CONTROL THE IMPORTANCE OBSERVABLE LAWS OF CHANGE RELIABILITY OVER OPERATION

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The problem of the control of the importance of observable laws of change of parameters of reliability (PR) at small statistical data of operating experience or experiment in conditions when the argument has a serial or nominal scale of measurement, concerns to number of the most difficult and insufficiently developed. In particular, at operation of electro installations the important role-played with data on reliability of units of the same equipment, on the reasons of occurrence and character of their damage, law of change PR of the equipment for various classes of a pressure and so forth

Let us agree to name the dependences empirical characteristics (ECh.) changes PR. Calculated on statistical data of operation of law of change ECh. caused by functional and statistical components. From the practical point of view the opportunity essentially is of interest to lower the importance of a statistical component.

To estimate laws of change of functional characteristics (FCh.) it is important for experts since these characteristics allow raise reliability of the equipment with the least expenses, to correct maintenance service, to improve the control of a technical condition, to lower expenses for scheduled repairs and so forth

Thus, the problem consists in establishing influence of casual character of estimations PR on laws of change ECh..

For the decision of this problem we shall enter into consideration following concepts and definitions:

- concept of statistical function of distribution (f.d.) the discrete argument measured in a serial scale or in a scale of names also we shall define this function under the formula:

$$F^*(i+1)=\sum_{\nu=1}^{i} Q_\nu^* = \sum_{\nu=1}^{i} n_\nu / n_\Sigma \qquad (1)$$

$$i=1,(m_r+1) \;\; F^*(1)=0; F^*(m_r+1)=1$$

where: Q_ν^* - estimation of probability of display ν-- version of an attribute (VA); n_Σ - number of displays of a considered attribute; m_r – number VA;

Physically $F^*(i)$ designates probability of display located in the certain order of the first i VA.

- concept hypothetical f.d. In particular, if to assume, that the probability of display of each of m_r VA the same and is equal 1/mr function of uniform distribution can be calculated under the formula:

$$F(i+1)=i/m_r \qquad (2)$$

where $i=(1),\ (m_r+1);\ F(1)=0;\ F(m_r+1)=1$;

- concept of statistical function of modeled distribution $F_M^*(i)$. Function $F_M^*(i)$ It is similar on structure of function $F^*(i)$ with that difference, that n_ν with $\nu=1,m_r$ defined at modeling ECh. on distribution $F(i)$;

- the same, but is defined at modeling ECh. on distribution $F^*(i)$. Let's designate this function as $F_M^{**}(i)$:

- alternative assumptions (hypothesis). Here it is necessary to distinguish two strategies. In the first it supposed, that observable law of change $F^*(i)$ corresponds valid. We shall designate this assumption through $H_{1,1}$. The second assumption consists that $F^*(i)$ casually differs from prospective FCh. and, in particular, $F(i)$ corresponds to the uniform law. We shall designate this assumption through $H_{1,2}$.

Let's consider characteristic examples of this strategy. The computer program representing to experts of the recommendation on increase of reliability of the equipment, according to algorithm of calculation chooses units with number of refusals above average value (initial assumption $H_{1,1}$). However the manufacturer of works has certain doubts regarding objectivity of recommendations. It considers (alternative assumption $H_{1,2}$), that the observable divergence is not enough for objective conclusions. It is necessary to note, that in many publications constructed ECh. form the basis for recommendations on change of reliability.

In the second strategy it is supposed, that there are no serious bases to consider, that reliability of units of object is various. We shall designate this assumption through $H_{2,1}$. At the same time statistical data of operation testify to some divergence of number of refusals of units of object which can be motivated those or other reasons (Let's designate the assumption of not casual character of a divergence $F(i)$ and $F^*(i)$ through $H_{2,2}$). It is obvious, that the problem of a choice of this or that assumption consists in comparison of casual character of realizations of distributions $F(i)$ (or $F^*(i)$) and casual character of a divergence of realizations $F(i)$ (or $F^*(i)$) from $F^*(i)$ (or $F(i)$).

