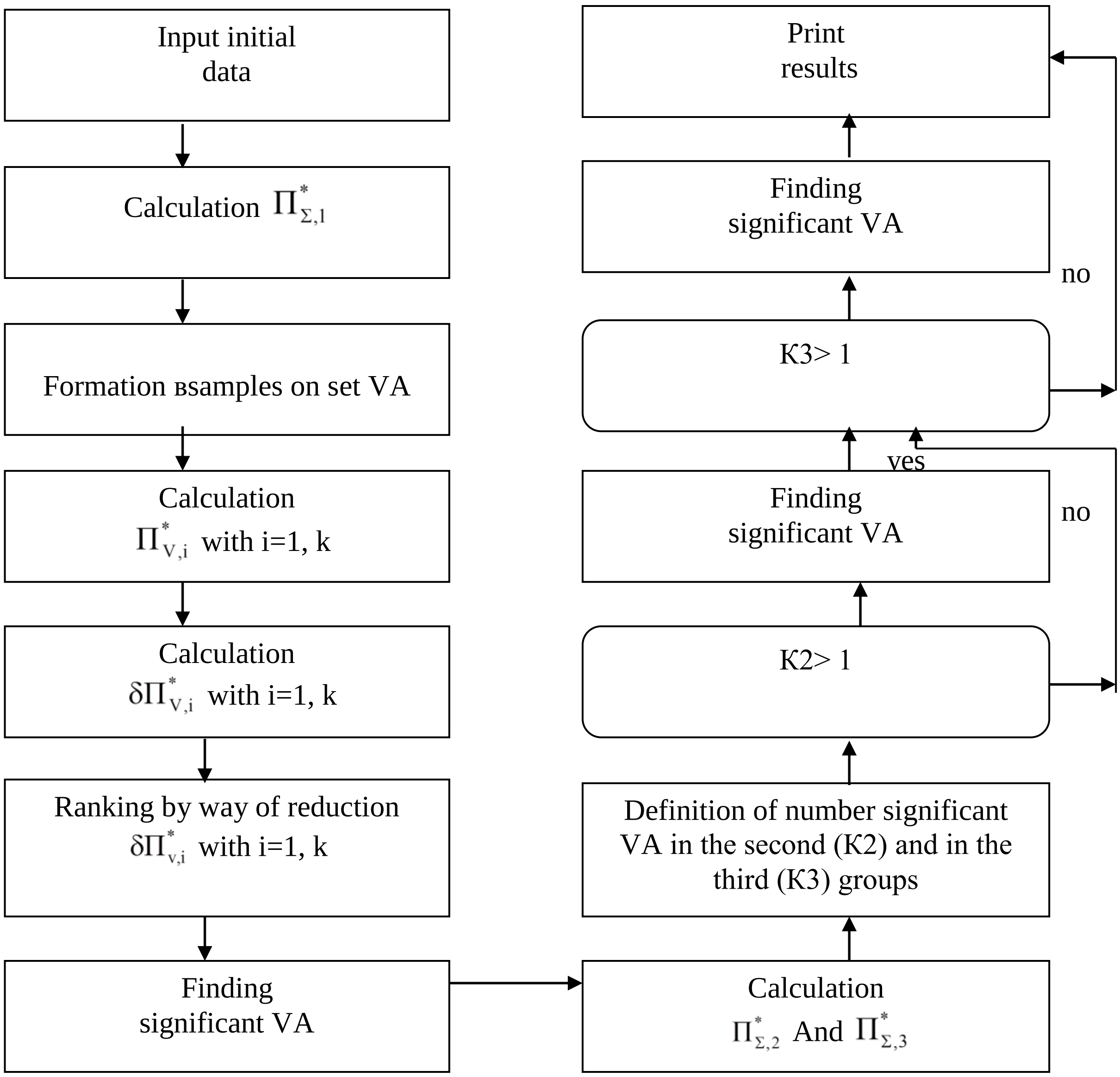

Fig.1. The integrated block scheme of algorithm of an estimation of importance VA.

