DETECTION AND UTILIZATION OF THERMAL RESERVES IN OPERATION OF OBSOLETE POWER UNITS OF THERMAL POWER STATIONS

Farzaliyev Y.Z., Farhadzadeh E.M.
•
Azerbaijan State University of Economics
yusif.farzaliyev@unec.edu.az

Abstract

This article deals with economic aspects, i.e. identification of reserves of thermal efficiency of obsolete equipment in the example of power units of thermal power plants, which have a useful life exceeding 50%. As a result of operation of such equipment, useful heat required for power generation is lost. The developed new approach allows to detect in time those reserves, which are not possible with the use of energy characteristics due to wear and tear of the equipment and in the end these reserves will remain latent. With the help of the new approach when comparing it with the intuitive one, by which the technical staff wastes more time, it is shown that by taking into account the actual technical condition, reliability and efficiency of equipment operation it is possible to achieve the desired result. The results showed themselves brilliantly when distributing the load between power units of a thermal power station. The exploitation data for solving the problem are technical and economic indicators that characterize the wear and tear of the equipment

Keywords: reserves of thermal efficiency, obsolete equipment, new approach, actual technical condition, reliability, efficiency, load distribution between power units, technical and economic indicators

I. Introduction

Traditionally, thermal efficiency reserves are developed by increasing the reliability of "weak links" and improving the quality of control of power unit modes [1]. Technical economic indicators (TEI) analysis is carried out by comparing actual and nominal indicators. Nominal indicators are understood as indicators that reflect the actually achievable "economy of equipment operation under actual loads and external conditions, the condition and level of operation of the equipment, meeting the requirements of the current rules for the operation of power plants and networks".

Timely delivery of these calculations to operating personnel allows making decisions on control actions on equipment.

The high technical level of operational analysis of the reliability and efficiency of power units allows us to hope for achieving this goal [2]. However, unfortunately, the quality of maintenance and wear restoration of power unit installations does not meet the requirements [3].

The technical literature has repeatedly noted the increasing influence of the "human factor" [4]. And this influence is manifested in an increase in the share of fault of personnel, especially boiler-turbine shop personnel, in accidents and damage to power plant equipment, and a decrease in the reliability and efficiency of their operation. The recommended approach to additional analysis of the TEI provides operational personnel with information about the "weak links", quality of management, maintainability and repair of the power unit and its installations relative to other similar power units of power plants. Ranking power units based on the reliability and efficiency of their operation allows us to take into account the operating experience of other power units, compare the quality of our work with the work of the operating personnel of other power units, and focus not only on some calculated TEI values, but also on the actual successes achieved by the operating personnel of other power units. This introduces into the process of organizing maintenance and repair elements of competition and material incentives for improving the TEI of the power unit [5].

The problem of load distribution between similar power units of thermal power plants is well known. Appropriate algorithms and calculation programs have been developed. Practical implementation requires, first of all, reliable energy characteristics, which in the conditions of increasing aging of the main and auxiliary equipment of the electrical energy supply in itself represents a serious problem. In this regard, heuristic approaches are often used, when, based on work experience, the workload of electronic equipment is assigned. Under these conditions, methodological support to the management of thermal power plants in the form of recommendations on the appropriate distribution of load between electrical units, depending on the reliability and efficiency of their operation, becomes important [6].

These recommendations can be obtained from estimates of integral indicators (B) of the reliability and efficiency of operation of energy blocks, calculated from the actual values of the technical and economic indicators of electric power plants [7]. Note that the desire to simultaneously increase the reliability and efficiency of operation in some cases is surprising, because additional costs are required to ensure operational reliability [8]. And that's true. However, in the formulation under consideration we are talking only about operating costs, which, with greater reliability, are naturally lower [9].