- statistics δ_m, defining the greatest divergence between f.d. We shall distinguish:

- empirical value of the greatest divergence between $F(I)$ and $F^*(I)$. It is calculated under the formula:

$$\delta_{m,Э} = \max\left\{\delta_{1,Э};\delta_{2,Э},...\delta_{m_r,Э}\right\}, \tag{3}$$

$$\delta_{i,э} = \left|F(i) - F^*(i)\right|; \quad i=2,(m_r+1) \tag{4}$$

- the greatest divergence between $F^*(i)$ and modeled realizations of this distribution $F_M^{**}(i)$. It is calculated under the formula:

$$\delta_{m,\nu}(H_{1,1}) = \max[\delta_{1,\nu}(H_{1,1});\delta_{2,\nu}(H_{1,1});...\delta_{m_{r,\nu}}(H_{1,1})] \tag{5}$$

$$\delta_{i,\nu}(H_{1,1}) = \left|F^*(i) - F^{**}_{M,\nu}(i)\right| \tag{6}$$

ν=1, N; i=2, (m_r+1); N-number of iterations of modeling $F^{**}_{M,\nu}(i)$.

- greatest divergence between $F^*(i)$ and modeled on $F(i)$ realizations $F_M^*(i)$. It is calculated under the formula:

$$\delta_{m,\nu}(H_{1,2}) = \max\{\delta_{1,\nu}(H_{1,2});\delta_{2,\nu}(H_{1,2});...\delta_{m_{r,\nu}}(H_{1,2})\} \tag{7}$$

$$\delta_{i,\nu}(H_{1,2}) = \left|F^*(i) - F^*_{M,\nu}(i)\right| \quad \nu=1, N; \quad i=2, (m_r+1) \tag{8}$$

- greatest divergence between $F(i)$ and modeled on $F(i)$ realizations $F^*_{M,\nu}(i)$. It is calculated under the formula:

$$\delta_{m,\nu}(H_{2,1}) = \max\{\delta_{1,\nu}(H_{2,1});\delta_{2,\nu}(H_{2,1});...\delta_{m_{r,\nu}}(H_{2,1})\} \tag{9}$$

where: $$\delta_{i,\nu}(H_{2,1}) = \left|F(i) - F^*_{M,\nu}(i)\right| \quad \nu=1,N; \quad i=1,m_r; \tag{10}$$

- greatest divergence between $F(i)$ and modeled on $F^*(i)$ realizations $F^{**}_{M,\nu}(i)$. It is calculated under the formula:

$$\delta_{m,\nu}(H_{2,2}) = \max\{\delta_{1,\nu}(H_{2,2});\delta_{2,\nu}(H_{2,2});...\delta_{m_{r,\nu}}(H_{2,2})\} \tag{11}$$

$$\delta_{i,\nu}(H_{2,2}) = \left|F(i) - F^{**}_{M,\nu}(i)\right| \quad \nu=1, N; i=2,(m_r+1); \tag{12}$$

- f.d. $\delta_m(H_{1,1})$, $\delta_m(H_{1,2})$, $\delta_m(H_{2,1})$ и $\delta_m(H_{2,2})$. The analytical kind of these distributions is unknown. We shall define these distributions by a method of statistical modeling.

The graphic illustration of sequence of calculations $F^*[\delta_m(H_{1,1})]$ also $F^*[\delta_m(H_{1,2})]$ is resulted on fig.1, and on fig.2 the graphic illustration of sequence of calculations $F^*[\delta_m(H_{2,1})]$ is resulted and $F^*[\delta_m(H_{2,2})]$

