

# RELEVANCE OF INFORMATION AND TECHNICAL SUPPORT OF STAFF IN MAINTENANCE AND REPAIR OF STEAM TURBINE DEVICES OF POWER UNITS OF THERMAL ELECTRIC STATION

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## Abstract

*The need to improve the efficiency of thermal electric station units increases significantly as their service life increases. If during the standard service life, the efficiency of operation was successfully calculated on the basis of a standard algorithm and experimental energy characteristics, then subsequently the correspondence of the initial energy characteristics to the actual characteristics becomes less and less accurate. In order to ensure the efficiency of power units, it is necessary to reduce the frequency of clarification of empirical characteristics, which causes a significant increase in operating costs. The forced approach to solving operational problems is taking into account operating experience, information about existing defects. In this case, the strict calculation method is replaced by an intuitive approach, the risk of an erroneous solution of which is significant, and improving the method for solving operational problems is transformed from desirable to necessary.*

**Keywords:** Efficiency, synthesis, steam turbine device, power unit, automated system, recommendations, technical condition profitability

## I. Introduction

By the efficiency of steam turbine devices (STD) we mean the combined consideration of reliability, cost effectiveness and safety of STD operation. Quantitatively, the efficiency of the power unit's STD is characterized by a number of technical and economic indicators (TEI). Some of them, and the number of TEIs is in the tens, are presented in the form of monthly average values in the 3-TEKH form [1].

In addition to this summary form, operational personnel can receive 28 more output forms upon request. All this numerous data is necessary for:

- ensuring efficient operation of power unit equipment
- selection of the power unit that is in greatest need of wear restoration
- assessment of the quality of work of operating personnel
- clarification of the technical condition of the power unit by conducting operational tests
- preparation of reports on thermal efficiency of the power unit

It is easy to see that the TEIs presented in Form 3-TECH to the greatest extent characterize the efficiency of the boiler and turbine units of the power unit, and to the least extent – the electrical equipment and the power unit as a whole. This is confirmed by the intuitive nature of the comparison and ranking of power units by work efficiency when:

- distribution of the load between power units (if the energy characteristics of a power unit do not correspond to its actual state)
- planning repairs of power units taking into account their technical condition
- the need to turn off one of the power units in reserve
- assessing the quality of work of each shift
- solving a number of operational problems related to those noted above

The infallibility of the intuitive approach depends not only on the qualifications of the personnel, but also on the number of statistically dependent TEIs. The greater the number of dependent TEIs, the greater the risk (probability) of an erroneous decision with the intuitive approach.

Traditionally, the performance of a power plant, individual power units and equipment is assessed by comparing actual and standard fuel consumption.

As the service life increases, the error of this comparison increases, since the influence of the technical condition of the power unit equipment, which naturally deteriorates, increases significantly. In [2], a method for comparing and ranking the work efficiency of STD of the thermal electric station (TES) was developed. This method is based on the peculiarity of calculating the integral indicator reflecting the difference in the scale, scale and unit of measurement of the TEI. It is shown that the reduction in the cumbersomeness of converting actual values of the TEI is achieved by classifying the TEI by STD nodes, which allows excluding from consideration the statistical analysis of the relationship of the TEI, the independence of which is obvious.

Let's consider some features of the automated generation of recommendations for improving the efficiency of the equipment of the STD of 300 MW power units. But so that these results do not look unfounded, Table 1, according to [2], shows the actual average monthly values of the TEI of the STD of 300 MW power units.