On it construction of three-level dependence of change of estimations PR from VA comes to an end. In some cases (for example when it is required to establish group most or the least reliable objects) the additional information on object can be received, having increased number of levels of classification FPMD. For what, from samples of the second group (provided that their number К2>1) is formed the second FPMD, and from samples of the third group (at К3> 1) – is formed the third FPMD. Further, according to the sequence stated above the estimation of the importance of everyone VA and specification of their quantitative estimations PR is spent.

In figure 1 the integrated block diagram of algorithm of the decision of a problem about importance VA is resulted

Example 1. In table 2 statistical data about duration of emergency idle time are cited τ_{em} eight power units on gas-and-oil fuel capacity 300 MVt in the same interval of time.

Table 2. Data on emergency duration idle time of power units hs.

i	Serial numbers of power units							
	1	2	3	4	5	6	7	8
1	64,42	46,12	78,59	61,36	63,5	49,15	66,29	36,05
2	15,31	46,27	3,36	236,3	38,07	91,17	47,02	6,23
3	53,5	298,58	3,48	123,59		99,51	93,13	15,35
4	94,55	134,12	42,05	358,15		39,11	54,03	
5	69,37	35,51	45,15			133,24	79,21	
6	5,48		62,36				57,2	
7	185,0		18,15				66,1	
8			29,42				1,3	
9			7,43					
10			25,5					
$\tau_{em,i}$, hs	48,71	560,5	320,0	780,0	102,0	412,0	464,0	57,6

It is required to define estimations of average duration of idle time of power units in an emergency condition $M^*_{V,i}(\tau_{ав})$ with i=1,8. It is necessary to note, that analogue of a serial number of the power unit is service life. The preference to an attribute "serial number" is caused by an invariance of its versions while service life of power units annually changes.

Results of calculations of number of realizations n_v, average arithmetic value of realizations $M^*_{V,i}(\tau_{em})$, relative change $\delta M^*_{V,i}(\tau_{em})$, an Errors I type $\alpha_{v,i}$, i.e. probabilities of a errors of the conclusion (acceptance of hypothesis H_2) about not casual divergence of estimations $M^*_{V,i}(\tau_{ав})$ and $M^*_{\Sigma}(\tau_{ав})$, critical values for $\delta M^*_{V,i}(\tau_{em})$ at a significance value $\alpha_{c=0,05}$, the conclusion about character of a divergence $M^*_{V,i}(\tau_{em})$ with i=1,8 and $M^*_{\Sigma}(\tau_{em})$ =72,4 hs. and recommended values $M^*_{V}(\tau_{ав})$ are resulted in table 3

Table 3. Results of an estimation of character of a divergence $M^*_{V,i}(\tau_{em})$ and $M^*_{\Sigma}(\tau_{em})$

Parameters	Serial numbers of power units							
	1	2	3	4	5	6	7	8
nv, i	7	5	10	4	2	5	8	3
$M^*_{V,i}(\tau_{em})$, Hour	69,7	112,1	32	195	51	82,4	58	19,2
$\delta M^*_{V,i}(\tau_{em})$, %	3,7	54,8	55,8	169,3	29,6	13,8	19,9	3,48
$\alpha_{v,i}$	0,96	0,03	<0,01	<0,01	0,37	0,60	0,35	0,02
$\delta_{0.05} M^*_{V,i}(\tau_{em})$, %	41,8	50,4	35,2	56,5	80,1	50,4	39,9	55,3
H	H1	H2	H2	H2	H1	H1	H1	H2

$M_V^*(\tau_{em})$, Hour	72,4	149	34,5	149	72,4	72,4	72,4	34,5

Estimations $M_{V,i}^*(\tau_{ав})$ are necessary, in particular, at calculations of duration of simultaneous idle time of some power units. In [3] it shown, that calculation of these estimations on the average parameters $M_\Sigma^*(\tau_{em})$ can lead to inadmissible inaccuracy. However, the inadmissible inaccuracy can be and owing to direct application in calculations of estimations $M_V^*(\tau_{em})$. As it has noted been earlier, application of estimations PR calculated on representative samples, is inexpedient. In other words, check of character of a divergence $M_\Sigma^*(\tau_{em})$ and $M_{V,i}^*(\tau_{em})$ with i=1,8 and is necessary for each of estimations $M_V^*(\tau_{ав})$ with other estimations. According to the algorithm stated above relative changes of estimations PR in percentage under the formula are allocated

$$\delta[M_{V,i}^*(\tau_{em})]=100\frac{\left|[M_\Sigma^*(\tau_{em})-M_{v,i}^*(\tau_{em})]\right|}{M_\Sigma^*(\tau_{em})},$$