II. Methods

For the method of calculation of load distribution between power units - the initial data are [10]:

n_Σ - total number of single-type EBs

n_b - number of EBs in operation

$P_{min,per}$ - minimum permissible load of the EB

P_{rat} - rated power of EB

B - integral indicator of reliability and economic efficiency of EB operation

$P_{ave}=P_\Sigma/n_b$ - average load per EB, where P_Σ - TPS load

- The calculation of the load sharing between n_b of EBs is carried out in the following sequence:

$$b_i = \frac{B_i}{B_\Sigma} \tag{1}$$

where i=1,n_b; $B_\Sigma = \sum_{i=1}^{n_б^+} B_i^+ = \left|\sum_{j=1}^{n_б^-} B_j^-\right|$; B+ and B- are, respectively, positive (+) and negative (-) values of Bi, $n_б^+$ and - $n_б^-$ respectively the number of EBs with B+ and B- in operation;

- The minimum (b_{min}) and maximum (b_{max}) values of realizations of the integral indicator b_i are determined according to the formulas:

$$b_{min} = \min (b_1, b_2, \ldots\ldots b_{nб}) \tag{2}$$

$$b_{max} = \max (b_1, b_2, \ldots\ldots b_{nб}) \tag{3}$$

It's obvious that b_{min}<0, b_{max}>04;

- The intervals of possible decrease (ΔP^-) and increase ($\Delta P+$) of the average load of EB are determined by the formulas:

$$\Delta P^- = P_{cp} - P_{min,per} \quad (4)$$

$$\Delta P^+ = P_{rat} - P_{ave} \quad (5)$$

- If $\Delta P^- \leq \Delta P^+$,then the calculation of load distribution between n_b EBs, taking into account their reliability and economic efficiency, is carried out according to the formula:

$$P_i = P_{ave} + \Delta P^- \cdot b_i \quad (6)$$

- If, however, $\Delta P- > \Delta P+$, then by the formula:

$$P_i = P_{ave} + \Delta P^+ \cdot b_i \quad (7)$$

Main directions for increasing the efficiency of EBs

_______ month 20__ year

The results of the calculations allowed us to establish and recommend:

1.Technical and economic indicators of EBs not meeting the requirements for ________ month

№ EB	Technical and economic indicators			
	Identification	Relative dev.	Actual val.	Recommen. val.
2	Maximum electrical load	**-1,439**	220,00	270,00
	Share of Electricity for own needs	**-1,333**	5,50	4,10
	Average load	**-1,330**	160,00	179,29
	Installed capacity utilization factor	**-1,310**	11,10	44,84
	Specific consumption of fuel equivalent	**-1,186**	344,00	329,61
3	Specific consumption of fuel equivalent	**-1,072**	342,80	329,61
	Installed capacity utilization factor	**-0,996**	19,20	44,84
	Share of Electricity for own needs	**-0,857**	5,00	4,10
	Maximum electrical load	**-0,571**	250,00	270,00
6	Average load	**-0,296**	175,00	179,29
7	Average load	**-0,365**	174,00	179,29

2. The coefficients of significance of the technical condition (TC) of EBs are equal to

№ EB	1	2	3	4	5	6	7	8
The coefficients of sign. of TC	0,486	**-1,318**	**-0,634**	0,482		0,126	0,255	0,604

3. The group of "bad" includes 2 and 3 EBs. It is recommended to reduce their load in inverse proportion to the relative values of TC significance coefficients.
4. The least efficient of the operating EBs should be considered as 2 EBs. This EB is recommended to be shut down for scheduled repair, and preliminary-to be placed in reserve or to reduce the load as much as possible.
5. The group of "good" includes 8, 1, 4, 7, and 6 EBs. It is allowed to increase their performance in proportion to the relative values of TC significance coefficients.
6. The most efficient is 8 EB. It is advisable to operate it with the maximum permissible capacity.

Figure1: Fragment of the monthly result of the analysis of technical and economic indicators and recommendations on the main directions for improving the efficiency of EB operation.

1. The results of calculations of relative values of bi coefficients according to the formula (1) characterizing TC EB are given in **Table 1.**

Table 1: Realization of relative values of coefficients of significance of TC of EBs

N (i)	Serial number of power units							
	1	2	3	4	5	6	7	8
b_i	0.249	-0.675	-0.325	0.242	-	0.064	0.13	0.309

2. The results of calculations of the load distribution between EB TPS for a number of values of P_{ave} are given in **Table 2.**

Table 2: Results of calculations of load distribution between the TPP EBs for a number of P_{ave} values

