TO THE QUESTION ON DISTRIBUTION OF LOADING BETWEEN POWER UNITS TES

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

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Azerbaijan Scientific-Research and Design-Prospecting Institute of Energetic
AZ1012, Ave. H.Zardabi-94

e-mail:fem1939@rambler.ru

ABSTRACT

Practical realization of existing programs of calculation of distribution of loading between power units TES being in working order demands authentic power characteristics. In conditions of increasing ageing the core and auxiliaries of power units, maintenance of reliability of power characteristics in itself represents serious problems. The method of distribution of loadings between power units TES in view of their technical condition, based on registered technical and economic parameters is developed. Practical approbation of this method testifies to essential advantage of a recommended method, as in comparison with uniform distribution of loading between power units, and in comparison with the intuitive approach to distribution of loading.

INTRODUCTION

A problem of distribution of loading between the same power units (EB) TES well-known [1]. Corresponding algorithms and programs of calculation are developed. Practical realization demands, first, authentic power characteristics, that in conditions of increasing ageing the core and auxiliaries EB in it represents a serious problem [2]. In this connection heuristic approach when because of an operational experience, loading EB appointed seldom applied.

In these conditions, the great value got with methodical support to management TES in the form of recommendations on expedient distribution of loading between EB depending on reliability and profitability of their work.

These recommendations received by estimations of integrated parameters (B) reliability and the profitability of work EB calculated on actual values of technical and economic parameters EB TES [3]. We shall notice that desire simultaneously to raise reliability and profitability of work in some cases is amazing, since for maintenance of reliability of work additional expenses are required. In addition, it is true. However, in considered statement it is a question only of operational expenses, which at greater reliability, naturally, is less.

Method of calculation of distribution of loadings. As initial data for calculations serve:

n - the general number same EB
n_b – number being in working order EB, $n_b \leq n$;
$P_{min,\,s}$ – minimally safe load EB;
$P_{пом}$ – rated power EB;

In – an integrated parameter of reliability and profitability of work EB;
P_{av}=P ∑/n_b – average loading on one EB, where P - loading TES;

Calculation of distribution of loading between n_b EB spent in following sequence:

1. The relative size of factors of the importance of the technical condition (TC) i-th EB under the formula defined

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

where i=1, n_b; $B_\Sigma = \sum_{i=1}^{n_b^+} B_i^+ = \left|\sum_{j=1}^{n_b^-} B_j^-\right|$; B^+ и B^- -accordingly, positive (+) and negative (-) values B_i; n_b^+ and n_b^- - accordingly number being in working order EB with B^+ и B^-;

2. Are defined minimal (b_{min}) and maximal (b_{max}) value of realizations of an integrated parameter b_i under formulas:

$$b_{min} = \min(b_1, b_2, \ldots \ldots b_{nb}) \tag{2}$$
$$b_{max} = \max(b_1, b_2, \ldots \ldots b_{nb}) \tag{3}$$

It is obvious, that b_{min} <0, and b_{max}> 0;

3. Intervals of possible decrease are defined (ΔP^-) and increases (ΔP^+) average loading EB under formulas

$$\Delta P^- = P_{cp} - P_{min,\, s} \tag{4}$$
$$\Delta P^+ = P_{пом} - P_a \tag{5}$$

4. If $\Delta P^- \le \Delta P^+$ calculation of distribution of loadings between n_b EB in view of their reliability and profitability is spent under the formula:

$$P_i = P_{av} + \Delta P^- \cdot b_i \tag{6}$$

5 If $\Delta P^- > \Delta P^+$, under the formula:

$$P_i = P_{av} + \Delta P^+ \, b_i \tag{7}$$

EXAMPLES OF CALCULATION OF DISTRIBUTION OF LOADING BETWEEN EB TES IN VIEW OF THEIR TC

1. On fig.1 the fragment of monthly result of the analysis of technical and economic parameters and recommendations in the basic directions of increase of overall performance EB is resulted.

The basic directions of increase of an overall performance of power units in __ month 20__ year

Results of calculations have allowed to establish and recommend:

1. Technical and economic parameters of power units (EB), not meeting shown requirements for _________ month

EB	Technical and economic parameters			
	The name	Relative deviation	Actual value	Recommended value
2	The maximal electric loading	**-1,439**	220,00	270,00
	Share el. energy for own needs	**-1,333**	5,50	4,10
	Average loading	**-1,330**	160,00	179,29
	Operating ratio established capacities	**-1,310**	11,10	44,84
	The specific charge of conditional fuel	**-1,186**	344,00	329,61
3	The specific charge of conditional fuel	**-1,072**	342,80	329,61
	Operating ratio established capacities	**-0,996**	19,20	44,84
	Share el. energy for own needs	**-0,857**	5,00	4,10
	The maximal electric loading	**-0,571**	250,00	270,00
6	Average loading	**-0,296**	175,00	179,29
7	Average loading	**-0,365**	174,00	179,29

