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Improving the system for the management of the efficiency of power engineering devices

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ABSTRACT

A new method and algorithm for ensuring the homogeneity of standardized samples of technical and economic indicators of power units of thermal power plants is presented. Homogeneity and normalization are prerequisites for evaluating the integrated indicators characterizing the efficiency of power units. The method is based on a fiducial approach. The boundary values of the fiducial interval are traditionally calculated by the statistical distribution function and a given significance level. I.e. they are basically calculated "mechanically." Since the "mechanical" approach is valid for homogeneous statistical data, and technical and economic indicators are multidimensional data, the application of this approach to the statistical function of the fiducial distribution is associated with a high risk of an erroneous decision. Many possible implementations of the actual values of technical and economic indicators have implementations due to "gross" errors when entering data into automated systems or when performing individual calculations manually. Non-typical implementations are often found, for instance, when working with a light load for 10 days of the month. This data forms boundary intervals and are named boundins by the authors. Automated search and removal of boundins provides reliable comparison and ranking of integrated indicators. It is shown that the rate of variation of boundins is significantly less than the rate of variation of typical implementations of technical and economic indicators. This fact became the basis for the recognition of boundins.

1. Problem statement

One of the main problems of ensuring the efficiency of powerful power plants of electric power systems (EPS) is the possibility of comparing the efficiency of power units. Attempts to maintain the traditional methodology of comparison are increasingly encountered with the need to more fully take into account the reliability and safety of operation [1]. If earlier, when the service life of the power units did not exceed the standards, the reliability and safety of operation was ensured by following the manufacturer's instructions and the operational regulations, and the comparison was carried out on the specific consumption of equivalent fuel, today adding only recommendations for taking into account the technical condition is no longer enough, because there

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is no methodology for such accounting. And if the quantitative assessment of operational reliability, due to ongoing research, approaches the necessary reliability [2], the quantitative assessment of operational safety at least requires the same attention. Well, the "light at the end of the long tunnel", the appearance of which depends on our efforts, is an analogue of the dream of a quantitative assessment of operational efficiency. It should be kept in mind that the indicators of operational efficiency, reliability and safety are calculated both for cases of "violations" (for instance, violation of the Safety Rules, failures), and for average monthly values of technical and economic indicators (TEI).

High technology, high labor intensity, cumbersomeness, lack of efficiency and the risk of erroneous decisions with manual calculation make it necessary to switch to computer technology. High technology, first of all, is manifested in the need to take into account the new paradigm of statistical analysis [3]. It consists in the fact that possible TEI implementations belong to the class of multidimensional data, i.e. depend on a large number of characters and their varieties. The application of the known methods of statistical analysis of homogeneous data to them is impractical, because it leads to a sharp increase in the risk of an erroneous decision. Comparison of the efficiency of power units can be performed by comparing their integrated indicators calculated on the basis of the fiducial approach [4].

The calculation of the integrated indicator is preceded by ensuring the accuracy and independence of TEI implementations, normalization and control of homogeneity of nonrandom samples from the set of possible TEI implementations. In [5], it was proposed to ensure homogeneity by recognizing and eliminating "gross" errors. In [6], the homogeneity of the sample was improved by excluding the non-stationary modes of power units from the consideration of TEI. Moreover, the homogeneity of the TEI series increased significantly, which was confirmed by histograms of their distribution.

A subsequent graphical analysis of the statistical functions of fiducial distributions if TEI revealed the boundary values of the intervals of fiducial distributions referred to by the authors as boundins, the elimination of which substantially clarified the critical values of the fiducial distributions and increased the reliability of comparing the reliability and cost-effectiveness of power units. It turned out that the right and left boundins of the fiducial distributions can differ significantly, and for the distribution of relative deviations of TEI, the right boundins are significantly larger than the left ones. But the assessment of the beginning of boundins, and thus the boundary values of the fiducial interval, remains, as before, subjective. It is also impossible to apply methods for calculating the boundary values of the confidence interval, the thickness and the length of the "tails" of the distribution, which are used for indicators and distribution parameters of one-dimensional random variables.

