IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

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To cite this article: M M Sultanov *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **552** 012007

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IOP Conf. Series: Materials Science and Engineering **552** (2019) 012007 doi:10.1088/1757-899X/552/1/012007

Research of dynamic characteristics of signals for calculation of technical and economic indicators and increase in power efficiency of the equipment of thermal power plant

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Abstract. The article is devoted to questions of effective management of the power equipment of a thermal power plant in the conditions of quickly changing operating modes of power systems. The results of a research of dynamic characteristics of the signals used for calculation of technical and economic indicators of the generating sources are given. The analysis is carried out and an assessment of a possibility of increase in efficiency of updating of the current values of technical and economic indicators on the example of package boilers of block and not block thermal power plants is given. The practical recommendations of use of a new approach of measurement of dynamic characteristics of signals for calculation of efficiency of the boiler and change of parameters of operation of the power equipment are formulated.

Keywords: power efficiency, technical and economic indicators, the package boiler, averaging, a mismatch, dynamic characteristics, thermal power plant

1. Introduction

The calculation of various parameters, including technological ones, related to the operation of the equipment, is an important task in the industry and, in particular, in the heat and power industry, where it is necessary to determine the technical and economic indicators (TEI), to assess the quality of the start/stop mode of the equipment, analysis of the water-chemical regime, etc. Performance of certain calculation tasks allows to estimate not only quality of work of the equipment, but also object as a whole, and also to give an assessment to actions of operational personnel that finally affects service life and reliability of work of the equipment [1].

For example, a comprehensive analysis of the start/stop of heat power equipment should contribute to the improvement of the operation technology and improve the technical level of personnel [2]. High-quality water treatment and compliance with the water-chemical regime is a guarantee of reliability and accident-free heat power equipment and heating networks, prevents corrosion damage to the equipment and elements of the network water route, as well as helps to save fuel. TEI calculation provides information to ensure the most economical operation of the equipment, allows to predict its re-

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pair, as well as to assess the quality of the operating personnel, to assess the performance of commissioning and operational tests [3, 4].

On the basis of the corresponding array (operational, shift, daily, monthly) of accumulated values and an array of regulatory and reference information, an array of output indicators (operational, shift, daily and monthly intervals) is formed, which is the result of the calculation of TEI.

In the considered cases, the input data are the values of technological parameters of the equipment obtained from a variety of different sensors (temperature, pressure, etc.). The set of sensors is part of the automatic control system (ACS), and the values of the process parameters that they receive and convert, allow you to create a comprehensive picture of the operating mode of the object under study [5].

The purpose of the APCS is the purposeful management of the technological process, and it includes the following components: operational personnel, information, organizational, software and technical support (see figure 1) [6].

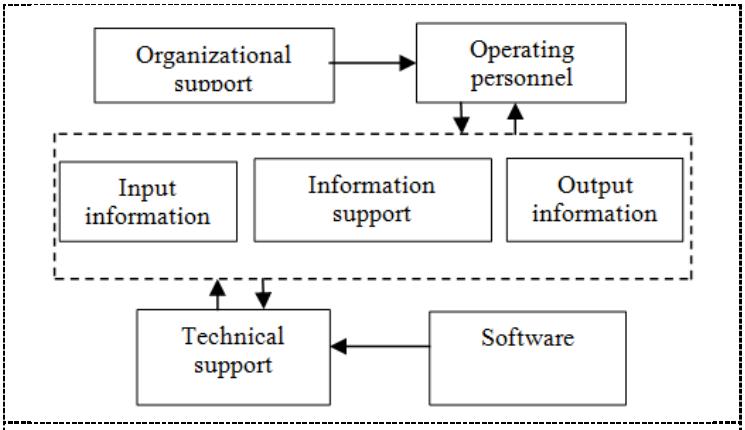

Figure 1. Simplified scheme of interaction of the main elements of ACS TP

There are also software and hardware systems (PTC), which are a comprehensive solution for the creation and interaction of systems of each level of ACS TP (see figure 2) therefore, as a rule, they embrace the entire system, organizing the process of removing and converting analog signals, their transmission, storage, processing and accessing them, control. Server equipment and automated workstations make up the upper level of PTC, which uses its own SCADA-system, but it should be noted that many PTC have the ability to integrate third-party [7].