**Table 1:** Actual average monthly values of thermal efficiency of the 300 MW STD of thermal electric station

No. TEI	No des	TEI		Actual average monthly values of technical and economic indicators of the steam-turbine device with a capacity of 300 MW, station No.								
		Conv desig	Unitmeas	1	2	3	4	5	6	7	8	
1	ST	$L_{e,av}$	MW	R	181,5	180,1	180,3	181,7	169,6	173,0	176,9	
2		$L_{e,max}$	MW		250	240	250	250	240	250	250	
3		$P_{f,st}$	Atm		222,3	215,0	218,1	210,5	220,8	189,8	208,8	
4		$T_{f,st}$	°C		E	540	539,2	540	540	540	540	539,7
5		$q_t^{gr}$	kcal/kWh		Z	1925	1925	1888	1895	1913	1905	1893
6		$\delta q_t$	r.u.		E	0,0166	0,0192	0,0190	0,0162	0,0188	0,0182	0,0184
7	RH	$\delta\rho_{rh}$	r.u.	R	0,126	0,125	0,130	0,131	0,123	0,126	0,117	
8		$T_{rh}^{out}$	°C	R	540	538,2	540	540	540	538,6	539,7	
9	Con	$\rho_{con}$	Atm.	V	0,089	0,060	0,084	0,072	0,091	0,067	0,064	
10		$\Delta T_{c,w}$	°C	E	7,7	7,5	6,5	5,4	6,5	6,9	7,6	
11		$\Delta T_h$	°C	E	12,8	16,1	14,3	8,2	10,0	16,0	17,2	
12	ON	$\omega_{o.n.}^{e,e}$	r.u.		1,44	1,66	1,7	1,47	1,64	1,51	1,61	
13		$\omega_{o.n.}^h$	r.u.		0,21	0,24	0,16	0,16	0,17	0,32	0,22	

The following symbols are used in the table below: ST – steam turbine; RH – reheater; Con – condenser; O.N. – own needs;  $L_{e,av}$  – average electrical load;  $L_{e,max}$  – maximum electrical load;  $P_{f,st}$  – fresh steam pressure;  $T_{f,st}$  – fresh steam temperature;  $q_t^{gr}$  – actual value of specific heat consumption “gross”;  $\delta q_t$  – relative difference between actual values of specific heat consumption “net” and “gross”;  $\delta q_t = \frac{(q_t^n - q_t^{gr})}{q_t^{gr}}$ , where  $q_t^n$  – actual value of specific heat consumption “net”;  $\delta \rho_{rh} = \frac{(\rho_{rh}^{out} - \rho_{rh}^{in})}{\rho_{rh}^{in}}$ , where  $\rho_{rh}^{out}$  и  $\rho_{rh}^{in}$  – the pressure of the intermediate superheater steam, respectively, at the outlet and inlet of the intermediate reheater;  $T_{rh}^{out}$  – steam temperature after reheating;  $\rho_{con}$  – condenser pressure;  $\Delta T_{c,w}$  – change in cooling water temperature;  $\Delta T_{c,w} = (T_{c,w}^{out} - T_{c,w}^{in})$  where  $T_{c,w}^{out}$  and  $T_{c,w}^{in}$  the temperature of the cooling water, respectively, at the outlet and inlet of the condenser;  $\Delta T_h$  – temperature head;  $\omega_{o.n.}^e$  and  $\omega_{o.n.}^h$  – specific consumption of electrical and thermal energy, respectively, own needs.

The ranking was carried out according to the total values,  $K_{i,\Sigma} = \sum_{\psi=1}^{n_b^{op}} K_{i,\Sigma,\psi}$  calculated taking into account the relationship between the various TEI of the STD, where  $i = 1, n_b^{op}$  is the number of operating power units  $n_b^{op} = 7$ .  $K_{i,\Sigma,\psi}$  – total ( $\Sigma$ ) significance of the TEI of the  $\psi$ -th node of the  $i$ -th power unit, determined by formula  $K_{i,\Sigma,\psi} = \sum_{\varphi=1}^{m_\psi} K_{i,\varphi,\psi}$ ,  $m_\psi$  – number of TEI of the  $\psi$ -th node of the STD;  $K_{i,\varphi,\psi}$  – significance of the implementation of the  $\varphi$ -th TEI of the  $\psi$ -th node of the  $i$ -th power unit in the five-point TEI measurement system.

## II. Methods

The algorithm for synthesizing the TEI and evaluating the integral indicator is as follows:

- The maximum possible value of the number of realizations  $K_{\Sigma,i}$  is determined by formula  $K_{\Sigma,max} = 5 * m_\Sigma = 50$ , where  $m_\Sigma$  is the calculated number of TEIs,  $m_\Sigma=10$  [2]
- The minimum possible value of the number of realizations  $K_{\Sigma,i}$  is determined by formula  $K_{\Sigma,min} = 10$
- An array of states of power units  $S(i)$  is formed with  $i = 1, n_b$ . It is accepted that the working state corresponds to one, and the non-working state corresponds to zero in the example under consideration:  $S(1)=0; S(2)=S(3)=...=S(8)=1$ , and  $n_b^{op} = 7$
- Given that the possible values of  $K_{\Sigma,i}$  vary from  $K_{\Sigma,min}$  to  $K_{\Sigma,max}$ , the interval of change of  $K_{\Sigma,i}$  with  $i = 1, n_b^{op}$  can be calculated by the formula
- The unit interval in the five-point system of assessing the significance of the integral indicator of the implementation of  $K_{\Sigma,i}$  with  $i = 1, n_b^{op}$  is calculated using formula  $K_\Sigma^\Delta = \frac{\Delta K_\Sigma}{5} = 8.2$

