Development of Water Quality Simulator for Thermal Power Plants

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As a means of quickly learning operational skills for thermal power plant facilities or passing skills to successors, operational training simulators with human machine interfaces and plant models that can recreate the same behavior as actual plants have been utilized at power plants and training centers. Recently, however, several plants had incidents caused by abnormal water quality, disturbing the stable supply of power. In terms of existing operational training simulators including the products of Mitsubishi Heavy Industries, Ltd. (MHI), there is room for improvement in training programs dealing with water quality-induced problems, and there are few incidents of actual problems occurring. It is therefore expected that the development and use of water quality simulators for thermal power plants, which can provide training programs in terms of operational procedures for abnormal water quality, can prevent the serious problems resulting from abnormalities in water quality, and shorten the duration of plant shutdown necessary for repair and restoration. This report gives a summary of our water quality simulator for thermal power plants, which is useful for operational training to handle abnormal water quality-induced problems.

1. Introduction

In domestic thermal power plants, water treatment is conducted to prevent problems such as corrosion in the boiler/turbine systems, scale formation and deposition and the consequent carryover to the turbine. Recently, there have been incidents in which deteriorating water quality due to aging facilities or insufficient operational actions to handle urgent situations including cooling water (seawater) leaks in the condenser caused an extensive area in the boiler/turbine systems to be affected by abnormal water quality, eventually leading to serious problems such as leakage from steam generating tubes in the boiler.

To prevent such serious problems related to water quality abnormalities, it is essential for operators or those in charge of water quality control to understand how numerical values obtained in the boiler/turbine systems change when there is something wrong with water quality, and have the ability to handle the situation by conducting appropriate treatment and operational procedures at the right time. This report introduces our water quality simulator for thermal power plants, which is useful for training. Its installed plant model can recreate the same behavior as actual plants. The simulator therefore can provide educational/training programs to improve operational skills at the occurrence of abnormal water quality-induced problems, as well as the ability to detect incipient problematic signs from the change in water quality indicators, under virtual circumstances matching actual power plants.

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2. Importance of water quality control in thermal power plants

Figure 1 shows a water/steam system used at thermal power plants. In this system, water circulates starting as condensate, followed by boiler feedwater, boiler water (in the boiler) and steam (in the turbine), and finally returning to condensate. When water quality is affected, its influence extends to downstream systems such as boiler/turbine systems over time because of the water circulation.

