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On the matter of the reliability of the chemical monitoring system based on the modern control and monitoring devices

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Abstract. The reliability of the main equipment of any power station depends on the correct water chemistry. In order to provide it, it is necessary to monitor the heat carrier quality, which, in its turn, is provided by the chemical monitoring system. Thus, the monitoring system reliability plays an important part in providing reliability of the main equipment. The monitoring system reliability is determined by the reliability and structure of its hardware and software consisting of sensors, controllers, HMI and so on [1,2]. Workers of a power plant dealing with the measuring equipment must be informed promptly about any breakdowns in the monitoring system, in this case they are able to remove the fault quickly. A computer consultant system for personnel maintaining the sensors and other chemical monitoring equipment can help to notice faults quickly and identify their possible causes. Some technical solutions for such a system are considered in the present paper. The experimental results were obtained on the laboratory and experimental workbench representing a physical model of a part of the chemical monitoring system.

1. Introduction

The reliability of power plant main equipment is very important today and depends on many factors.

One of the important factors is correct water chemistry, the other is the reliability of the industrial control system and chemical monitoring system installed at the power plant unit. Today the chemical monitoring system can be either a part of the industrial control system of the unit or a separate subsystem.

Modern chemical control systems have some features and problems which must be taken into consideration, they are given below.

First, optimization of equipment working modes is going on at many Russian power plants now, because of it redundancy cuts of the personnel take place. The quantity of work for each specialist on measuring instruments (chemical included) is bigger, it can cause lower reliability of the measuring equipment, because some faults and broken sensors can be not detected promptly. That is why the present system of information presentation and distribution of the plants should be supplemented and modified.

Chemical monitoring devices are special devices that require maintenance according to some exact schedule and prompt detection of faults in the monitoring system. It is necessary to check operability of the sensors[8], do washing of the electrodes (approximately once a week), calibration, change electrodes and membranes and so on. Untimely fault detection and incorrect maintenance may lead to water chemistry upset, main equipment faults, lower reliability and efficiency of the unit.

Second, the modern chemical measuring instruments consist not only of a sensor and a transducer but also of a touch screen (Fig. 1) which performs some functions, for example, local indication, data transformation into the digital form, automatic correction, detection of faults and so on. The touch screen can break down, moreover, software faults are possible and the power supply of the touch screen or the whole workbench may disappear (especially for small plants).

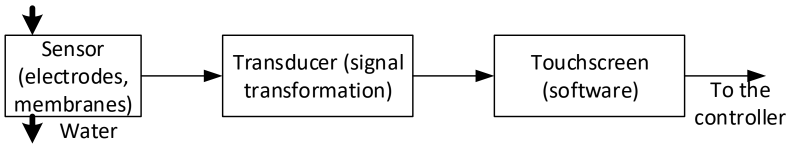


Figure 1. The structure of a modern chemical instrument.

Third, the monitoring system can work in starting, transient and rated modes and in the starting and transient modes the sensors may be polluted and break down because of it. When these modes are over, specially trained workers must do the sensors washing that requires high operating culture and is rather time consuming.

Fourth, some chemical analysis operation are made manually by laboratory devices, therefore, the data obtained from these operations are input manually as well. According to [3], the quantity of parameters input manually on a power plant unit is two-three times higher than the quantity of analogue and discrete signals from measuring instruments. Because of all the factors mentioned, it is necessary to pay certain attention to so-called human factor, because a worker can make errors while inputting the data.

This paper considers some matters of the monitoring system reliability.

2. Typical engineering solutions

A wide-spread typical engineering solution for increase of the reliability of thermal plants monitoring systems is redundancy[4], but this solution in unacceptable in the case under consideration for some financial reasons. The chemical measuring instruments are rather expensive, that is why the monitoring system has only one device of each kind (for example, one chemical monitoring workbench for one waterflow is equipped with one oxygen meter, one pH-meter, etc.).

Because of the given reasons other solutions should be found. First, each modern chemical device is equipped with a self-diagnostics system [1, 8], which can identify some breakdowns. It is also offered to equip the chemical monitoring system with a consultant system for the maintenance personnel, the system can detect possible faults and inform the personnel.

3. Offered engineering solutions

The reasons mentioned in the second section make it necessary to develop new technical solutions. Some algorithms for a fault detection consultant system are considered below.

3.1. The consultant system. General issues

Consultant systems for the power plants have been known and used for a long time [7] and they are still important. Usually such systems give the operators controlling some technological process information and advice. It is offered to widen the sphere of application of such systems and develop and introduce a consultant system for the chemical monitoring system maintaining personnel as well. In the future this consultant system may even be transformed into an expert system. This system can help to increase the monitoring system and the information reliability, because it will inform the personnel promptly that some device need maintenance or may be faulty and identify possible causes of the fault.

The information that the maintenance is required may include the following [8]:

- electrodes of a pH-meter (or another device) should be changed;
- a membrane of an oxygen meter should be changed;
- a device should be calibrated, etc.