Table 2 shows the results of the evaluation of the performance indicators of the STD of the TES and the STD as a whole. In addition to the calculations presented in a similar table in [2], Table 2 calculates the refined values of the integral indicator  $I_{In,i}$  and the ordinal number  $M_{r,i}$  of the STD ranked by performance (in order of increasing efficiency). The integral indicator of the significance of the thermal efficiency of the power units of the steam turbine plant ( $Iin_i$ ) is calculated according to the following algorithm-formula:

$$\left. \begin{aligned}
 & i = 1,8 \\
 & \text{if } S_1 = 0 \text{ then go to 1, otherwise} \\
 & \text{if } K_{\Sigma,i} \leq (K_{\Sigma,min} - 1 + K_\Sigma^\Delta) \text{ then } Iin_i \Rightarrow \text{unacceptable, go to 1, otherwise} \\
 & \text{if } K_{\Sigma,i} \leq (K_{\Sigma,min} - 1 + 2K_\Sigma^\Delta) \text{ then } Iin_i \Rightarrow \text{unsatisfactory, go to 1, otherwise} \\
 & \text{if } K_{\Sigma,i} \leq (K_{\Sigma,min} + 3K_\Sigma^\Delta) \text{ then } Iin_i \Rightarrow \text{satisfactory, go to 1, otherwise} \\
 & \text{if } K_{\Sigma,i} \leq (K_{\Sigma,min} + 4K_\Sigma^\Delta) \text{ then } Iin_i \Rightarrow \text{good, go to 1, otherwise } Iin_i \Rightarrow \text{excellent, go to 1}
 \end{aligned} \right\} \quad (1)$$

Here the index  $\Rightarrow$  denotes the phrase “is taken to be equal to”.

**Table 2:** Results of the evaluation of the efficiency of the STD of the thermal electric station

No. node STD ( $\psi$ )	Nodes STD	Ind. of work effect	Results of the assessment of the efficiency of the operation of the STD and the STD as a whole of the power units of the TES; station number of the STD								TTotal TTES
			1	2	3	4	5	6	7	8	
1	ST	$K_{\Sigma,i,\psi}$	R	21	12	21	24	10	13	19	17.1
		$Iin_{i,\psi}$		good	unsat	excl.	excl.	unsat	sat	good	good
		$M_{r,i,\psi}$		6	2	5	7	1	36	4	-
2	RH	$K_{\Sigma,i,\psi}$	Z	4	3	5	5	3	4	1	3.6
		$Iin_{i,\psi}$		good	sat	excl.	excl.	sat	good	unaccl.	good
		$M_{r,i,\psi}$		5	2	6	7	3	4	1	-
3	Con	$K_{\Sigma,i,\psi}$	R	3	5	4.5	9	4.5	5.5	6	5.4
		$Iin_{i,\psi}$		unsat	sat	unsat	excl.	unsat	sat	sat	sat
		$M_{r,i,\psi}$		1	4	2	7	3	5	6	-
4	O.N	$K_{\Sigma,i,\psi}$	E	9	4	6	10	7	5	6	6.7
		$Iin_{i,\psi}$		excl.	unsat	sat	excl.	good	sat	sat	good
		$M_{r,i,\psi}$		6	1	3	7	5	2	4	-
Total STD		$K_{\Sigma,i}$		37	24	36,5	48	24,5	27,5	32	32,8
		$Iin_i$		good	unsat	good	excl.	unsat	sat	sat	sat
		$M_{r,i}$		6	1	5	7	2	3	4	-

**Note:** According to [2]  $[I_m \rightarrow \text{unacceptable}]$  denotes the correspondence of the integral state to the unacceptable.

In accordance with [3], as information and methodological support to the TES personnel, depending on the position held, every month, before discussing the efficiency of the power units, the automated system provides certain forms of analysis and synthesis of the TEI. All of them consist of two sections: conclusion and recommendations.