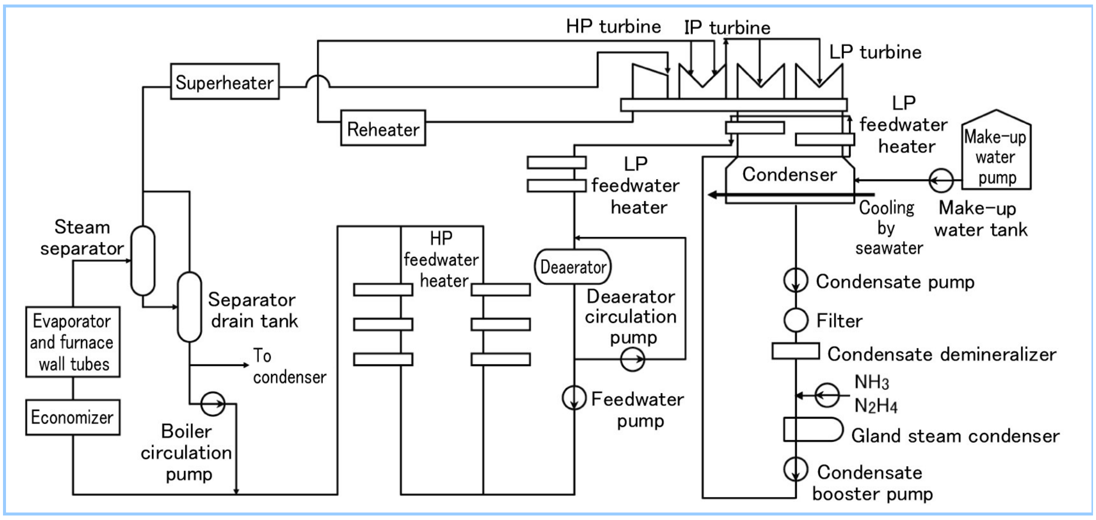

Figure 1 An example of water systems at thermal power plants

One frequently-caused problem is leakage from steam generating tubes in the boiler. **Figure 2** shows water-induced problems and the sites where they occur. The number of incidents in which the cause is contamination by impurities such as ion-exchange resins and chemicals (e.g., hydrochloric acid) from the demineralizer is increasing, thus posing a problem for aging water treatment facilities. There are also other water-induced or -related problems such as flow-accelerated corrosion (FAC) and scale deposition. Controlling water quality is becoming increasingly important.

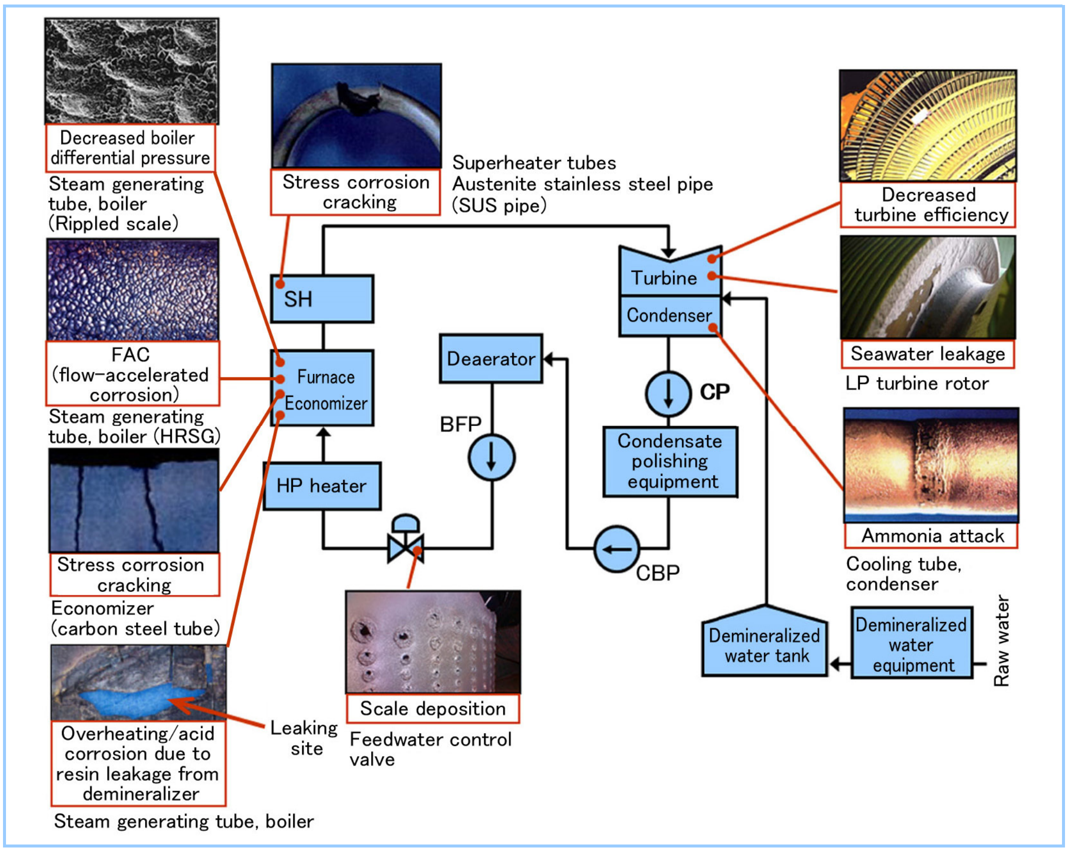

Figure 2 Water-induced problems and occurrence sites

The connections between abnormal water quality and the causes of serious problems, including leakage from steam generating tubes in the boiler and equipment damage, are shown in **Figure 3**. Accurate interpretation of deviations from the normal water quality values during start up/shut down operations of the plant enables the detection of incipient signs of problems and the prediction of forthcoming symptoms (e.g., equipment failure), whereby necessary treatment can be applied at the proper timing and ultimately the occurrence of serious problems can be prevented. We consider this as the principal duty of those in charge of water quality control.