Loads P_{ave}, MVt	Conditional numbers of EBs							
	1	2	3	4	5	6	7	8
110	115	96,5	103,5	114,9	-	111,3	112,6	116,2
130	140	103	117	139,9	-	132,6	135,2	142,4
150	164,9	109,5	130,5	164,8	-	153,9	157,8	168,6
170	189,9	116	144	189,7	-	175,2	180,4	194,8
190	214,9	122,5	157,5	214,7	-	196,4	203	220,9
210	232,4	149,2	180,8	232,2	-	215,8	221,7	237,9
230	247,4	182,7	207,3	247,3	-	234,5	239,1	251,7
250	262,4	216,2	233,8	262,3	-	253,2	256,5	265,5

Experience of calculations of load distribution between EBs shows that application of formulas (6) and (7), despite their error-free nature, does not sufficiently utilize the adjustment intervals of EBs (ΔP^+ and ΔP^-). A substantially greater effect is obtained if, instead of formulas (6) and (7), formulas (8) and (9) are used, which are of the form:

$$P_i = P_{ave} - \Delta P^- \frac{b_i}{b_{min}} = P_{ave} - (P_{ave} - P_{min,per}) \frac{b_i}{b_{min}} \quad (8)$$

$$P_i = P_{ave} + \Delta P^+ \frac{b_i}{b_{max}} = P_{ave} + (P_{rat} - P_{ave}) \frac{b_i}{b_{min}} \quad (9)$$

where $i=1,n_b$

Thus formula (8) is used if $\frac{\Delta P^-}{b_{min}} \le \frac{\Delta P^+}{b_{max}}$, if, on the other hand $\frac{\Delta P^-}{b_{min}} > \frac{\Delta P^+}{b_{max}}$ then the formula is used (9).
The results of calculations of load distribution between EBs of TPS according to formulas (8) and (9) are given in **Table 3.**

Table 3: Recommended power plant load distribution between EBs for a number of P_{ave} values.

Loads P_{ave}, MVt	Conditional numbers of EBs							
	1	2	3	4	5	6	7	8
110	117,4	90	100,4	117,3	-	111,9	113,9	119,2
130	144,8	90	110,7	144,6	-	133,8	137,7	148,3
150	172,1	90	121,1	171,9	-	155,7	161,6	177,5
170	199,5	90	131,5	199,2	-	177,6	185,5	206,7
190	226,9	90	141,9	226,5	-	199,5	209,3	235,8
210	254,3	90	152,2	253,9	-	221,5	233,2	265
230	281,6	90	162,6	281,2	-	243,4	257	294,2
250	290,2	140,9	197,5	289,9	-	260,4	271,1	300

Let's determine the interval of change in the EB load in the first and second methods of calculating load distribution. Suppose that $\Delta P^- < \Delta P^+$. When calculating by the first method:

- нижнее граничное значение нагрузки $(\underline{P})$ в соответствии с формулой (6) будет равно:

$$\underline{P^{(1)}} = P_{ave} + \Delta P^{-} \cdot b_{min}$$

- верхнее граничное значение нагрузки $(\overline{P})$ в соответствии с формулой (7) будет равно:

$$\overline{P^{(1)}} = P_{ave} + \Delta P^{-} \cdot b_{max}$$

- the value of the load change interval is calculated by the formula:

$$\Delta_1 = \overline{P^{(1)}} - \underline{P^{(1)}} = \Delta P^{-}(b_{max} - b_{min} \quad (10)$$

When working in the second (2) method, the value of the load change interval (Δ_2) is calculated by the formula:

$$\Delta_2 = \overline{P^{(2)}} - \underline{P^{(2)}} = \Delta P^{-} \left[\frac{b_{max} - b_{min}}{b_{min}}\right] \quad (11)$$

Let's determine the degree of change of EB load interval from the ratio Δ_2 and Δ_1

$$\frac{\Delta_2}{\Delta_1} = b_{min}^{-1} \quad (12)$$

Thus, the load variation interval increases by a factor of $|b_{max}^{-1}| = \frac{1}{0.675} = 1.48$

If $\Delta P^{-} > \Delta P^{+}$, then similar calculations allow us to establish that,

$$\frac{\Delta_2}{\Delta_1} = b_{max}^{-1} = \frac{1}{0.309} = 3.23 \quad (13)$$

The significant excess of (Δ_2) over Δ_1 indicates the undoubted economic advantages of the second method.

