BWR Water Chemistry Evaluation and Diagnosis System For Supporting Plant Operation

Naoshi Usui, Nobuyuki Ota and Motomasa Fuse

Power and Industrial Systems Nuclear Systems Division, Hitachi Ltd.
3-1-1 Saiwai-cho, Hitachi-shi, Ibaraki-ken, 317-8511, Japan
*E-mail: naoshi_usui@pis.hitachi.co.jp

For the purpose of supporting plant operation, water chemistry evaluation and diagnosis system have been developed. The systems consist of the expert system of anomaly detection and diagnosis and the evaluation service system. The expert systems supports stable plant operation with detecting minute change of water quality and suggesting countermeasure of occurred symptoms. And the knowledge base of the expert system can be extended by chemical staff with mouse operation, when new knowledge is gained or the water chemistry control method is changed. The evaluation service system that we call e-Chem page provides technical information and know-how of BWR water chemistry management through the interactive communications between a water chemistry personnel of utilities and a staff of plant maker using the Internet.

1. Introduction

Water quality in Boiling Water Reactor(BWR) plants is controlled and managed to keep the integrity of reactor internals and minimize radiation exposure to personnel. For this purpose, corrosive oxidants and impurities entering the primary water system are carefully controlled to ensure enduring stable plant operation.

In recent years, methods of water chemistry control in BWR plants have become more sophisticated due to increasingly higher purity of water quality as a result of improvement of water chemistry control techniques.

The advancement of water chemistry control techniques and facilities in nuclear power plants has diminished occurrence of chemical abnormality and brought stable plant operation. And chemical management staff in nuclear plants has experienced less and less trouble of chemical abnormality.

In addition, sensors and chemical analysis items for monitoring the water quality have been increasing with advancement of water chemistry control technique, which results in the increase of chemical management staff's work. On the other hand, it is required to accumulate empirical knowledge and technologies on plant chemical control for stable plant operation.

Hence, the effective water chemistry control system is preferable to support chemical staff's work in plants. For this purpose, water chemistry evaluation and diagnosis systems have been developed.

2. Expert system for Water Chemistry

The unit operation and failure of equipments in a reactor cooling water system affects water chemistry sensitively because the base water of BWR is kept in high purity condition. On the basis of this characteristic feature of BWR cooling system, the expert system is provided to detect very small changes in the water chemistry at an early stage so as to identify causes of water change and to guide maintenance personnel in deciding the countermeasures for the failure. This system combines two expert systems : one for detecting an anomaly in the plant operating condition and quickly inferring its cause (Anomaly detection system), and the other performing a detailed diagnosis of the detected anomaly (Anomaly diagnosis system). The water chemistry and plant operation data for diagnosis are provided from water chemistry acquisition system. The construction of system is shown in Fig. 1.

Chemical staffs can maintain the knowledge base of diagnosis system without know-how of programming language. A configuration of the systems in nuclear power plant is shown in Fig. 2. And the feature of each system is described under section.

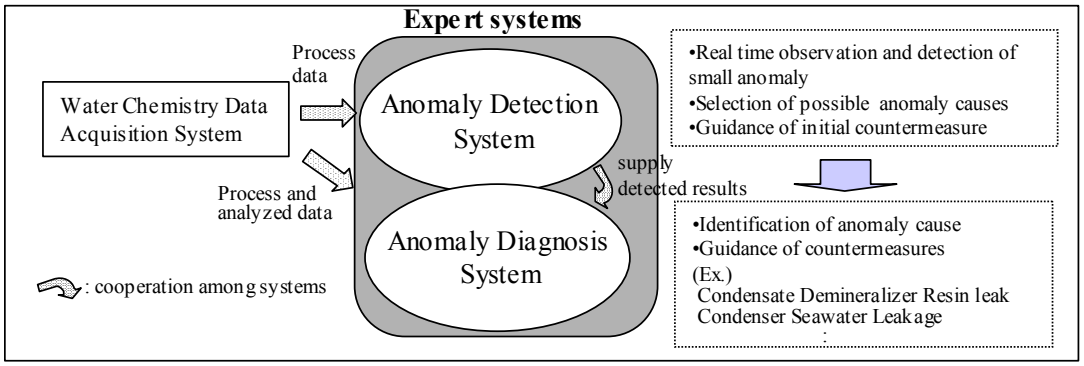

Fig.1. The construction of water chemistry evaluation and diagnosis system.

2.1. The Anomaly Detection System

2.1.1. Basic procedure

The anomaly detection system supports plant operations by detecting minute changes in the quality of the water and identifying the cause of the change, and giving the guidance for initial countermeasures. This system utilizes the database, which the water chemistry data acquisition system collects from the process computer and on-line automatic analyzers.