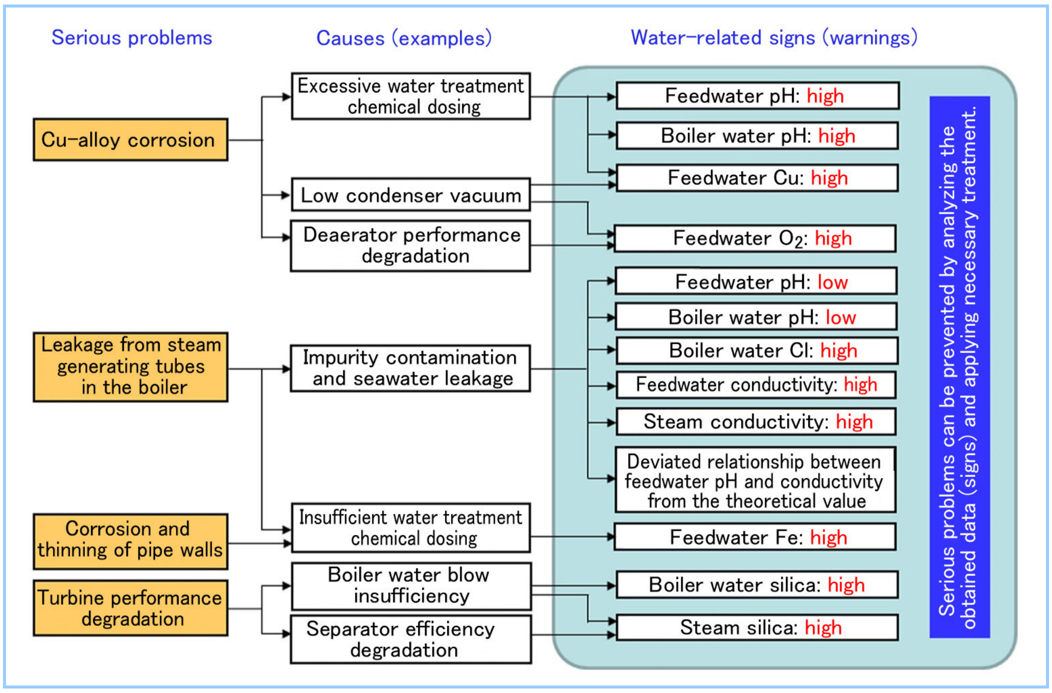

Figure 3 Expected problems according to diagnosis results of water quality (example)

3. Status of development of operational training simulator

At present, the capability of accurately detecting signs of problems largely depends on the experience of those in charge of plant operation or water quality control. It is therefore a meaningful challenge to establish a method for passing on their expertise and knowledge, which are founded on their rich and valuable experience, by means of data that can be interpreted.

In 1978, based on the expertise obtained as a plant manufacturer and through our rich experience in boiler/turbine design, manufacture and operation, as well as knowledge supported by scientific evidence such as accumulated relevant data and dynamic characteristics analysis results, we developed and installed an in-house training simulator for facility operation at an overseas thermal power plant. Its main purpose was the education of plant operators. Since then, we have provided many simulators for thermal power plant operation both inside and outside Japan. Our progress in simulation technology development is summarized in **Figure 4**

Figure 5 shows an example of our simulation architecture used for operational training. The simulation results are highly accurate in terms of not only the static characteristics of actual plants, but also their dynamic characteristics. This has been enabled by adopting a method of diligently solving plant-model characteristic formulas (physical balance, equation of motion, and heat balance), which are formulated according to the physical equations based on our design technologies as a plant manufacturer such as expertise in boiler heating surfaces and turbine blade design. **Figure 6** gives a comparison of simulation results to data from an actual plant: the behavior of an actual plant (on the left) and its plant-model behavior simulated by our simulator (on the right). The realization of static and dynamic characteristics similar to actual plants in simulation has allowed the provision of highly reliable, reproducible and flexible training programs for plant start up/shut down procedures and responses to urgent events, such as the occurrence of something unusual in these processes and the incidence of problems.

