A Method And An Algorithm For Comparing The Performance Of Reciprocating Engine Power Plants In Electric Power Systems

E.M. Farhadzadeh*, A.Z. Muradaliyev, S.A. Abdullayeva

Azerbaijan Scientific-Research and Design-Prospecting Power Engineering Institute, Baku, the Republic of Azerbaijan

Abstract — **An increase in the performance of thermal power plants is the most important and pressing issue. Its importance is due to both a permanent rise in the fuel cost and an increase in the fleet of equipment whose service life has expired. In this context, traditional methods designed to maintain the efficient operation of the equipment call for improvement. A good example of that is the recommendations of operating rules and regulations, which suggest establishing the amount of planned maintenance based on the technical condition of the equipment rather than on a set periodicity. This increases the significance of measurements of the equipment diagnostic parameters and justifies the transition to the equipment longevity parameters. Intensive aging leads to an intensive change in energy characteristics of power units and a growing risk of their being improperly loaded. The improvement in the methods of quantitative estimation of plant performance tends to lower the risk of a wrong solution. Some operational problems, however, today are still solved at a qualitative level. These include the identification of significant kinds of attributes, i.e. significant factors influencing the performance; an estimation of the parameters of individual reliability, i.e. reliability of specific equipment; ranking the same equipment according to performance; an assessment of the repair quality, and some others. The improvement in the methods for solving these problems reduces the risk of erroneous solutions, and in the end, decreases the operational costs and enhances the overall performance.**

One of the most important facilities in electric power systems is a reciprocating engine power plant (REPP). The undoubted advantages of these plants are mobility, environmental compatibility, reliability, and cost-effectiveness of operation. There are however neither data on the experience of their operation, nor the methods of comparing their efficiency. The paper presents a method and an algorithm for periodic (monthly) comparison of the performance of large-power reciprocating engine power plants manufactured by Wartsila (Finland) by calculating an integrated index of the significance of realizations of monthly average values of technical and economic indices (TEIs). As a result, the Heads of these power plants (PPs) and the Management of the electric power system are provided with the data on technical and economic indices and receive recommendations for increasing the performance of the plant as methodological support.

Index Terms — **Method, algorithm, periodicity, comparison, efficiency, performance, reliability, profitability, reciprocating engine power plant, methodological support, recommendations.**

I. INTRODUCTION

In the current context, characterized by an increasing fleet of aging equipment in electric power systems and a rising fuel cost, the importance of enhancing the performance of thermal power plants (TPPs) increases greatly. [1].

The known methods for solving this problem requires considerable additional expenses, which are not always available [2]. Significant success here can be reached by switching from qualitative estimations of solutions to the

* Corresponding author.
E-mail: elmeht@rambler.ru

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problems of operation (organization of maintenance service and repair of worn pieces of equipment) to quantitative estimations, and by improving the methods for comparing the performance of thermal power plants (TPPs).

Traditionally, such a comparison is based on one of the basic technical and economic indices (TEIs). As a rule, this is the actual value or deviation between the design and actual values of the specific reference fuel consumption. Besides, according to [3], the correctness of the methods of calculating the specific reference fuel consumption has been disputed since the times of GOELRO (Russia's electrification plan). There have been about ten techniques, each of which purports to be the most exact. The paradox, however, lies in that we cannot check whether a technique is "correct" or "incorrect". An analysis of foreign experience shows that power engineers in other countries encounter similar problems.

In European countries, the comparison of economic efficiency in a broad sense is defined by the term benchmarking [4]. Benchmarking is a system of methods to achieve the highest results by comparing the considered objects. Benchmarking is not a single action. It is a continuous process.

This method, however, is not sufficient to consider the reliability of the TPPs operation. Therefore, the risk of erroneously solving operational problems can be significant. Consideration of the reliability of operation requires the comparison of corresponding thermal power plants. Here we encounter difficulties in simultaneously considering several thermal power plants. The calculation of an integrated index can help to overcome these difficulties.

