MATCHING OF CRITERIA THE DISCERNMENT OF THE FUNCTIONAL CHARACTERISTICS OF INDEXES OF RELIABILITY OF PLANTS EES

Farhadzadeh E.M., Muradaliyev A.Z., Farzaliyev Y.Z.

Azerbaijan Scientific-Research
and Design-Prospecting Institute of Energetic

References on variation of reliability on the curves received at analysis of statistical data can appear erratic if not to consider a random in character of assessments of indexes of reliability. The comparison method of criteria of a discernment of the functional characteristics indexes of reliability reduced at ordinal and nominal dials of variation of argument.

While in service the equipment and systems of plants EES there is a necessity for a reliability analysis of their activity. The reliability analysis implies an assessment and matching of some indexes of reliability (IR), describing those or other properties. As a result, of analysis the certain references on build-down of working costs formed. The greatest propagation was received with data on «weak links » plant, about conditions and character of originating of failures, a type of failures and so forth. These data in many respects determine volume of plan repair work, measures on perfecting system of maintenance, perfecting of methods verification availability index.

The solution so important for build-down of working costs of problems, in an essential degree is at a loss a small amount of information about availability index of the equipment and systems of plants EES. The averaged IR and their empirical characteristics (EC) often do not mirror a singularity of particular plant, and individual IR and matching them EC, application of special methods and the approaches considering a random in character of assessments of IR require and the statistical odelling es orientated on check. Under EC IR we shall agree to fathom empirical regularity of IR in function of some varieties of indications (VI). Instances EC are regularity variation of IR on calendar years, duration of exploitation, a season and day, depending on the class-room of a voltage, the dispatcher numbers of the equipment, systems and electric sets, configuration items, etc. Real regularity of variation of IR in function VI we shall agree to name the functional characteristics (FC).

The urgency of a problem of the account of a random in character assessments of IR causes steadfast notice of technicians. Are developed series of criteria for matching assessments of the same type IR and their characteristics for continuous random quantities [1]. At a reliability analysis, not less characteristics of IR which scale of measurement of argument concerns to the classroom ordinal or nominal [2] often are used. For these scales of measurement, the criteria considering a random in character of watched regularities require the perfection since insufficiently full mirror as modes of an assessment of the fundamental and additional IR, and the discrete character of variation of argument. Therefore, there are reasons to believe, that the number will increase them in due course. Thus, there is a problem of matching of criteria for the purpose characteristics of their reliability (probability of a correct solution).

It is known, that in theory checks of statistical hypothesizes the preference is returned criterion, for which at the fixed value of an error of first kind, an error of second kind the least. As it noted in [1], comparison of statistical criterions constitutes rather a challenge of modern mathematical statistics.

The most simple and illustrative mode is graphical map of characteristics of intercoupling of errors first [α(x)] and second [β(x)] stems in the form of function $\beta(x) = f[\alpha(x)]$, or in the form of intercoupling of power of criterion $W(x) = 1 - \beta(x)$ and α(x). However, a seeming ease of this

mode is deceptive. For a case history of originating difficulties, we shall survey sequence of a presence of dependence $\beta(x) = f[\alpha(x)]$. She provides following determinations and evaluations:

1. Shaping of suppositions (hypotheses) concerning character of variation of examined dependence. As agency of a random in character of assessments IR is considered, normally surveyed two hypotheses. Considered, that actually a development all VI equiprobable (hypothesis H_1). For example, assemblies of the cutout have equal reliability, and the watched divergence of assessments VI coupled only to a small amount of information, random.

The second (alternative) hypothesis (H_2) also is natural – the watched regularity of variation of IR mirrors a real quantitative ratio of significance VI.

2. Account of distribution functions $F(x_i / H_1)_s$ and $F(x_i / H_2)_s$ where x_i – statistician of i-th criterion i=1,s; s – number of compared criteria. If the distribution function of the discrete random quantity is known, formulas of account, as a rule, are known $F(x_i / H_1)$ and $F(x_i / H_2)$. For example, if the model of experiment matches to a binomial low distribution, formulas of account $F(x_i / H_1)$ and $F(x_i / H_2)$ will differ only, accordingly, with usage for account $F(x_i / H_1)$ hypothetical probability, and for account $F(x_i / H_2)$ - empiric probability.