2. Factors of the importance TC EB are equal

EB	1	2	3	4	5	6	7	8
Factor of the importance of the TC	0,486	**-1,318**	**-0,634**	0,482		0,126	0,255	0,604

3. To group "bad" concern 2 and 3 EB. Decrease in their loading in inverse proportion relative sizes of factors of the importance of the TC is recommended.
4. Least effective of operating EB should consider 2 EB. This EB is recommended to switching-off on scheduled repair, and preliminary - in a reserve or to the greatest possible decrease in loading
5. To group "good" concern 8, 1 4, 7, and 6 EB. Increase of their productivity to proportionally relative sizes of factors of the importance of the TC supposed.
6. To the most effective is 8 EB. Its work with as much as possible admissible productivity is expedient.

Fig.1. Fragment of monthly result of the analysis of technical and economic parameters and recommendations in the basic directions of increase of overall performance EB.

2. Results of calculations of relative values of factors b_i under the formula (1) describing TC EB are resulted in table 1

Table 1. Realizations of relative sizes of factors of the importance of TC EB

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

Results of calculations distribution of loading between EB TES for of some values P_{av} are resulted in table 2.

Table 2. Results of calculations distribution of loading between EB TES for of some values P_{av}

Loadings P_{av}, MWt	Conditional numbers of power units							
	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 distribution of loadings between EB shows, that application of formulas (6) and (7), despite of their faultlessness, insufficiently full use adjusting intervals EB (ΔP^+ and ΔP^-). Essentially greater effect turns out, if instead of formulas (6) and (7) to use formulas (8) and (9), looking likes:

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

$$P_i = P_{av} + \Delta P^+ \frac{b_i}{b_{max}} = P_{av} + (P_{nom} - P_{av})\frac{b_i}{b_{bin}} \quad (9)$$

where $i=1,n_b$

Thus the formula 8 is used, if $\Delta P^- / b_{min} \le \Delta P^+ / b_{max}$. If $\Delta P^- / b_{min} > \Delta P^+ / b_{max}$, the formula (9) is used. Results of calculations of distribution of loadings between EB TES under formulas (8) and (9) are resulted in table 3.

Table 3. Recommended distribution of loading of power station between EB for of some values $P_{av.}$

Loadings Pcp, MWt	Conditional numbers of power units							
	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

We shall define an interval of change of loading EB at the first and second ways of calculation of distribution of loadings. We shall assume, that $\Delta P^- \le \Delta P^+$. At calculation by the first way:

- The bottom boundary value of loading $(\underline{P})$ according to the formula (6) will be equal:

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

- The top boundary value of loading $(\overline{P})$ according to the formula (7) will be equal:

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

- The size of an interval of change of loading calculated under the formula:

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

At work as the second (2) ways size of an interval of change of loading (Δ_2) it calculated under the formula:

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

Degree of change of an interval of loading EB we shall define from parity Δ_2 and Δ_1

$$\frac{\Delta_2}{\Delta_1} = b_{min}^{-1} \tag{12}$$

Thus, the interval of change of loading increases in $\left|b_{min}^{-1}\right| = 1/0.675 = 1.48$.

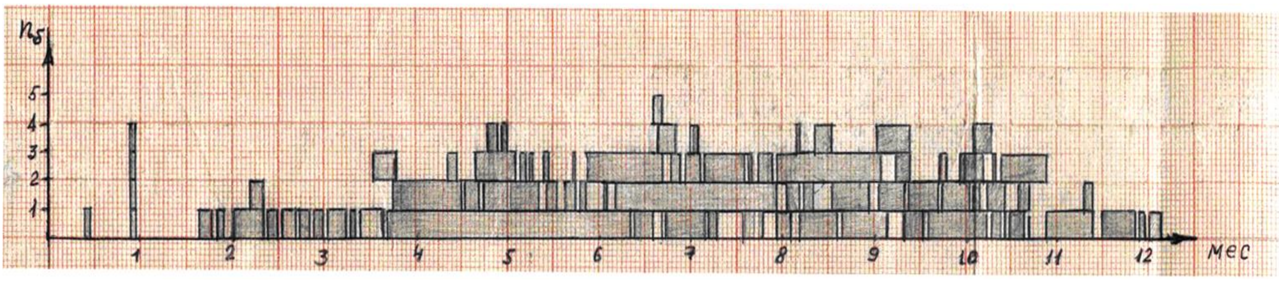
If $\Delta P^{-} > \Delta P^{+}$, similar calculations allow to establish, that

$$\frac{\Delta_2}{\Delta_1} = b_{max}^{-1} = 1/0.309 = 3.23 \tag{13}$$

Essential excess Δ_2 above Δ_1 testifies to doubtless economic advantages of the second way.