Specific features of the integrated index calculation. The basic difficulties in estimating the integrated index include:

- The difference in measurement units of technical-economic indices (TEIs). It is impossible to sum specific reference fuel consumption, which is measured in g/kWh, and electricity output (in MWh);
- The difference in the dimensions of the main TEIs. There is no point in summing the duration of the forced outage (t_e), measured in hours, and service life (T_{sl}), measured in years. Conversion of measurement Tsl into hours does not solve the issue, since $T_{sl} >> t_e$. The difference in the TEIs is also observed for relative magnitudes. For example, the relative magnitude of auxiliary power consumption is estimated in units of percentage points while the capacity factor- in tens of percentage points;
- The difference in the TEI measurement directions. An increase in the capacity utilization factor is indicative of an increase in the power plant performance, while a rise in the auxiliary power consumption is evidence to its decrease;
- The interrelation of changes in some TEIs. For example, an increase in electricity output within a set time interval leads to a decrease in the specific reference fuel consumption, whereas an increase in the capacity utilization factor results in a rise in the conventional number of operation hours with rated power. The presence of interrelated TEIs leads to errors in the estimation of an integrated index;
- A short period (a month, quarter, week, shift) during which the comparable TEIs are measured. The smaller the time interval during which the thermal power plant performance is compared, the higher the effect due to a decrease in the risk of erroneous solution. The short control intervals, however, not only reduce the accuracy of TEI estimations but also exclude the possibility of using individual parameters. Even for a monthly interval, it is impossible to calculate such reliability parameters as availability factor,utilization coefficient, the failure probability of power unit when started, etc.;
- A potential difference in production processes leads to a difference in TEIs characterizing them, and consequently, to a decreasein the number of TEIssimultaneously characterizingthe power plants compared;
- The difference in the significance of the absolute magnitudes of TEIs. For example, the significance of specific reference fuel consumption and the significance of auxiliary power consumption differ greatly.
- A considerable divergence between the lower and (or) upper possible values of TEI. The use of the TEI "electricity output" to characterize the comparable power plants with different rated power leads to a high risk of an erroneous solution;
- The used TEIs should characterize the performance of all compared power plants. The employment of TEI "specific reference fuel consumptionfor electricity production" is inadmissible when comparing the performance of thermal power plants and hydropower plants;
- Insignificant variations in the values of individual TEIs of compared power plants. When the power plants are put into service almost simultaneously, it is not advisable to use the TEI "service life" to compare them.

Ranking the power plants in decreasing order of their performance makes it possible to identify the most reliable and economically viable power plants, to find out their "weak points", establish the sequence of using backup capacity, whereas ranking the kinds of the attributes allows determining the most significant factors.

II. Transformation of technical-economic indices of reciprocating engine power plants

This paper presents a method of a quantitative estimation and objective comparison of the performance of reciprocating engine power plants (REPPs) with a simple cycle, which work under semi-peak conditions. Similar to the comparison of REPP performance is the comparison of the performance of the same type 300 MW oil/gas power units of steam-turbine power plants (STPP) [5], and comparison of the performance of their boiler plants [6] and steam turbines [7]. The findings of the comparison show that the transition from intuitive load distribution between the power units to a recommended method alone provides an average annual reduction in the reference fuel consumption from 0.25% to 0.45% [8]. It is worth emphasizing that this concerns power units with the service life essentially exceeding the rated one. In this case, the pace of change in power characteristics is significant, and, therefore, the use of standard methods for calculating the optimal loading of power units is associated with great risk of erroneous solution.

As is known [9], the reciprocating engine power plants have higher efficiency, and a lower level of emissions of harmful substances, compared to other thermal power plants They are more reliable in operation, can work for a long time at partial loading without damage to their technical condition and decrease in performance. The specific gas consumption makes up 256 g/kWh of electric power, and the time between repairs is 12 years.

Some monthly average TEI values characterize these features. The main of these indices are the specific reference fuel consumption (Uf), auxiliary power consumption (Won), actual value of electricity output (W_Σ^{f}), capacity utilization factor ($K_u W_\Sigma^{\mathrm{f}}$ / W_Σ^{r} where $W_\Sigma^{\mathrm{rp}}=P_{rp}\cdot T_M$, P_{rp} is rated power of REPP, Tм is month duration, Tм=730 hr), the number of gas engine units (GEUs) removed from service for emergency repair (n_e) [10].

The TEI calculations also need some nameplate data of power plants. These are the rated power and the number of GEUs at the power plant (P_i and n_i), year of the power plant commissioning ($t_{y,i}$). By way of illustration, Table 1 presents the quantitative estimates of basic monthly average values of TEIs of REPP together with P_i, n_i, and t_i. As noted above, the basic conditions for estimating an integrated index include the interrelation between TEIs and REPP performance, the identity of TEI measurement units and dimensions.