Thus, the senior machinist of the STD is given form 1FNTU at the beginning of each month (before the discussion) (F - form, N - dispatcher number of the STD, TU - turbine unit).

It should be noted that senior machinists who know their STD “like the back of their hand” and, as a rule, are fully aware of current information about the efficiency of the STD, are not without interest in learning not only the average monthly values of the TEI and their significance in comparison with the significance of the TEI of other STDs, but also be prepared for a “conversation” with the head of the turbine shop [4].

Figure 1 shows a fragment of form 1F6TU for the STD of the 6th power unit of the TES. The efficiency of the STD of the 6th power unit is assessed as *unsatisfactory*.

Form 1FNTU						
CHARACTERISTICS OF THE PERFORMANCE OF THE 6TH POWER UNIT OF TES FOR THE MONTH _____ OF YEAR 20__						
<b>CONCLUSION</b>						
<ol style="list-style-type: none"> <li>1. The efficiency of the STD is assessed as <i>unsatisfactory</i></li> <li>2. In the ranking of the efficiency improvement among the seven operating power units of the TES, the 6th STD ranks <b>5th</b></li> <li>3. Among the four nodes of the 6th STD, there are two “weak links” (nodes that do not meet the requirements)</li> <li>4. The significance of the TEI in a five-point system, the actual average monthly and recommended values of the TEI of the 6th STD were determined</li> </ol>						
No TEI	No des 6 <sup>th</sup> STD	Technical and economic indicators of STD of the TES				
		Name of TEI	Unit Mesr. TEI	Estimation TEI		Signif TEI
Actual	Recomm.					
1	ST	Average electric load	MW	162,6	175,7	1
2		Maximum electrical load	MW	240	245	1
3		Fresh steam pressure	Atm.	220,8	222,3	5
4		Specific heat consumption "gross"	Kcal/kWh	1913	1906,5	2
5		Rel. meas. spec. heat consum. "net"	rel. unit	0,0188	0,0179	1
<i>Work efficiency) (Iin<sub>1</sub>)</i>			<b>unsatisfactorily</b>			
6	RH	Relative change in pressure	rel. unit.	0,123	0,128	3
<i>Work efficiency) (Iin<sub>2</sub>)</i>			<b>satisfactorily</b>			
7	CO N	Condenser pressure	Atm.	0,091	0,0755	1
8		Rel. change of temp. of cool. wt.	rel. unit.	6,5	5,4	4
9		Temperature head	°C	10,0	8,2	5
<i>Work efficiency) (Iin<sub>3</sub>)</i>			<b>unsatisfactorily</b>			
10	O.N	Specific energy consum. for O.N.	%	1,64	1,57	2
11		Spec. consum. of H.E for O.N.	%	0,17	0,16	2
<i>Work efficiency) (Iin<sub>4</sub>)</i>			<b>good</b>			
<b>STD</b>		<i>Work efficiency) (Iin<sub>2</sub>)</i>	<b>unsatisfactorily</b>			<b>2,45</b>
<b>RECOMMENDATIONS</b>						
<ol style="list-style-type: none"> <li>1. Ensure improvement of the TEI in accordance with the recommended values</li> <li>2. Improve the efficiency of the walk-through by “targeted inspection” of the steam turbine and condenser</li> <li>3. Provide test control of personnel knowledge on ways to improve the thermal performance of a <i>steam turbine and condenser</i></li> <li>4. Ensure the availability of Instructions and Rules for improving the efficiency of the <i>sixth</i> STD in the workplace</li> </ol>						
						Date

