Use of Modern Information Technologies to Improve Energy Efficiency of Thermal Power Plant Operation

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Abstract. The report shows the need for the development and implementation of new approaches to operational management of the modes and the efficiency of the equipment of thermal power plants on the basis of modern information technologies to significantly improve the economy of operation of thermal power plants by complex solution of the tasks of block and station levels. The proposed approach is the adjustment of measured parameters, ensuring the accuracy of all the main parameters required for material, heat and energy balances for each unit and the station in general.

1. Introduction
In connection with the big term of operation of production facilities and energy sector and increasing every year failure rate associated with the moral and physical aging equipment, education, technological equipment non-repairable defects, the use of traditional algorithmic methods and models of decision-making and control modes of operation of the equipment is not effective. Accordingly, the development and implementation of new approaches to operational management modes and performance of the equipment, current and predictive diagnostics, optimization of the timing and types of maintenance and remedial repairs to ensure their reliable operation and considerable reduction on maintenance costs is of paramount importance.

In this regard, it is proposed to develop the introduction of more efficient information technologies – namely, technologies for continuous monitoring and diagnostics based on the concept of decision support systems optimal control solutions in real time. The specificity of the system of support of decision-making, operating in real time, is that they are developed on the basis of existing standard tools and strictly focused on a specific subject or problem area. Such subject or problem orientation is due to the fact that intellectual property for them to serve as a knowledge base about entities of managed objects and processes, and "embedded" into the system mechanisms, which correspond to the established processes and decision-making models, the relevant challenges to be solved on the basis of real and reliable information about the current technical and economic status of the study objects.

2. The main approaches to improve energy efficiency of power plants
Studies conducted by a number of organizations and scientists revealed a real opportunity to significantly improve efficiency of operation of thermal power plants by means of complex solutions to the following problems [1, 2]:

- calculation and analysis of deviations of the current technical and economic indicators (TEI) each piece of equipment and the plant as a whole from the regulatory and the development of measures to minimize such deviations (task management TEI);

Technically this system is based on a comparison of the current performance of each element of the power unit, power unit and station in the whole economy from "basic" the same performance (as the "base" can be used: calculated, obtained on the basis of computational studies; the best performance of the investigated object in the previous operation, etc.). The result of this comparison to reveal the "weak" links are determined by their causes, analyze possible options of their elimination, estimated the damage in the continued operation and the costs associated with various options for addressing them, and recommendations on the timing and types of repair or replacement.

- system management operation modes of the equipment and power station at its exit on the market of electricity and capacity, consisting of subsystems: the selection of the optimal composition of the generating equipment and the optimal distribution of thermal and electric load between the generating equipment; the optimization of modes and parameters on aggregate and block levels; selection of optimal technology of power backup units when passing gaps of the load curve;

The method of complex decision of problem of optimal control modes for power plant equipment with a complicated composition of equipment - multi-criteria approach considering criteria of cost, reliability and the environment, with the additional important factor which in the same task is considered for the first time is: the current economic and technical condition of the equipment, and for the first time in world practice, the solution to the dynamic problem of choosing the optimal sequence of downloading/loading of the equipment with the passage of the failures of the loads considering the dynamic losses associated with the transitional and transient modes. In this case, the optimization criterion in addition to achieving minimum fuel consumption (or total fuel cost, the maximum profit stations, etc.) at the station as a whole, to maximize the use of remaining equipment life. This can be achieved if the choice of the generating equipment, particularly when dealing with issues of the passage of the failures of the graphs of energy consumption, in addition to the criteria of economy and reliability, also take into account a factor that characterizes the overall decline of the resource generating equipment, in both the short and long time intervals.

- selection of optimal strategy for repair and maintenance of equipment in view of the current technical condition.

3. Method of correction of measured parameters

The decision of the given task requires rapid calculations of various parameters and performance of the equipment and TPP as a whole using the results from multiple measurements of process parameters. A well-known problem of providing acceptable values of the calculation results is the reliability of the results of measurements of process parameters. As shows operating experience, for a significant number of parameters on thermal power plant measurement accuracy below requirements. However, the analysis of the TEI and optimization of equipment operation modes require a large amount of reliable indicators in this plan requires the development of methods for correction of the measured parameters.

For the correction of measured parameters, the following presuppositions.

1. The process measurements contain systematic and random errors of instrumental and methodological origin of the species and the nature of the origin of the errors is unknown.

2. The limit of permissible error for the $i$-th individual measurement result can be calculated and set by one of the methods [3-5]:

- the accuracy class of the measuring channel of the $i$-th technological parameter;
- the standard uncertainty of type A - obtaining statistical estimates of the variances of the probability distributions based on measurement results of the $i$-th technological parameter;
- the standard uncertainty type B - obtaining dispersions based on non-statistical a priori information of the \( i \)-th technological parameter.

3. For each measuring channel installed within one of the methods of limits of allowable errors, the results of measurement can be any value.

On the basis of accepted assumptions as a criterion of reliability of the results of multiple complex simultaneous measurements of technological parameters \( \{x_1, x_2, \ldots, x_i, \ldots, x_n\} \), we use the natural physico-mathematical condition for the functioning on the time interval of the production technological schemes.

For the TPP these include: the equations of material balance of the systems of transport and distribution between the intra-station unit consumers streams of gaseous fuels, steam and water; equation of heat balance of boilers, turbine generators and other energy conversion installations; the equation of the energy balance of the entire station.