Among monthly average values of TEIs shown and set in Table 1, the magnitudes $t_{y,i}$, W_Σ^{f}, W_{ac}, P_i, n_i and ne do not characterize the REPP performance. Thus, the REPP performance is determined not by the year of power plant commissioning but by the service life calculated as $\Delta t_{sl}=(t_c-t_{y,i})$ where t_c is the current year of REPP operation. Wac is determined, first of all, by the capacity of a power plant and cannot be used for comparison of the power plant performance. The possibility of the use changes when the absolute values Wac are converted to the relative ones under the formula $\delta W_{ac} = W_{ac}/W_\Sigma^{\mathrm{f}}$

Alongside with the capacity utilization factor, to characterize the REPP performance one can use the TEI "monthly average number of capacity utilization hours" (T_u), and for more complete characterization of power plant reliability - the GEU emergency repair time $K_e=n_e/n_i$, where ni is the number of GEUs, ne is the number of GEUs removed from service for emergency repair. Thus, the REPP performance is characterized by the following TEIs: Δt_{sl}, Uf, δW_{ac}, T_u, K_u, and K_e. The results of their quantitative estimation according to Table 1 are given in Table 2.

In [6], the authors propose two methods to overcome the differences in measurement units and dimensions,

Table 1. Some nameplate data and monthly average values of TEIs of REPP

Technical-economic indices (TEIs)	Symbol	Unit of measurement	Reciprocating engine power plant					
			PP1	PP2	PP3	PP4	PP5	PP6
Year of commissioning	t_{yi}	Year	2006	2006	2006	2007	2008	2009
Rated power and number of GEUs	P_i; n_i	MW	8,7x10	8,7x10	8,7x10	8,7x12	16,6x18	8,7x12
Electricity output	W_Σ^{f}	MWh	17.526	20.542	21.176	42.224	95.477	33.373
Auxiliary power consumption	W_{ac}	Thousand kWh	280.8	370.9	428.6	652.5	1.175.2	411.2
Specific reference fuel consumption	U_r	g/kWh	292,3	281,3	274,0	267,0	272,1	276,9
Number of GEUs removed from service for emergency repair	n_e	Piece	3	1	1	1	4	1

Table 2. The monthly average quantitative estimates of TEIs describing the REPP performance

Technical-economic index	Symbol	Unit of measurement	Reciprocating engine power plant					
			PP1	PP2	PP3	PP4	PP5	PS6
Service life	T_{sl}	year	12	12	12	11	10	9
Auxiliary power consumption	δW_{on}	%	1.60	1.81	2.02	1.55	1.23	1.23
Specific reference fuel consumption	U_f	g/kWh	292.2	281.3	274.5	267.0	272.1	276.9
The conventional number of operating hours at rated load	T_u	h.	201	236	243	404	320	319
Capacity utilization factor	K_u	%	27.5	32.3	3.3	55.3	43.8	43.7
Forced outage factor	K_e	%	30	10	10	8.3	22.2	8.3

Table 3. Data on the calculated technical-economic indices of reciprocating engine power plants

№	Index	Symbol	Unit of measurement	Direction of changes	Realization		Length of individual interval	Intervals of change	The importance of an interval	The formula of calculation of a relative deviation
					min	max				
1	Service life	T_{sl}	year	Opposite	0	35	7	≤ 7 8 - 14 15 - 21 22 - 28 > 29	5 4 3 2 1	$\sigma T_{sl} = \frac{T_{sl} - T_{sl}^{min}}{T_{sl}^{max} - T_{sl}^{min}}$
2	Auxiliary power consumption	δW_{ac}	%	Opposite	1.0	3.3	0.5	≤ 1.50 1,51 – 2.00 2.01 – 2.50 2.51 – 3.00 > 3.01	5 4 3 2 1	$\sigma\delta W_{ac} = \frac{\delta W_{ac} - \delta W_{ac}^{min}}{\delta W_{ac}^{max} - \delta W_{ac}^{min}}$
3	Specific reference fuel consumption	U_f	g/kWh	Opposite	260	300	8	≤ 268 269 – 276 277 – 284 285 - 294 > 295	5 4 3 2 1	$\sigma U_f = \frac{U_f - U_f^{min}}{U_f^{max} - U_f^{min}}$
4	Capacity utilization factor	K_u	p.u.	Coincides	0.23	0.70	0.1	≤ 0.33 0.34 – 0.43 0.44 – 0.53 0.54 – 0.63 > 0.64	1 2 3 4 5	$\sigma K_u = \frac{K_u^{max} - K_u}{K_u^{max} - K_u^{min}}$
5	Forced outage factor	K_e	p.u.	Opposite	0	0.5	0.1	≤ 0.10 0.11 – 0.20 0.21 – 0.30 0.31 – 0.40 > 0.41	5 4 3 2 1	$\sigma K_e = \frac{K_e - K_e^{min}}{K_e^{max} - K_e^{min}}$

which are simultaneously considered while comparing TEIs. These are the method based on converting the TEI deviation from the reference value to relative values, and the interval method.