For the calculation and evaluation of various parameters of the object or the enterprise as a whole at the upper level of the PTC used calculation stations with access to the archive station, recording the values of technological parameters during the operation of the object. As well as SCADA-system, the calculation station can be made in the form of a separate module, independent software (SOFTWARE), and work together with PTC; in this case, it needs to have access to the values of the process parameters of the APCS, which can be implemented in different ways depending on the permissions and functions of the PTC integration:

- reading the archive station directly if it is accessed or not encrypted;
- receiving data from PTC by sending it through the server;
- importing the data.

The need to use a third-party calculation station can be caused by the presence of the necessary functions, user-friendliness of the interface or a more advanced calculation algorithm.

Analysis of the averaging period of initial parameters for calculation of technical and economic indicators

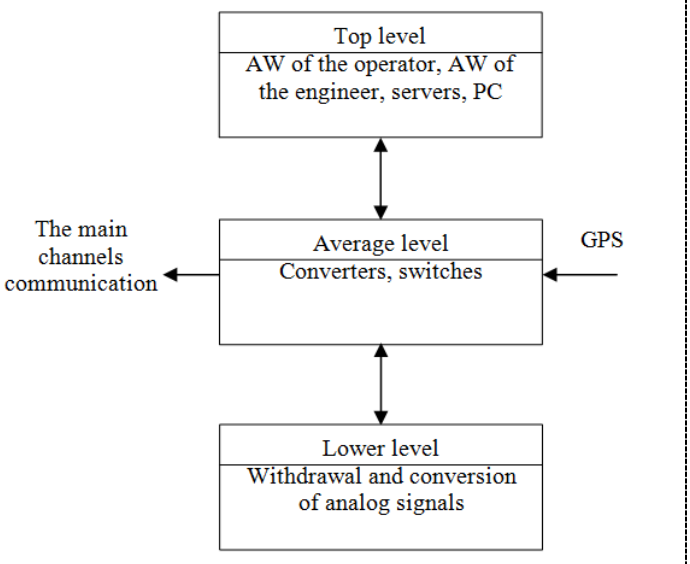

Figure 2. General structural scheme of APCS in power engineering

The questions of increase in power overall performance of a thermal power plant in the conditions of the wholesale market of the electric power and power (OREM) and a fierce competition of the generating sources demand not only search of new methods of development of technological and economic advantages, but providing a rational fuel consumption and an ecological safety of the operating thermal power plants [8]. Influence of service life, indicators of an operation, a repair and, in this regard, change of power characteristics of the power equipment have to be coordinated by questions of ensuring high of reliability level [9] and use of calculation procedures and optimization of an operation of the capital equipment of a thermal power plant. Sufficient attention is paid to researches of mathematical modeling of output characteristics of the equipment of the generating systems [10, 11], questions of calculations and optimization of parameters of management and their errors [12, 13, 14].

In the automated control system (ACS) for power units of a thermal power plant the calculation of the technical and economic indicators (TEI) takes an important place. The results of calculations of TEI allow to create information base for automation of the solution of problems of optimum control of technological process of the equipment of the power unit, including for operational impact on adjustable parameters. It is known that calculation of TEI with use of instant values of the parameters of technological process entering them is incorrect. Between the warmth introduced in a copper fire chamber with the burned fuel, and thermal power of primary and secondary steam there is a time shift because of thermal inertia of the boiler. Averaging of controlled parameters which enter settlement formulas of assessment of TEI is made for compensation of the specified shift. According to [15] calculation of TEI it is made on the values of quick and adjustable parameters average in 15 minutes.

In the analysis of a mismatch the value of the period of averaging two minutes has been determined by time of the current values of technological parameters of the power unit of Konakovo state district power plant for power units with direct-flow coppers optimum [13]. The research of values of parameters of work of a not block thermal power plant with drum coppers conducted on the example of the Volzhskiy TPP shows (see figure 3) existence of a mismatch on time bigger, than for direct-flow package boilers.