On distribution of the possible realizations $\delta M_{V,i}^*(\tau_{em})$ modeled (**) according to [4], values of an Errors I type corresponding empirical values $\delta M_{V,i}^*(\tau_{em})$ are calculated $\alpha_{v,\ i}$. Further $\alpha_{v,\ i}$ are compared to critical value α_c, accepted equal 0,05. If $\alpha_{v,\ i}>\alpha_c$, then $H\Rightarrow H_2$ (an index $\Rightarrow$ Designates "corresponds"), if $\alpha_{v,\ i}<\alpha_c$, $H\Rightarrow H_2$. Here results of calculation of critical values quantile of distributions $F^*\{\delta[M_{V,i}^*(\tau_{em})]\}$ under the formula [3] $\delta M_{V,i}^*(\tau_{em}) = 1.13\big/\sqrt{n_v}$ that confirms essential simplification of procedure of an estimation of expediency of classification of population of realizations are resulted τ_{em} on VA. As follows from table 2 of an estimation $M_V^*(\tau_{em})$ 1, 5, 6 and 7 power units casually differ from $M_\Sigma^*(\tau_{em})$ and equal 72,4 hours should be accepted, 3 and 8 power units concern to the second group (with the least values $M_V^*(\tau_{em})$), and 2 and 4 power units concern to the third group (with the greatest values $M_V^*(\tau_{em})$).

Average value of duration of emergency idle time of power units of the second group equally $M_{\Sigma,II}^*(\tau_{em}) = 34{,}5 hours.$, and the third group- $M_{\Sigma,III}^*(\tau_{em}) = 149 hours.$. In the illustrative purposes we shall estimate character of a divergence $M_\Sigma^*(\tau_{em}) = 72.4$ and $M_{\Sigma,II}^*(\tau_{em}) = 34{,}5$. For what we shall define:

1. $\delta M_{\Sigma,II}^*(\tau_{em}) = 100\cdot\left|M_\Sigma^*(\tau_{em}) - M_{\Xi,II}^*(\tau_{em})\right|\big/M_\Sigma^*(\tau_{em}) = 52{,}3\%$
2. $\delta_{0,01}M_{\Sigma,II}^*(\tau_{em}) = 1.42\big/\sqrt{n_{v,II}} = 39.5\%$

As $\delta M_{\Sigma,II}^*(\tau_{em}) > \delta_{0.01}M_{\Sigma,II}^*(\tau_{em})$ the divergence $M_\Sigma^*(\tau_{em})$ also $M_{\Sigma,II}^*(\tau_{em})$ can be accepted not casual with a significance value not less α_c=0,01.

We shall assume now, that it is necessary for us to define the power unit with the least value $M_V^*(\tau_{em})$. For definition $M_{V,min}^*(\tau_{em})$ it is spent following calculations:

1. As $M_{V,3}^*(\tau_{em}) = 32 > M_{V,2}^*(\tau_{em}) = 19.2$, size
   $\delta M_{v,8}^*(\tau_{em}) = 100\cdot\left|M_\Sigma^*(\tau_{em}) - M_{v,8}^*(\tau_{em})\right|\big/M_{\Sigma,II}^*(\tau_{em}) = 44.3\%$
2. $\delta_{0,01}M_{v,8}^*(\tau_{em}) = 1.42\big/\sqrt{3} = 82.1\%$

As $\delta M^*_{v,8}(\tau_{em}) < \delta_{0.01} M^*_{v,8}(\tau_{em})$, the assumption of not casual divergence $M^*_{\Sigma,II}(\tau_{em})$ and $M^*_{v,8}(\tau_{em})$ is erroneous.