Table 3 presents the data on the direction of changes in TEIs with respect to changes in REPP performance; the minimum and maximum TEI values; the length of a single interval; the calculated boundary values for five TEI variation intervals (the five-point system is assumed for assessing the significance of the TEI actual value); the TEI significances (points), which coincide with the ordinal numbers of the variation intervals in terms of the direction of their change; and the formulas for the calculation of a relative divergence of TEI.

The resulting range of TEI variation is selected by the minimum and maximum values of TEI during the previous year for all considered REPPs, allowing for the difference in the monthly average values of the range of changes in TEI of the considered REPPs by month of the year. For this very range, the length of an individual interval and

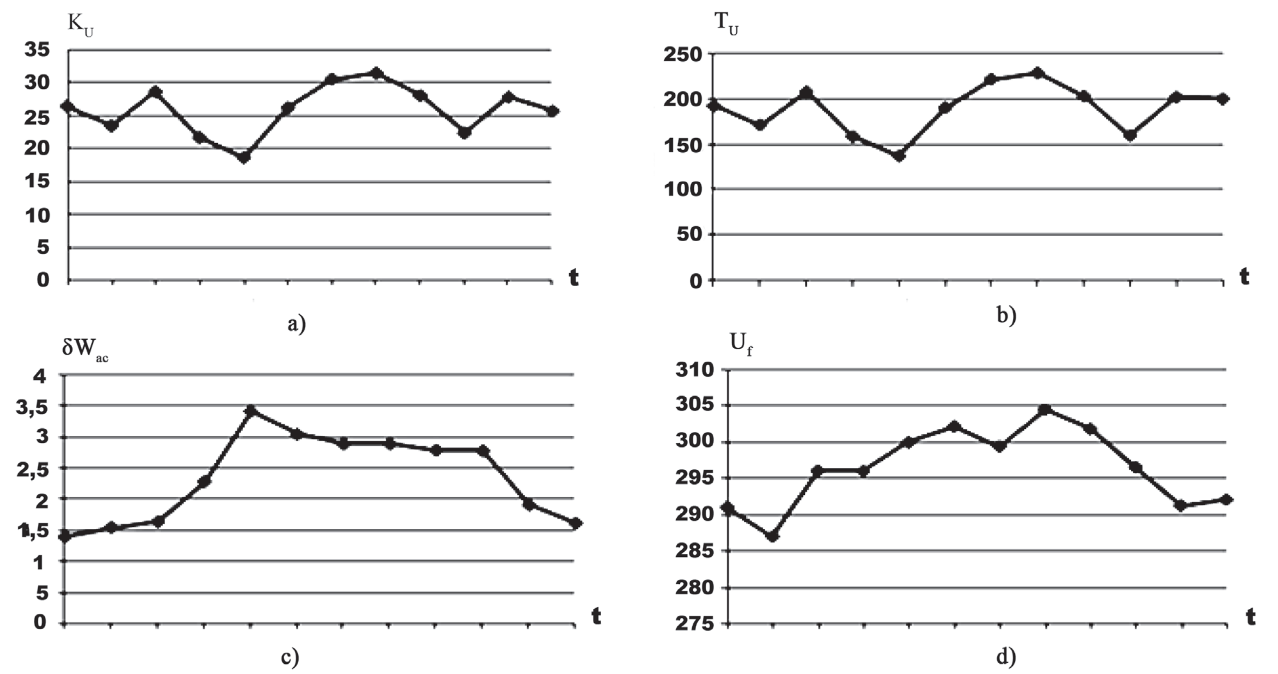

Fig.1. Dynamics of changes in TEIs by month of the year.

boundary values of the variation intervals are calculated.