Apparently from figure 3, account characteristics of fuel and steam at change of loading of the boiler have a mismatch (see the period 504,5 – 507,8 minutes). The analysis of signals shows that time of a mismatch of input and output parameters of a copper is 2,3 minutes.

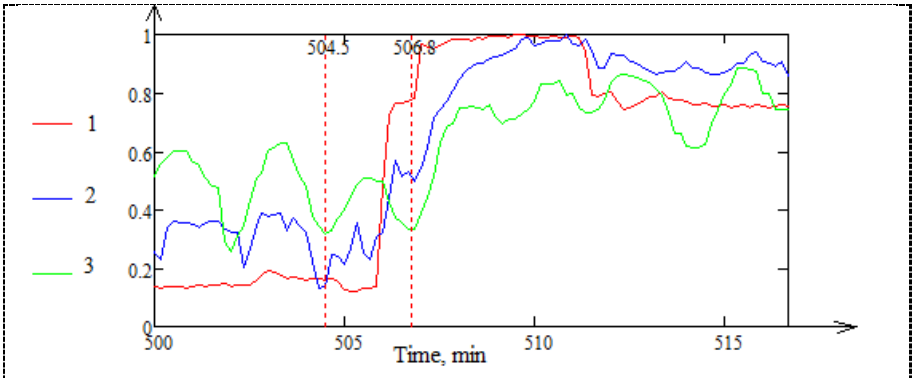

Figure 3. Account characteristics of the boiler, Art. No. 7 of the Volzhskiy TPP: 1 – gas consumption, 2 – the consumption of superheated steam, 3 – a feed water expense

2. Materials and Methods

2.1. Research of algorithms efficiency of averaging of values

The basic data for calculation of TEI are average values of technological parameters. A number of software and hardware complexes, including Kvint-SI, contains the built-in functions of averaging by an arithmetic average, however application of such methods as the sliding average, the digital exponential filter of the first order, etc. is possible [16-19].

The arithmetic average value is often used as an averaging algorithm. However, this way of averaging is subject to strong influence of big deviations. The received average value can not correspond to real "average". When calculating of the sliding average the value of function is calculated every time anew, at the same time the final significant set of the previous values is considered. The exponential filter – the simplest and widespread filter, but having a big delay [20].

The research of a mean square error of a deviation of average values shows that, in relation to values of technological parameters of a thermal power plant, the algorithm of the sliding average has the largest accuracy. Values of errors are presented in table 1.

Table 1. The error of the deviation average from reference values

	Arithmetic average algorithm	**Algorithm of the sliding average**	**Algorithm of the exponential filter**
mean square deviation, %	7,8	37,1	9,0

In figure 4 the results of use of various algorithms of averaging of technological parameters at change of an operating mode of the power unit are given.

The further analysis of the calculation results of TEI was carried out for the values average by an arithmetic average algorithm by criterion of a minimum of a mean square deviation.

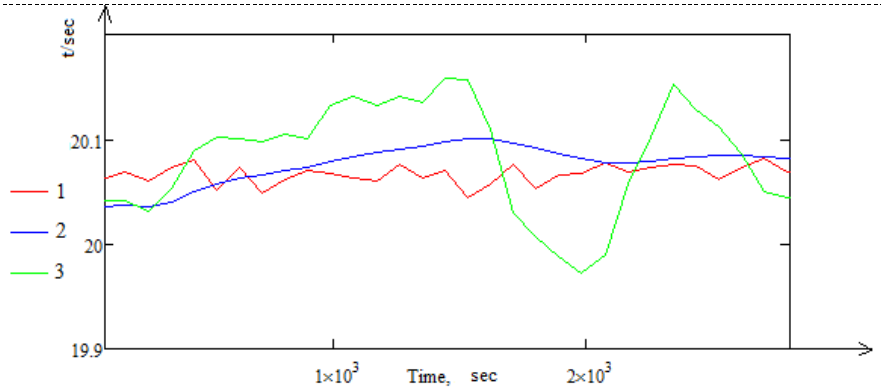

Figure 4. Average Signal of the Gas Consumption: 1 – The gas consumption average by an arithmetic average algorithm, 2 – the gas consumption average by an algorithm of the sliding average, 3 – the gas consumption by an average algorithm of the exponential digital filter

