# ANALYSIS FIDUCIALLY DISTRIBUTIONS OF POSSIBLE REALIZATIONS OF TECHNICAL AND ECONOMIC PARAMETERS OF POWER UNITS

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To fiducially distributions of multivariate random variables, i.e. random variables, which estimations depend from of some attributes and their versions concern. A bright example of multivariate random variables is technical and economic parameters of power units of power stations. Laws fiducially distributions depend on power units of factors (attributes) influencing an overall performance. Therefore, unlike set of one-dimensional random variables, fiducially distributions characterized not by the concrete law of distribution, and only experimentally established statistical function of distribution and the histogram. Boundary values fiducially interval defined not by a significance value, and the set combination of versions of attributes. At classification of multivariate data on the set significant versions of attributes, the number of possible realizations decreases. However, unlike a confidential interval of estimations of parameters of distribution of sample of general set, the width fiducially interval decreases, that corresponds to increase of accuracy of calculation of individual reliability. One of versions of possible realizations of technical and economic parameters is the realizations caused by "rough" mistakes at calculation or corresponding non-stationary modes. The automated system of recognition of these erroneous realizations essentially raises objectivity of comparison and ranging of power units. But development of algorithm of the automated system is preceded with the graphic analysis fiducially distributions of the technical and economic parameters, allowing to formulate corresponding criteria.

**Keywords:** accuracy, reliability, fiducially interval, safety, efficiency, power unit.
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## 1. INTRODUCTION

Transformation of technical and economic parameters (TEP) power units of thermal power stations (TPS), with the purpose of transition to integrated parameters, demands overcoming of some methodical difficulties. These difficulties caused:

Increase in relative number of units of the capital equipment (objects) which service life exceeds normative value [1]. For new objects, operational reliability and safety were consider provided as a factory the manufacturer and kept at performance of corresponding factory instructions and rules. In process of increase in service life of objects, the size of residual deterioration increases. Thus, instructions of instructions and rules all in a smaller measure correspond to a real technical condition of objects, i.e. their real reliability and safety. Considering, that replacement of objects at excess of normative term of their service on new is economically inexpedient, and practically - is unreal, the overall performance of these objects provided mainly intuitively. Thus, the personnel know, that reliability of work and safety of service of such objects have essentially decreased (essentially the number of obvious defects) increases, and possible consequences of this decrease became so significant, that have appeared inadmissible. Recommendations necessarily the organizations of maintenance service and repair of objects according to their technical condition known also. However, methodical instructions on maintenance service and repair of objects of "growing old" type are absent;

Having agreed, that at comparison of an overall performance of objects, which service life is close to normative and even more than normative term, it is necessary to consider not only profitability, but also reliability of work, and safety of service [2], it is necessary to have in view of, that the methodology of such account requires essential perfection. Moreover, there are no methods and algorithms of calculation of an integrated parameter of separate properties of an overall performance - reliability, profitability and safety. For example, it is impossible to compare safety of service of power units;

Statistical data about monthly average values TEP of power units depend on the big number of versions of attributes. It both capacity, and type of power units, their loading and an operating mode, a level of operation and service life, and many other things. Therefore, realizations TEP cannot be considered homogeneous and to carry to sample of general set. It is set of possible realizations of multivariate data. To apply to the statistical analysis of multivariate data known methods of the analysis for samples from general set, it is inadmissible [3]. At their use initial preconditions of these methods (type of the law of distribution, number of realization) are broken, that, in opinion of authors of these methods, leads to essential increase of risk of the erroneous decision. Methods of the statistical analysis of multivariate data are specific to each object and demand the further development;

The estimation of an integrated parameter of an overall performance can be executed on the basis of fiducially the approach [4]. For what it is necessary to develop corresponding algorithm and criterion of decision-making. Labor input and bulkiness of the manual account are so great, that necessity of transition to computer technologies does not raise the doubts. These technologies should come to the end with results of the decision of operational problems and be

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formalized in the form of the document providing methodical support of the personnel;

In present clause in section 2 the graphic analysis fiducially distributions TEP of boiler installations (BI) power units 300 MW on gas black oil fuel, in section 3 - the analysis of frontier intervals fiducially distributions (prigrin) is resulted, and in section 4 is given the conclusions of results of the analysis of distributions TEP.