We shall estimate character of a divergence $M^*_{\Sigma,II}(\tau_{em})$ and $M^*_{v,3}(\tau_{em})$, we calculate:

1. $\delta M^*_{v,3}(\tau_{em}) = 100 \cdot \left| M^*_{\Sigma}(\tau_{em}) - M^*_{v,3}(\tau_{em}) \right| \Big/ M^*_{\Sigma,II}(\tau_{em}) = 7.2\%$
2. $\delta_{0,01} M^*_{V,3}(\tau_{em}) = 1.42 \Big/ \sqrt{10} = 45.6\%$

Erroneous there was also an assumption of not casual divergence $M^*_{\Sigma,II}(\tau_{em})$ and $M^*_{v,3}(\tau_{em})$. Hence, $M^*_{v,3}(\tau_{em})$ = $M^*_{v,8}(\tau_{em})$ = 34,5hours.

Calculations for an estimation of character of a divergence $M^*_{\Sigma,III}(\tau_{em})$ are similarly lead and $M^*_{v,2}(\tau_{em})$, together with $M^*_{\Sigma,III}(\tau_{em})$ $M^*_{v,4}(\tau_{em})$. It is established, that $\delta M^*_{v,2}(\tau_{em}) = 24.8\%$ less than critical value $\delta_{0,05} M^*_{v,2}(\tau_{em}) = 50.4\%$, and $\delta M^*_{v,4}(\tau_{em}) = 30.9\% < \delta_{0,05} M^*_{v,4}(\tau_{em}) = 56.5\%$. Hence, $M^*_{V,2}(\tau_{em})$ and $M^*_{V,4}(\tau_{em})$, casually differ from $M^*_{\Sigma,III}(\tau_{em})$, and classification is inexpedient.

2. Method and algorithm of an estimation of parameters of individual reliability of objects

Despite of essential distinction of names of the first and second problem, algorithm of the decision of the second problem is easier. The estimation of expediency of classification FPMD on the set versions of one of attributes (the first problem) provides both an estimation significant VA, and an estimation of expediency of representation of an attribute the set list significant VA. The matter is that PR for some versions of one attribute, despite of the importance of these VA, can differ casually. This distinction can be caused by small number of realizations of random variables samples. I.e. the aspiration to so detailed representation of an attribute appears unjustified.

At estimation PIR analyze only importance VA, subjectively setting individuality of object [3]. The block scheme of algorithm of estimation PIR is resulted on fig. 2. If in algorithm of an estimation of importance VA (see fig. 1) is estimated the importance of each sample from FPMD in algorithm of estimation PIR consecutive classification originally FPMD is spent, further classification of the sample corresponding $\Pi^*_{V,max}(X)$, further classification of the sample corresponding of two most significant VA, etc.

Calculations come to the end at the first casual divergence $\Pi^*_{\Sigma}(X)$ and $\Pi^*_{V}(X)$

Example 2. In the present example, we shall consider sequence of estimation PIR. For decrease in bulkiness of calculations, we shall consider only two attribute and their version – a serial number of the power unit and the basic devices of the power unit. Allocated: steam turbine and a boiler installation, system of own needs, a turbo generator, block transformers.

Data on duration of emergency idle time of the power unit, owing to refusal of one of these devices, are resulted in table 4.

