A new approach to multi-version decision-making to improve the reliability of environmental monitoring parameters

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Abstract. The article is described a new decision-making algorithm in multi-version environments using the developed process models as versions. It permits to compare the measured values of various parameters and diagnose failures in the measurement systems of each of the parameters. As a whole, it will increase the reliability of the obtained parameters of the technological process. A simulation environment is described, which allows to study the applicability and effectiveness of the proposed model, algorithm, and it obtains to estimates of its characteristics.

1. Introduction

For implementation the provisions of the Climate Doctrine of the Russian Federation [1] and the Orders of the Government and the President of the Russian Federation [2,3], a Concept was developed to form a monitoring, reporting and verification system for greenhouse gas emissions [4]. This document emphasizes that one of the main difficulties in implementing international agreements aimed at implementing the Kyoto Protocol in our country is the lack of reporting on the contribution of specific enterprises (sources of pollution) to the total greenhouse gas emissions, and, accordingly, the inability to track the effectiveness reduction of greenhouse gas emissions by specific enterprises.

In this regard, the need to organize monitoring of anthropogenic emissions of greenhouse gases from sources in the subjects of the Russian Federation is regulated. There is also a need of preparing regional national inventories as well as collecting information about greenhouse gas emissions by the specific enterprises.

2. The method of organizing production and environmental monitoring

One of the first steps to implement an emission monitoring system of the greenhouse gas emission in Russia is an emissions inventory. The experience of international companies [5] have already implemented. In addition, it has shown that taking an inventory of emissions allows reporting to the state regulatory authority, which is currently operating in most developed countries.

The guidelines for conducting voluntary inventory of greenhouse gas emissions in the regions of the Russian Federation was approved by the order of the Ministry of Natural Resources of Russia dated...
04.16.2015 No. 15-p [6]. This document permits the organizations to plan measures for reducing the emissions and monitor effectiveness, and provides an opportunity to carry out the first stage of preparation for entering the European market of emission allowances. Thus, at present, Russia has a regulatory framework that is sufficient for the transition to new environmental principles and, in particular, for introducing a system for monitoring emissions of anthropogenic sources into the atmosphere.

A significant contribution to environmental pollution is made by industrial enterprises; now the main pollutant of atmospheric air is the fuel and energy complex, primarily thermal power plants (TPP). At the same time, boiler plants, with flue gases of which nitrogen, make the main contribution to environmental pollution and sulfur oxides, carbon monoxide, fly ash and other pollutants are released into the atmosphere.

For assessment of a negative impact degree of the thermal power plants (TPP) on the atmosphere three types of monitoring are applied [2]. The term “monitoring the source of pollution” means the second type of monitoring, namely, the monitoring emissions of pollutants on the chimney. In this case, measurement tools can be installed directly on the source of air pollution, such as a chimney, through which the flue gases are discharged into the atmosphere, as a rule, from several boilers.

In accordance with the Federal Law 219 [3], all enterprises of the first category (that is, the majority of large TPP) must be equipped with automatic means for accounting and controlling emissions of pollutants. It is the monitoring of emissions of pollutants in the chimney or the “monitoring of emissions at the source of education” that is emphasized in the Reference document on the general principles of EU monitoring [7], which is designed to implement Directive 96/61 / EU [8]. In development of this Directive, Directive 2010/75 / EU “On Industrial Emissions” [9] was subsequently adopted. Requirements [9] regulate the level of emissions in the European Union and are reflected in most national regulatory documents of EU member states.

In determining the technical requirements for the designed monitoring systems, the necessary measurement frequency and averaging time should be taken into account. In many ways, these indicators determine the choice of method. The continuous monitoring has several advantages, such as the ability:
- to obtain more data and, accordingly, increasing the sample size and the reliability of the results of the analysis;
- to use the obtained data to optimize the combustion processes and, consequently, increase the economic efficiency of the monitoring system;
- to control of excessive emissions and increasing public confidence in the results of monitoring.