For illustration, Figure 1(a-d) presents the principles of changes in K_u, T_u, δW_{ac}, and U_f by month of the year. Of interest is the identity of changes in Ku and Tu, some rise in estimates of U_f and δW_{ac} in summer months and reduction in winter months.

Let us consider the interrelation among these TEIs. A necessary condition for the objective estimation of the integrated index is the independence of TEIs [7].

Table 4 presents the calculated coefficients of Pearson correlation (according to Table 5) and Spearman correlation (according to Table 6). Given that for the number of TEI sample realizations equal to 6 the critical value of correlation coefficients for the Pearson and Spearman criteria is identical and equals 0.989, for a significance level of 0.05 [11], one can claim that for the analyzed TEIs, the correlation is significant only for K_u and T_u, which is proved by Figure 1 and formulas of their calculation. This method of the analysis is called a method of solving the inverse problems when the result of one of the comparisons is known in advance, and if it is confirmed, we can trust the other similar calculations made by the algorithm. From the foregoing, it is apparent that the joint use of K_u and T_u for the calculation of an integrated index is pointless.

Thus, the following independent TEIs will be subject to transformation: Δt_{sl}, U_f, δW_{ac}, K_u, and Ke.

III. Results of a performance analysis

Table 5 presents the relative values of TEIs calculated using the formulas given in Table 3. Since the possible deviation of TEIs is calculated with respect to a range of their change, these deviations characterize the extent to which the power plant is worn. The higher the value of the integrated significance of wear, the lower the performance of the power plant. The arithmetic mean for wear is a characteristic of the wear index (Iz(PP)) as a whole. It is obvious, that both In(Iz) and Iz(PP) allow ranking the compared REPPs and assessing the performance of the power plants.

Table 6 presents the results of calculation made by the interval method of estimating the integrated index of TEI significance, the ordinal number of the compared power plants in a ranked series and the estimates of the performance of the considered REPPs.

In [6], the authors show that the results of power plant ranking differ in both methods: since in the interval method the continuous TEI estimates are transformed into discrete ones, the results of ranking the integrated indices of the

Table 4. Estimates of factors of correlation of realizations TEI.

№	Criteria	Ordinal number of TEI					
	Pearson \ Spearman	1	2	3	4	5	6
1	T_{sl}	//////////	-	-	-	-	-
2	δW_{on}	0.877	///////////	0.571	0.557	0.571	0.657
3	U_f	0.401	0.165	///////////	0.214	0.600	-0.029
4	T_u	-0.530	-0.505	-0.849	///////////	0.843	0.557
5	K_u	-0.581	-0.505	-0.849	1	///////////	0.314
6	K_e	0.194	-0.212	0.634	-0.464	-0.465	///////////

Table 5. Results of calculation of monthly average relative deviations of REPP TEIs.

Index	Reciprocating engine power plants					
	PP1	PP2	PP3	PP4	PP5	PP6
Service life	0.343	0.343	0.343	0.314	0.288	0.257
Auxiliary power consumption	0.261	0.352	0.443	0.239	0.100	0.100
Specific reference fuel consumption	0.805	0.533	0.363	0.175	0.300	0.425
Capacity utilization factor	0.904	0.802	0.761	0.313	0.557	0.560
Forced outage factor	0.600	0.200	0.200	0.166	0.444	0.166
Integrated index of wear significance	2.913	2.210	2.210	1.207	1.589	1.508
Integrated index of power plant wear	0.583	0.442	0.424	0.242	0.318	0.302
Power plant ordinal number in a ranked series	6	5	4	1	3	2
Power plant performance	Satisfactory	Satisfactory	Satisfactory	Good	Good	Good

Table 6. Average monthly performance of reciprocating engine power plant.

Index	Reciprocating engine power plant						Total
	PP1	PP2	PP3	PP4	PP5	PP6	
Service life	4	4	4	4	4	4	24
Auxiliary power consumption	4	4	3	4	5	5	25
Specific reference fuel consumption	2	3	4	5	4	4	22
Capacity utilization factor	2	2	2	4	3	3	16
Forced outage factor	3	5	5	5	3	5	26
Integrated index of TEI significance	11	14	14	18	15	17	89
Ordinal number of a power plant in a ranked series	6	4-5	4-5	1	3	2	
Performance	Satisfactory	Satisfactory	Satisfactory	Good	Good	Good	Good

Table 7. A standard deviation and a variation coefficient of monthly average TEI estimates.

