Assessment models for the generalized quality criterion for the production processes of thermal power plants

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Abstract. In order to increase the information reliability of the hardware and software technology for industrial and environmental monitoring, we obtained models of the thermal power plants production processes that can give an assessment of a generalized quality criterion for the occurrence of such technological processes as the preparation of fuel, fuel combustion, removal of flue gases and suspended particles. To form the measured values of the parameters of each technological process, a multiversion approach is used, which is based on obtaining the n-th amount of measured data.

1. Introduction
There are many different types of power plants in the world. These are, for example, solar, nuclear and hydroelectric power plants, wind generators, thermal power plants (TPPs). Thermal power plants are of power plants type that in the production of electric energy and heat, as a rule, harms the environment and people who are living in the immediate vicinity of thermal power plants [1-3].

Emissions of harmful gases, soot particles, etc. constantly monitored by special monitoring systems of thermal power plants [4]. The creation of such monitoring systems is impossible without the use of special devices: sensors and gas analyzers [5]. The development of these devices is also evolving, and now many of these devices are intelligent enough to make the right decisions about the composition of harmful gases, the volume and size of particles, their temperature and other properties. However, all these devices are located in a very aggressive environment. For example, inside boilers, chimneys, on the components of technological equipment of thermal power plants, which are characterized by complex actuators, automation tools and, often, do not allow sensors and gas analyzers to work without interruption for a long time. Many of them refuse or give false information. However, this information is necessary for automated flue gas monitoring systems to make decisions about the situation happens during technological processes at thermal power plants and the danger degree of the thermal power plants emissions to humans, and most importantly, their environmental impact. From this point of view, improving the information reliability of industrial and environmental monitoring of thermal power plants is an urgent research problem, especially for industrialized regions of the Russian Federation [6].
The present work is devoted to modeling the production processes of thermal power plants that can give an estimate of the generalized criterion of the technological process quality by n-1 inputs and evaluate the allowable range of the n-th parameter values [7-9].

2. Technological processes of thermal power plants
As the main function of thermal power plants, it is possible to single out the production of electric energy by converting heat. Ensuring this function is associated with many technological (production) processes implemented in accordance with their own regulations.

The enlarged technological processes of thermal power plants can be divided into the following types:

- Fuel preparation.
- Burning fuel.
- Discharge of flue gases and suspended particles.

To implement the above technological processes at thermal power plants, a number of special equipment is used, such as:

- Drying plants (figure 1).
- Furnace installations (figure 2).
- Smoke exhaust systems (figure 3).

![Figure 1. Structural diagram of the drying installation: 1 - place of the crude fuel input; 2 - place of the drying agent (steam) input; 3 - sensor installation locations in accordance with the multi-point measurement principle ($t_{11}$, $t_{12}$, $t_{13}$, $w_{11}$, $w_{12}$, $w_{13}$); 4 - sensor installation locations in accordance with the multi-point measurement principle ($t_{21}$, $t_{22}$, $t_{23}$, $w_{21}$, $w_{22}$, $w_{23}$); 5 - place drainage agent; 6 - place of the dry fuel withdrawal.](image)

The structural diagrams of the objects show the sensors locations of a multi-point measuring system, based on which it is required to determine the functional dependences of each technological process parameters [10].
3. Models for assessing a generalized quality criterion

As a result of the study, functional dependencies were obtained that allow expressing a generalized quality criterion in terms of measured parameters of the technological process (formulas 1, 2, 3) and their expected values, as well as possible ranges of accepted values of the quality criterion itself.
Models of production processes for preparing fuel, burning fuel, removing flue gases and dust that for the formation of fuel residue, which will allow us to compare the measured values of the production process (models) as versions in a multi-input system and vote on the set of outputs of the proposed measurement system for significantly increase the reliability of the measured parameters, diagnose failures in the measurement system, according to n-th parameter.

\[
\frac{|T_1 - X_1|}{x_1} + \frac{|T_2 - X_2|}{x_2} + \frac{|W_1 - X_3|}{x_3} + \frac{|W_2 - X_4|}{x_4} = K, \tag{1}
\]

where \(T_1, T_2, W_1, W_2\) – measured process variables;
\(X_1, X_2, X_3, X_4\) – specified values of the technological process parameters (temperature, humidity), characterizing the regulated flow of the fuel preparation technological process (drying of raw fuel);
\(K\) – generalized criterion for the quality of the technological process, according to n-th inputs.