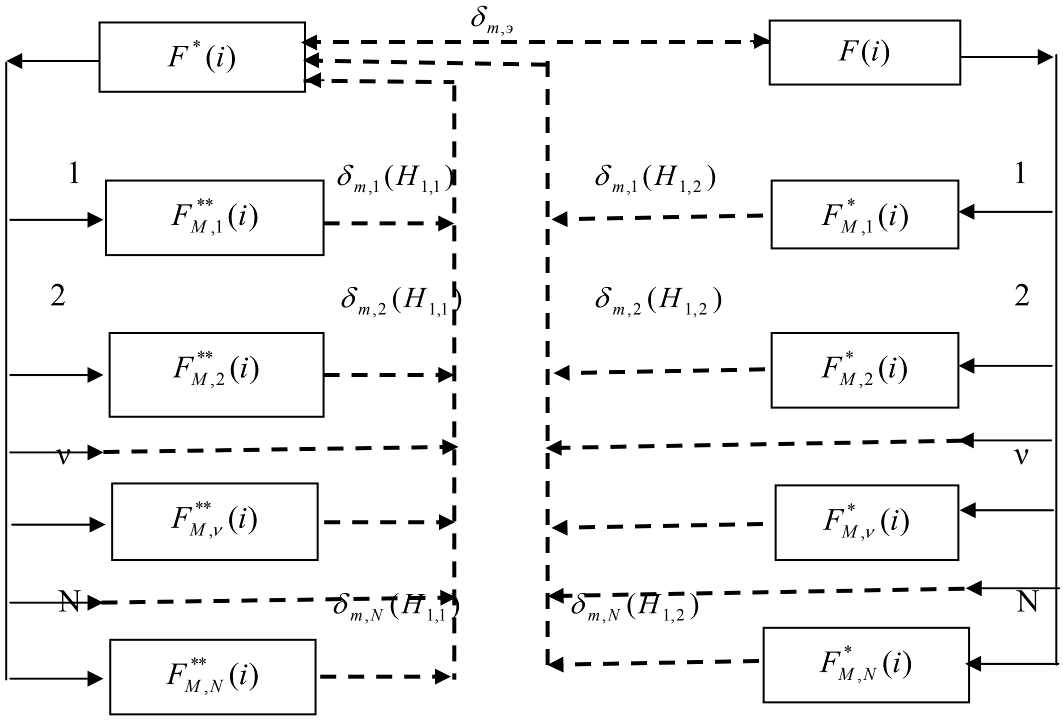

Fig.1. The block diagram of sequence of calculation of distributions $F^*[\delta_m(H_{1,1})]$ and $F^*[\delta_m(H_{1,2})]$

Here by continuous lines the sequence of modeling of distributions $F^{**}_{M,\nu}(i)$ and $F^*_{M,\nu}(i)$, and dotted structure of an estimation of realizations of the greatest deviation of distributions $\delta_{m,\nu}(H_{1,1})$ is shown and $\delta_{m,\nu}(H_{1,2})$.

According to fig.1. The algorithm of calculation $F^*[\delta_m(H_{1,1})]$ also $F^*[\delta_m(H_{1,2})]$ reduced to following sequence of calculations:

1. By program way are modeled n_Σ random numbers with uniform distribution in an interval [0,1]
2. Direct use of these random numbers, especially at small n_Σ leads to essential disorder of probability of occurrence of discrete values δ_m, which kept, and at big enough number of iterations N. As it has been shown in [1] effective method of decrease in a dispersion of distribution $F^*[\delta_m(H_{1,1})]$ as well as $F^*[\delta_m(H_{1,2})]$ application of criterion of Kolmogorov for check of distribution of sample $\{\xi\}_{n_\Sigma}$ to the uniform law is.

According to [2], at factor of trust R calculations spent under the formula:

$$\left(\sqrt{n}+0{,}12+\frac{0{,}11}{\sqrt{n}}\right)D_n > C_R \tag{13}$$

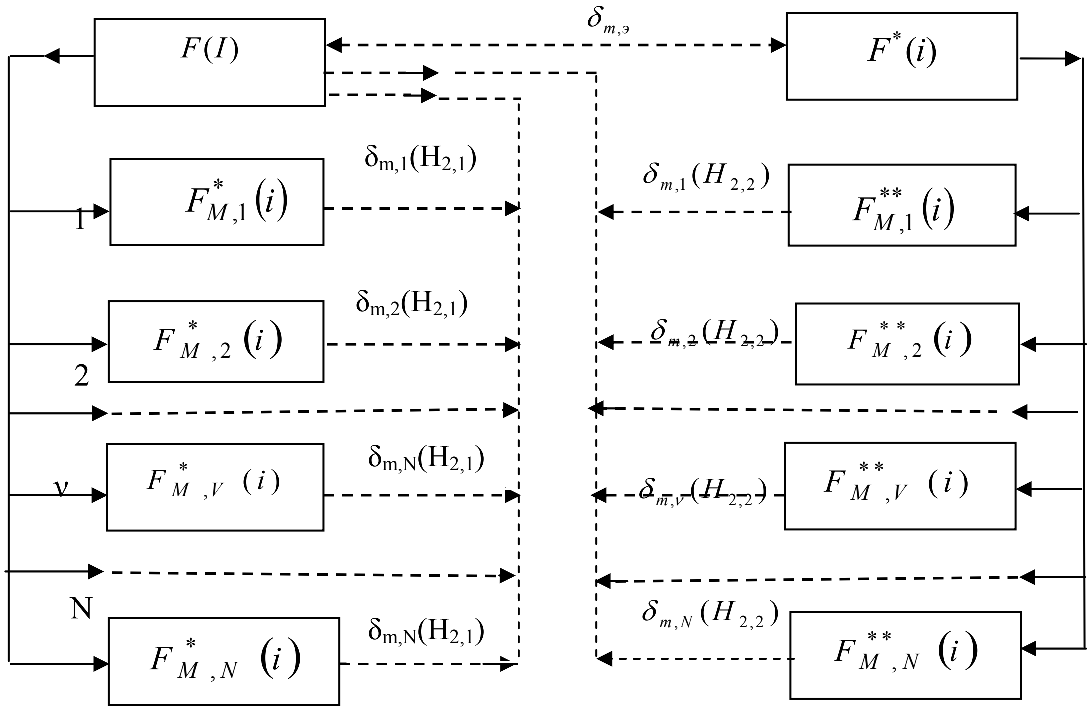

Fig.2. An alternative variant of the block diagram of sequence of calculation of distributions $F^*[\delta_m(H_{2,1})]$ and $F^*[\delta_m(H_{2,2})]$

3. Frequencies of display of each of $m_{r,j}$ VA, by comparison of each of n_Σ random numbers to intervals of distribution $F^*(i)$ under the formula modeled:

$$F^*(i) < \xi \le F^*(i+1) \text{ with i=1,(m}_r\text{+1)} \qquad (14)$$

4. Under the formula (1) the first realization $F^{**}_{M,1}(i)$ pays off; Decrease in a dispersion of distributions $F^*[\delta_m(H_{1,1})]$ and $F^*[\delta_m(H_{1,2})]$, alongside with application to sample of random variables $\{\xi\}_{n_\Sigma}$ of criterion of Kolmogorov, is reached also by application of a method of the general random numbers. Therefore, if sample $\{\xi\}_{n_\Sigma}$ does not contradict Kolmogorov's criterion, it is remembered;

5. Under formulas (5) and (6) realization $\delta_m(H_{1,1})$ pays off

6. Having repeated 1÷6 (N-1) time, we count N realizations $\delta_m(H_{1,1})$, having arranged which in ascending order we shall receive statistical function of distribution $F^*[\delta_m(H_{1,1})]$.

Calculation statistical function of distribution $F^*[\delta_m(H_{1,2})]$ spent as follows.

7. Random numbers $\{\xi\}_{n_\Sigma}$ in each iteration are not modeled, and undertake from a file $N \cdot n_\Sigma$ of the random numbers, generated at modeling distribution $F^*[\delta_m(H_{1,1})]$.

8. Repeats п.3 with that difference, that comparison is spent under the formula:

$$F(i) < \xi \le F(i+1) \qquad (15)$$

where $i = 1,(m_r + 1); F(0) = 0; F(m_r + 1) = 1$;

9. Under the formula similar (1) distribution $F^*_M(i)$ pays off.

10. Under formulas (7) and (8) realization $\delta_m(H_{1,2})$ pays off;

11. Having repeated 8÷11 (N-1) time, we count N realizations $\delta_m(H_{1,2})$, having arranged which in ascending order, we shall receive statistical function of distribution $F^*[\delta_m(H_{1,2})]$.

