

## Measurement accuracy of real time parameters in environmental monitoring

**M V Saramud<sup>1\*</sup>, I V Kovalev<sup>1,2,3</sup>, D I Kovalev<sup>1</sup>, A A Voroshilova<sup>1,3</sup> and A S Kuztensov<sup>2</sup>**

<sup>1</sup> Reshetnev Siberian State University of Science and Technology, 31, Krasnoyarsky Rabochy Av., Krasnoyarsk, 660037, Russia

<sup>2</sup> Siberian federal university, 79 Svobodny avenue, Krasnoyarsk, 660041, Russia

<sup>3</sup> Krasnoyarsk Science and Technology City Hall of the Russian Union of Scientific and Engineering Associations, 61 Uritskogo street, Krasnoyarsk, 660049, Russia

\*E-mail: msaramud@gmail.com

**Abstract.** The article deals with the problem of environmental monitoring execution in case of thermal power plants impact on the environment. The regulating documents in compliance with which this problem is solved have been provided. The problem of obtaining valid values under multi-metering of environmental monitoring parameters has been described. The method for this problem solution via application of multi-version approach of decision-making has been offered. Simulation environment for the research of the offered approach has been delivered. Results received in the environment have been analyzed.

Implementation of environmental monitoring of exhaust combustion gases from coal-dust thermal power plants is one of the most important ways of implementing the Clause 1.1.7. of "Power facility worker's job responsibilities" of SO 153-34.20.501-2003 ("Rules of technical maintenance of power plants and networks of the Russian Federation") [1], required from each worker:

- to reduce the harmful effect on people and environment;
- to use scientific and technical achievements in order to increase cost-effectiveness, reliability and safety, improve ecology and environment of the power facility.

The main regulatory document which classifies measurements of exhaust gases "Practical guidelines on the scope of technological measurements, alarms, automatic control on thermal power plants" SO 34.35.101-2003 [2] obliges all thermal power plants to exercise continuous control and maintenance of O<sub>2</sub>, CO and NO<sub>x</sub> in combustion gases, as well as in case of ash control, desulphurization and gas purification availability, concentration of oxides of sulfur in terms of SO<sub>2</sub> and concentration of nitrogen oxides in terms of NO<sub>2</sub>.

Currently a large number of domestic enterprises are engaged in development and production of instruments and systems for ecologic monitoring of combustion gases to be used by thermal power plants. The question of equipment provision is required by the Federal law of 21.07.2014 N 219-FL "About introduction of amendments to the Federal law "On Environmental Protection" and separate acts of the Russian Federation" within the program of environmental efficiency of enterprises and setting increased coefficients when calculating costs of negative impact on the environment for legal entities and businessmen who are involved in economic activity to stimulate them to take actions to lower negative impact on the environment.



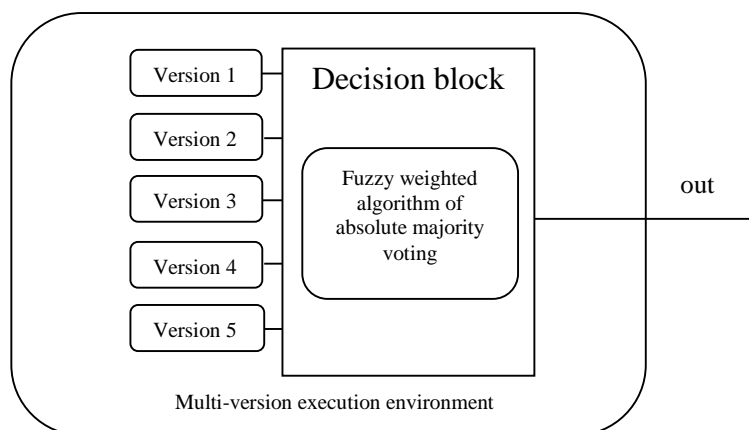
One of solutions to this question is equipping and renovating already existing systems of gas purification and environmental monitoring of combustion gases at coal-dust thermal power plants.

In this context it must be noted that since 2000 developers and vendors of the boiler equipment within the requirements on the scope of continuous measurements of boiler equipment technological parameters define a separate requirement for equipment with means of continuous environmental monitoring of exhaust gases.

In this respect, there is a task to increase reliability of ecologic monitoring data since many power stations were upgraded and the instruments of monitoring have become diversified, both in technical characteristics, on protocol support, and in operation principles. In case of due approach of metrological service to ensure instruments' compliance with metrological characteristics, there is one problem left – the one of valid measured parameter value formation in case of multipoint measurement in one plane surface.

It is also particularly important to conduct monitoring in real time, avoiding a delay in the response of the system. Many processes in production can develop very quickly (transiently) and without a timely response to a change in critical parameters, a catastrophe can occur. Excess pressure, temperature, etc., to which the system has not responded in a timely manner, can cause rupture of the tanks, the transition of the production process to an uncontrolled state, the release of harmful substances and other negative consequences.

For these reasons, the monitoring system must not only be reliable, but also operate in real time. To solve these problems, it is most efficient to use a multi-version real-time execution environment. The real-time mode of operation will provide the required delays, and the multi-version approach will increase system reliability.