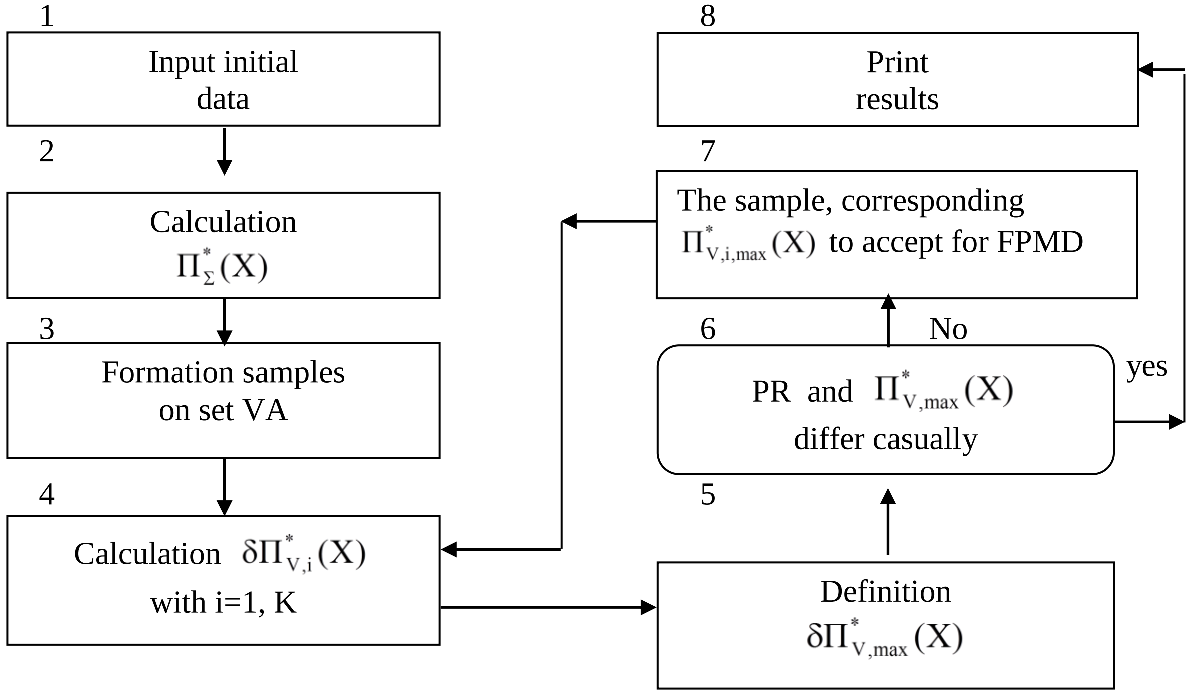

Fig. 2. The integrated block scheme of algorithm estimation PIR.

Table 4. Data on duration of emergency idle time at refusal of devices of power units, hs.

i	Devices									
	Steam turbine installations		Boiler installation		Own needs		Generators		Transformers	
	N PU	Hour	N PU	Hour	N PU	Hour	N PU	Hour	N PU	Hour
1	1	64,4	1	15,3	2	298,5	8	6,2	8	15,3
2	1	94,5	1	53,5	2	134,1	3	7,4	2	35,5
3	1	185,0	1	69,3	3	29,4	1	5,4		
4	2	46,2	2	46,1	3	25,5				
5	3	3,3	3	78,6	4	358,1				
6	3	3,4	3	42,0	6	133,2				
7	4	61,3	3	45,1						
8	4	236,3	3	62,3						
9	4	123,5	3	18,1						
10	6	49,1	5	63,5						
11	6	91,1	5	38,0						
12	7	66,2	6	99,5						
13	7	47,0	6	39,1						
14	7	93,1	7	54,0						
15	7	78,2								
16	7	57,2								
17	7	66,1								
18	7	1,3								
19	8	36,0								
$\tau_{em,i}$, hs	1404		725,2		979,2		19,2		50,9	
n_i	19		14		6		3		2	
$\Pi^*_{V,i}(X)$, hs	73,9		51,8		163,2		6,4		25,4	

Let's assume that it is necessary to estimate average duration of emergency idle time of the third power unit owing to refusal of boiler installation. As $M^*_\Sigma(\tau_{em}) = 72.4\,\text{hour}$, and $M^*_{V,3}(\tau_{ав}) = 32\text{hour}$ and $M^*_{V,ку}(\tau_{em}) = 51{,}8\,\text{hour}$, $\delta M^*_{\Sigma,\max}(\tau_{em}) = \delta M^*_{v,\max}(\tau_{em})$. But according to an example 1 the third power unit concerns to significant VA. We shall execute sample of realizations τ_{em} at refusals of boiler installation from a data population about refusals of the third power unit. It (see table.3): 78,59; 42,05; 45,15; 62,36; 18,15hour. It is necessary to establish expediency of such classification. According to algorithm fig.2 the relative deviation of average duration of emergency idle time of the power unit at refusals of its boiler installation $M^*_{V,3,bi}(\tau_{em}) = 49{,}3\,\text{hour}$ from $M^*_{V,3}(\tau_{em})$ will be equal