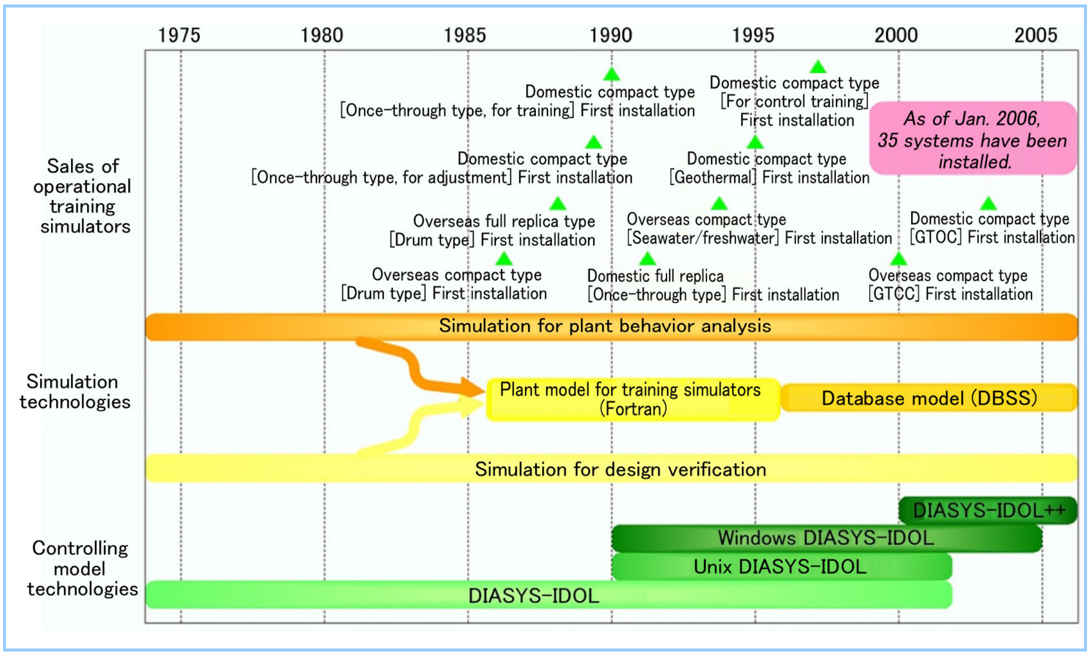

Figure 4　MHI progress in simulation technology development

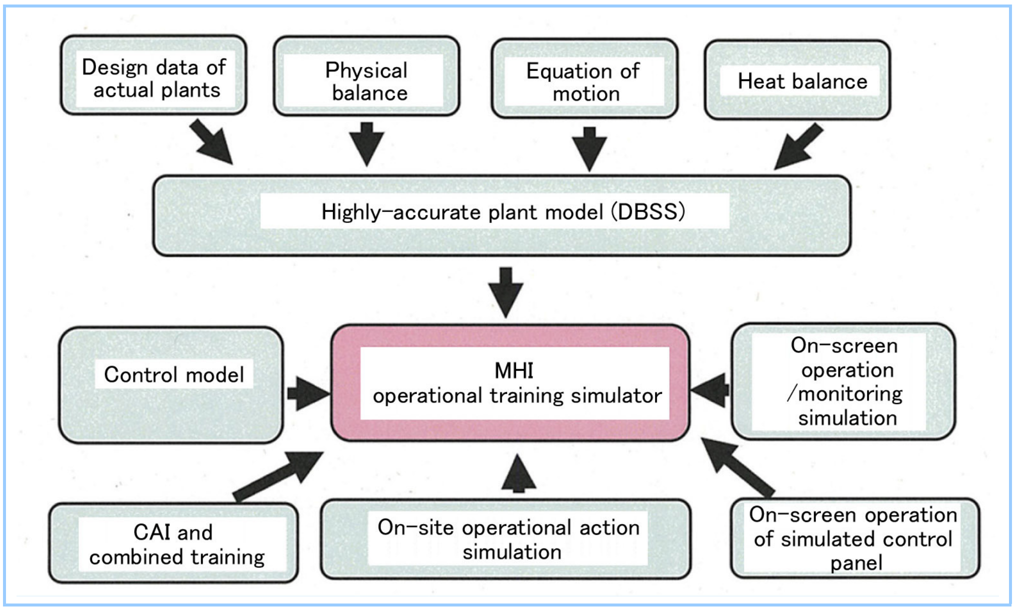

Figure 5　Simulation architecture for our operational training simulator

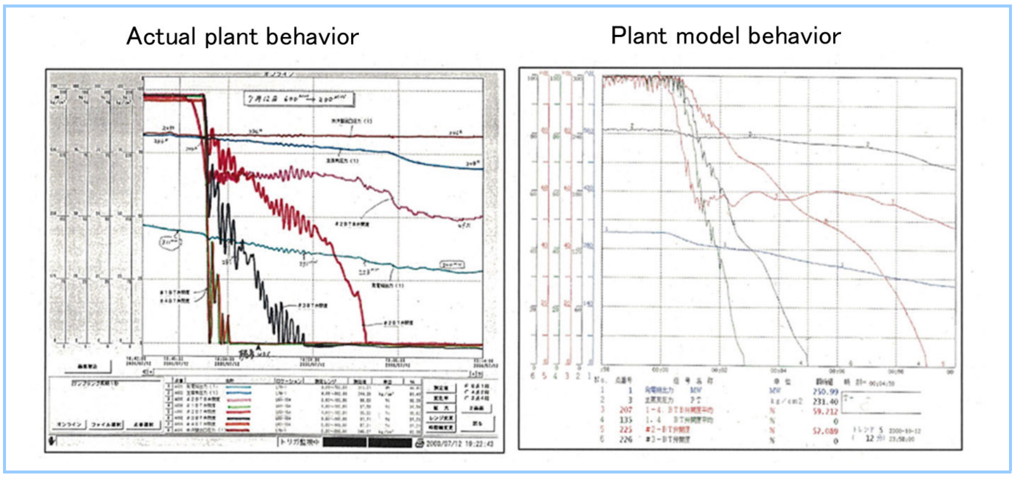

Figure 6　Simulation comparison example

In order to create more realistic virtual reality, there have been requests for operational training simulators by which plant start up/shut down procedures can be carried out using centralized command functions equivalent to those found in actual plants, or photographs of real machines in actual plants to be used when handling simulated problems to restore the normal condition. Owing to improved computational performance, simulation speed can be set 10 times faster than the normal level. Situations resulting from water treatment problems, which took a long time until the simulation was completed, can now be reproduced easily. Detailed physical models can also be used for situations that were virtually created as a simplified simulation, and therefore training can now be provided under virtual circumstances that are more similar to actual plants.

4. Outline of our water quality simulator for thermal power plants

4.1 Functions of our water quality simulator for thermal power plants

In our water quality simulator for thermal power plants, detailed physical models related to water treatment were developed and adopted by expanding the functions of conventional operational training simulators. The simulation results are similar to actual plants. It therefore can provide plant operators educational and training programs to improve their on-site ability to handle problems caused by abnormal water quality or detecting, from warnings on water quality, the signs that can lead to problems in facilities and plant systems.

4.2 Method of installation

Figure 7 illustrates the method of installation of the water quality simulator for thermal power plants. If it is the first operational training simulator to be installed, only a small facility including a plant model and the operator station is needed for the installation, because the simulator specifically focuses on plant water quality. If there is an existing operational training simulator, the functions for water quality simulation can be added.