The algorithm of calculation $F^*[\delta_m(H_{2,1})]$ also $F^*[\delta_m(H_{2,2})$ is practically similar to the above-stated with that difference, that in p.3 modeling is spent under the formula (15), and in under the formula (14).

- Concepts initial (G_1) and alternative (G_2) hypotheses.

We shall agree that if between estimations of a population mean of realizations of the greatest divergence of distributions the below-mentioned inequality takes place:

$$M^*[\delta_m(H_{1,1})] < M^*[\delta_m(H_{1,2})] \text{, то } G_1=H_{1,1};\ G_2=H_{1,2} \tag{16}$$

where:

$$M^*[\delta_m(H_{1,1})] = \sum_{j=1}^{N} \delta_{m,j}(H_{1,1})/N$$

$$M^*[\delta_m(H_{1,2})] = \sum_{j=1}^{N} \delta_{m,j}(H_{1,2})/N$$

If the inequality looks like

$$M^*[\delta_m(H_{1,2})] > M^*[\delta_m(H_{1,2})] \text{, то } G_1=H_{1,2};\ G_2=H_{1,1} \tag{17}$$

- we shall define the distributions reflecting a mistake of the first sort $\alpha[\delta_m(G_1)]$ and the second sort $\beta[\delta_m(G_2)]$ under formulas:

If the parity (12) is fair:

$$\left.\begin{aligned} \alpha^*[\delta_m(G_1)] &= 1 - F^*[\delta_m(H_1)] \\ \beta^*[\delta_m(G_2)] &= F^*[\delta_m(H_2)] \end{aligned}\right\} \tag{18}$$

If the parity (13), is fair

$$\left.\begin{aligned} \alpha^*[\delta_m(G_1)] &= 1 - F^*[\delta_m(H_2)] \\ \beta^*[\delta_m(G_2)] &= F^*[\delta_m(H_1)] \end{aligned}\right\} \tag{19}$$

Distributions $\alpha^*[\delta_m(G_1)]$ also $\beta^*[\delta_m(G_2)]$ are necessary for definition of critical values $\delta_m^*(\alpha_k)$ and $\delta_m(\beta_k)$, where α_k and β_k – a significance value of mistakes of the first and second sort.

However, as distributions $\alpha^*[\delta_m(G_1)]$ also $\beta^*[\delta_m(G_2)]$ are discrete, direct definition $\delta_m^*(\alpha_k)$ and $\delta_m^*(\beta_k)$ appears impossible. The values α_k accepted in an engineering practice and β_k, equal 0,1 or 0,05 in the list of discrete values of distributions $\alpha^*[\delta_m(G_1)]$ and $\beta^*[\delta_m(G_2)]$, as a rule, are absent. As critical values of statistics for mistakes of the first and second sort values $\delta_m(\alpha \le \alpha_k)$ and $\delta_m(\beta \le \beta_k)$, corresponding their nearest smaller values get out. We shall designate them through $\delta_m(\alpha_k^\partial)$, $\delta_m(\beta_k^\partial)$ where the index «∂» will mean the valid critical values of mistakes of the first and second sort.