2. Method and algorithm for calculating the boundary values of the fiducial interval of TEI implementations

The transition from a "mechanical" assessment of the boundary values of the fiducial interval (practiced for estimating critical values of the confidence interval by a given significance coefficient) is proposed to be carried out on the basis of distinguishing features of boundins – the rate of variation of relative deviations of implementations of TEI of boundins is significantly lower than for implementations of TEI of the fiducial interval.

A comparison of the probability $F_0^* = N_b^{-1}$, where N_b is the set of implementations of the sample of TEI, and increments of the relative value of deviation of implementations of TEI $\Delta\varepsilon(\Pi_{i,j}) = [\varepsilon(\Pi_{i,j}) - \varepsilon(\Pi_{i,j-1})]$ is proposed as a criterion. Thus:

if

$$\Delta\varepsilon(\Pi_{i,j}) < N_b^{-1} \text{то} \varepsilon(\Pi_{i,j}) \in \Phi(\Pi_i) \quad (1)$$

where $\Phi(\Pi_i)$ is the set of implementations of the fiducial interval $[\underline{\Pi}_i; \overline{\Pi}_i]$; $\in$ is the index of membership in the set of implementations. Let us refine the expression (1)

- for the left boundin:

if

$$\Delta\varepsilon\left(\Pi_{i,j}\right) > N_b^{-1} \text{то} \, \varepsilon(\Pi_{i,j}) \in \Phi_{л}(\Pi_i) \quad (2)$$

where $\Delta\varepsilon\left(\Pi_{i,j}\right) = \left[\varepsilon\left(\Pi_{i,j+1}\right) - \varepsilon\left(\Pi_{i,j}\right)\right]$; $\Phi_л(\Pi_i)$ is the set of implementations of TEI of the left boundin; $j=1,m_i$; m_i is the number of analyzed implementations of the i-th TEI

- for the right boundin

if

$$\Delta\varepsilon\left(\Pi_{i,(N_b-j+1)}\right) > N_b^{-1} \text{то} \, \varepsilon(\Pi_{i,(N_b-j+1)}) \in \Phi_{п}(\Pi_i) \quad (3)$$

where $\Delta\varepsilon\left(\Pi_{i,(N_b-j+1)}\right) = \left[\overline{\varepsilon}(\Pi_{i,(N_b-j+1)}) - \varepsilon\left(\Pi_{i,(N_b-1)}\right)\right]$; $\Phi_п(\Pi_i)$ is the set of implementations of TEI of the right boundin; $j=1,m_i$.

Fig. 1 shows a structure flowchart of the algorithm for determining the boundary values of the fiducial interval. Let us consider briefly the content of each block:

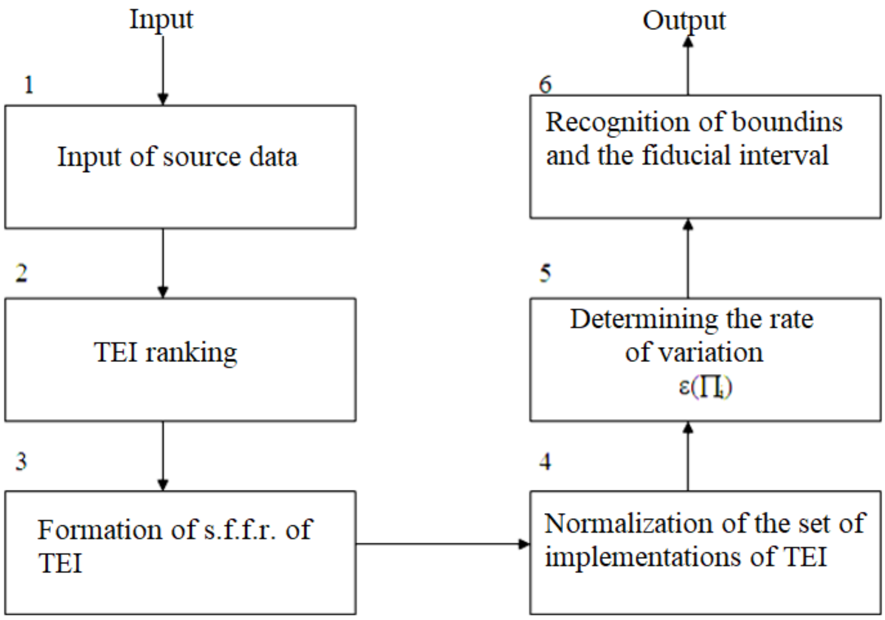

Fig. 1. A structure flowchart for the analysis of TPI of TPP units

Block 1. When the "TEI Analysis" subsystem is put online, the monthly average values of independent TEI are entered in the database. The following specifics are taken into account:

– in order to take into account the influence of external factors and the change in the technical condition of the equipment and devices of the power unit, it is recommended to consider many possible implementations of TEI during the year, i.e. 12 months;

– alongside with implementations of TEI, their code is entered, i.e. information about the number of the month of the year in which these implementations took place, and the dispatch number of the TPP power unit;

– monthly change in the TEI data array. The change is made by entering implementations of TEI for the current month instead of implementations of TEI in the same month of the last year.

Block 2. All TEI are arranged in ascending order of their numerical values. Since when the power unit is in the idle (disabled) state during the current month, the TEI are assumed to be zero, when ranking the TEI, the first m_0 values of the implementations of each TEI will be zero, where m_0 is the total number of power units that are not working all month during the year. Excluding them from consideration, we get a set of ranked possible implementations of TEI during the last year of operation, which we denote as $B(\Pi_i)$ c $i=1,n_п$.

Block 3. If we juxtapose the j-th implementation of the set $B(\Pi_i)$ equal to $\Pi_{i,j}$ with the probability $F^*(\Pi_{i,j}) = \frac{j}{N_{b,i}}$, where $j=1,N_{b,i}$, and $N_{b,i}$ is the number of implementation of the set $B(\Pi_i)$, then we get s.f.f.r. TEI

Block 4. The difference in dimension and scale of TEI excludes the possibility of comparing their significance. This difficulty is overcome by the transition to normalized values of TEI [5]. The normalization of TEI does not change their ranking, unless for A=0, the ranking is performed in the order of increasing implementations, and for A=1, in the order of decreasing. Here A is the directivity factor of TEI. If with an increase in TEI the efficiency of an object increases, then A=1. Otherwise, A=0. Therefore, for A=0 we get s.f.f.r. $F^*[\varepsilon(\Pi_i)]$, and for A=1 – the distribution $R^*[\varepsilon(\Pi_i)]=1-F^*[\varepsilon(\Pi_i)]$.

Block 5. Based on criteria (2) and (3), the rate of variation of the relative values of deviations of TEI is calculated from the formula:

$$\upsilon^*[\varepsilon(\Pi_i)] = \frac{N_{b,i}^{-1}}{\Delta\varepsilon(\Pi_{i,j})} \tag{4}$$

and the greater the difference in neighboring values of the ranked set of realizations $B(\Pi_i)$, the smaller the estimate $\upsilon^*[\varepsilon(\Pi_i)]$. However, when performing the calculations, a comparison of $\Delta\varepsilon(\Pi_{i,j})$ with $N_{b,i}^{-1}$ is quite sufficient. A significant spread of values $\varepsilon(\Pi_{i,j})$ leads to a spread of $\upsilon^*[\varepsilon(\Pi_i)]$ and difficulties in estimating the set of implementations of boundins. A decrease in the spread $\Delta\varepsilon(\Pi_{i,j})$ can be achieved by the moving average method. Even when averaging two adjacent implementations, $\Delta\varepsilon(\Pi_{i,j})$ decreases sharply and allows establishing the boundary values of boundins and the fiducial interval. With the neighboring three implementations, the possibility of "failure" is eliminated.

Block 6. Comparison of changes in relative values of TEI with the critical value $N_{b,i}^{-1}$ allows setting the boundary values of boundins and the fiducial interval.

3 Illustration of the fiducial approach in the analysis of the efficiency of 300 MW power units of TPP

In accordance with the flowchart of the performance analysis algorithm, Table 1 shows s.f.f.r. $F^*[\varepsilon(\Pi_i)]$ with i=1.6 and randomly selected variation interval.