$$\delta M^*_{v,3,bi}(\tau_{em}) = 100 \cdot \left| M^*_{v,3,bi}(\tau_{em}) - M^*_{v,3,bi}(\tau_{em}) \right| \Big/ M^*_{v,3}(\tau_{em}) = 100 \cdot |30 - 49.3| / 32 = 59{,}3\%$$

Critical value $\delta_{0.05} M^*_{v,3,bi}(\tau_{em}) = 50{,}4\%$. Hence, with a significance value not less α_c=0.05 It is possible to approve, that $M^*_{V,3,bi}(\tau_{em})$ not casually differs from $M^*_{V,3}(\tau_{em})$ and it is equal 49,3hour.

3. Method and algorithm of an estimation of parameters and characteristics of reliability cluster' objects EPS

Having calculated PIR for population of the same objects it is easy to notice, that for significant VA there is not one, and the whole group of objects with equal PIR. For example, three-phase (the first VA), two winding (the second VA) transformers (the third VA), a voltage with 110 kV (the fourth VA), established on substations of distributive networks (the fifth VA) make about 20 % from the general number of transformers EPS.

In this connection, the opportunity of classification of analyzed objects on groups (clusters), their ranking by criterion of reliability of work and preparation of recommendations on perfection of system of maintenance service, the control of a technical condition and quality of repair of each group is of interest. Classification on three groups is as a first approximation sufficient: group high, group of average and group of low reliability.

If for calculation of parameters and characteristics of individual reliability initial data are one version of each attribute of object for calculation of parameters and characteristics of reliability clusters objects initial data are all versions of attributes. It would seem, enough to calculate PIR for of some the same objects and it is possible on VA to find clusters. However, this opinion as well as, equality PIR and PR clusters, wrongly. And first of all fixed VA at calculation PIR can appear significant, but classification on them – inexpedient. Also there is it because at calculations PIR character of a divergence between significant versions of same attribute is not considered. That is why significant it is necessary to consider VA, PR which differ not casually not only from PR, calculated on FPMD, but also between significant versions of same attribute. The essence of a method of calculation PR clusters FPMD reduced to following sequence of calculations:

1. For each of attributes of considered objects from the general number allocated VA significant combinations VA (see algorithm of an estimation of importance VA) are established. We shall designate number of significant combinations of versions i^{th} an attribute through r_i with i=1,m, where m - number of attributes of object;
2. For each attribute are calculated significant VA and are defined VA with the greatest estimation PR $\Pi^*_{V,i,\max}$, where $\Pi^*_{V,i,\max} = \max[\Pi^*_{V,1,1}; \Pi^*_{V,2,2}; \ldots \Pi^*_{C,n,r_i}]$; i=1, n; n – number of attributes; r_i – number of significant versions i^{th} an attribute;

3. Among $\Pi^*_{V,i,max}$ with i=1,n the greatest value PR $\Pi^*_{V,i,max} = \max[\Pi^*_{V,1,max};\Pi^*_{V,2,max};...\Pi^*_{C,n,max}]$ is defined;
4. Sample of realizations of conformity $\Pi^*_{V,i,max}$ is represented as FPMD and for all significant combinations of each attribute, except for corresponding $\Pi^*_{V,i,max}$, the greatest values among versions of each attribute and the greatest average of all (m-1) attributes are calculated. Classification of this sample proceeds until estimation PR on FPMD and an estimation on sample with $\Pi^*_{V,i,max}$ will not disperse casually.

At achievement of this event, current FPMD it is withdrawn from initial FPMD. It is analyzed new FPMD. Process of classification FPMD proceeds until distinction of estimations PR calculated on FPMD and sample with $\Pi^*_{V,max}$ will not appear casual.