Index	Symbol	Unit of measurement	Reciprocating engine power plant					
			PP1	PP2	PP3	PP4	PP5	PP6
Auxiliary power consumption	$\sigma^*[\delta W_{ac}]$	%	0.67	0.67	0.42	0.39	0.25	0.37
	r_{ac}	p.u.	0.28	0.27	0.18	0.2	0.18	0.23
Specific reference fuel consumption	$\sigma^*[U_f]$	g/kWh	4.97	6.60	5.78	3.43	2.88	6.94
	r_f	p.u.	0.015	0.022	0.02	0.013	0.01	0.024
Capacity utilization factor	$\sigma^*[K_u]$	p.u.	3.61	2.80	4.88	3.62	4.41	5.34
	r_u	p.u.	0.13	0.099	0.15	0.066	0.097	0.127
Ordinal number of PP in a ranked series			5-6	3-4	3-4	1-2	1-2	5-6

discrete TEIs significance under a small number of TEIs appear to be somewhat larger. This difference can be seen when comparing Tables 5 and 6.

A great advantage of TEIs measured with a discrete scale is the possibility of their joint use with the TEIs measured by a qualitative scale.

The reciprocating engine power plants can also be classified according to the range of variation in the integrated indices of a series of monthly average values. Table 7 indicates the standard deviation $\sigma^*[\delta W_{ac}]$, $\sigma^*[U_f]$ and $\sigma^*[K_u]$ and variation coefficient of monthly average TEI values $r_{ac} = \sigma^*[\delta W_{ac}] / \delta W_{ac}$, $r_f = \sigma^*[U_f] / U_f$ and $r_u = \sigma^*[K_u] / K_u$ for a year of operation. These data are used to rank the considered power plants. Although earlier we considered the comparison of the performance of power plants during the previous month and based on this comparison recommended ways to enhance their performance, the results of a calculation using the data of TEI variation for a year almost completely coincide. This confirms the statement, according to which a decrease in the power plant performance leads to an increase in the TEI variation. According to Table 7, the greatest variation is observed at PP1 and PP6, average variation - at PP2 and PP3, and an insignificant variation is at PP4 and PP5.

Certainly, the operating personnel of the power plants, as well as the management staff of power plants and power systems do not need to know the details of integrated index calculations. There should be a methodology aimed at assessing the technical condition of power plants, the results of comparing the performance of other similar power plants, and providing the data on "weak points" and other similar data.

At the same time, these data, especially when the number of TEIs is small, cannot be absolutized. The decisions made reflect only the considered TEIs. For example, the TEI list does not include the data on financial capabilities and capacities available for repair work. Although the power plants and power systems are not always provided with necessary means to cope with the wear or they may have no equipment and materials to repair. In some cases, the managers completely agree with the recommendations. This consent in the majority of cases coincides with an intuitive solution, which provides grounds to trust these recommendations even without experts capable to recommend an objective solution to the operational problems.

Below is an example of the results of an automated analysis of monthly average TEI values. Along with TEIs, the presented recommendations include the proposals prepared by corresponding Departments of Management. They can be refined with time and depending on the energy system to be considered.

These results can serve as the basic document to carry out monthly discussion of TEI data recommended by Operating rules and regulations and as the methodological support for the decisions to be made. They (results) are monthly submitted to the Chief engineer of a power system and the Head of the Electricity Generation Department.

IV. Results of an analysis of reciprocating engine power plant performance

1. Initial data on TEIs for the calculated month.

Index	Unit of measurement	Reciprocating engine power plant					
		PP1	PP 2	PP 3	PP 4	PP 5	PP6
Year of commissioning	year	2006	2006	2006	2007	2008	2009
Rated power	MW	87	87	87	104,4	299,25	104,4
Electricity output	MWh	17.526.028	20.542.000	21.176.000	42.224.000	95.477.100	33.373.700
Auxiliary power consumption	MWh %	280.8 (1.60)	370.9 (1.81)	428.6 (2.02)	652.5 (1.55)	1.175.2 (1.23)	411.2 (1.23)
Specific reference fuel consumption	g/kWh	292.17	281.28	274.51	267.02	272.14	276.91
The number of GEUs removed from service for emergency repair	piece	3	1	1	1	4	1