If the distribution function of a random quantity is unknown, that occurs for a greater unit of IR, allocations $F(x_i / H_1)$ and $F(x_i / H_2)$ evaluated by a method of simulation modeling. An instance of such characteristics are regularity of variation of an average of failures of cutouts of various class-rooms of a voltage, variation of an emergency shut-down coefficient depending on duration of exploitation and others;

3. Account of allocations $\alpha(x_i)$ and $\beta(x_i)$. The solution of this problem simple enough would seem

$$\alpha(x_i / H_1) = 1 - F(x_i / H_1) \quad (1)$$

$$\beta(x_i / H_2) = F(x_i / H_2) \quad (2)$$

However, such inference is fair, if assessments of expectation of a statistician x_i for H_1 and H_2 satisfy to a following condition:

$$M^*(x_i / H_1) < M^*(x_i / H_2) \quad (3)$$

Otherwise, i.e. when

$$M^*(x_i / H_1) > M^*(x_i / H_2) \quad (4)$$

following equalities are fair

$$\alpha(x_i / H_2) = 1 - F(x_i / H_2) \quad (5)$$

$$\beta(x_i / H_1) = F(x_i / H_1) \quad (6)$$

If neglect a parity of means statistician x_i serious errors in an adoption of a decision are possible. The account of a parity $M(x_i / H_1)$ и $M(x_i / H_2)$ it is especially important at automatic application of criteria in program models. The graphical case history of a short of an erratic solution reduced on fig.1.

As follows from fig.1, not account parities $M^*(x / H_1)$ and $M^*(x / H_2)$ leads to sharp variation of critical value of quintiles of allocations $\alpha(x / H_2)$ and $\beta(x / H_1)$. If at physically correct comprehension of errors the first and second stem, critical value of quintiles at $\alpha_k = \beta_k = 0{,}1$ are accordingly peer $\overline{X}^{(1)}$ and $\overline{X}^{(2)}$, that at their erratic comprehension ($M^*(x / H_1) > M^*(x / H_2)$), these quintiles are accordingly peer $\underline{X}^{(1)}$ and $\underline{X}^{(2)}$, that $\overline{X}^{(1)} << \underline{X}^{(1)}$ and $\overline{X}^{(2)} >> \underline{X}^{(2)}$. If $\overline{X}^{(1)} < \overline{X}^{(2)}$, that $\underline{X}^{(1)} > \underline{X}^{(2)}$;

4. Construction of dependence $\beta(x_i) = f[\alpha(x_i)]$. To build this dependence it is necessary to consider following singularities:

4.1. Levels of discrete samplings of allocations $F(x_i / H_1)$ and $F(x_i / H_2)$ can completely and partially differ. Here there is in view of not the partial overlapping of spacing of possible value of argument of allocations and not a complete divergence of these spicing. Difference of discrete samplings watched on the interval overlapping of possible value. It is established, that a necessary condition of existence of generic points of a discrete sampling is proportionality x_m to value $\varepsilon = 1/n_\Sigma$, where n_Σ - total number of failures

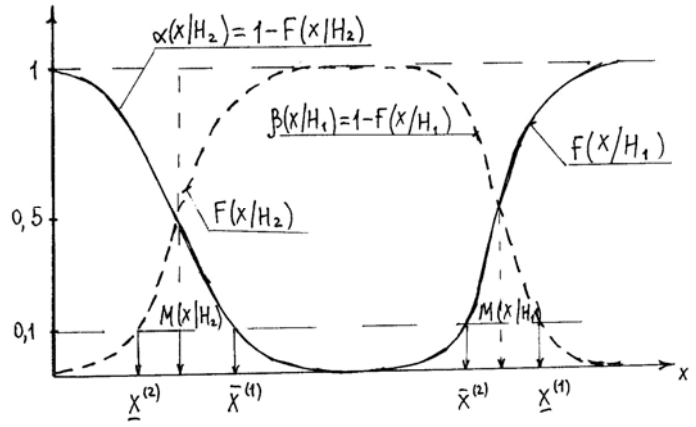

Fig. 1. A graphical case history of aftereffects of disregard a parity $M^*(x / H_1)$ and $M^*(x / H_2)$

4.2. Between dependences $\beta(x) = f[\alpha(x)]$, builted for conditions (3) and (4), there is a divergence. In the first event, we have dependence of probability erratic disallowance hypothesis H_1 in function of probability erratic disallowance hypothesis H_2, i.e. $\beta(x / H_2) = f[\alpha(x / H_1)]$, and in the second event $\beta(x / H_1) = f[\alpha(x / H_2)]$. In discover the reflecting noted in item.3 serious errors in an adoption of a decision.

Therefore, it is necessary to compare not with value of error of second kinds at fixed error figures of the first stem, and an error at adoption of hypothesis H_2 for the fixed error figure at disallowance hypothesis H_1.