Example 3. To lower bulkiness of calculations illustration of estimation PR clusters we shall lead on statistical data tab. 2 and 4, i.e. classification we shall lead only to two attributes "serial number" of the power unit and "device" of the power unit. In an example 1 the sequence of calculations PR for an attribute – a serial number of the power unit has been resulted. It established that the greatest value $M^*_V(\tau_{ав})$ takes place for group of the second and fourth power units and 149 hour is equal. Results of the calculations, allowing estimating the importance of versions of an attribute of the device of power unit Thermal Power Stations (TPS), are resulted in table 5

Table 5. An estimation of character of a divergence $M^*_\Sigma(\tau_{ав})$ and $M^*_{V,i}(\tau_{ав})$ with i=1,5

Parameter	Devices of power unit TPS				
	Steam turbine installation	Boiler installation	Own needs	Turbo generator	The block transformer
$\delta M^*_{v,i}(\tau_{em})$, %	2,1	28,5	125	91.2	64,9
$\delta_{0,05} M^*_{v,i}(\tau_{em})$, %	25,9	30,2	46,1	65,3	80,1
H	H_1	H_1	H_2	H_2	H_1
$M^*_i(\tau_{em})$	72,4	72,4	163,2	6,4	72,4

As excess of a relative deviation $\delta M^*_{v,i}(\tau_{em})$ of critical value $\delta_к M^*_{v,i}(\tau_{em})$ follows from table 5 is observed at refusals in system of own needs and refusals of the generator. In other words, these two VA appear significant. Having established significant versions of each attribute, we shall define the most significant VA by comparison of relative deviations $\delta M^*_v(\tau_{em})$. These are realizations τ_{em} at refusals in system of own needs. We shall lead classification of six realizations τ_{em} at refusals in system of own needs (see table.4) on serial numbers of power units. We shall notice, that results of calculation of character of a divergence of estimations of average duration of emergency idle time of power units $M^*_{v,i}(\tau_{em})$ where i=1,8 with $M^*_\Sigma(\tau_{em})$ can and not coincide with an estimation of character of distribution of average duration of emergency idle time of power units owing to refusals in system of own needs. According to table 3 and the stipulated condition of classification n_v>1, $M^*_{v,i,ON}(\tau_{em})$ can be calculated and compared with $M^*_{v,ON}(\tau_{em}) = 163{,}2$ hour only for the second $M^*_{v,2,ON}(\tau_{em}) = 216{,}4$ hour and third $M^*_{v,3,ON}(\tau_{em}) = 27{,}5$ hour power units. However, considering, that $M^*_{v,3,ON}(\tau_{em}) < M^*_{v,ON}(\tau_{em}) < M^*_{v,2,ON}(\tau_{em})$, we shall be limited only to calculations for the second power unit. At nv=2 $\delta M^*_{v,2,ON}(\tau_{em}) = 100 \cdot \left| (216.4 - 163.2) / 163.2 \right| = 32.6\%$; $\delta_{0.05} M^*_{v,2,ON}(\tau_{em}) = 80.1\%$. Hence, sample τ_{em} for the second power unit at refusals in system of own needs the divergence between $M^*_{v,ON}(\tau_{em})$ and $M^*_{v,2,ON}(\tau_{em})$ with a high probability casually cannot be considered as unpresentable, i.e. For transition to the second stage of calculations from FPMD it is withdrawn six realizations τ_{em}, connected with refusals in system of own needs. For new FPMD are calculated:

- Average arithmetic value FPMD $M^*_{\Sigma,2}(\tau_{em}) = 58.6\,hs$;
- Average arithmetic value $M^*_v(\tau_{em})$ for everyone VA except for τ_{em} at refusals in system of own needs;
- Absolute value of a relative deviation $\delta M^*_v(\tau_{em})$ for everyone VA;
- Critical values $\delta_{\alpha_c} M^*_v(\tau_{em})$ at α_c=0,05;
- Are allocated significant VA;
- The most significant is defined VA.