Table 1

Statistical functions of the fiducial distribution of normalized implementations of TEI

N	j	$F^*[\varepsilon(\Pi_i)]$	$\varepsilon(T_{уг.j})$	$\varepsilon(Э_{т.j})$	$\varepsilon(\eta_{в.j})$	$\varepsilon(T_{в.j})$	j	$F^*[\varepsilon(\Pi_i)]$	$\varepsilon(К_{в.j})$	$\varepsilon(\Delta S_j)$
1	4	0.048	0.1	0.0115	0.079	0.074	3	0.038	0.02	0.262
2	8	0.095	0.129	0.0161	0.12	0.096	6	0.077	0.067	0.307
3	12	0.143	0.15	0.0253	0.149	0.11	9	0.115	0.09	0.352
4	16	0.19	0.204	0.0277	0.252	0.123	12	0.154	0.14	0.385
5	20	0.238	0.257	0.0323	0.298	0.126	15	0.192	0.167	0.417
6	24	0.286	0.286	0.0415	0.314	0.15	18	0.23	0.2	0.423
7	28	0.333	0.325	0.0484	0.351	0.164	21	0.269	0.233	0.449
8	32	0.381	0.393	0.053	0.376	0.173	24	0.308	0.253	0.455
9	36	0.429	0.407	0.0553	0.401	0.191	27	0.346	0.27	0.456
10	40	0.476	0.439	0.0645	0.43	0.202	30	0.384	0.28	0.481
11	44	0.524	0.507	0.0714	0.496	0.22	33	0.423	0.303	0.493
12	48	0.571	0.532	0.076	0.55	0.233	36	0.462	0.317	0.512
13	52	0.619	0.564	0.0806	0.583	0.257	39	0.5	0.33	0.532
14	56	0.667	0.582	0.0876	0.607	0.277	42	0.538	0.356	0.539
15	60	0.714	0.625	0.0945	0.624	0.287	45	0.577	0.367	0.571
16	64	0.762	0.664	0.0991	0.636	0.299	48	0.615	0.37	0.589
17	68	0.81	0.743	0.104	0.64	0.308	51	0.654	0.387	0.622
18	72	0.857	0.818	0.118	0.649	0.328	54	0.692	0.403	0.641
19	76	0.905	0.854	0.129	0.657	0.374	57	0.731	0.423	0.66
20	80	0.952	0.921	0.177	0.707	0.426	60	0.769	0.447	0.679
21	84	1	1	1	1	1	63	0.808	0.467	0.744
22							66	0.846	0.487	0.756
23							69	0.883	0.507	0.763
24							72	0.923	0.543	0.878
25							75	0.962	0.85	0.907
26							78	1	1	1

This illustrates a typical situation where the number of implementations TEI $N_{b,i}^{-1}$ may vary. Based on these data, Fig. 2 shows a graphical illustration of these distributions.