Figure 1: Fragment of form 1F6TU

Form 1FNTU						
CHARACTERISTICS OF THE PERFORMANCE OF THE 5TH POWER UNIT OF TES FOR THE MONTH _____ OF YEAR 20__						
<b>CONCLUSION</b>						
1. The efficiency of the STD is assessed as <i>excellent</i>						
2. In the ranking of the efficiency improvement among the seven operating power units of the TES, the 5th STD ranks <i>7th</i>						
3. Among the four nodes of the 5th STD, there are <i>no</i> "weak links" (nodes that do not meet the requirements)						
4. The significance of the TEI in a five-point system, the actual average monthly and recommended values of the TEI of the 5th STD were determined						
No TEI	No des 5 <sup>th</sup> STD	Technical and economic indicators of STD of the TES				
		Name of TEI	Unit Mesr. TEI	Estimation TEI		Sign TEI
				Actual	Recom.	
1	ST	Average electric load	MW	181,7	-	5
2		Maximum electrical load	MW	250	-	5
3		Fresh steam pressure	Atm.	210,5	222,3	4
4		Specific heat consumption "gross"	Kcal/kWh	189,5	188,8	5
5		Rel. meas. spec. heat consum. "net"	rel. unit	0,0162	-	5
<i>Work efficiency) (Iin<sub>1</sub>)</i>			<i>excellent</i>			
6	RH	Relative change in pressure	rel. unit.	0,131	-	5
<i>Work efficiency) (Iin<sub>2</sub>)</i>			<i>excellent</i>			
7	CO N	Condenser pressure	Atm.	0,072	0,06	4
8		Rel. change of temp. of cool. wt.	rel. unit.	54	-	5
9		Temperature head	°C	8,2	-	5
<i>Work efficiency) (Iin<sub>3</sub>)</i>			<i>excellent</i>			
10	O.N	Specific energy consum. for O.N.	%	1,47	1,44	5
11		Spec. consum. of H.E for O.N.	%	0,16	-	5
<i>Work efficiency) (Iin<sub>4</sub>)</i>			<i>satisfactorily</i>			
<b>STD</b>	<i>Work efficiency) (Iin<sub>2</sub>)</i>		<i>excellent</i>			<b>4,8</b>
<b>RECOMMENDATIONS</b>						
1. Ensure improvement of the TEI in accordance with the recommended values						
2. Discuss the experience of ensuring compliance of the TEI with the requirements						
3. To identify reserves for increasing the efficiency of STD by analyzing the efficiency of technical maintenance of each shift						
4. Ensure the availability of Instructions and Rules for improving the efficiency of the <i>fifth</i> STD in the workplace						
						Date

Figure 2: Fragment of form 1F5TU

### III. Results

In the 1FNTU form, the following results of the synthesis of the TEI are presented in conclusion:

- assessment of the performance of the N-th STD on five-point scale relative
- the ranking is carried out in order of increasing the integral indicator of work efficiency
- "weak links" of STD

Degree of compliance of the TEI with the requirements in a five-point system (significance of the TEI), actual and recommended TEI. The non-compliant requirements include assessments  $In_{i,j}$ , which are assigned 1 or 2 points in a five-point system. The nodes of these TEI are referred to as "weak links". For example, for the STD of the 6th power unit - this is the steam turbine and condenser, and for the STD of the 3rd power unit - this is the steam turbine and the O.N. system and in Figure 2 - a fragment of form 1F5TU for the STD of the 5th power unit. The efficiency of the STD of the 6th power unit is assessed as **unsatisfactory**, and the STD of the 5th power unit - as **excellent**.

### IV. Discussion

If the actual value of the  $i$ -th TEI ( $In_{i,j}$ ), does not exceed the median ( $Md^*(In_{i,j})$ ) of the observed implementations, the recommended value of the TEI  $In_{i,j}^{Rec}$  is taken to be equal to the median. If  $In_{i,j} > Md^*(In_{i,j})$ , then the best value among the implementations of this TEI should be taken as the recommended value [5].

The decision-making algorithm-formula, given that the work efficiency increases with an increase in the TEI, is as follows:

$$\left. \begin{aligned} & \text{if } In_{i,j} < Md^*(In_{i,j}), \text{ then } In_{i,j}^{Rec} = Md^*(In_{i,j}) \\ & \text{if } In_{i,j} \geq Md^*(In_{i,j}), \text{ then } In_{i,j}^{Rec} = In_{max,j} \end{aligned} \right\} \quad (2)$$

If, however, the work efficiency decreases with an increase in the TEI, then the decision-making algorithm-formula looks like this:

$$\left. \begin{aligned} & \text{if } In_{i,j} > Md^*(In_{i,j}), \text{ then } In_{i,j}^{Rec} = Md^*(In_{i,j}) \\ & \text{if } In_{i,j} \leq Md^*(In_{i,j}), \text{ then } In_{i,j}^{Rec} = In_{max,j} \end{aligned} \right\} \quad (3)$$

The above data defines the information support of the staff.