## 2. ANALYSIS FIDUCIALLY DISTRIBUTIONS TEP

In [5, 6] we had been considered features of distribution of following four monthly average values TEP of BI power units 300 MW on gas black oil fuel:
- temperature of a feed water ($T_{fw}$)with normalize value $\varepsilon(T_{fw})$ and statistical function fiducially distributions (s.f.f.d.) F*($T_{fw}$);
- the charge of the electric power in system of own needs (o.n) ($E_t$) with normalize value $\varepsilon(E_t)$ and s.f.f.d. $F^*(E_t)$;
- efficiency net ($\eta_n$) with normalize value $e(\eta_n)$ and s.f.f.d. $F^*(\eta_n)$;
- the specific charge of conditional fuel ($b_f$) with normalize value $\varepsilon(b_f)$ and s.f.f.d. $F^*(b_f)$.

Normalize values were calculated in conformity with following algorithm:

$$\text{If } A_i=1,\ \varepsilon_1(P_{i,j}) = (\overline{P_i^f} - P_{i,j}) / \overline{P_i^f} - \underline{P_i^f}$$
$$\text{If } A_i=1,\ \varepsilon_0(P_{i,j}) = (P_{i,j}) - \underline{P_i^f}) / \overline{P_i^f} - \underline{P_i^f} \quad (1)$$

Here, $A$-factor of orientation TEP. If with increase TEP overall performance BI will increase, $A$=1. Otherwise $A$=0; $P_{i,j}$ a-symbol of $j$-th possible realization of $i$-th TEP, with $i$=1,$n_p$ and $j$=1,$m_i$, where $n_p$ - number TEP, $m_i$ - number of possible realizations of $i$-th TEP; $\underline{P_i^f}$ and $\overline{P_i^f}$ -accordingly, the bottom and the top boundary values fiducially interval of $i$-th TEP.

The essence of formulas for calculation of relative change $\varepsilon(P_{i,j})$ is simple enough. First, it is easy to notice, that $\varepsilon_1(P_{i,j}) + \varepsilon_0(P_{i,j}) = 1$. The formula for $\varepsilon_1(P_{i,j})$ is used, if $\overline{P_i^f}$ concerns to the most preferable realization TEP. For example, the high efficiency is more preferable than low efficiency. The deviation from $\overline{P_i^f}$ more, the an overall performance below. If the size $\underline{P_i^f}$ the formula applied for $\varepsilon_0(P_{i,j})$ is preferable. For example, small values of the charge of the electric power for own needs it is more preferable, than greater. It is established, that unlike a confidential interval, boundary values fiducially interval should will be defined at analysis TEP not "mechanically" proceeding from the set size of factor of the importance, in summary exceptions of set of possible values (for example, within a year) not typical realizations. "Rough" mistakes and possible realizations TEP concern to them in non-stationary operating modes BI.

Below we shall continue the graphic analysis and of some others independent TEP BI power units 300 MW with the purpose of transition to the generalized algorithm of automated analysis TEP of power units. Possible realizations of following TEP considered:

- temperature of leaving gases, $T_{lg}$, with $A$=0
- the charge of thermal energy on o.n., $E_t$ with $A$=0
- factor of surplus of air, $K_a$, with $A$=0
- suction air on a path, $\Delta S$, with $A$=0
- temperature of air after RWH, $T_a$, with $A$=1
- efficiency brutto, $\eta_b$, with $A$=1

In fig. 1 are resulted s.f.f.d. listed above absolute values TEP.