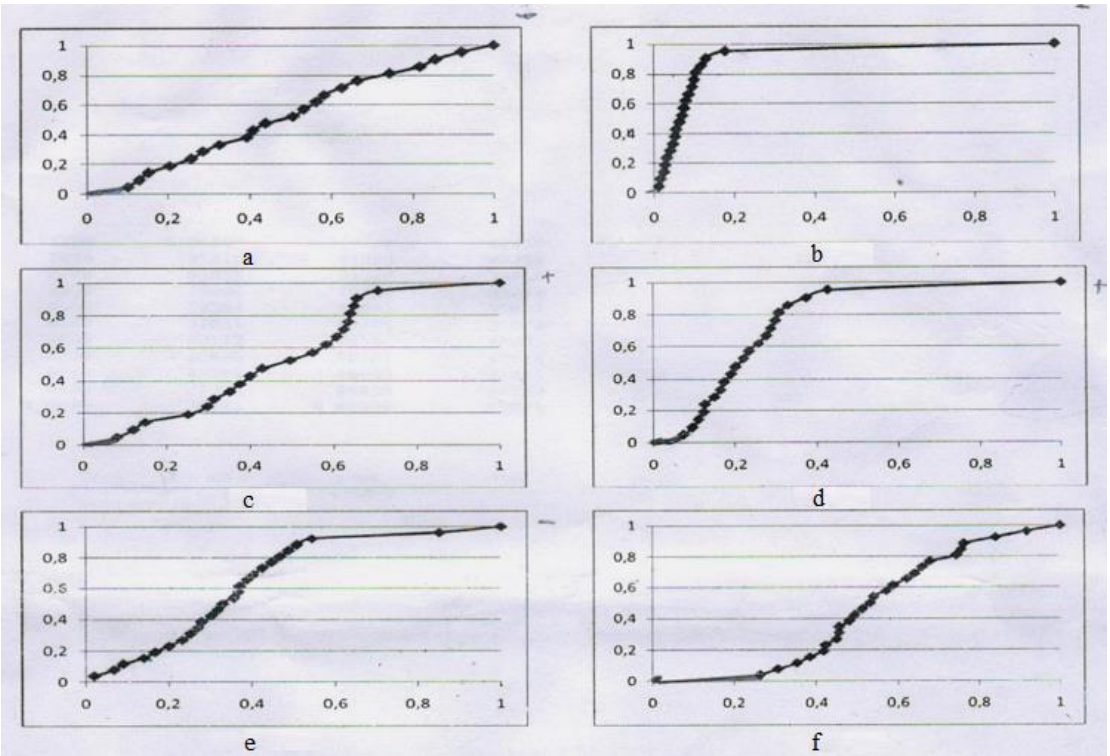

Fig. 2. Fiducial distributions of the relative deviation of possible implementations TEI: a – F*[ε($T_{уг}$)]; b – F*[ε($Э_т$)]; c – F*[ε(T_b)]; d – F*[ε($η_б$)]; e – F*[ε(K_b)]; f – F*[ε(ΔS)];

Here, we can clearly see the boundins, the number of implementations of which does not exceed 10. All six distribution arguments vary from zero to one and are independent.

Table 2, for illustrative purposes, shows the results of calculations of the boundary values of the fiducial interval and the boundaries of the left and right boundins for TEI $T_{УГ}$. Here the distributions were determined not for ε($П_i$), and for mean values of adjacent implementations TEI. Accordingly, the mean values are denoted as M^*[ε($П_i$)], and their difference as ΔM^*[ε($П_i$)].

Table 2

Results of calculating the boundary values of the fiducial interval and boundins for TEI $T_{уг}$

j	left			j	right		
	ε($T_{угj}$)	$M_ε$($T_{уг}$)	ΔM($T_{уг}$)		ε($T_{угj}$)	$M_ε$($T_{уг}$)	Δ$M_ε$($T_{уг}$)
1	0	0.0107	0.0339	84	1.0	0.9910	0.0321
2	0.0214	0.0446	0.0394	83	0.9821	0.9589	0.0268
3	0.0679	0.0840	0.0231	82	0.9357	0.9321	0.0185
4	0.1000	0.1071	0.0107	81	0.9285	0.9136	0.0132
5	0.1142	0.1178	0.0054	80	0.8987	0.8904	0.0118
6	0.214	0.1232	0.0036	79	0.8821	0.8786	0.0036
7	0.1250	0.1268	-	78	0.8750	0.8750	
8	0.1286	-	-	77	0.8750		

As follows from Table 2, the boundary values of the left boundin of implementations $T_{УГ}$ are [0; 0,1], the boundary values of the fiducial interval are [0.1142; 0.8750], and the right boundin [0.8821; 1].

The calculation results of the boundary values of the fiducial intervals and boundins of all 10 TEI CU under consideration are given in Table 3. These data are interesting not only for their relationships, but also as the basis for recalculating the relative deviations of the set of implementations of the fiducial interval.

Table 3

Results of calculating the boundary values of the fiducial interval and boundins

i	$П_i$	Boundary values					
		left boundin		fiducial interval		right boundin	
		lower	upper	lower	upper	lower	upper
1	$Т_П$	0	0	0	0.2224	0.2382	1
2	$Т_В$	0	0.0617	0.0677	0.4120	0.4256	1
3	$Т_{У.Г}$	0	0.1000	0.1142	0.8750	0.8821	1
4	$К_В$	0	0	0	0.5133	0.5333	1
5	ΔS	0	0.2949	0.3013	0.8905	0.9075	1
6	$\eta_б$	0	0.1157	0.1198	0.6942	0.7066	1
7	$Э_Э$	0	0.0284	0.0394	0.2385	0.3042	1
8	$Э_Т$	0	0	0	0.1450	0.1500	1
9	$\eta_Н$	0	0.0460	0.0630	0.3220	0.331	1
10	$В_т$	0	0	0	0.2296	0.2360	1