- choice of one of two assumptions (H_1 and H_2) is spent by the control of performance below-mentioned of some heuristic restrictions [3]:
- it is considered, that if minimal (optimum from the point of view of a minimum of mistakes of the first and second sort) risk of the erroneous decision less than admissible (critical) value $\gamma_к$ the divergence of assumptions H_1 and H_2 is essential, and the preference is given hypothesis G_1 if $\delta_{m,э}^*$ does not exceed optimum value $\delta_{m,opt}^*$ (corresponding γ_{opt}). Otherwise, i.e. when $\delta_{m,э}^* > \delta_{m,opt}^*$, the preference is given hypothesis G_2;
- it is considered, that if $\delta_{m,э}^*$ more or it is equaled $\delta_m(\alpha_k^\partial)$, hypothesis G_1 should be rejected;
- it is considered, that if $\delta_{m,э}^*$ less or it is equaled $\delta_m(\beta_k^\partial)$, hypothesis G_2 should be rejected;
- it is considered, that if $M^*[\delta_m(G_1)] > \delta_m(\beta_k^\partial)$, and $M^*[\delta_m(G_2)] < \delta_m(\alpha_k^\partial)$ the preference is given hypothesis G_1. If $M^*[\delta_m(G_1)] \le \delta_m(\beta_k^\partial)$, and $M^*[\delta_m(G_2)] \ge \delta_m(\alpha_k^\partial)$ the preference is given hypothesis G_2.

If $M^*[\delta_m(G_1)] \le \delta_m(\beta_k^{\partial})$, and $M^*[\delta_m(G_2)] < \delta_m(\alpha_k^{\partial})$ or $M^*[\delta_m(G_1)] > \delta_m(\beta_k^{\partial})$, and $M[\delta_m(G_2)] \ge \delta_m(\alpha_k^{\partial})$, that management transferred by blocks of an estimation of risk of the erroneous decision;

- it is considered, that if the risk of the erroneous decision $\gamma > \gamma_k$, however risk of the erroneous decision of hypothesis G_1 does not exceed, the preference is given hypothesis G_2. If the risk of the erroneous decision of hypothesis G_2 does not exceed, the preference given G_1;
- it is considered, that if $\gamma > \gamma_k$ also risks of erroneous decisions at deviation G_1 and G_2 are great enough, it is required to reconsider classification of data and in particular, to reduce number VA m_r.

Practical use of the developed program model is preceded with a stage of its research. The basic purpose thus is the control of adequacy of the decision over possible changes of initial data. As adequacy of the decision, we shall understand ability of recognition on ECh. conformity (or discrepancies) probabilities of display VA to the uniform law provided that functional component ECh. us is known. This quality monitoring is called as a method of the decision of "a return problem» and is realized under the special program on the computer. The integrated block diagram of algorithm of the control of adequacy we shall result on fig.3.

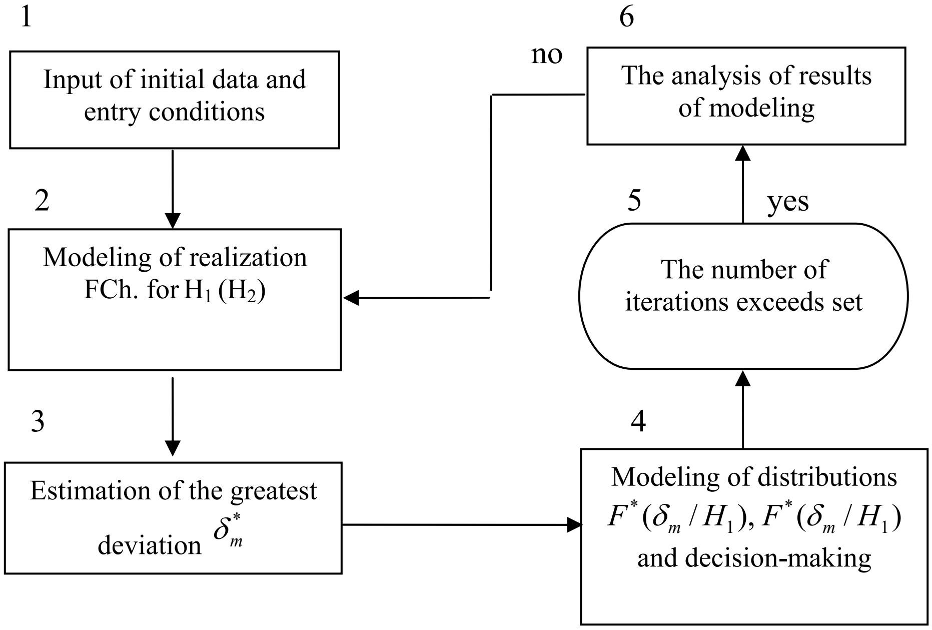

Fig. 3. The integrated block diagram of the control of adequacy of the decision.