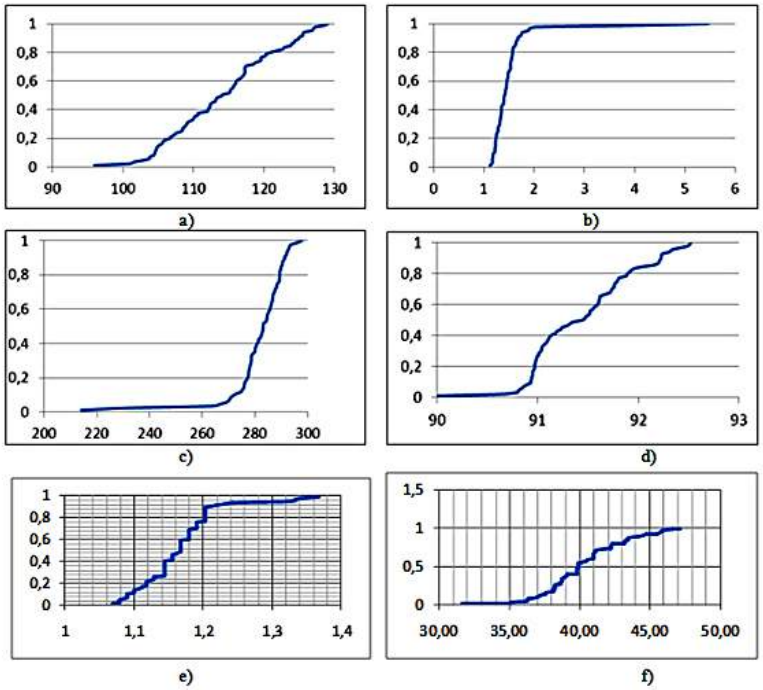


*Fig. 1.* Fiducially distributions of possible realizations TEP a - $F^*(T_{lg})$; b - $F^*(E_t)$; c - $F^*(T_a)$; d - $F^*(\eta_b)$; e - $F^*(K_a)$; f - $F^*(\Delta S)$.

As follows from this figure, for:

$$\left.\begin{array}{l}
\text{Fig. 1a } \left(\underline{T^f_{lg,\alpha/2}} - T_{lg,min}\right) = \left(T_{lg,max} - \overline{T^f_{lg,\alpha/2}}\right) \text{ at } A=0 \\
\text{Fig. 1b } \left(\underline{E^f_{t,\alpha/2}} - E_{t,min}\right) < \left(E_{t,max} - \overline{E^f_{t,\alpha/2}}\right) \text{ at } A=0 \\
\text{Fig. 1c } \left(\underline{T^f_{a,\alpha/2}} - T_{a,min}\right) > \left(T_{a,max} - \overline{T^f_{a,\alpha/2}}\right) \text{ at } A=0 \\
\text{Fig. 1d } \left(\underline{K^f_{a,\alpha/2}} - K_{a,min}\right) < \left(K_{a,max} - \overline{K^f_{a,\alpha/2}}\right) \text{ at } A=0 \\
\text{Fig. 1e } \left(\underline{\eta^f_{b,\alpha/2}} - \eta_{b,min}\right) < \left(\eta_{b,max} - \overline{\eta^f_{b,\alpha/2}}\right) \text{ at } A=0 \\
\text{Fig. 1f } \left(\underline{\Delta S^f_{\alpha/2}} - \Delta S_{min}\right) = \left(\Delta S_{max} - \overline{\Delta S^f_{\alpha/2}}\right) \text{ at } A=0
\end{array}\right\} \quad (2)$$

Parities (2) confirm essential dependence of the sizes fiducially interval from frontier intervals (named by us prigrin) even at a "mechanical" estimation of critical values fiducially interval with a significance value $\alpha/2$. In fig. 2, histograms of distribution normalize values of possible realizations considered TEP are resulted.