The integrated performance indicators of TPP power unit can be calculated based on one of the following three transformations:

- normalized values of possible implementations of TEI;
- replacing possible implementations with ranks, for which purpose the fiducial interval is divided into r equal segments. The ranks of TEI implementations correspond to the segment numbers including these implementations. E.g., for a five-point system r=5;
- re-normalization ensuring homogeneity of TEI.

Characterizing given varieties of signs, integral indicators, although all are defined as the arithmetic mean of normalized TEI implementations, they differ significantly in the terms of this sum. For a particular power plant, two classifications of possible varieties of TEI are introduced.

The first variety is intended to characterize the performance of each power unit for the purpose of comparing and ranking them. I.e. integrated indicators are calculated for the sign “power unit” and a variant of the sign “dispatch number of the power unit”. They are calculated as the arithmetic mean of the normalized TEI values characterizing the power units.

The second variety is determined by classifying the totality of TEI by type, it characterizes the significance of each TEI, thereby allowing comparing their significance, identifying “weak links” and minimizing the cost of improving work efficiency. It is calculated as the arithmetic mean of the possible implementations of each TEI. Summing the implementations of the normalized values of all TEI makes it possible to evaluate the overall TPP performance and compare it with the performance of similar TPPs.

Table 4 below contains the evaluation of the operational efficiency according to the monthly average values of TEI of power units for the current month by each of the three possible transformations of TEI

Table 4
Results of the estimation of integrated indicators by the normalized values of possible implementations of TEI

i	$\varepsilon(\Pi_i)$	Unit dispatch number								Mean value	Ranking results
		1	2	3	4	5	6	7	8		
1	$\varepsilon(T_{П})$	0.145	0.090	-	0.087	0.128	**0.334**	0.109	0.041	0.099	**3**
2	$\varepsilon(T_{В})$	0.328	0.134	-	0.302	0.141	**0.507**	0.233	0.245	0.231	**5**
3	$\varepsilon(T_{УГ})$	0.304	0.686	P	**0.100**	0.782	0.207	0.150	0.232	0.393	**8**
4	$\varepsilon(K_{В})$	0.372	0.142	E	0.252	0.329	0.372	0.367	0.252	0.298	**7**
5	$\varepsilon(\Delta S)$	0.603	**1.361**	M	0.532	0.385	0.532	0.449	**0.000**	0.500	**9**
6	$\varepsilon(\eta_{б})$	0.632	0.645	O	0.649	0.653	0.686	0.214	0.612	0.584	**10**
7	$\varepsilon(Э_{Э})$	0.105	0.098	H	0.160	0.089	0.188	0.050	0.098	0.115	**4**
8	$\varepsilon(Э_{Т})$	0.071	0.092	T	0.094	0.099	0.129	0.079	0.076	0.091	**2**
9	$\varepsilon(\eta_{Н})$	0.232	0.235	-	0.280	0.235	0.322	0.192	0.221	0.246	**6**
10	$\varepsilon(в_{Т})$	0.034	0.125	-	0.118	0.089	0.135	0.039	0.016	0.077	**1**
Integrated indicator		0.283	0.269	-	0.275	0.294	0.257	0.188	0.192	0.254	-
Ranking results		**6**	**4**	**-**	**5**	**7**	**3**	**1**	**2**	-	-

In Table 4, the boldface font indicates the implementations of TEI related to boundins. The results of evaluation of the integrated performance indicators of CU of the power units made it possible to rank the CU and TEI. The data in Table 4 shows that the tasks are successfully solved. However, the reliability of the ranking is still carried out without taking into account the random nature of TEI and the conditions for the violation of homogeneity due to the elimination of boundins.