In principle, it is possible to make instrumental measurements of the composition of the flue gases in any section of the gas path of the boiler plant, starting from the rotating chamber of the boiler to entering the chimney and even on the chimney itself (figure 1). In the first approximation, the working temperature ranges will determine this for which gas analysis systems are calculated. In practice, at the TPP, the following sections of the gas path are used for instrumental measurements.

Section A-A is the mode section of the boiler. Measurement results in this section is used primarily to regulate the furnace processes, because this section is as close as possible to the firebox, and “local” concentrations of oxygen, carbon monoxide and nitrogen oxides adequately characterize the completeness of the combustion process. Temperatures in the range of 500-700 ° C and speeds in the heating surfaces - 7-15 m / s, which must be taken into account when choosing the type of measuring systems, characterize the parameters of the flue gases in this section, depending on the type of fuel burned.
Section B-B is an extreme section of the gas path of the boiler plant, located behind the exhaust fan with gas temperatures of 120-150 °C. This section, on the contrary, is characterized by maximum remoteness from the boiler furnace, completeness of combustion processes and greater uniformity of concentration and temperature fields of the gas stream.

For mass harmful emissions account from the flue gases of section for the first approximation of the smoke exhauster is the most convenient place in terms of the placement of the measuring systems and their working conditions. It used to account for mass emissions of harmful substances mainly in cases when a small number (1-2) of the boilers is connected to the chimney or if the costs of installing the equipment on the chimney are excessive. At the same time, the consumption of combustion products in this section can be determined either directly (based on the measurement of the velocity of gases) or indirectly (according to the fuel consumption or power output of the boiler).

However, this cross section of the gas path does not permit for the monitoring and diagnostics of fuel burning modes and, accordingly, their regulation in order to optimize the fuel burning modes.

Section C-C is a section on a chimney in which control of the harmful emissions into the atmosphere is possible. A significant advantage of organizing continuous monitoring of harmful emissions on a chimney is that one measuring system allows determining the total mass emissions of all boilers connected to this chimney.

The system of continuous control and accounting of harmful emissions from the thermal power plants should provide continuous, direct and reliable content measurements controlled impurities in the composition of the flue gases during the whole period operating a system of continuous monitoring and accounting of emission-controlled impurities in the composition of the flue gases.

3. The new approach

For solving the problem of increasing the reliability of measurement data, it is proposed to apply the multi-version approach. The high efficiency of the multi-version approach confirmed by many years of successful using in decision problems of this class. However, it can be directly applied only for multipoint measurements of one quantity in one plane, when the values of the measured parameter can be compared. It must coincide with some known faults (spread). At best, the parameter, for example, the temperature of the outgoing gases of the TPP, is measured at different distances from the furnace, from its outlet to the upper segments of the pipe. It is obvious that the readings of these sensors should differ. However, their readings are correlated. Therefore, it is enough to introduce a correction factor or, in a more complex case, a model, and we will be able to compare the reduced values.

Accordingly, we will be able to use the outputs of these models as versions in the multi-version system and vote on the set of outputs of these models. This approach will help increasing the reliability of the measured parameters. In the case when it is not directly possible to compare the values obtained at different points and under different conditions. In addition, it will allow detecting equipment failures.
For example, we know that when the temperature at the outlet of the furnace is 600 degrees and the temperature at the extreme cross section of the gas path of the boiler plant, located behind the exhauster at 135 degrees, the temperature in the pipe should be in the range from 45 to 53 degrees. Therefore, if in this example, the readings of the two sensors correspond to the model, and the third one does not, we declare a high degree of probability that it transmits invalid values.

However, the case of multiple measurements of one size described above is also not always available and feasible for all measured indicators of the process. In this case, we use the proposed new approach to decision making in multi-version environments (systems). This approach permits to compare the measured values of various parameters of production and environmental monitoring.

The approach uses the developed process models as versions, which will make it possible to compare the measured values of various parameters and diagnose failures in the measurement systems of each of the parameters. In general, it permits to increase the reliability of the obtained process parameters. That is, we propose to use not N values of one parameter, for example, temperature, but a set of values of different parameters, for example, temperature, pressure, content of different substances in the supplied and exhaust gas. It should be noted that this is possible only within a single technological process and provided that the values are correlated. The measured parameters affect this process, and consequently, the other parameters and environmental characteristics.