Recommendations for improving the efficiency of STD in the form of 1FNTU constitute methodological support and include the following options:

- elimination of the "weak links" identified as a result of calculations, the TEIs of which do not meet the requirements. In the table of form 1FNTU- these are TEIs whose significance coefficients are estimated as 1 or 2
- increasing the frequency of assessment of the average value of the TEI that does not meet the requirements
- if the significance coefficient is characterized as satisfactory, then it is recommended to switch to averaged estimates within half a month

- If this coefficient is characterized as unsatisfactory (2) or unacceptable (1), then it is recommended to switch to averaged estimates within a week
- increasing the efficiency of inspection and control of TEI nodes, the technical condition of which is the reason for the decrease in the efficiency of the STD
- systematic monitoring of personnel knowledge about ways to improve TEI of the STD. Test control systems are the most suitable for this
- the presence of relevant instructions allows to increase the reliability of decisions taken to improve the efficiency of the STD when the load and operating mode change.

Improving the efficiency of the TES' steam turbine device is implemented in two ways.

The first method is based on the assumption that improving the efficiency of the TES' steam turbine device is achieved by improving the efficiency of each STD. This method has found wide application, primarily because there is no generally accepted method for ranking STD by efficiency [6].

The second method, without excluding the importance of the first method, considers the TES' steam turbine device as a certain set from which the most efficient units of the STD can be identified, as well as the TEIs that do not meet the requirements for the majority of the TES' steam turbine device [7].

The first method is implemented based on the TEI analysis, and the second on the TEI synthesis [8].

Forms 1FNTU for  $N = [1, n_b]$  contribute to increasing the objectivity of the TEI analysis.

In accordance with [3], the analysis is carried out at least once a month. The head of this event is the head of the steam turbine shop, and the participants are the chief machinists of the TES' steam turbine devices. The second method is implemented, as a rule, during a discussion of the efficiency of the power units with the participation of the heads of production shops, including the head of the turbine shop, under the leadership of the Chief Engineer of the TES.

Form 1FETU provides information and methodological support to the head of the turbine shop. The information component is highlighted in the conclusion and includes:

- assessment of the work efficiency STD of the TES. Overall, the efficiency of the power units are assessed as satisfactory
- results of comparison and ranking of integrated indicators of STD in order of increasing work efficiency
- assessment of the degree of compliance of the STD nodes with the requirements the results of the comparison of the efficiency of the STD nodes in the form of a list of "weak links"
- comparison of the TEI significance indicators, allowing to establish a list of indicators indicating unsatisfactory operation of the STD nodes
- the provision according to which the elimination of "weak links" leads to an increase in the efficiency of the STD with a quantitative assessment of at least four
- list of ways to improve the efficiency of STD of the TES

This list includes:

The first shutting down the least efficient STD for scheduled maintenance and ensuring that the TEI of this STD meets the requirements. This is a traditional method. Its disadvantage is the wide range of materials, equipment and devices required for replacement, long duration of maintenance, high operating costs

The second elimination of "weak links" among the nodes of the STD. For example, as shown down, an increase in the efficiency of the STD of a TES can be achieved by restoring the wear of only three capacitors, the efficiency of which is unsatisfactory.

Form 1FETU									
CHARACTERISTICS OF THE EFFICIENCY OF OPERATION OF STD OF POWER UNITS OF TES FOR A MONTH _____ OF YEAR 20__									
<b>CONCLUSION</b>									
1. The efficiency of STD of the TES operation is assessed as <i>satisfactory</i>									
2. The ranking of the TES' STD was carried out in order of increasing efficiency. The least efficient STD should be considered the 3 power units, and the most efficient STD should be considered the 5 power units									
Indicator	Serial number of power units								On ave.
	1	2	3	4	5	6	7	8	
Ord. num. in a ranked series	-	6	1	5	7	2	3	4	-
Work efficiency	-	good	unsat	good	excell	unsat	sat	sat	sat
3. Unsatisfactory performance was established for the ST power units: third, sixth. The group of power units with the following performance efficiency: - satisfactory, includes: <b>seventh; eighth</b> ; - good, includes: <b>second, fourth</b> ; - excellent, includes: <b>fifth</b>									
4. The degree of compliance of the efficiency of the nodes of the STD with the requirements has been established									
STD nodes	Serial number of power units								On Ave.
	1	2	3	4	5	6	7	8	
Steam turbine	-	good	unsat	excell	excell	unsat	sat	good	good
Reheater	-	good	sat	excell	excell	sat	good	unacc	good
Condenser	-	unsat	sat	unsat	excell	unsat	sat	sat	sat
Own needs	-	excell	unsat	sat	excell	good	sat	sat	good
5. «Weak links» of STDs of the power units identified									
STD nodes	Number of STD with work efficiency								
	unsat	sat	good	excell					
Steam turbine	2	1	2	2					
Reheater	1	2	2	2					
Condenser	3	3	-	1					
Own needs	1	3	1	2					
The "weak links" among the nodes of the STD (the efficiency of operation is no more than "sat") include: a <b>condenser</b> . For a number of STDs, the following apply to TEIs with $K_{i,j} \leq 3$ , where $i=1,7; j=1,10$ : - relative flow rate of the actual value of the specific heat consumption "net" and "gross" of the <b>steam turbine</b> - change in temperature of chilled water in the <b>condenser</b> - temperature head in <b>condenser</b>									
<b>RECOMMENDATIONS</b>									
Improving the assessment of the efficiency work of STD of the TES can be achieved by:									
1. Restoration of wear of condensers of the <b>second, fourth and sixth</b> power units;									
2. For TEIs with unsatisfactory significance, move from monthly change analysis to weekly;									
3. Improving the efficiency of daily inspection of STD by analyzing changes in the TEI of which the significance is unsatisfactory;									
4. Ensure that courses are conducted to eliminate non-compliance of TEIs of the STD with the requirements									
5. Provide personnel with instructions for maintenance of capacitors									
									Date