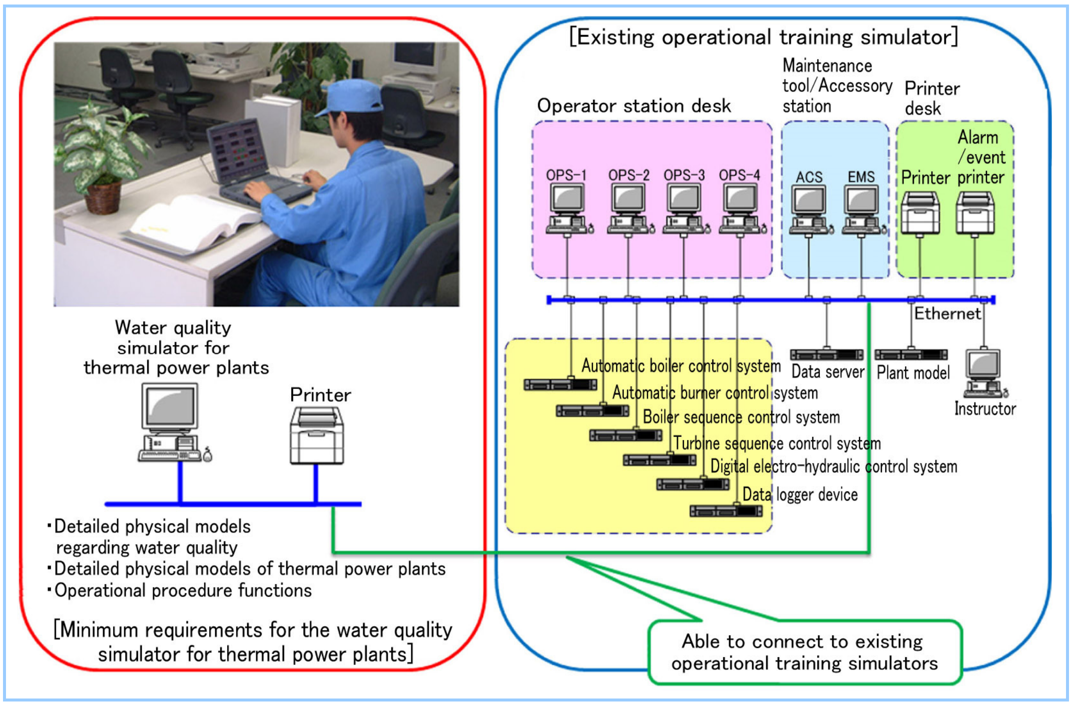

Figure 7 Method of installation of water quality simulator for thermal power plants

4.3 Simulation and operational training examples

Figure 8 shows the behavior of cation conductivity (mS/m) at each sampling point in the case of seawater leakage from cooling tubes in the condenser of a once-through boiler. Cation conductivity, which is subject to chlorine in seawater, is an important numerical value for monitoring operational conditions and leaking seawater amounts. Our water quality simulator for thermal power plants can reproduce the same behavior of cation conductivity as seen in actual plants. Plant operators are required to interpret increased cation conductivity levels as a precursor (incipient sign) of seawater leakage and conduct appropriate procedures and treatment.