4. The software implementation

For testing the proposed approach, a simulation execution environment has been implemented. It implements 5 process models, receiving as input values 4 of 5 measured parameters. In each of the models one parameter is not taken into account. The environment simulates the outputs of the measurement systems of parameters in the specified ranges and generates faults with a given probability on the form. The “correct” parameter values are stored in a separate data stack. However, they are not used in voting and decision-making, but are needed only to enable verification of the system output. Thus, we can count the number of faults made by the system.

Figure 2 shows the simulation environment interface. The form specifies the reliability of the five measurement systems. According to the simulation results, the faults that occurred in each of the systems, the voting faults (when the maximum class weight was less than half the sum of the version weights) and the faults made by the system (that is, cases where the wrong value passed the output) are calculated.

![Figure 2. A simulation environment modeling.](image)

It is necessary to clarify the difference between the last two types of faults. There may be situations when several measurement systems make a mistake at the same time. In this case, when implementing
a vote the maximum class weight may not get the required value in half the sum of the version weights. Then the result of the vote will be the return of a fault, and not one of the values. However, a situation may occur when the class gains the weight necessary for the voting algorithm, but will contain an incorrect value, which will sent to the output of the system. This situation is extremely unlikely. It is possible only when “interversion” faults occur. This is necessary that several systems not only fail, but also produce matching incorrect.

The system also builds a graph of the magnitude values at each of the iterations of the multiversion voting. On the presented graph, it is clear that versions often return erroneous values but the value at the output of the system is always correct.

In the simulation 500 iterations carried out the results of which calculate the total number of faults in each version, the number of voting faults and faults at the system output. The graph can be built at different scales; in the example in Figure 2, the first 250 points are shown.

The results show each of the versions made dozens of faults, but the correct value always passed to the output of the system. Two times in 500 iterations, the decision-making algorithm returned a voting faults due to the inability to select the correct output. To consider on the used algorithm in more details.

As a decision-making algorithm in the multi-version systems, this software implementation uses the author's modification of a fuzzy weighted algorithm of absolute majority voting. The version weights provided for by this algorithm (necessary for the operation of the algorithm) are, in their sense, an assessment of the quality of the version, and therefore the models it implements. The presence of version weights will allow not only to increase the reliability at the stage of making a decision, but also to obtain estimates of the quality of versions. Thus, we will get additional information that allows us to diagnose the failure of various sensors and systems for collecting indicators.

Using of absolute majority voting caused by the specifics of the measurement data processing system. In the case when less than half of the versions voted for one answer, for example - 2 out of 5, firstly, it is impossible to guarantee the correctness of the answer received, secondly, it is necessary to report a failure that occurred, because inconsistent answers were received from more than half of the versions. In this case, it is already necessary to take corrective action.

The element of fuzzy logic in turn will allow increasing the resistance to measurement inaccuracies and transformations of the measured values. This will allow excluding situations when the answer of one of the versions is considered erroneous due to inaccuracy of measurement, digitization, lack of capacity, etc.

If the obtained indicators differ from each other by no more than the value of the specified tolerance, in this case the indicators will vote for the same class that win the vote with a higher probability. Thus, the fuzzy logic using will increase the overall reliability of the system.

In this software implementation, the weights sum of versions are calculated. The necessary condition for voting by an absolute majority is the weight of the class, exceeding half of the weights sum of all versions.

5. Conclusion
The proposed decision-making approach in multiversion environments using process models as versions makes it possible to compare the measured parameter values, which obtained in different conditions also the values of various parameters. Through using of version weights, the new approach will make it possible to diagnose failures in the measurement systems of each of the parameters and, in general, to increase the reliability of the obtained process parameters.

The simulation-modeling environment implements the resulting software model and a new approach of multi-version fuzzy voting, in order to increase the information reliability and resiliency of the automatic continuous monitoring system and the recording of harmful emissions into the environment. In addition, this permits testing the applicability and effectiveness of the proposed approach.

The results obtained in the simulation environment confirm the high efficiency of the proposed approach.
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