ACCOUNT OF CHARACTER OF CHANGE OF NUMBER OF THE POWER UNITS THAT ARE BEING IN WORKING ORDER IN TIME.

As an example on fig.2 dynamics of change n_b within a year is resulted.



As change n_b the casual character caused by automatic switching-off EB, their switching-off under the emergency application, in a reserve or on scheduled repair follows from fig.2 monthly have in many respects. Inclusion and switching-off EB demands revision of distribution of loading between EB. The basic stage thus is the estimation of relative values of integrated parameters (B), describing reliability and profitability of everyone EB. As the initial information for calculation B_i with $i=1,n_\Sigma$ last results of measurement and calculation of technical and economic parameters EB. The special program preparing this information is developed.

It is natural, that at calculations that part of these data which reflects the TC being in working order n_b EB is used only. It is necessary to have in view of, that planned loading PES specified and known not less than for 15 minutes before execution. This feature makes the basic difficulty of operative management of operating modes EB. Fluctuation of loading can be operatively considered at constant sizes B_i c $i=1,n_{\Sigma}$. The block diagram of algorithm of definition of loading EB in view of their reliability and profitability is resulted on fig.3.

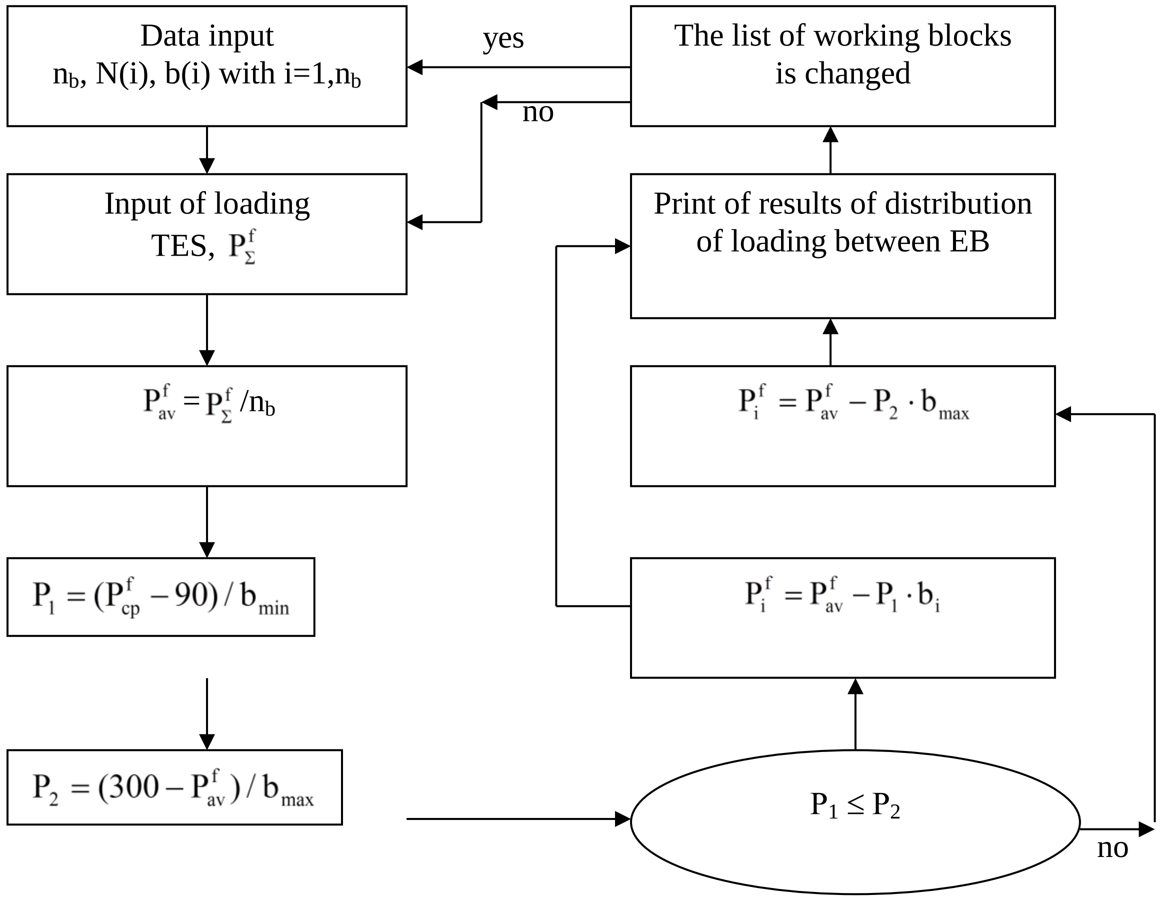


Fig.3 The Block diagram of algorithm of calculation of distribution of loading between EB TES

ESTIMATION OF ECONOMIC EFFICIENCY

The basic purpose of the account of reliability and profitability of work EB at distribution of loading YES, is decrease in operational expenses and first of all, the charge of fuel. The sparing mode of operation insufficiently reliable and economic EB by restriction of their loading allows not only to lower the charge of fuel on TES, but also to reduce speed of deterioration and an idle time in emergency repair. Most operatively and precisely efficiency of the account of reliability and profitability EB can be estimated by calculation of the charge of conditional fuel. We shall consider some features of these calculations.

