On the matter of the development of automatic chemical control system for thermal power plants using modern hardware and software

N S Dolbikova¹, E I Merzlikina¹ and N S Nikitina¹

¹ National Research University "MPEI", Russia, 111250 Moscow, Krasnokazarmennaya, 14

MerzlikinaYI@mpei.ru

Abstract. This article considers development of modern chemical monitoring systems using modern hardware and software. Application of these means gives a lot of possibilities for improving reliability of the chemical monitoring systems, main power plant equipment and water chemistry maintenance. An information system is described, the system contains a decision support module, that allows to identify faulty chemical measuring instruments, inform the plant staff about the scheduled maintenance operations and identify the reason of a water chemistry upset. A model of such a system is developed using Tehnopribor and Owen hardware and CODESYS 2 and Trace Mode 6 software.

1. Introduction

Nowadays implementation of chemical monitoring systems (CMS) is important because of a number of reasons. They are: increasing heat carrier parameters at thermal power plants, strengthening of requirements to ecological safety and reliability of the power plant equipment, considerable wearing of equipment in many plants, strengthening of requirements to the water chemistry maintenance. Many chemical measurements are still performed manually by laboratory equipment [1], but nevertheless there are a lot of complex intelligent devices working in the real-time mode. They have a digital output, and this signal contains not only the value of the measured parameter, but also some information about other parameters (for example, the heat carrier temperature) and about the instrument performance [2, 3]. In many plants and factories this information is not used at all and it is not logical. This information use allows to recognize faulty instruments and unreliable measurement results, and, consequently, it can improve the CMS and basic equipment reliability.

In addition to it, one should remember, that automatic chemical instruments are complex devices that require regular maintenance (electrode replacement, calibration, etc.). If the maintenance is not carried out properly or on time, the measurement results may be incorrect. There are different reasons of the maintenance absence, the employees may be overloaded and too busy and so on. So, it seems logical to develop a digital system reminding the employees about the maintenance schedule.

As it was mentioned above, nowadays in many industries, including power engineering, there is a tendency to cutting the staff and consequently to increasing the staff load. Employees of power plants perform hard duties and their responsibilities are high, so their psychological tension is high too. It may result in mistakes because of so-called “human factor”, and it is a very important matter. According to [4], more than 50% of industrial accidents occur because of the human factor, and it must be taken into consideration. Some other researches [5] say that the employees are the least reliable elements of all the manufacturing cycle, so they need help. But specialists estimate that if the
The possibilities of the digital equipment are used in full scale, more than 80% of industrial failures may be discovered at early stages or prevented [6]. Because of all the reasons mentioned above, we suggest an information system for power plant employees working with chemical instruments and CMS, the system is equipped with a decision support module. This system is developed using Tehnopribor [2] and Owen [7] hardware and CODESYS 2 [8] and Trace Mode 6 [9] software. Technically this system is built on the basis of a standard workbench [2], equipped with automatic chemical measuring instruments with digital outputs and a controller PLC 154 [7]. The controller collects and processes information from the instruments and sends it to the computer where CODESYS and Trace Mode are installed. The structure of the system is shown in figure 1.

![Diagram showing the structure of the information support system](image)

**Figure 1.** The structure of the information support system.

The program developed consists of three modules. The first module is responsible for reminding the employees of the maintenance schedule. The second one informs about possible failures of the instruments, and the third one is a decision support module helping to identify the reason of parameters deviation from the normal values. Let us consider all the modules more closely.

### 2. The alarm module

As it was said above, many modern smart chemical sensors have digital output [2,3]. For example, a modern pH-meter has a digital output signal [2]. This signal contains information about the smart sensor status, pH value, pH value normalized to 25°C, current sample temperature, faults of the pH-sensor calibration, etc. It is logical to use all this information, but it is necessary to take into consideration a very important matter.

Now many employees of the power plants are overloaded with information, so it is may be hard for them to acquire these additional data. That is why the system shows only small message and the employees may get further information, if necessary (the system works on an as-needed basis).

The working principle of this module is illustrated in figure 2. Similar messages are developed for the conductometer, oxygen analyzer, sample preparation system and so on. All this information is saved in a data base, and employees, if necessary, can use these data.

This module can help the power plant employees to identify faulty devices promptly and improve the reliability of the CMS.