Graphical case history of difference of curves $\beta(x / H_2) = f[\alpha(x / H_1)]$ and $\beta(x / H_1) = f[\alpha(x / H_2)]$ it reduced on fig.2. These curves are builted for criterion of matching of an assessment of chances of failure Q^* with hypothetical probability Q_0, where $Q^* = n_i / n_\Sigma = 3/60 = 0.05$, and $n_\Sigma = \sum_{i=1}^{m_r} n_i$

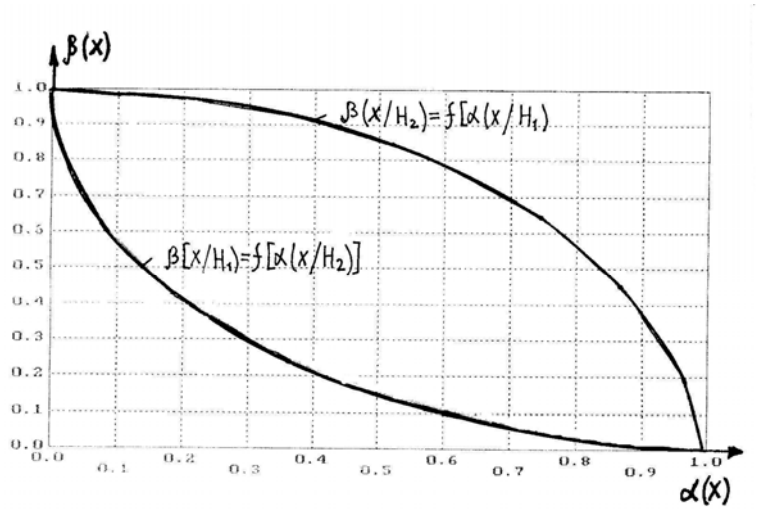

Fig. 2. A graphical case history of difference curves of intercoupling of errors of the first and second stem.

To simplify the subsequent account, to consider (3) and (4), we shall agree probability erratic disallowance hypotheses H_2 to designate through $Sh(x/H_2)$ and probability erratic disallowance hypotheses H_1 to designate through $Sh(x/H_1)$.

The subsequent treating of singularities of matching of criteria of discernment distribution functions of variation of IR at nominal and ordinal dials of argument we shall continue on a particular instance.

5. To have a possibility to evaluate reliability of a solution, EC has been received by a method of statistical modeling, by:

а) software prototyping n_Σ random numbers ξ with an even distribution in the interval [0,1];

б) compliance test of these (n_Σ) random numbers to the uniform law Kolmogorov's criterion;

в) arrangement n_Σ random numbers in m_r peer spacing by comparison ξ_v with the upper boundary values m_r spacing by formula

$$i/m_r < \xi_v \le (i+1)/m_r \qquad \text{c i=1,}(m_r+1)$$

г) assessments of probability of a development set VI by formula $Q_i^* = n_i / n_\Sigma$.

The first criterion is based on the supposition of correspondence of probability of a development of each of i=1, m_r VI to binomial low. Critical value of errors of the first and second stem for each spacing were sampled in view of theorem Touke according to which $\alpha_{K,i} = \alpha_K / m_r$ and $\beta_{K,i} = \beta_K / m_r$ c i=1, m_r. Let's designate it conditionally through K_B.

The second criterion based on an assessment of allocation of the greatest divergences of simulated implementation of allocations $F(i)$ и $F^*(i)$, where $F(i) = i/m_r$; $F^*(i) = \sum_{i=1}^{m_r} n_i / n_\Sigma$; $n_\Sigma = \sum_{i=1}^{m_r} n_i$ .. We shall designate it conditionally through K_δ

In table 1 value of argument X and conforming discontinuous distributions are reduced $\alpha(x_1/H_1)$, $\beta(x_1/H_2)$, $\alpha(x_2/H_1)$ and $\beta(x_2/H_2)$, where $x_2 = x_m \cdot n_\Sigma$. As follows from this table, to the same x there match various value $\alpha(x_1/H_1)$ and $\alpha(x_2/H_1)$, that brings ambiguity of

comparison of criteria and comparison bears that $\beta(x_1 / H_2)$ and $\beta(x_2 / H_2)$ at fixed $\alpha(x / H_1)$ it is impossible, and consequently, and it is erratic.