III. Results

Evaluating the effectiveness of an intuitive approach to load distribution.

Analysis of the relationship between the average load of power units (P_{ave}) with the specific consumption of equivalent fuel (S_f) and with the integral indicator of the technical condition of power units (In), i.e. P_{ave}=f1(S_f) and P_{ave} =f2(In) allows us to judge the features of the existing approach to load distribution between power units of thermal power plants. We will evaluate this relationship by comparing the values of $P_{ave,i}$, ranked in descending order of significance, with S_f and with In [11].

The results of ranking P_{ave}, S_f and In_i power units by month of the year are given in **Table** 4.

Table 4: Information on the relationship of $P_{ave,i}$ with S_f and with In_i

Month of year	Indicators	Power unit number in the order of TEI deterioration							
1	P_{ave}	1	4	8	3	disabled	6	7	2
	In	8	4	1	7	disabled	6	3	2
	S_f	1	8	6	7	disabled	4	3	2
2	P_{ave}	1	7	8	4	disabled	2	6	3
	In	1	8	7	2	disabled	6	4	3
	S_f	1	8	7	4	disabled	2	6	3
3	P_{ave}	7	1	8	4	disabled	2	6	3
	In	1	7	7	6	disabled	2	3	4
	S_f	1	8	7	4	disabled	2	3	6
4	P_{ave}	7	disabled	4	1	disabled	8	3	6
	In	4	disabled	7	7	disabled	8	3	6
	S_f	1	disabled	1	8	disabled	4	3	6
5	P_{ave}	8	disabled	1	4	disabled	disabled	3	7
	In	8	disabled	3	1	disabled	disabled	4	7
	S_f	8	disabled	1	4	disabled	disabled	3	7
6	P_{ave}	1	7	3	disabled	2	disabled	8	5
	In	1	7	3	disabled	8	disabled	2	5
	S_f	7	1	3	disabled	8	disabled	2	5
7	P_{ave}	4	5	1	2	7	disabled	3	disabled
	In	7	4	2	1	3	disabled	5	disabled
	S_f	7	1	2	4	5	disabled	3	disabled
8	P_{ave}	1	5	2	6	3	7	4	disabled
	In	1	7	5	2	3	4	6	disabled
	S_f	7	3	2	1	4	5	6	disabled
9	P_{ave}	1	5	4	6	3	2	7	8
	In	4	2	7	1	3	6	5	8
	S_f	7	1	6	2	4	5	3	8
10	P_{ave}	4	8	7	3	5	disabled	2	1
	In	7	8	4	3	1	disabled	2	5
	S_f	7	3	2	1	4	disabled	6	5
11	P_{ave}	7	3	4	2	1	disabled	8	5
	In	8	7	1	2	8	disabled	4	5
	S_f	3	1	2	3	7	disabled	4	5

Analysis of the data in this table shows:

1. On an intuitive level, based on experience in operating power units:
   - The highest load P_{ave}^{max} at power units with the best technical condition is set only in 36.4% of cases;
   - The lowest load P_{ave}^{min} is set at power units with the worst technical condition of 77.8%;
   - In general, the coincidence of load distributions on the power unit with the integral characteristic of its technical condition is observed in 34.2%.
2. If the value of specific consumption of fuel equivalent is taken as the basis for load distribution, then:
   - The highest load of the power unit coincides with the lowest value of specific fuel consumption only in 27.3% of cases;
   - The lowest load of the power unit coincides with the highest value of specific fuel

consumption in 77.8% of cases;

- In the general case, the coincidence of load distributions between power units with the distribution of specific fuel consumption of a power unit is 30.1%.

Thus, operational data show that at load distribution between power units the degree of intuitive consideration of their reliability and efficiency and the degree of consideration of only the value of specific consumption of fuel equivalent is practically not different and amounts to about 30%. In this case, naturally, the question arises about interchangeability of the integral indicator and specific consumption of fuel equivalent arises [12]. According to the data of **Table** 4 it is easy to establish that coincidence of serial numbers of power units ranked by P_{ave}, In and S_f indicators is observed only in 16.4% of cases, of which in 58% of cases coincidence takes place at the worst power unit. And without taking into account these power units the coincidence takes place only in 6.9% of cases. These calculations show that both indicators (In and S_f) cannot be interchangeable and, first of all, because they are independent [13].