The boundary values of the fiducial interval $[\underline{\varepsilon(\Pi_i)};\overline{\varepsilon(\Pi_i)}]$; $[\underline{\varepsilon(\Pi_i)};\overline{\varepsilon(\Pi_i)}]$ allows proceeding to the TEI ranking system. The following rank classification is accepted (L):

$$\left.\begin{array}{ll} \text{if} & \varepsilon(\Pi_i) \le \varepsilon(\Pi_i) < 0.2[\overline{\varepsilon(\Pi_i)} - \underline{\varepsilon(\Pi_i)}],\ \text{then L=5} \\ \text{if} & \varepsilon(\Pi_i) < 0.4[\overline{\varepsilon(\Pi_i)} - \underline{\varepsilon(\Pi_i)}],\ \text{then L=4} \\ \text{if} & \varepsilon(\Pi_i) < 0.6[\overline{\varepsilon(\Pi_i)} - \underline{\varepsilon(\Pi_i)}],\ \text{then L=3} \\ \text{if} & \varepsilon(\Pi_i) < 0.8[\overline{\varepsilon(\Pi_i)} - \underline{\varepsilon(\Pi_i)}],\ \text{then L=2} \\ \text{if} & \varepsilon(\Pi_i) \le \overline{\varepsilon(\Pi_i)},\ \text{then L=1} \end{array}\right\} \quad (5)$$

Re-ranking is carried out according to an algorithm similar to (1) and has the form:

$$\left.\begin{array}{l} \text{if A=1, then } \varepsilon_1\left[\varepsilon\left(\Pi_{i,j}\right)\right] = \dfrac{[\overline{\varepsilon(\Pi_{i,j})} - \varepsilon(\Pi_{i,j})}{[\overline{\varepsilon(\Pi_i)} - \underline{\varepsilon(\Pi_i)}]} \\ \text{if A=0, then } \varepsilon_0\left[\varepsilon\left(\Pi_{i,j}\right)\right] = \dfrac{[\varepsilon(\Pi_{i,j}) - \underline{\varepsilon(\Pi_i)}}{[\overline{\varepsilon(\Pi_i)} - \underline{\varepsilon(\Pi_i)}]} \end{array}\right\} \quad (6)$$

The results of comparison of methods for evaluating the efficiency of operation on the example of natural gas-fired reciprocating power plants are given in [7] with the significant difference that the boundary values of the fiducial interval were estimated by the significance level. It is shown that:

- the results of the ranking of power units and TEI when replacing possible implementations of the actual TEI values with their ranks or standard values are the same. Their discrepancy only indicates the inaccuracy of the calculation algorithm;

– the transition to ranks on a five-point system simplifies the perception of the results but somewhat averages the ranking results. Coincidences of integrated indicators for power units and mean values of implementations of TEI are possible;
– transformations of TEI based on the normalization of possible implementations are devoid of these shortcomings;
– thus, normalization of TEI should be considered the main transformation of TEI. The application of a ranking approach should still be considered as alternative but contributing to a better perception of the results of ranking and comparison of integrated indicators of TEI.

The practice of calculating the efficiency of TPP power units made it possible to simplify the calculation algorithm. Simplification is achieved by recognizing boundins and the fiducial interval by s.f.f.r. of actual values of TEI and subsequent normalization of TEI based on the established boundary values of the fiducial interval. A simplified flowchart of this algorithm is shown in Fig. 3.