Results of calculations are resulted in table 6 and 7

Table 6. Results of an estimation of the importance of versions of an attribute « number of the power unit »

Number of the power unit (i)	Parameters			
	$M^*_{v,i}(\tau_{em})$	$n_{v,i}$	$\delta M^*_{v,i}(\tau_{em})$	$\delta_{0.05} M^*_{v,i}(\tau_{em})$
1	69.7	7	18.9	42.6
2	42.6	3	27.3	65.3
3	33.1	8	43.5	39.9
4	140.6	3	140	65.3
5	51.0	2	12.9	79
6	69.7	4	18.9	56.5
7	58.0	8	1.0	43.5
8	19.2	3	67.2	65.3

Table 7. Results of an estimation of the importance of versions of an attribute of "device"

Devices	Parameters			
	$M^*_{v,i}(\tau_{em})$	$n_{v,i}$	$\delta M^*_{v,i}(\tau_{em})$	$\delta_{0.05} M^*_{v,i}(\tau_{em})$
Steam turbine installation	73,9	19	26,1	25,9
Boiler installation	51,8	14	11,6	30,2
System of own needs	-	-	-	-
Turbo generator	6,4	3	89	65,3
The block transformer	25,4	2	56,5	79

Analysis of given these tables show that to significant it is necessary to carry following VA: the third, fourth and second power units, steam turbine installation and a turbo generator. However, to compare follows only given the fourth power unit and idle times in emergency repair at refusal of a turbo generator. Excess of size $\delta M^*_{v,i}(\tau_{em})$ the fourth power unit above other power units, obviously. Classification of data of the fourth power unit is impossible, since all idle times in emergency repair passed at refusals steam turbine installations (see table 4).

To pass to the third stage, we shall exclude FPMD the second stage data about τ_{em} the fourth power unit. We shall receive $M^*_{\Sigma,3}(\tau_{em}) = 51\,\text{hour}$.

Having executed the calculations similar in detail presented for second stage, we shall receive:

1. For an attribute «number of the power unit » significant versions are absent;
2. For an attribute of "device», one significant version is revealed only: data about τ_{em} turbo generators. As average arithmetic value of realizations of this PΠ $M^*_{v,i}(\tau_{em}) < M^*_{v,3}(\tau_{em})$. Classification on VA with $M^*_{v,i}(\tau_{em})$ exceeding $M^*_{\Sigma}(\tau_{em})$ it is possible to consider that completed;
3. Classification of the sample corresponding significant VA is not spent, since number of realizations for each of three power units n_v=1

Calculations of the fourth stage of calculations testify to full absence significant VA, uniformity FPMD (for two attributes).

Thus, 4 groups of data are allocated. The first, most representative group, covers 73 % of data, has $M^*_v(\tau_{em}) = 55\,hour$. The second group reflects τ_{em} power units at refusals in system of own needs, it $M^*_v(\tau_{em}) = 163\,hour$. The third group characterizes τ_{em} the fourth power unit, it $M^*_v(\tau_{em}) = 140\,hour$. The fourth group allocates τ_{em} because of refusals of turbo generators observable in the considered period, it $M^*_v(\tau_{em}) = 6\,hour$. So small duration of idle time does not cause surprise if to consider, that this device includes not only actually a turbo generator, but also its system of cooling, system of excitation, system of relay protection, automatics and management, duration of which restoration of refusal are essentially various.

Average durations of idle time in emergency repair of separate groups allow to pass from s.f.d. realizations of duration of emergency idle time $F^*(\tau_{em})$ to integrated s.f.d. duration of emergency conditions T_{em} of power units $F^*(T_{em,i})$

CONCLUSION

1. Methods, algorithms and programs are developed:
   - Estimations of the importance of versions of attributes;
   - Estimations of parameters of individual reliability of objects;
   - Estimations of parameters of reliability clusters objects
2. Essential advantage of these methods is the opportunity to raise objectivity of the decision of many operational problems on had statistical data;
3. Results of researches allow pass from the traditional analysis of statistical data of operation of the equipment and devices of electro power systems as representative sample of general population to methods of the analysis, these data considering multivariate character

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