M. To reduce $\alpha(x_1 / H_1)$ and $\alpha(x_2 / H_1)$ to the same argument, we shall compare argument X with quotients of a significance of power of the criteria computed by formula:

$$A(x) = \left[1 - \beta(x / H_2)\right] / \alpha(x / H_1) = W(x / H_2) / \alpha(x / H_1) \quad (7)$$

at $M^*(x / H_1) < M^*(x / H_2)$

$$B(x) = \beta(x / H_1) / \left[1 - \alpha(x / H_2)\right] = W(x / H_1) / \alpha(x / H_2) \quad (8)$$

at $M^*(x / H_1) > M^*(x / H_2)$

Numerical values of allocations $\alpha(x / H_1)$ and $\beta(x_{2,i} / H_2)$

Table 1

x_i	$\alpha(x_{1,i} / H_1)$	$\beta(x_{2,i} / H_2)$	$\alpha(x_{2,i} / H_1)$	$\beta(x_{2,i} / H_2)$
2	0,8861	0,0015	0,9810	0,0030
3	0,7471	0,0063	8322	0,0659
4	0,5672	0,0202	0,5275	0,3336
5	0,3899	0,0512	0,2178	0,6613
6	0,2312	0,1081	0,0579	0,8721
7	0,1241	0,1958	0,0090	0,9590
8	0,0596	0,3120	-	0,9860
9	0,0258	0,4464	-	0,9940
10	0,0100	0,5834	-	0,9980
11	0,0036	0,7079	-	0,9990
12	0,0011	0,8097	-	-
13	0,0003	0,8848	-	-

Outcomes of accounts $A(x_1)$ and $A(x_2)$ are reduced in table 2. As follows from table 2, at the fixed value of argument X quotient of a significance $A(x_1)$ for criterion K_B it is more, than value $A(x_2)$ for criterion K_δ.

Outcomes of accounts of empirical value of quotients $A(x_1)$ and $B(x_2)$

Table 2

x_i	$A(x_{1,i})$	$A(x_{2,i})$
2	1,13	1,02
3	1,13	1,12
4	1,73	1,26
5	2,47	1,56
6	3,86	2,21
7	6,48	4,56
8	11,54	-
9	21,46	-
10	41,66	-

It is necessary to mark, that comparison of criteria should conducted not for the same arguments x, and for critical value $x_K = X\left[\alpha(x / H_1) < \alpha_K\right]$, i.e. to argument with the greatest value

$\alpha(x/H_1)$, satisfying to a condition $\alpha(x/H_1) < \alpha_K$. For example, according to table 1 for criterion K_B at $\alpha_K = 0.05$ value $x_{1,K} = 9$, and for criterion K_δ - pearly 8.

7. Comparison of criteria can carried out and a little differently. In a fig 3 curves are reduced $Sh(x/H_2) = f[Sh(x/H_1)]$. For conforming critical value of probability $Sh(x/H_1)$ value are determined $Sh(x/H_2)$. In the received statement of conditions of comparison of criteria, than $Sh(x/H_2)$ for matching $Sh(x/H_1)$ it is less, that the criterion is more preferable. According to a fig 3 it is criterion K_B.

8. Despite of a seeming finality the tasks in view separate, multiply the checked out facts were not matched with noted in item 6 and 7 outcomes of comparison of criteria. To them concerned:

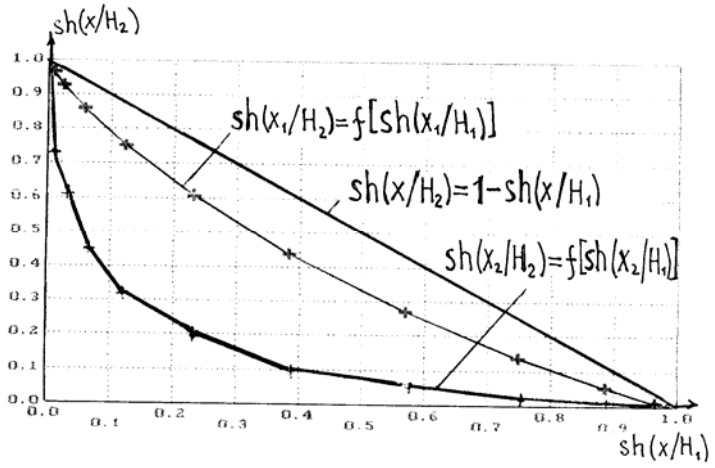

Fig. 3. The Graphical case history of matching of criteria

8.1. If $F(x/H_1) = F(x/H_2)$, i.e. H_1=H_2, that irrespective of type FC function $Sh(x/H_2) = f[Sh(x/H_1)]$ looks like $Sh(x/H_2) = 1 - Sh(x/H_1)$. If $H_1 \neq H_2$, that $Sh(x/H_2) \neq 1 - Sh(x/H_1)$;

8.2. The empirical value of the greatest divergence between EC and FC is less, the incurvation (bulge) of curves is less $Sh(x/H_2) = f[Sh(x/H_1)]$ and the more error figure $Sh(x/H_2)$;

8.3. At small difference EC and EC, including practically insignificant, a solution of matching EC and FC will be: «the information has not enough for an adoption of a decision »;

8.4. With magnifying of number of experiences n_Σ and correspondences $F^*(i)$ to even distribution, value $Sh(x/H_2)$ increases.