Analysis ECh. following questions have been considered:

1. The result of the decision how much will change at modeling distributions of the greatest deviation on algorithm of the schemes represented on fig. 1 and 2.
2. What basic requirements are shown to methodology of calculation $F^*[\delta_m(H_1)]$ and $F^*[\delta_m(H_2)]$ with the purpose of their subsequent joint consideration? As distributions $F^*[\delta_m(H_1)]$ also $F^*[\delta_m(H_2)]$ are discrete, the essence of requirements should is reduced to identity of levels of digitization.
3. How the result of the decision will change at arrangement VA in decreasing order (increases) of probability of their display for nominal scale VA? In practice the arrangement of these VA is made subjectively. Thus any arrangement is supposed.
4. How the significance value of criterion of Kolmogorov (affects at the control of conformity software sold random numbers to the uniform law of distribution) on result of calculation of distributions $\alpha(i)$ and $\beta(i)$? It is obvious, that the significance value less, the probability of a mistake of the second sort is more. In our case, this probability reflects an opportunity of

conformity of distribution of random numbers to the law distinct from uniform. With reduction of number of realizations this probability grows.
5. How check of assumptions increase in number VA influences result? In particular, how inclusion in list VA of a version affects, the number of which cases of display is equal to zero?
6. What influence renders on results of calculation the account of parities of average values статистик $\delta_m(H_1)$ and $\delta_m(H_2)$?

Results of calculations have allowed establishing:
1. At the fixed number VA, equal m_r, and number of casual events (for example, refusals) n_Σ:
- distribution $F[\delta_m(\Gamma_1)]$ does not depend on laws of change as $F(i)$, and $F^*(i)$;
- at fixed f.d. $F(i)$ and $F^*(i)$ distribution $F[\delta_m(G_2)]$ for $\delta_m(G_2)$, calculated under formulas (7) and (8) or under formulas (11) and (12) one and too;
2. If to assume, that casual character of realizations $F_M^*(i)$ is rather calculated $F(i)$ under the formula:

$$\delta_{m,\nu}(H_1) = \max\{\delta_{1,\nu}(H_1); \delta_{2,\nu}(H_1); ... \delta_{m_r,\nu}(H_1)\} \quad (20)$$

$$\delta_{i,\nu}(H_1) = \left|F(i) - F^*_{M,\nu}(i)\right|; \quad \nu=1, N;\ i=1, (m_r+1);$$

and rather $F^*(I)$ - under the formula:

$$\delta_{m,\nu}(H_2) = \max\{\delta_{1,\nu}(H_2); \delta_{2,\nu}(H_2); ... \delta_{m_r,\nu}(H_2)\} \quad (21)$$

$$\delta_{i,\nu}(H_2) = \left|F^*(i) - F^*_{M,\nu}(i)\right|; \quad \nu=1, N;\ i=1, (m_r+1);$$

That this way of calculation $F^*[\delta_m(H_1)]$ also $F^*[\delta_m(H_2)]$ will lead to that the number of identical digitization of distributions $F^*[\delta_m(H_1)]$ and $F^*[\delta_m(H_2)]$ will be equal many cases to zero, i.e. joint consideration of these distributions will appear impossible. Really. Under the formula (20)

$$\delta_{i,\nu}(H_1) = \left|\frac{i}{m_r} - \frac{n_{i,\nu}(H_1)}{n_\Sigma}\right| \quad (22)$$