In General, each \( j \)-th equation of the system of balance relations can be written in the form

\[
F_j(\overline{X}) = F_j(x_1, x_2, \ldots, x_i, \ldots, x_n) = 0; \quad j \in 1, m; \quad i \in 1, n;
\]

where: \( \overline{X} \{x_1, x_2, \ldots, x_i, \ldots, x_n\} \) - vector of dimension \( n \) of the true values of technological parameters included in the system of equations (1) \( m \) dimensional.

In practice, the balances usually are not met. The appearance in the equations of balance of residuals \( \Delta F_j \) due to the following reasons.

1. The results of the measurements can be taken at different points in time for different modes of operation of the equipment or one-time, but the technology worked in a dynamic transitional mode.

2. The results of measurements of technological parameters contain errors due to the error of the measurement.

A convincing confirmation of the presence of measurement errors is the occurrence of residuals \( \Delta F_j \) of the balance sheet ratios after the substitution they averaged over a sufficient time interval that is greater than the inertia of the process equipment.

In this case the unbalance \( \Delta F_j \) can be eliminated by the target offset (correction) values of the measured values within their ranges of uncertainty. The system balance relations (1) are performed only by substituting the true values \( x_i \). If they contain absolute measurement error \( \Delta x_i \) due to the accuracy class of the measuring channel,

\[
x_i = x_i^{\prime} + \Delta x_i,
\]

When setting the vector of measured parameters \( \overline{X}^\prime \{x_1^\prime, x_2^\prime, \ldots, x_i^\prime, \ldots, x_n^\prime\} \) in the equation system (1) it will look like:

\[
F(\overline{X}^\prime) = F_j(x_1^\prime, x_2^\prime, \ldots, x_i^\prime, \ldots, x_n^\prime) = \Delta F_j, \quad j \in 1, m; \quad i \in 1, n.
\]

Based on the assumption that the functions of the system (3) is continuous and differentiable in all variables, they can be expanded in a Taylor series in powers of the increments \( \Delta x_i \):

\[
F_j(x_i^\prime, \Delta x_i) \cong F_j(x_i^\prime) + \sum_{i=1}^{N} \frac{\partial F_j(x_i^\prime)}{\partial x_i} \cdot \Delta x_i + \ldots
\]

In the operating conditions compared to the absolute values of the measured values of the increments \( \Delta x_i \) are small (usually \( 1 \)-\( 2 \)%), so you cannot take into account the nonlinear terms of the series, containing as factors the values of higher order \( (\Delta x_i)^k \), where \( k = 2, 3, \ldots \). Then get:
\[ \Delta F_j = F_j(x^a, \Delta x_i) - F_j(x^u) = \sum_{i=1}^{N} a_{j,i} \cdot \Delta x_i, \quad (5) \]

where: \( a_{j,i} = \frac{\partial F(x^u)}{\partial x_i} \) - partial derivatives of the functions (4) for the variable \( x_j \) in point \( x_i^u \).

Values \( \Delta x_i \), can correct the balance equation, can be found from the solution of the problem of optimal distribution

\[ \sum_{i=1}^{N} p_i \cdot (\Delta x_i)^2 \rightarrow \text{min}, \quad (6) \]

or given \( m \) the total constraints

\[ \sum_{i=1}^{N} a_{j,i} \cdot \Delta x_i = \Delta F_j. \quad (7) \]

The weighting factors \( p_i \), that take into account the difference in precision of measurement of the parameters \( x_j \), calculated by the formula:

\[ p_i = \frac{1}{\Delta k_i} \left( 1 - \frac{1}{\sum_{i=1}^{N} \frac{1}{\Delta k_i}} \right), \quad (8) \]

where: \( k_i \) – metrological indicator limit values of the measurement error, calculated for any of the above prerequisites; \( \Delta \) - the range of possible values of the measure and, for example, the scale output of the device measuring the \( i \)-th parameter.

The algorithm is designed to solve the problem of obtaining estimates of the values of technological parameters the results of measurements using system of equations balance relations units and all. The problem of minimizing expression (6) can be solved for any number of measured values. In the expression (6) takes into account the weight of the measurement results during the whole set of required parameter estimates. The solution to (6) is unambiguous, if the balance equations contain all measurement results, i.e. included in constraint equations (7) and mathematical correctness is the singularity of the matrix \( a_{j,i} \) in the equation system (7). This implies that in a real system the number of adjustable parameters, \( n \) should be larger than the number of balance equations \( m \) and to ensure the singularity of the matrix \( a_{j,i} \) retained its coherence. Otherwise, the task is divided into two or more independent tasks.

It should be noted that the evaluation and calculation of performance of technological schemes often require estimates of non-measurable process parameters. These parameters can be introduced in the balance equations and found their indirect evaluation of the proposed algorithm with many adjustable parameters measured. A mathematical procedure for finding values of such parameters will not differ from the calculation of estimates of parameters in measurement results. Not measured parameters minimally affect the results of the correction of the measurement results with the established margin of error, they should set a minimum level of trust, for example, class 4 or above. Their initial values can be taken from operating experience or from the passport or regulatory documents. The number entered in a task estimates are not measured parameters should not be larger than the number of balance equations.
4. Conclusion
The proposed approach provides the necessary adjustment of all basic settings needed for material, heat and energy balances for each unit and for the station as a whole, creating a reliable information base the calculation and analysis of TEI and completion of all the necessary calculations for optimal control of technological processes and modes of operation of power equipment, both at the level of the power plants, and supervisory control.

5. References

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