The information about the possible faults may be given by the self-diagnostics system of the chemical device or by some additional algorithm which analyses and compares data from this and other devices and can produce an operator prompting. The self-diagnostics system, for example, detects the following things [8]:

- condition of a measuring channel (working, turned off locally, no connection with a sensor, etc.);
- condition of a smart sensor (working, faulty, an interface board is overheated, a short circuit, etc.);
- a parameter measured is not in the acceptable limits (a sample flow is too low, pH is higher than 14, etc.).

Sample preparation devices are able not only to monitor the condition of the device and possible faults but also turn off and on the power supply of sample shutdown valves remotely, it allows operators immediately to stop water flow to the sensors if necessary and thus to prevent their pollution and damage.

3.2. Detection of the software and touch screen's faults

As it has already been shown of fig. 1 modern chemical devices have touch screens. This device can break down partially or totally, the power supply of the device can disappear or a software breakdown can happen. This things should also be detected.

Let us consider the following situation of a touch screen malfunction. The structure of the system under consideration is given in figure 2.

In this case the chemical workbench has a touch screen installed, the touch screen works with three chemical measuring instruments, they are a pH-meter, a Na-meter and an oxygen meter. The information from the touch screen goes to the controller through RS-485 interface and from the controller it goes to the operator's PC through Ethernet. Each of the instruments mentioned is equipped with a temperature sensor for making automatic temperature correction, the information about the temperature also goes to the touch screen, then to the controller and finally to the computer. All the temperature sensors are installed near each other, so the values of the temperature obtained from them must be close. Let us consider that all the chemical instruments work properly and the touch screen shows the information correctly (the situation that took place in the experiment). During the experiment a breakdown happen in the touch screen and as a result the operator's PC obtained wrong data from the oxygen meter (channel 3), the temperature value for this channel was very different from the others. Because the operator's PC software had a special module, the operator got the following message: "Fault in channel 3 (O_2) of pH-Na-O_2 device. Possible causes:

- Oxygen meter sensor is broken;
- Oxygen meter transducer is broken;

- The touch screen of pH-Na-O_2 device is broken."

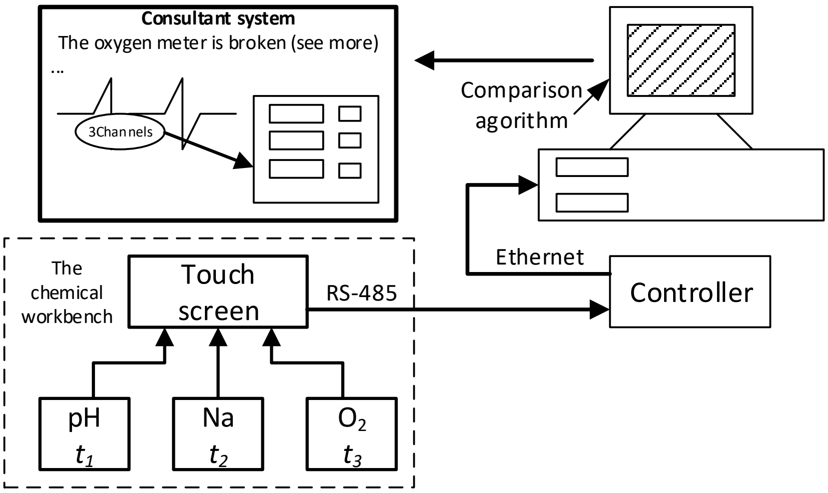


Figure 2. The structure of a part of a chemical monitoring system

The experimental workbench is equipped with three-channel touch screens (except the sample preparation device), so it has such software modules for all touch screens. The application of this software module allows to draw the personnel attention to the problem and give the personnel some additional information that may help to identify the fault cause.

If the workbench is equipped with one-channel touch screens the software module (slightly modified) can also be used, because it works on the basis of so-called "two from three" algorithm and the temperature sensors of different chemical devices are installed near each other anyway. It must be mentioned that for reasons of cost efficiency three-channel touch screens (one touch screen for three chemical instruments) are preferable, but one-channel touch screens (one touch screen for each chemical instrument) are more reliable, because if the one-channel touch screen breaks down totally the controller looses the connection with one chemical device only.

3.3. Detection of faults on the basis of mathematical models

Sometimes it is possible to calculate one parameter using other parameters which are also measured. The value calculated can be rather approximate, but some faults may be detected this way.