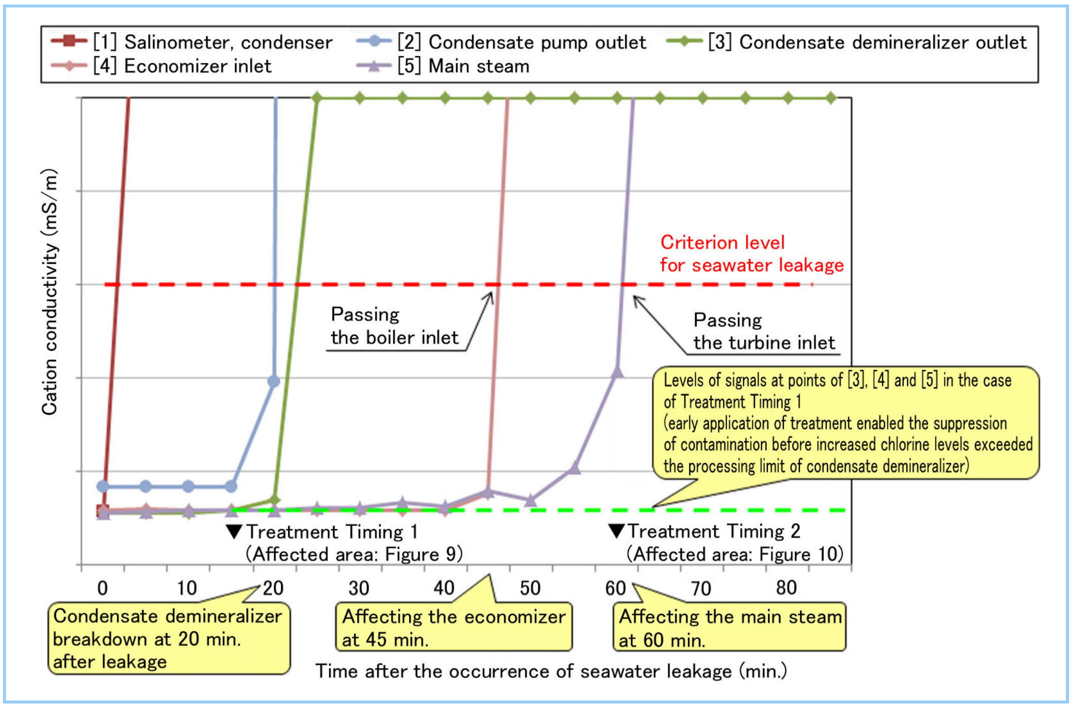

Figure 8 Behavior of water quality in the case of seawater leakage (once-through boiler)

In terms of the development of this incipient sign over time, **Figure 9** shows a case in which countermeasures (e.g., load decrease or shutdown) were taken according to the values indicated by the salinometer of the condenser, and the seawater-contaminated area was minimized. On the other hand, **Figure 10** is a case in which no countermeasures were taken until an increase in cation conductivity was detected in main steam, causing all the systems to be contaminated by seawater.

As shown in these figures, by visualizing and determining how the countermeasures taken during operation and their timings can change the degree of impact and the affected area, the water quality simulator for thermal power plants can be used as a teaching tool for operational training to assess the effectiveness of actions.