2.2. Calculationerrorof TEI atchange research

Assessment of influence of the period of averaging of initial signals on the result of calculation of TEI has been carried out for the power unit of Konakovo state district power plant [21]. As a key indicator efficiency gross of a copper is used (further ηбр). Calculation ηбр is made with use of functions of determination of specific volume of superheated steam and feedwater, enthalpy of superheated steam, steam of hot and cold intermediate overheating and feedwater, expenses of gas, superheated steam, feedwater, network water behind the reducing cooling installation (RCI). Also in calculation ηбр interpolation of the two-dimensional massif is used.

The calculation algorithm ηбр when determining TEI of power units of Konakovo state district power plant is presented in [22-25].

In figure 5 the comparison of the results of calculation ηбр is shown at averaging intervals of 2 minutes and 15 minutes.

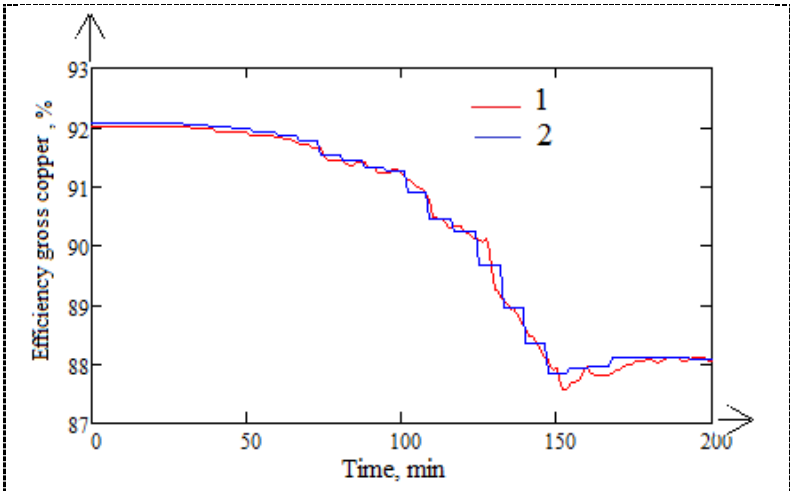

Figure 5. Efficiency gross copper: 1 – an averaging period 2 minutes, 2 - a period of averaging of 15 minutes

It is possible to estimate change of accuracy of calculation of TEI at variation of an interval of averaging a relative dynamic error δд. The mathematical model of calculation of a relative dynamic error

is presented in [13]. The results of calculation of a relative dynamic error ηбр on various periods of averaging are presented in figure 6.