Elimination "rough" erroneous and of some not typical realizations TEP, has led to elimination of dissymmetric distributions. Full elimination of not typical realizations leads to practically uniform distribution TEP inside fiducially interval.

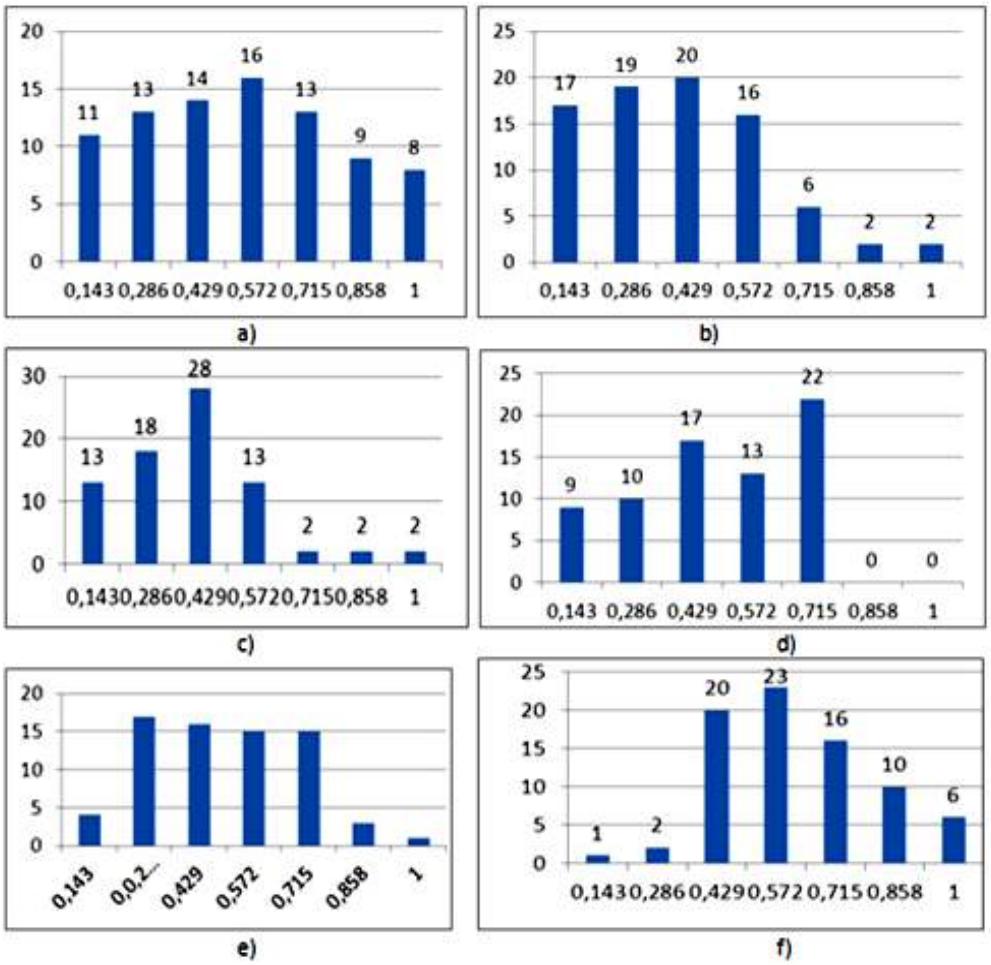


*Fig. 2.* Histograms of distribution of possible realizations normalize TEP for: a - $T_{lg}$; b - $E_t$; c - $K_a$; d - $\eta_b$; e - $T_a$; f - $\Delta S$.

## 3. ANALYSIS OF FRONTIER INTERVALS (PRIGRIN)

In table 1, codes of the power units are resulted, allowing estimate mid-annual parameters of a technical condition of power units. First two figures of codes designate a serial number of month, and the third figure - a serial number of the power unit.

Codes of power units correspond to relative deviations TEP placed in ascending order. Thus, the codes presented by table 1 allocate power units, TEP, which have the greatest $\varepsilon(P_i)$.