Figure 3: Fragment of form 1FETU

In this case, not only the list of necessary materials, equipment and devices is reduced, but also the total duration of downtime of power units, the diversity of the list of works, and ultimately significantly lower costs are required [9].

The third elimination of the discrepancy between the requirements of the most typical for all STDs TEI. Additional advantages compared to the elimination of "weak links" is the choice among TEIs that have an unsatisfactory assessment, the TEI improvement of which will require the least effort and funds.

Figure 3 shows the 1FΣTU form, which summarizes the work efficiency of the TES power units included in the time interval under consideration

If the selection of such TEIs for personnel does not present any difficulties, then for the expected effect the number of TEIs requires certain calculations [10]. Calculations are carried out according to the formula:

$$m_{\Delta} = |(3,4 * m_n - K_{\Sigma,ave}) * n_b^{op}| \quad (4)$$

where  $m_n$  - is the number of TEIs;  $K_{\Sigma,ave}$  - is the sum of TEI significances averaged over all  $n_b^{op}$ , STDs;  $n_b^{op}$  - is the number of operating power units. If, as a result of wear restoration, the significance of the TEI of the STD has changed from "unsatisfactory" to at least "good", then the number of TEIs required to improve the efficiency of the STD of the TES will be equal to  $0.5m_{\Delta}$ . Thus, in the conditions of the example under consideration, when  $m_n = 10$ ,  $K_{\Sigma,ave} = 328$ , and the  $n_b^{op} = 7$  of TEIs requiring a change in significance from "unsatisfactory" to "good" is four. Consequently, in order to increase the efficiency of STD of the TES from "satisfactory" to "good", it is necessary to increase the significance of "unsatisfactory" to "good" for 4 TEIs.

Recommendations based on the synthesis of the TEI includes:

- restoration of wear of similar units with the lowest operating efficiency
- reducing the frequency of monitoring the TEI of units with the lowest operating efficiency from monthly to weekly
- increasing the efficiency of monthly inspection of units with the lowest operating efficiency by monitoring changes in the TEI
- conducting short-term courses by the head of the steam turbine shop to eliminate non-compliance of the TEIs of the STD with the requirements
- Providing personnel with Instructions for the maintenance of units with low operating efficiency and Instructions for improving the TEI that do not meet the requirements.

## Conclusions

1. Information and methodological support for the management and personnel of the steam turbine shop is an essential condition for increasing the work efficiency of STD of the TES
2. Information and methodological support of personnel allows to significantly reduce the risk of erroneous decision of operational tasks related to load distribution, selection of power units disconnected for scheduled repairs, in reserve, testing. It is the objective solution of problems that ensures the required reliability, economy and safety, i.e. the work efficiency of STD of the TES
3. It is advisable for the head of the steam turbine shop to discuss the results of the analysis of the TEI of the STD with the shop staff, and to participate in a meeting of the chief engineer of the TES with the heads of the production shops of the power plant with the results of the synthesis of the TEI

4. Integral performance indicators of power unit installations allow calculating the integral indicator of a power unit, ranking power units, and justifying the solution of operational problems.

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