The basic procedure of the system is as follows:

1) Real time monitoring of process data (process computer and on-line automatic analyzers data)
2) Detection of chemical data changes and identity of its causes
3) Confirmation of the detected data changes
4) Display on monitor screen (possible anomaly causes, guidance, etc.)

2.1.2. Functions of the Anomaly Detection System

2.1.2.1. Detection of Chemical data changes and identification of its causes

This system uses fuzzy inference in detection and identification of causes [1,2].

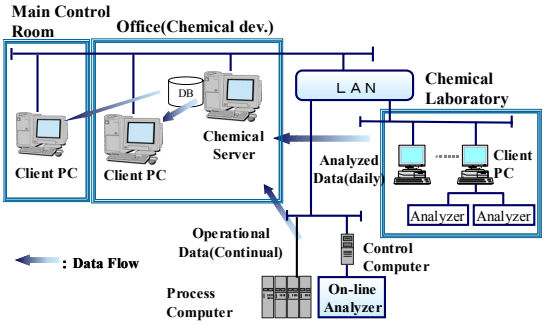

Fig. 2. Configuration of the water chemistry management systems.

This method enables us to accomplish early detection and identification of causes by the fuzzy relationship between the symptoms appearing in the plant process data and their causes (knowledge base of anomaly detection system).

Table 1 shows an example of the knowledge base. As the knowledge base is represented by matrix, it's easy to correct and add the knowledge base for users when new knowledge is gained.

2.1.2.2. Confirmation of the detected data changes

Plant process monitor has possibility of producing anomaly signals simply by electric noise with plant operations or trouble of sampling line. Therefore, this system has a correcting function by which detected data and their correlative data measured by another instrument are automatically evaluated based on their interrelations to improve reliability of anomaly detection.

2.1.2.3. Display on monitor screen

When chemical abnormality is detected,

Table 1. An Example of the Knowledge Base for Anomaly Detection .

Parameters (Symptoms) \ Causes		Condenser Seawater Leakage	CD Resin Leakage	CD Resin Reverse Regeneration
Hotwell Outlet	Conductivity	◎	—	—
Condensate Demineralizer (CD) Inlet	Conductivity	○	—	—
	Chlorine	◎	—	—
	TOC	—	—	—
Condensate Demineralizer (CD)Outlet	Conductivity	△	—	○
	Chlorine	◎	—	—
	TOC	—	◎	—

◎ (Strong Correlation) ○ (Normal Correlation)
△ (Weak Correlation) — (Non Correlation)

this system can display probable causes of anomaly onto the client's monitor screen and with the easy mouse operations, provide initial guidance for plant operation, trend graph and correlation graph of anomaly detected data and so on.

These data support plant operators and chemical management staffs to confirm the situation of occurred abnormality and the adequate countermeasure for plant operation.

2.2. Anomaly Diagnosis System When abnormal symptom is detected by the anomaly detection system, root cause investigation or proper countermeasure should be required.

The detailed diagnosis system comprises expert systems that can serve in tracing the symptoms to potential causes. Each system indicates to operators a more detailed identification of causes, degree of anomaly or prediction of changes, and offer appropriate guidance for these.

For example, when condenser seawater leakage is occurred, this system instructs analyzing chlorine in Condensate water for identification of occurrence, predict reactor water estimating capacity of ion-exchange resin in condensate demineralizer, calculate leakage rate and suggest countermeasures for occurred scale.

The knowledge base of this system is constructed with the production rule (If … ,then …) and Plant Chemical staffs can make new knowledge base with mouse operation.

3. Evaluation service using Internet

In addition to expert system described in the proceeding section, the evaluation service system which we call e-Chem page have provided technical information and know-how of BWR water chemistry management through the interactive communications between a water chemistry personnel of utilities and Hitachi, Ltd. using the Internet.

3.1. Configuration All programs and database of this system are constructed in web server of Hitachi, Ltd. Chemical management staffs in nuclear power plants operate the e-Chem page on their PC's web browser to utilize its interactive functions, such as inquiry & its history retrieval, as well as reference to documents [3].

Figure 3 shows the system configuration of the e-Chem page. Security is a concern for Web application, and the e-Chem page keeps the data

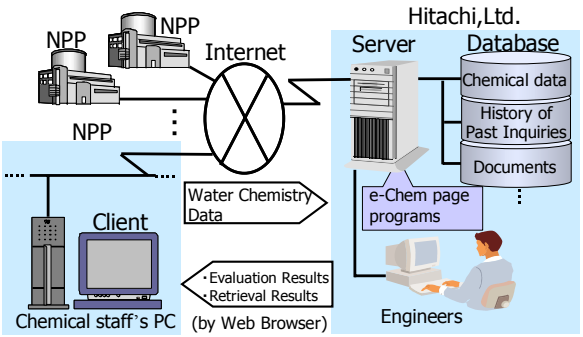

Fig.3. e-Chem page system configuration.

secure by applying access control using firewall technology and code technology using a secure socket layer (SSL).