1. Economic profit (δU_Σ) in the form of relative reduction of size of the charge of fuel can be calculated by comparison of the charge of conditional fuel at identical actual (f) loadings EB equal P^f_{av} (designate it through $U_{\Sigma,1}$) and recommended (r) in view of reliability and profitability of work of loadings EB P^r_{av} (we shall designate it through $U_{\Sigma,2}$).

$$\delta U_{\Sigma} = 100 \frac{U_{\Sigma,1} - U_{\Sigma,2}}{U_{\Sigma,1}} \% \qquad (14)$$

where $U_{\sum,1}$ and $U_{\sum,2}$ can be calculated:

- For each hour (h) daily production schedule TES under the formula:

$$\left. \begin{aligned} u^{(h)}_{\Sigma,1,i} &= P^{(f)}_{av,i} \cdot \Delta t_i \sum_{j=1}^{n_b} U^{(m)}_{av,j} \\ U^{(h)}_{\Sigma,2,i} &= \sum_{j-1}^{n_b} P^{(r)}_{i,j} \cdot U^{(м)}_{av,j} \cdot \Delta t_j \end{aligned} \right\} \qquad (15)$$

where i=1,24; U_j – average value of the specific charge of conditional fuel of j-th EB for preceded month; $\Delta t \le 1$;

- For each day (d) month:

$$\left. \begin{aligned} U^{(d)}_{\Sigma,1} &= \sum_{i=1}^{24} U_{\Sigma,1,i} \\ U^{(d)}_{\Sigma,2} &= \sum_{i=1}^{24} U_{\Sigma,2,i} \end{aligned} \right\} \qquad (16)$$

- For each month (m) year:

$$\left. \begin{aligned} U^{(m)}_{\Sigma,1} &= \sum_{j-1}^{n_b} P^{(f)}_{av,j} \cdot \Delta T_j \cdot U^{(m)}_{av/} \cdot \Delta t_j \\ U^{(m)}_{\Sigma,2} &= \sum_{j-1}^{n_b} P^{(r)}_{av,j} \cdot \Delta T_j \cdot U^{(m)}_{av} \cdot \Delta t_j \end{aligned} \right\} \qquad (17)$$

If to consider, that cost 1 t. conditional fuel on 01.01.2014г. was equal S_0=229$. That economic benefit in cost expression calculated under the formula:

$$S_{\sum} = (U_{\sum,1} - U_{\sum,2})\, S_0 \qquad (18)$$

In table 4 settlement, values are resulted $\delta U_{\sum}$ and $S_{\sum}$ for of some P_{av} for an interval of time 1 hour.

Table 4. Parameters of efficiency of uniform distribution of loadings EB for of some P_{av} and Δt=1hour.

P_{av}	110	130	150	170	190	210	230	250	270
$\delta U_{\sum,}$ %	0,23	0,42	0,54	0,62	0,7	0,75	0,8	0,53	0,3
$S_{\sum,}$ %	137	296,4	433,2	570	707	821	980,4	752	456

As one would expect with increase P_{av} $\delta U_{\sum}$ and $S_{\sum}$ increase, reach the greatest value equal:

$$P_{av} = \frac{P_{nom} \cdot |b_{min}| + P_{min} \cdot b_{max}}{b_{max} + |b_{min}|} \qquad (19)$$

and further decrease.

According to table.1

$$P_{av.max} = \frac{300 \cdot 0.675 + 90 \cdot 0.309}{0.309 + 0.675} = 234 \text{MWt}$$

Thus, the most economic mode TES takes place, when $P_{av}/n_b = P_{av} = P_{av,max}$. This dependence of change $\delta U_{\Sigma} = f(P_{av})$ and $S_{\Sigma} = f(P_{av})$ it is typical and does not depend on technical and economic parameters. Their change conducts only to change $P_{av,\,max}$.

CONCLUSION

1. The new method of distribution of loadings between power units TES, considering reliability and profitability of each power unit is developed;
2. At formation of structure of working power units, distribution of loading is practically instantly calculated for each step of daily production schedule TES;
3. Change of structure of working power units demands recalculation of factors of the importance of a technical condition;
4. Economic benefit of distribution of loading a recommended method makes approximately 0.45% from total expenses for fuel.

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