Table 1

Codes of realizations TEP right prigruns

| *N n/n* | $F^*[\varepsilon(P_{i.j})]$ | $\varepsilon(T_{lg.j})$ | $\varepsilon(E_{t.j})$ | $\varepsilon(\eta_{b.j})$ | $\varepsilon(T_{a.j})$ | $\varepsilon(K_{a.j})$ | $\varepsilon(\Delta S_j)$ |
|---|---|---|---|---|---|---|---|
| 1 | 0,89 | 0,92 | 0,16 | 0,15 | 0,32 | 118 | 0,46 |
| 2 | 0,91 | 0,62 | 0,32 | 0,42 | 0,41 | 128 | 0,21 |
| 3 | 0,92 | 0,35 | 0,54 | 126 | 0,91 | 0,96 | 0,62 |
| 4 | 0,93 | 0,25 | 0,26 | 0,37 | 114 | 106 | 0,35 |
| 5 | 0,94 | 0,65 | 114 | 0,16 | 121 | 114 | 0,42 |
| 6 | 0,96 | 0,72 | 0,67 | 0,22 | 0,72 | 0,42 | 106 |
| 7 | 0,97 | 0,75 | 124 | 124 | 117 | 0,45 | 0,74 |
| 8 | 0,98 | 0,45 | 0,45 | 124 | 124 | 0,55 | 0,76 |
| 9 | 0,99 | 115 | 126 | 0,36 | 0,16 | 0,46 | 0,12 |
| 10 | 1 | 125 | 0,94 | 0,31 | 126 | 0,48 | 0,86 |

The primary analysis of data of this table shows:

– most often from the general number of the presented data the overestimated values $\varepsilon$ ($P_i$) were observed on the average for the sixth (25%), the fifth (20 %) and the second (18 %) power units;

– for the period November- April it was observed almost in 2,5 times more than the overestimated values of relative deviations TEP, than in second half of year (May- October) months. In many respects defined by character of change of loading of power stations;

– simultaneous discrepancy of realizations of two and more TEP the power unit to shown requirements met only twice, that with probability it is not less than 0,999 confirms actual independence considered TEP;

– at the sixth power unit relative deviation TEP was overestimated for suction air ($\Delta S$) - 31%, the charge of thermal energy on own needs ($E_t$) - 25% and temperatures of air after RWH ($T_a$) - 19%. The fifth power unit most «a weak part» had a temperature of leaving gases ($T_{lg}$) - 58%, and for the second power unit all considered TEP in regular intervals differed the discrepancy to shown requirements.

## 4. CONCLUSION

1. It is necessary to consider as the major problem of power system engineering of maintenance service and repair of the capital equipment which service life is approximately equal or exceeds normative;

2. For the new equipment reliability and safety of work guaranteed by a manufacturer during normative service life under condition of performance of factory instructions, Rules of technical operation and safety of service. The control of reliability and safety thus is important for revealing a level of operation. At the long operation of the capital equipment equal or exceeding normative service life, the account of reliability and safety from desirable transformed in obligatory. Consequences from refusals can be so significant, that become inadmissible.

3. Analysis fiducially distributions of possible realizations TEP has allowed to establish following general laws:

- fiducially distributions TEP are asymmetric;
- essential dependence of width fiducially interval from a significance value of its boundary values is observed. Even at $\alpha$ =0,05 sizes fiducially interval decrease in some times;
- elimination "rough" erroneous and of some not typical realizations TEP leads to elimination of asymmetry of distributions TEP and transition for of some TEP to practically uniform distribution;
- independence TEP causes absence of simultaneous discrepancy of realizations of several TEP to shown requirements;
- assumption of an admissibility of equality of significance values of boundary values fiducially interval wrongly. The risks of the erroneous decision show in decrease in accuracy and reliability of calculation fiducially interval.


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