The above-mentioned indicates large reserves of thermal efficiency allowing to reduce the specific consumption of conditional fuel by eliminating the shortcomings of maintenance.

IV. Discussion

The results of power units ranking by average monthly values of TEI show:

- When distributing the load between power units, the degree of intuitive consideration of their reliability (technical condition) and efficiency (specific fuel equivalent consumption) and the degree of consideration of only the efficiency of operation are approximately the same and equal to 34.2%, in other words, the technical condition is practically not taken into account;
- The minimum load of the most "bad" power unit (power unit with the maximum value of the integral index) is observed in 77.8% of cases, and the maximum load of the most "good" power unit (power unit with the minimum value of the integral index) - in 36% of cases;
- The economic effect of load distribution using the recommended method (with seven or eight power units operating) is approximately 0.2÷0.5% of the total fuel costs.

References

[1] Farkhadzade, E.M., Muradaliev, A.Z., Rafieva, T.K. Development of methods for planning the restoration of the technical condition of power unit devices // - Moscow: Electric Stations. – 2007. No. 4, - p. 17-21.

[2] Dyakov, A.F., Isamukhamedov, Ya.Sh. Current state of the Russian electric power industry and factors reducing the reliability of power supply // Methodological issues in studying the reliability of large energy systems. Issue 63. Problems of reliability of energy systems in market conditions, - Baku: - 2013, - p. 7-15.

[3] STO-34.01-35-001-2020. Guidelines for the technical examination of substation equipment, power lines. "Rosseti", 2020, 20p.

[4] Akimova, G.P. Methodological approach to determining the influence of the human factor on the performance of information systems / G.P. Akimova, A.V. Soloviev, E.V. Pashkina. - Moscow: Proceedings of ISA RAS, - v.27. -2007. - With. 102-117.

[5] Farkhadzade E.M., Farzaliev Yu.Z., Muradaliev A.Z. Method and algorithm for ranking boiler installations of block power plants according to the criterion of reliability and efficiency of operation // - Moscow: Teploenergetika, - 2015. No. 10, - p. 22-29.

[6] Farkhadzade E.M., Muradaliev A.Z., Farzaliev Yu.Z. Ranking of power units of power

plants according to the reliability and efficiency of their operation // - Baku: Problems of Energy, - 2014. No. 2, - p. 8-16.

[7] Potrebich, A.A. Integrated system for solving technological problems of IASU PES // - Electric Power Plants, - Moscow: - 2001. No. 8, - p. 28-31.

[8] Makoklyuev, B.I., Polizharov, A.S. Information systems for solving technological problems at power facilities // - Moscow: Energetik, - 2007. No. 8, - p. 35-38.

[9] Yagovkin, G.N., Yagovkin, N.G., Panyukova, S.A. Reliability management in the implementation of the maintenance and repair strategy in power supply systems // - Moscow: Industrial Energy, - 2010. No. 9, - p. 12-15.

[10] Farhadzadeh, E.M., Muradaliyev, A.Z., Farzaliyev, Y.Z. To the question on distribution of loading between power units TPS // Journal of «Reliability: Theory&applications», – USA: RT&A (Vol.10 No.2(37), - 2015. June; - pp. 42-49.

[11] Farkhadzadeh, E.M. Automated analysis of a fleet of switches / E.M. Farkhadzade, A.Z. Muradaliev, T.K. Rafieva, S.A. Abdullaeva // Energetik, - Moscow: - 2014. No. 5, p. 11-15.

[12] Duel, M.A. Automation of determination of energy characteristics of power equipment / M.A. Duel, G.I. Kanyuk, T.N. Fursova, E.N. Bliznichenko // energy saving, energy, energy audit - Kyiv: - 2013. No. 2(108), - pp. 13-19.

[13] RD 34.09.454 Standard algorithm for calculating the technical and economic indicators of condensing power units with a capacity of 300, 500, 800 and 1200 MW // - Moscow: part 1, VTI Soyuz Techenergo. Date of update - 2016. - p. 37.