\[
\frac{|C_1 - X_1|}{x_1} + \frac{|T_2 - X_2|}{x_2} + \frac{|T_3 - X_3|}{x_3} = K, \tag{2}
\]

where \(C_1, T_2, T_3\) – measured process variables;
\(X_1, X_2, X_3\) – specified values of the technological process parameters (average oxygen content in flue gases, temperature of the flame and zones of the upper tier active combustion, temperature of the flame and zones of the lower tier active combustion), characterizing the regulated flow of the technological process of burning fuel;
\(K\) – generalized criterion for the quality of the technological process, according to n-th inputs.

\[
\frac{|T_1 - X_1|}{x_1} + \frac{|C_1 - X_2|}{x_2} + \frac{|W_1 - X_3|}{x_3} + \frac{|T_2 - X_4|}{x_4} + \frac{|C_2 - X_5|}{x_5} + \frac{|W_2 - X_6|}{x_6} + \frac{|T_3 - X_7|}{x_7} + \frac{|C_3 - X_8|}{x_8} = K, \tag{3}
\]

where \(T_1, C_1, T_2, C_2, V_1, T_3, C_3\) – measured process variables;
\(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8\) – specified values of the technological process parameters (gas temperature at the sampling points after filtration, concentration of substances and suspended particulate matter after filtration, gas flow rate after filtration, gas temperature at the sampling points before filtration, substance concentration and suspended particulate matter before filtration, substance concentration and the content of suspended particles before filtration, temperature of the exhaust gases, the average oxygen content in the flue gas, can be determined (measured) to obtain objective information on the process flow in an object having a volumetric principle of action), characterizing the regulated flow of the fuel combustion process;
\(K\) – generalized criterion for the quality of the technological process, according to n-th inputs.

It should be clarified that for the formation of each technological process parameters measured values, a multiversion approach is used, based on obtaining the n-th amount of measured data [11]. The resulting value is obtained by voting [12]. Accordingly, we will be able to use the outputs of the proposed models of production processes as versions in a multi-version system and vote on the set of outputs of these models. This approach will help to significantly increase the reliability of the measured parameters, in the case when it is directly impossible to compare their values obtained at various points and under different conditions. It will also help identify equipment failures.

4. Conclusion

Thus, models of production processes for preparing fuel, burning fuel, removing flue gases and suspended particles from a thermal power plant have been developed, capable of evaluating the generalized quality criterion for a technological (production) process by n-th inputs and evaluating the allowable range of values of the n-th parameter.

An approach is presented that consists in using the developed functional dependencies of the production process (models) as versions in the event of the measurement system failure, which will allow us to compare the measured values of various parameters, diagnose failures in the measurement system.

\[
\frac{|T_1 - X_1|}{x_1} + \frac{|T_2 - X_2|}{x_2} + \frac{|W_1 - X_3|}{x_3} + \frac{|W_2 - X_4|}{x_4} = K, \tag{1}
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where \(T_1, T_2, W_1, W_2\) – measured process variables;
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\frac{|C_1 - X_1|}{x_1} + \frac{|C_2 - X_2|}{x_2} + \frac{|T_3 - X_3|}{x_3} = K, \tag{2}
\]

where \(C_1, T_2, T_3\) – measured process variables;
\(X_1, X_2, X_3\) – specified values of the technological process parameters (average oxygen content in flue gases, temperature of the flame and zones of the upper tier active combustion, temperature of the flame and zones of the lower tier active combustion), characterizing the regulated flow of the technological process of burning fuel;
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\frac{|T_1 - X_1|}{x_1} + \frac{|C_1 - X_2|}{x_2} + \frac{|W_1 - X_3|}{x_3} + \frac{|T_2 - X_4|}{x_4} + \frac{|C_2 - X_5|}{x_5} + \frac{|W_2 - X_6|}{x_6} + \frac{|T_3 - X_7|}{x_7} + \frac{|C_3 - X_8|}{x_8} = K, \tag{3}
\]

where \(T_1, C_1, T_2, C_2, V_1, T_3, C_3\) – measured process variables;
\(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8\) – specified values of the technological process parameters (gas temperature at the sampling points after filtration, concentration of substances and suspended particulate matter after filtration, gas flow rate after filtration, gas temperature at the sampling points before filtration, substance concentration and suspended particulate matter before filtration, substance concentration and the content of suspended particles before filtration, temperature of the exhaust gases, the average oxygen content in the flue gas, can be determined (measured) to obtain objective information on the process flow in an object having a volumetric principle of action), characterizing the regulated flow of the fuel combustion process;
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An approach is presented that consists in using the developed functional dependencies of the production process (models) as versions in the event of the measurement system failure, which will allow us to compare the measured values of various parameters, diagnose failures in the measurement system.
systems of each parameter, and increase the reliability of the obtained parameters of the production processes of thermal power plants presented above.

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