If to consider, that the size $\delta^*_{i,\nu}(H_2)$ (see the formula 21) is equal

$$\delta^*_{i,\nu}(H_2) = \left|\frac{n_{i,(\nu+1)}(H_1)}{n_\Sigma} - \frac{n_{i,\nu}(H_2)}{n_\Sigma}\right|, \quad (23)$$

that is easy for noticing, that if m_r and n_Σ have no same factors values $\delta^*_{i,\nu}(H_1)$ and $\delta^*_{i,\nu}(H_2)$ with $\nu = 1, N$ will differ.
3. If to lead modeling realization ECh. of probability display on $F(i)$, corresponding the uniform law, m_r VA at n_Σ "experiences" and to check up the assumption of a casual divergence of distributions $F(i)$ and $F^*(i)$ (hypothesis H_1) the method resulted above and criterion it will appear, that at initial casual arrangement VA and at the set significance value, hypothesis H_1, as one would expect, proves to be true. If now to place estimations of probability of display m_r VA in ascending order (or decrease) application of criterion testifies that observable law of change ECh. is not casual. The important practical conclusion from here follows: arrangement VA on experimental data at a nominal scale of change should be casual. Casual character of accommodation is provided with application of a method of Monte-Carlo;
4. The disorder of values of distributions $\alpha^*(i)$ and $\beta^*(i)$ in points of digitization $i = 1, m_r$ with growth of a significance value of criterion of Kolmogorov up to (0,4-0,6) nonlinear decreases. At the subsequent decrease in significance value influence of a deviation of random numbers from the uniform law on disorder $\alpha^*(i)$ also $\beta^*(i)$ becomes invariable small. Some increase in duration of calculation at $\alpha_k = 0{,}6$ is completely compensated decrease in number of iterations;
5. More detailed display of versions of an analyzed attribute, for example, units of the equipment, leads to that data becomes insufficiently for a choice of one of two assumptions. This conclusion is

put forward, if VA with $Q_i^* = 0$ are distributed on m_r VA casually. If all VA with $Q_i^* = 0$ are concentrated in one group, the conclusion about not casual divergence of estimations of probability of display VA follows. Hence, there is some optimum number VA at which functional characteristic shown precisely enough;

6. If estimations of average value of the maximal deviations (δ_m) of distributions $F^*(\delta_m / H_1)$ also $F^*(\delta_m / H_2)$ are practically equal, result of check of hypotheses H_1 and H_2 is the conclusion that the preference should given hypothesis H_1. Practical equality of estimations $\delta^*_{m,av}(H_1)$ also $\delta^*_{m},_{av}(H_2)$ causes necessity of application of criterion. A condition of the consent with casual character of change ECh. is the inequality:

$$\Delta\delta_{m,cp} = \left|\delta^*_{m,av}(H_1) - \delta^*_{m,av}(H_2)\right| \le \varepsilon = 1/n_\Sigma \qquad (24)$$

As a practical example, we shall consider results of check of the assumption of not casual character ECh. change of the importance of units of switches 110 кv (hypothesis H_1).

Experimental data are borrowed from work [2] and resulted in table 2. Here results of modeling of number of displays of each of VA for switches with Un=110 кv $(m_r = 9$ and $n_\Sigma = 29)$ provided that theoretical probabilities of refusals of each of units are equal are resulted. Calculations show, that assumption H_1 cannot be accepted. As follows from table 2, the greatest number of refusals equal 8, observable on experimental data is observed at modeling and at other units of switches, that indirectly confirms results of check of hypothesis H_1.

Table 2

Comparative estimation of experimental and modeled structure of refusals actually switches with drive $U_н$=110 кv

The damaged element and the reason of refusals	Experim. Data	Data of modeling				
		1	2	3	4	5
Drive	4	3	**8**	6	6	1
Arc extinguisher camera	4	4	2	**7**	2	3
Separator	2	0	2	1	0	2
Inputs	1	1	2	0	3	0
Supporting-pivotal insulation	3	**8**	1	3	2	5
Consolidation	3	2	2	2	1	2
Case of management	**8**	6	**8**	5	5	**13**
Not classified attributes	2	2	2	2	**9**	4
The obscure reasons	3	4	3	4	2	0

Conclusion.

The method, algorithm and the program for MSDB PARADOX. Is developed, allowing to estimate objectivity of observable laws of change parameters of reliability the equipment on retrospective data

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