3.2. Functions of the e-Chem page system

3.2.1. Water Quality Evaluation Function

Usually, chemical personnel in plants gather chemical data to estimate water quality. In recent year, sensors and chemical analysis items for monitoring the water quality have been increasing.

The water quality evaluation function in the Web server automatically compares the current data with past data of the last month and the last cycle. Figure 4 shows an example of comparison between current and past data. The standard value is calculated from the correct value of the past data. The normal range is defined by the variance of these data. If the current data are outside the normal range, the system decides that the water quality of the target plant has experienced a significant fluctuation. If there is significant fluctuation in the water quality, the function highlights the corresponding factors in the trend monitoring display on the Web page. This is illustrated in Fig. 5. The item of comparison with the last month in conductivity is highlighted and is displayed as an upward pointing arrow because the current data of conductivity are above the normal range. In addition, this system has a function to sort the fluctuation factor and draw a trend graph.

3.2.2. Inquiry and History Retrieval Functions

The inquiry and history retrieval functions enable chemical personnel in plant to ask the engineers in Hitachi, Ltd. about BWR water chemistry, and to search for past questions and answers by keywords.

An illustration of the inquiry function is given in Figure 6. Each of the questions has a root number and branch number in order to manage the inquiry history. If the question title is clicked on, the system displays the input field for the question, the

content of the reply and the attached file. With these functions, the knowledge related to BWR water chemistry can be stored in the database, so

that the knowledge is shared between engineers of Hitachi, Ltd. and the electric power company.

3.2.3. Reference to Documents Function

The reference function for documents on BWR water chemistry provides convenient information retrieval. Users can easily display documents on BWR water chemistry regarding condensate, feed water, etc. by selecting a component in a system diagram. After picking the component, the system informs the client user of related documents about water chemistry and displays them in the PDF format.

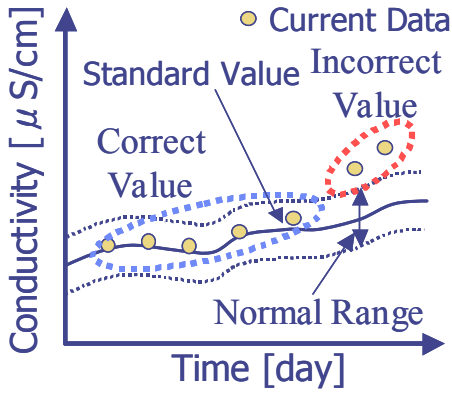

Fig.4. Comparison between current and past data.

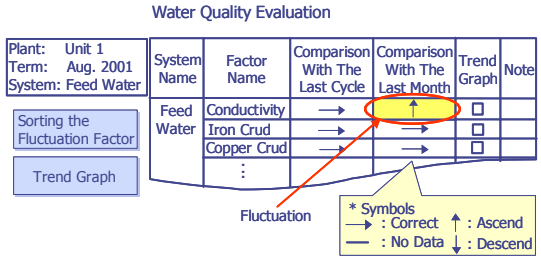

Fig.5. Example of fluctuation in water quality.

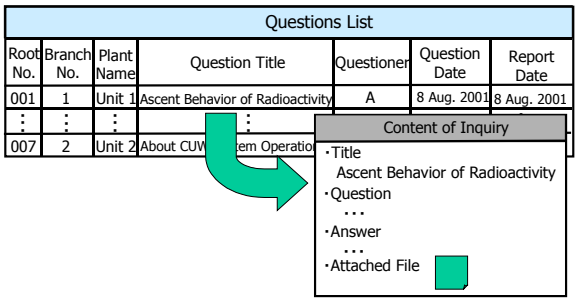

Fig.6. Illustration of inquiry function.

4. Conclusions

BWR water chemistry evaluation and diagnosis system for supporting plant operation is consisted of the expert system (anomaly detection system and anomaly diagnosis system) and the evaluating service system. The expert system support stable plant operation with detecting minute change of water quality and suggesting countermeasure of occurred symptoms. And the knowledge base of the expert system is able to improve by chemical staff with mouse operation, when new knowledge is gained or the water chemistry control method is changed.

The evaluation service system that we call e-Chem page provides technical information and know-how of BWR water chemistry management through the interactive communications between a water chemistry personnel of utilities and Hitachi, Ltd. using the Internet.

Both systems have educational functions for water chemistry.

References and Notes

[1]K.Morita, N.Ota,"Maintenance Support Systems Incorporating Networks",Hitachi Review Vol.48,1999.

[2] Igarashi et al., "Water Chemistry Diagnosis System for Nuclear Power Plants", Hitachi Hyoron, 72, August 1999.

[3] N.Kusumi ,T.Kasahara et al.,"e-Chem page A support system for remote diagnosis of water quality in boiling water reactors ", Proceedings of ICONE10,Arlington,April 14-18,2002.