**Figure 1.** Applying multi-version approach in multi-point measurements.

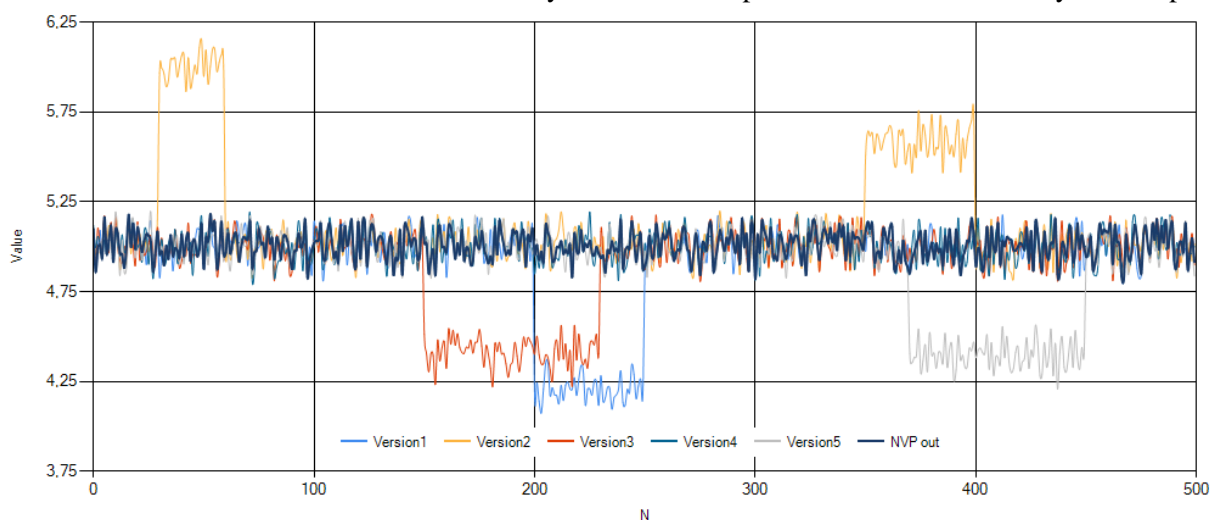
To solve the similar task offered is a multi-version approach [3] in compliance with which multi-point metering is made; decision making is done with the voting block in the multi-version environment [4] (Figure 1). It will allow to receive valid data even in case of one or several sensors failure (but not more than  $(N/2)-1$  where  $N$  – a total number of versions (sensors). Multi-version approach will allow to not only increase reliability of measurements, but also to reveal machine failures in the metrological equipment as the system can automatically report about versions which responses are recognized as incorrect sufficient number of times, showing the need for verification of the relevant equipment.

In case of sensors position in different sections of a tube's plane surface, or under other circumstances which involve constant correction to readings, it needs to be compensated programmatically, so that in case of properly functioning, equipment readings from all pool of sources match. It is necessary for multi-version voting and faults detection [5].

For ecological parameters monitoring systems under a group of sensors it is appropriate to apply fuzzy algorithms of decision-making in the multi-version systems, since in this case minor differences

of the measured parameters do not exert impact on system solutions, besides, errors of measurements can always occur. The system works better with the introduction of elements of fuzzy logic, since very close but not matching versions due to small errors of measurements or digitization, belong to one class. In case of weighted vote it allows a more correct evaluation of versions on each vote and more correct weights of versions, respectively [6]. It also simplifies automatic detections of equipment malfunctions when not the responses are found incorrect, differing within a measurement error, but only incorrect ones.

For the offered approach verification simulated environment was executed in which sensors outputs were simulated where mathematical expectation is the real value of the measured data; dispersion in the amount of a sensor error was entered. Failures of each version were simulated. In the program fuzzy algorithm of absolute majority voting with 5 versions was realized. As the results show provided in fig.2 – failures of one or two versions simultaneously do not exert impact on correctness of the system output.



**Figure 2.** Simulation environment output.

The data obtained in the simulation environment confirmed the applicability of the multi-version approach for solving this problem. After that, testing was conducted within the framework of a real multi-version real-time execution environment. This environment is based on the real-time operating system FreeRTOS v10 and represents a set of C source files for compilation. This allows you to make modifications and extensions to the code of the environment itself and to develop new modules.

The execution environment itself has rather low hardware requirements and allows assembly for most modern single-chip platforms. This fact allows you to organize data processing measurements directly within the system, that is, to implement an embedded system. This fact also helps to ensure the required level of delays, since the delays associated with data transmission are eliminated in the case of an external system.

As a decision-making algorithm in 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. The use 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 to increase the resistance to measurement inaccuracies and transformations of the measured values. This will allow to exclude situations when the answer of one of the versions is considered erroneous due to inaccuracy of measurement, digitization, lack of capacity, etc.

Applying multi-version approach allows to increase resistance of the monitoring system of ecological parameters to malfunctions of measuring devices and also enables automated detection of technical failures.

However, in actual production it is not always possible to obtain N measurements of one parameter, and various parameters cannot be compared with each other explicitly. To solve this problem, you can use a technological process model. The output of the model is a numerical value - the quality coefficient of the process according to the parameters of interest to us. The model can be constructed using various inputs - by pressure, temperature, gas content, etc. Thus, we get a set of models of the same production process, which use different input data, but have the same output. This makes it possible to compare the numerical outputs of these models and implement a multi-versee voting. Since we compare the results of calculating models using different input parameters, this possibility allows us to identify incorrect input parameters, since models based on them will not be calculated correctly.

## Conclusion

A new decision-making algorithm in multi-version environments using the developed models of the production process as versions, allows comparing the measured values of various parameters and diagnosing failures in the measurement systems of each of the parameters and, in general, increasing the reliability of the obtained process parameters. It proves to be effective decision of multipoint measurements of environmental monitoring parameters arrangement as it not only solves the problem of obtaining value under a set of measurements, but also increases reliability of the obtained data. Imitation in simulation environment justifies efficiency of the offered approach.

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