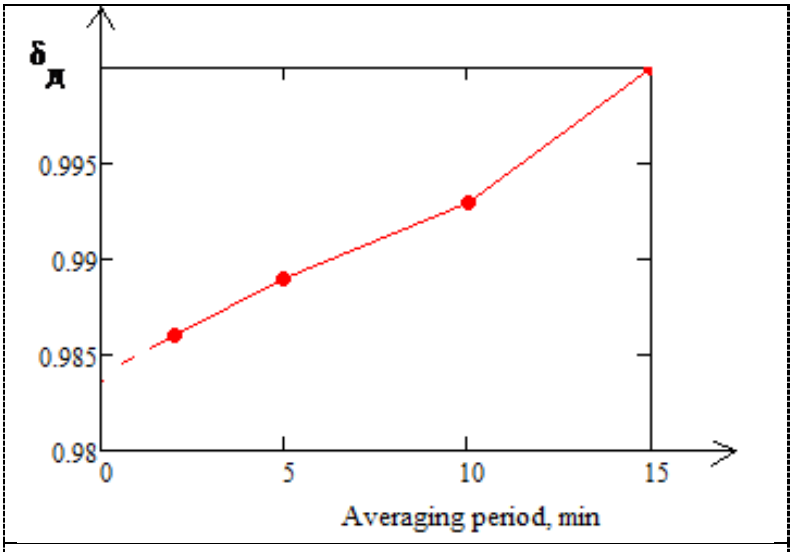

Figure 6. Dependence of a Relative Dynamic Error on the Averaging Period

2.3. Dynamic characteristics of initial signals for calculation of TEIresearch

Measuring information on the basis of which calculation of TEI is carried out represents the values of technological parameters transferred on measuring channels. Owing to influence of production factors and also hindrances, measuring information is stochastic therefore for the analysis and creation of metrological characteristics of system for measurement of TEI it is expedient to use statistical methods. The exponential model of correlation functions of signals and hindrances of a look has been applied to the description of properties of measuring information:

$$K_X(t) = D_x \cdot \exp(-\alpha t),$$

where D_x - dispersion of a signal; α – the speed of change of correlation function of a signal.

3. Results

A type of autocorrelated functions of signals of key parameters of the drum package boiler on the example of a drum copper of the station No. 7 of the Volzhskiy TPP are presented in figure 7. Characteristics of signals are specified in table 2.

Table 2. Characteristics of correlation functions of signals of key parameters of the package boiler

	Feedwater expense	**Gas consumption**	**Superheated steam consumption**
Dx, $(t/h)^2$	125,8	0,5	92,4
α, t/h·s	0,2	10,0	1,0

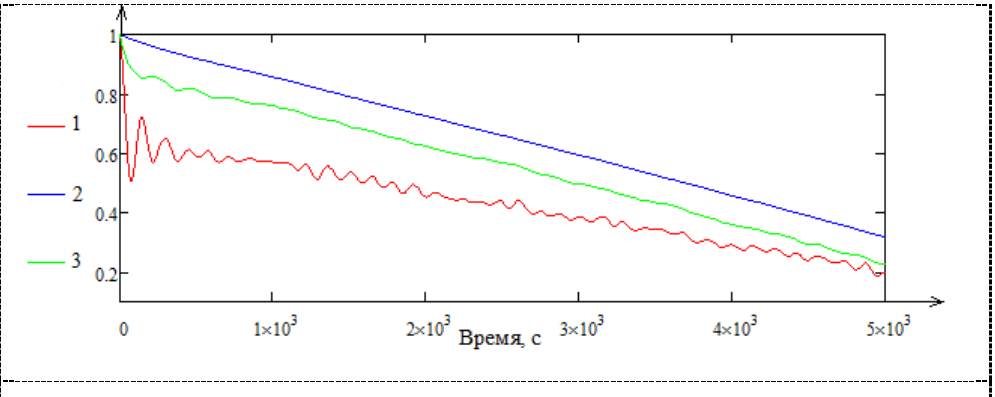

Figure 7. Autocorrelated functions of initial signals of the package boiler: 1 – Autocorrelated function of a signal of an expense of feedwater, 2 – Autocorrelated function of a signal of a consumption of gas, 3 – Autocorrelated function of a signal of superheated steam

The correlation functions describe dynamic characteristics of the corresponding signals and can be used for formation of realization of the signals imitating initial for the purpose of assessment of accuracy of calculation of TEI in various modes.

4. Discussion

Reduction of an interval of averaging will allow to increase the accuracy and efficiency of calculation of TEI for more optimum entering of the correcting influences into an operating mode of the equipment of power units. It will allow to improve, both ecological, and economic indicators of a power plant.

5. Conclusion

1. Providing a rational fuel consumption and technical and ecological safety of the operating thermal power plants is important. It can be reached, including increase in accuracy and efficiency of calculation of technical and economic indicators of a thermal power plant. The conducted researches show a possibility of a reduction period of calculation of TEI from current 15 minutes to 3 minutes.

2. .An assessment of accuracy of various algorithms of averaging in relation to values of initial parameters for calculation of TEI shows optimality of use of an algorithm of average algorithm.

3. The models of the description of properties of measuring information - values of the technological parameters used for calculation of TEI – in the form of correlation functions of an exponential look which can be used for imitation of signals in various rates are received.

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