As a rule, almost all the chemical workbenches are equipped with a pH-meter and a conductometer. For many practically important cases, for example, for the all-volatile water chemistry [5] the pH and the conductivity are unambiguously connected, the formula for calculating pH on the basis of the conductivity measured is given in []. The conductometers are more reliable and work faster, so it is possible to measure the pH and the conductivity, after that to calculate the value of the pH and to compare the measured and the calculated values. The formula that may be used for this case is [6]

$$pH = 8.261 - lg\frac{\lambda_{OH^-}(t) + \lambda_{M^+}(t)}{\lambda_{H^+}(25) + \lambda_{OH^-}(25)}K_W(t) * 10^{14} + lg\kappa$$

where κ – the solution conductivity, $\lambda_{OH^-}(t)$, $\lambda_{OH^-}(25)$, $\lambda_{H^+}(25)$, $\lambda_{M^+}(t)$ – equivalent conductivities of the ions H^+ and OH^- when the temperature is t or 25°C, $\lambda_{M^+}(t)$ – equivalent conductivity of the cation of the solved matter (ammonia, for example), K_W – the ionic product of water. After that the calculated and the measured values of the pH are compared and on the basis of their difference the conclusion about the performance of the pH-meter and the conductometer is drawn. If the values are very different, the personnel gets the following message: "The pH measured and calculated are different. Possible reasons:

- The ph-meter is broken (see more);

- The conductometer is broken (see more);
- The chemical dosing system is broken (see more)."

This message must be sent to the operator controlling the technological process and also to the personnel maintaining the chemical instruments. The most possible reason is placed in the first line of the message. The personnel can require additional information, for example, if it is chosen to see more about the pH-meter possible fault, the personnel will be given:" Possible reasons and recommendations (pH-meter)

- No water in the sensor, check the water;
- The temperature or the pressure of the water in the sensor are wrong, check the temperature and the pressure of the water;
- Check the parameter (pH) manually;
- Check the schedule of the electrodes replacement."

For the conductometer the message is generally the same, but in the fourth entry it will be recommended to check the schedule of the hydrogen cation exchange unit replacement. This system can help to improve the reliability of the chemical monitoring system.

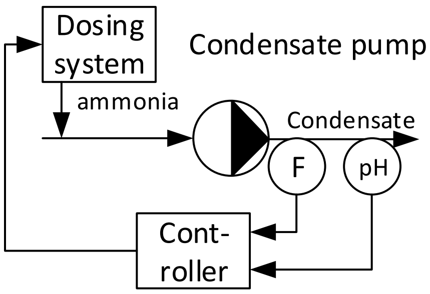
It also should be mentioned that for higher reliability of the system it may be recommended to install a redundant power supply source or an uninterruptive power supply unit.

3.4. Detection of faults for dosing systems

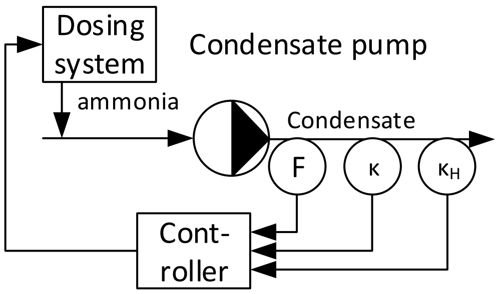
The proper water chemistry depends on the proper performance of chemical dosing systems. The latter depends on the proper work of the sensors collecting information about the technological process. For example let us consider an ammonia dosing system.

The ammonia may be dosed on the input of the condensate pump 2 (see figure 3), the structure of the dosing system depends on the chosen water chemistry[5,7]. The ammonia can be dosed on the basis of the following parameter values:

- the condensate flow (in this case the value of the condensate pH may differ from the required one);
- the condensate flow and pH (figure 3a), it must be mentioned that the pH-meter may work in different ways when the water chemistry is different, the pH-values may be shifted [6], especially in the high-purity waters;
- the condensate flow and $\Delta\kappa$ (the difference between the electrical conductivity of the ordinary sample and the one of the H-cationized sample), the structure is presented in figure 3b. This variant is not widely used because here two conductometers are necessary, moreover, periodical replacement of the hydrogen cation exchange unit is necessary.



a. with a pH-meter



b. with two conductometers

Figure 3. The structure of ammonia dosing system

Here the second structure (based on the flow and pH) is considered. The consultant system is also possible and useful for this system, one of the algorithms is given in figure 4.

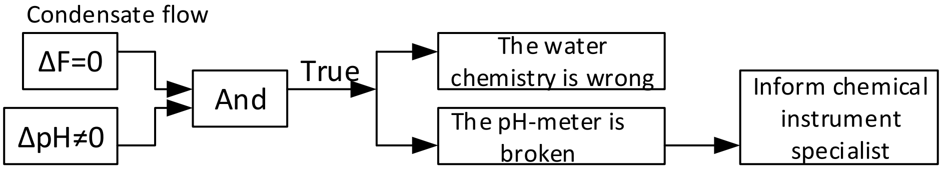


Figure 4. Consulting algorithm for the ammonia dosing system

The application of this algorithm will promptly inform the maintenance personnel that the chemical device is broken.

4. Conclusion

The described consulting system is being developed and tested at the moment on a workbench representing a physical model of a part of a chemical monitoring system. In the future it is offered to develop and apply mathematical models which will be able to identify other problems in the monitoring system and further improve its reliability. The models now can help to get and compare the results only in some cases, but, nevertheless it can improve the reliability of the chemical monitoring system. It also should be mentioned that in order to improve the reliability it is necessary to use modern devices which require proper maintenance and operating culture, so the consultant system in this case is important and even necessary.

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