9. These data allow to conclude, that if EC is received by statistical modeling on some allocation $F(i)$ with i=1,m_r, that value $Sh(x/H_2)$ characterizes probability of an erratic deflection of hypothesis H_2 owing to a random in character of assessments of the IR computed for each of m_r VI. In this case it is easy to explain, why with decrease of a divergence between EC and FC value $Sh(x/H_2)$ at the fixed number of "experiences" increases (the less divergence, the more than data it is necessary for a discernment of this divergence) and why with magnifying of a divergence between EC and FC $Sh(x/H_2)$ diminished

10. If to receive, that at equiprobable development VI value $Sh(x/H_2) = \overline{Sh}(x/H_2)$, that value

$$\Delta Sh(x/H_2) = \left| Sh(x/H_{2S}) - \overline{Sh}(x/H_2) \right| \qquad (9)$$

it will be proportional to an error in a discernment of difference EC from the uniform law. At the fixed value $Sh(x_K/H_1)$ the preference is returned criterion with greater value $Sh(x/H_2)$, and with allowance for item.6 the preference is returned criterion, for which greatest divergence of quotients A(x) or B(x) and units of the fixed value $sh(x_K/H_1)$ the least on matching with other criteria.

Systematizing the above-stated, the method and algorithm of matching S of criteria is represented the following amalgamated sequence of evaluations:

1. Allocations pay off $F(x/H_1)$ and $F(x/H_2)$;
2. Subject to the conditions (3) and (4) allocations are formed $Sh(x/H_1)$ and $Sh(x/H_2)$;
3. Real critical value of probability erratic disallowance hypotheses H_1 by formula are determined

$$Sh_d(x/H_1) = \max\{Sh(x/H_1) < \alpha_K\} \qquad (10)$$

4. It is determined $Sh(x/H_2)$, matching $Sh_d(x/H_2)$;
5. The probability erratic disallowance hypotheses H_2, caused by algorithm of criterion by formula is evaluated

$$\Delta Sh(x/H_2) = \left| 1 - Sh_d(x/H_1) - Sh(x/H_2) \right|$$

6. The preference returned criterion, for which $\Delta Sh(x/H_2)$ the least.

Inference

1. The account of an error of second kind in conditions when aftereffects from erratic solutions are indiscernible, so important, as well as an error of first kind. The disregard to physical nature of both errors leads in practical accounts to incorrect solutions;

2. Known references with reference to criteria of a discernment of the functional characteristics of indexes of reliability at ordinal and nominal dials of argument are unacceptable for matching criteria;

3. Erratic solutions at usage of these references originate owing to:

Insufficient sharpness of the gear of the account of physical nature of errors of the first and second stem. Such "gear" the parity of means of argument of allocations can minister $F(x/H_1)$ and $F(x/H_1)$;

Difference of levels of a discrete sampling of arguments allocations $\alpha(x/H_1)$ and $\beta(x/H_2)$. Characteristics $\beta(x) = f(\alpha(x))$ should be under construction for the same value x;

Comparisons of error of second kinds of criteria at the fixed value of an error of first kind. It is necessary to compare with an error in disallowance hypotheses H_2 at the fixed value erratic disallowance hypotheses H_1;

Differences erratic disallowance hypothesis H_1 for equal levels of a discrete sampling of statistician of compared criteria. Overcoming of this nonconformity is reached by comparison of criteria on regularities of variation of a relative significance of power of criteria under formulas (7) and (8)

Irregular interpreting matching $Sh(x/H_1)$ probabilities $Sh(x/H_2)$, only as probabilities erratic to deny hypothesis H_2. Actually $Sh(x/H_2)$ characterizes probability erratic disallowance hypotheses H_2 owing to roundedness of statistical data for a discernment of the functional junctions;

4. The method, algorithm and programs model of matching of criteria of a discernment of the functional characteristics of indexes of reliability of plants EES is developed. Probability of the supervision of reliability of a solution were ensured with a solution technique of "inverse problem" when empirical the characteristics of indexes of reliability were simulated on the sampled regularity of variation VI.

5. Matching of the criterion based on binomial model of probability of development VI and criterion, the greatest deflection of empirical and hypothetical characteristics based on value bears to doubtless advantage of the second criterion.

Literature

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