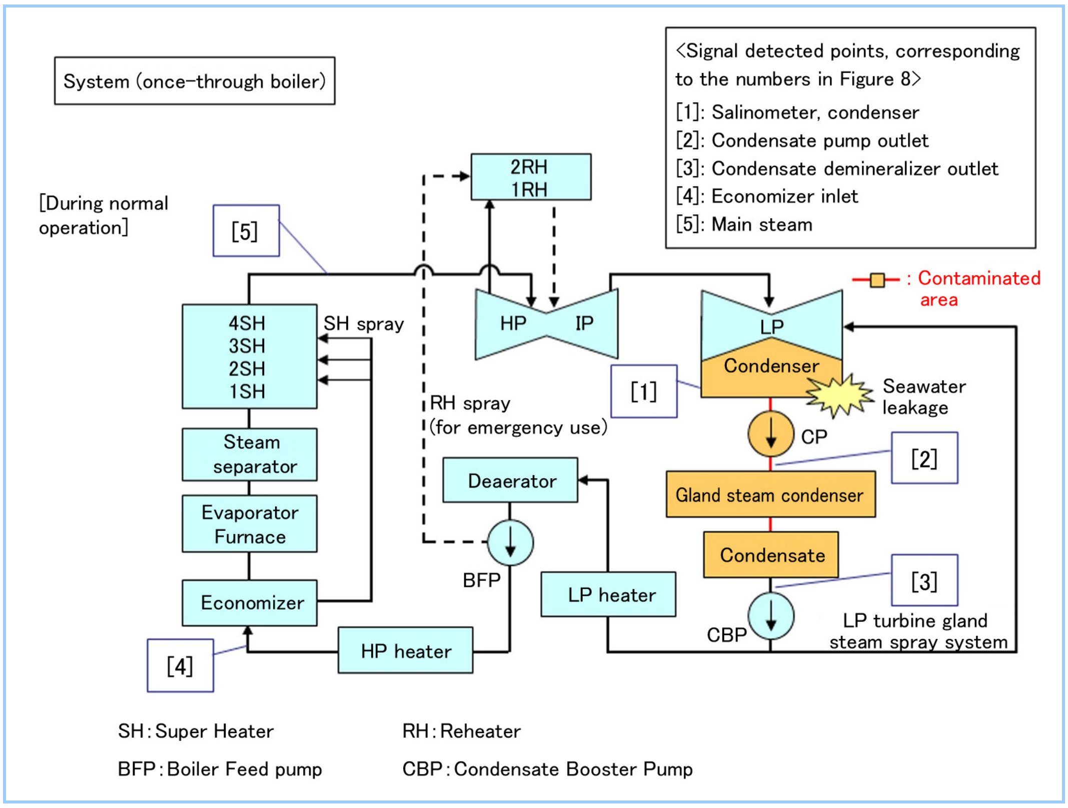

Figure 9 Contaminated area in the water/steam system caused by seawater leakage (once-through boiler) In this case, the seawater-contaminated area is minimized.

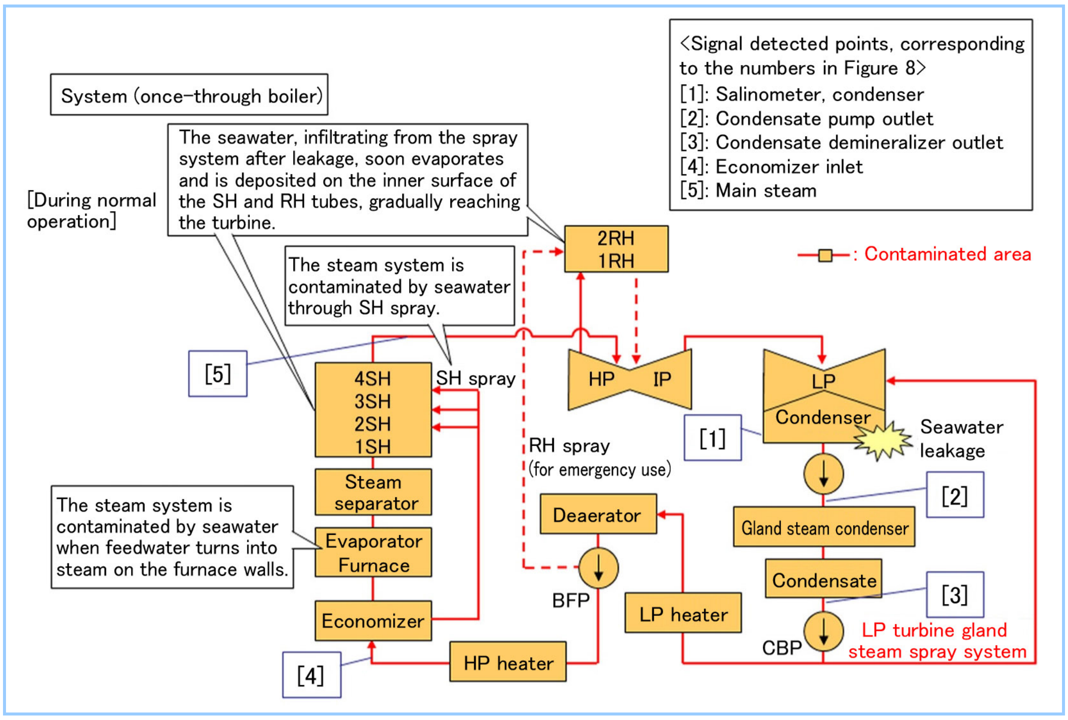

Figure 10 Contaminated area in the water/steam system caused by seawater leakage (once-through boiler) In this case, all the systems is contaminated by seawater.

5. Conclusion

For operators or those responsible for water quality control, the required capabilities at the time of abnormal water quality occurrence are “the detection of water quality abnormalities (signs),” “the prediction of expected symptoms (equipment failure),” and “the application of appropriate treatment according to the abnormalities (minimizing the area to be affected).” We have developed a water quality simulator for thermal power plants that is useful for training and skill learning.

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