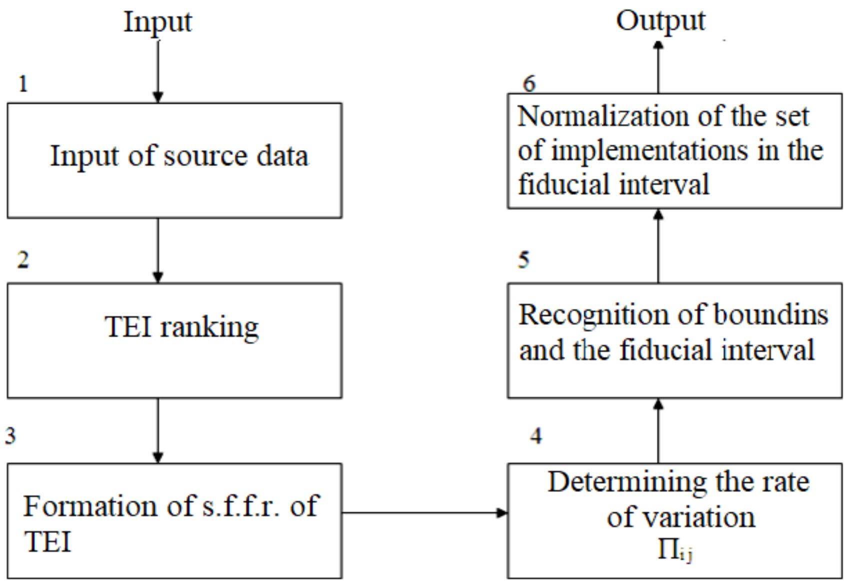

Fig. 3. Recommended algorithm of transformation of TEI

4. Conclusion

1. A full account of profitability, reliability and safety, as components of work efficiency, requires the development of an integrated approach methodology, calculation of integrated indicators. These indicators allow comparing and ranking the efficiency of TPP units, identifying "weak links" and "unstable states", eliminating them and thereby increasing the efficiency of TPP at the lowest cost.

2. A method and algorithm for calculating the integrated indicator is developed taking into account the requirements of error-free monthly average values of technical and economic indicators. The method is based on a fiducial approach, ensures homogeneity of normalized values and monthly procedural support of personnel in ensuring the effectiveness of TPP. It is in this that efficiency of management of the TPP power unit is manifested.

References

[1] А.Ф. Дьяков, Пути повышения надежности электроснабжения страны, Вестник РАН. No3 (2012) 214-224 [In Russian: A.F. Dyakov, Ways to improve the reliability of the country's power supply, Vestnik RAN].

[2] Н.И. Воропай, Г.В. Ковалев и др., Концепция обеспечения надежности в электроэнергетике, Москва, ООО ИД «Энергия, 2013 [In Russian: N.I. Voropay, G.V. Kovalev et al., The concept of ensuring reliability in the electric power industry, Moscow, Energiya Publishing House,].

[3] А.И. Орлов, Основные черты новой парадигмы статистического анализа, Политематической сетевой электронный научный журнал Куб ГАУ. 06 No 90 (2013) [In Russian: A.I. Orlov, The main features of the new paradigm of statistical analysis, Political network electronic scientific journal Kub GAU].

[4] И.В. Павлов, О фидуциальном подходе при построении доверительных границ для функций многих неизвестных параметров, Докл. АН СССР. 258 (1981) 1314-1317 [In Russian: I.V. Pavlov, On the fiducial approach in constructing confidence boundaries for functions of many unknown parameters, Proceedings of AS USSR].

[5] Э.М. Фархадзаде, А.З. Мурадалиев, Т.К. Рафиева, А.А. Рустамова, Обеспечение безошибочности данных при автоматизированном анализе технико-экономических показателей котельных установок энергоблоков, Москва, Теплоэнергетика. No 9 (2019) [In Russian: EM. Farhadzadeh, A.Z. Muradaliyev, T.K. Rafiyeva, A.A. Rustamova, Ensuring the accuracy of data in the automated analysis of technical and economic indicators of boiler units of power units, Moscow, Teploenergetika].

[6] Э.М. Фархадзаде, А.З. Мурадалиев, Т.К. Рафиева, А.А. Рустамова, Обеспечение достоверности методической поддержки руководства объектов EPS, Москва, Электричество. No 10 (2019) [In Russian: EM. Farhadzadeh, A.Z. Muradaliyev, T.K. Rafiyeva, A.A. Rustamova, Ensuring reliability of procedural support for the management of EPS facilities, Moscow, Elektrichestvo].

[7] Э.М. Фархадзаде, А.З. Мурадалиев, Э.И. Джалагова, С.А. Абдуллаева, Метод и алгоритм сравнения эффективности работы газопоршневых электростанций электроэнергетических систем, Москва, Известия РАН, Энергетика. No 2 (2019) 106-117 [In Russian: EM. Farhadzadeh, A.Z. Muradaliyev, E.I. Jalagova, S.A. Abdullayeva, Method and algorithm for comparing the performance of natural gas-fired reciprocating power plants of electric power systems, Moscow, Izvestiya RAN, Energetika].

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