### 3. Maintenance schedule

Automatic chemical control instruments demands proper maintenance. For example, according to the user manual, the pH-meter should be calibrated once a fortnight, its parts should be cleaned once in three months [2,3]. Besides that, it is necessary to check periodically the electrolyte level in the comparison electrode, because if the level is too small, the measurement result may be incorrect.
Smart sensor status

- ADC is faulty
- Temperature sensor short circuit
- Temperature sensor breakout
- pH value is not in 0-14
- ...........

pH smart sensor error

pH value is not in 0-14
pH value is 15.3

More details

Figure 2. The alarm module.

If the maintenance is not performed according to the schedule, it may result in incorrect measured values and consequently in the water chemistry upsets, financial losses, unjustified claims to the instrument manufacturers and so on.

In order to avoid the situation described, the maintenance schedule module is developed. According to the calendar date it informs the employees about the current maintenance operations, and it also allows to check the maintenance operations made before. The working principle of this module is illustrated in figure 3.

Date: 01.07.2020
Operations: check the electrolyte level in the pH-meter comparison electrode
See previous operations
Record todays operations

Date: 01.07.20
Operation: check the electrolyte level in the pH-meter comparison electrode
Name: Ivanov I.I.

Login:
Password:

Date: 01.07.20
Operation:
Name: Sidorov A.A.

Figure 3. The maintenance schedule module.

The maintenance operations are performed manually, and it also should be recorded in the data base. The time of the operation is the point from that the system begin to count the new maintenance period for this operation.

As one can also see from figure 3, only authorized users may put records in the data base because of the power plant rules. The access to this function is protected by password.

4. Decision support module

The heat carrier parameters may deviate from the normal values because of many reasons. It is necessary to identify the reason in order to take proper measures. For example, if the parameter value deviates from the normal one because the instrument is faulty, it is necessary to repair the instrument. If the reason is a water chemistry upset, one should find the reason of it and remove it. There are many reasons of the water chemistry upsets. It may be difficult for the employees to find the reason quickly and correctly and a decision support module can help in this case.

For example, if the water chemistry is neutral-oxygen, the feed water pH value is, according to the standards, 7±0.5. The pH value may deviate from this value because of some reasons, they may be identified by the algorithm, a part of which is given in figure 4. The structure of the algorithm is...
simple, firstly it gives the operator the most probable reasons, then – less probable. The reasons and their probabilities were collected through an expert survey.

The most probable reason on the pH value deviation is the pH-meter breakdown, so at the first step the system recommends to measure the pH manually by laboratory instruments. If the value measured manually differs from the normal one, that means, that the pH meter may be faulty, and the system recommends to check the instrument. If the values measured by the automatic and laboratory instruments are the same, that means, that the one should consider another reason, and the system recommends to check if the ammonia dosing system works properly, if the ammonia level in the tank is not less than acceptable and so on. A part of the interface is given in figure 5. Similar algorithms, if necessary, may be developed for other parameters.

5. Conclusion
The article considered the information system for employees of power plants working with chemical measuring instruments. This system can help the employees to identify faulty instruments, to find the reason of the water chemistry upset and so on, and this way it can improve the reliability of the CMS and the primary equipment.

This system may be considered as a part of the distributed control system of the whole power plant, so it should be integrated to this system, exchange information with other control system modules and so on. In the future it may help to improve the reliability of the control system and the whole power plant.

6. References
[1] Egoshina O.V. Chemical monitoring systems. 2013. Publishing house of MPEI, Moscow. 48 Pages.
[2] Official web-site of Tehnopribor, URL-address: www.tehnopribor.ru, date: 1.07.2020.
[3] Official web-site of Vzor, URL-address: www.vzorn.ru, date: 1.07.2020.
[4] Pavlov V.I., Aksyonova T.V., Aksyonov V.V. Efficiency of information support for operators controlling power plants. Tomsk Polytechnical university bulletin. Tomsk, 2015. Vol. 326, №3, pages 70-75.
[5] Pashchenko F.F., Durgaryan I.S., Pashchenko A.F., Belova O.N., Medvedeva E.Yu. Information decision support systems in power engineering. Sensors and Systems. 2014. №6, pages 24-33.
[6] Medvedeva E. Digital power engineering. ComNew Standard. 2017. №4-5, pages 16-19.
[7] Official web-site of Owen, URL-address: www.owen.ru, date: 1.07.2020.
[8] Official web-site of 3S-Smart Software Solutions GmbH, URL-address: www.codesys.com, date: 1.07.2020.
[9] Official web-site of Adastra, URL-address: www.adastra.ru date: 1.07.2020.