2. Initial data on TEIs for the previous month

Index	Unit of measurement	Reciprocating engine power plant					
		PP1	PP 2	PP 3	PP 4	PP 5	PP6
Electricity output	MW	17.739.49	18.570.000	20.741.000	38.088.000	94.146.400	33.083.600
Auxiliary power consumption	MWh %	335.544 (1.89)	413.731 (2.31)	457.865 (2.21)	735.610 (1.93)	1.220.530 (1.30)	413.024 (1.25)
Specific reference fuel consumption	MWh	293.33	291.21	285.06	269.88	273.25	286.88
The number of GEUs removed from service for emergency repair	g/kWh	3	2	1	2	4	1

3. Results of ranking the power plants according to performance

Index	Month	Reciprocating engine power plant					
		PP1	PP 2	PP 3	PP 4	PP 5	PP6
Ordinal number when ranking the power plants by the data	C	6	5	4	1	3	2
	P	4	5	6	3	1	2
Performance according to the data	C	Satisfactory	Satisfactory	Satisfactory	Good	Good	Good
	P	Satisfactory	Satisfactory	Unsatisfactory	Satisfactory	Satisfactory	Satisfactory
Change in the performance	C→P	NC	NC	IN	IN	IN	IN

Note: C and P are calculated and previous months, respectively; (IN), (DE) and (NC) are an increase, a decrease, or no change in the performance, respectively; C→P - calculated relative to previous.

4. In calculated (C) month:
   - The REPPs with unsatisfactory performance – no
   - The REPPs with satisfactory performance – PP1, PP2, and PP3
   - The REPPs with good and excellent performance – PP4, PP5, and PP6
   - On average, the overall performance of diesel reciprocating engine power plants is estimated to be good.
5. The main TEI limiting REPP performance is the capacity utilization factor.
6. The results of ranking the REPPs according to their performance for the calculated and previous months demonstrate their differences
7. The performance of REPPs in the calculated period
   - increases for PP3, PP4, PP5 and PP6
   - does not change for - PP1 and PS2
8. On average, the performance of the considered REPPs in the calculated month has increased

Recommendations for the improvement of REPP performance. The general recommendations are:

- provide conditions for the use of exhaust gases heat;
- control changes in diagnostic parameters of REPP equipment every month and develop recommendations to increase the reliability of GEU;
- analyze TEIs of REPPs and provide recommendations to enhance the performance of REPPs;
- reduce the pace of equipment wear by improving the professional skills of the personnel;
- maintain an extramural system of professional skill improvement with the intramural one, to control if the qualification of personnel meets the requirements imposed, which makes it advisable to control the availability of an established set of technological normative materials;

Special recommendations are:

- analyze the pace of change in the GEU wear due to poor-quality operational control;
- improve the value of TEI “capacity utilization factor” by fulfilling the requirements of Operating rules and regulations;
- provide a qualitative repair of the worn 4-th GEU at PP1, 2-nd GEU at PP4, 7-th GEU at PP6;
- ensure that the engine oils used at REPPs meet the requirements.

V. Conclusion

1. A method and an algorithm for estimating an integrated index of the overall performance of the reciprocating engine power plants are developed;
2. The integrated index allows:
   - ranking the compared reciprocating engine power plants by performance values that reflect their reliability and economic viability;
   - estimating the performance of reciprocating power plants in the five-point system;
3. A mechanism for the practical use of this method is developed.
4. An increase in the REPP performance is achieved by providing the Management of a power system and power plants with the results of TEI analysis, which represents the necessary methodological support when solving the operational problems;
5. Along with monthly average values of technical and economic indices, of great importance are the ranges of variations in these values. The equality of monthly

average values of TEIs does not mean the equality of the performance of power plants. The larger the variation the worse the technical condition. A decrease in variation leads to an increase in the overall performance.

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Elmar M. Farhadzadeh (Professor, D. Sc.) received the D.Sc. degree from Novosibirsk Electro-Technical Institute in 1982. Currently, he is Head of the Laboratory for Reliability of the Equipment of Electric Power Systems at ASRDPPEI, Baku. His research interests are the reliability and efficiency of electric power systems.

Aydin Z. Muradaliyev is the head of the Department for Reliability of Equipment of Electric Power Systems at ASRDPPEI, Baku. He received the Ph.D. degree in 2013. His research interests include quantitative estimation of the reliability of equipment and devices of electric power systems.

Samira A. Abdullayeva graduated from the Energy Department of the Azerbaijan Oil and Chemistry Institute in 1990. She is a leading engineer of the Department for Reliability of Equipment of Electric Power Systems at ASRDPPEI, Baku. She is a postgraduate student.