Failure Sign Monitoring System for Large-scale Plants Applying System Invariant Analysis Technology (SIAT)

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Abstract

The Failure Sign Monitoring System is an application for plant operation management of the System Invariant Analysis Technology (SIAT), NEC's original big data technology. This system aims at the early and accurate detection of signs of equipment failure. In order to achieve this, the "normal status" of a plant is defined automatically by examining the huge amount of operations data, which includes the accumulated temperature and pressure data. "Unusual conditions" based on real-time comparative analysis of the latest operations data are also detected. NEC deployed the first operational system at the Chugoku Electric Power Co., Inc.'s Shimane Nuclear Power Plant Unit 2 in July 2014.

Keywords

big data, System Invariant Analysis Technology (SIAT), sign detection, plant monitoring, atomic power plant

1. Introduction

A large-scale plant such as a power plant is organized by managing a large range of equipment facilities including, turbines, power generators and pumps. These are monitored by installing advanced monitoring systems. It is not uncommon for such a large-scale plant to possess thousands of sensors and other measuring instruments. In order to operate a large-scale plant and to be confident of finding abnormalities with a limited number of operators such a plant usually functions by setting a threshold value to each sensor. Operators perform monitoring basically by following these thresholds (e.g. an alarm tone is generated when the liquid temperature exceeds 50 degrees centigrade.)

Such a function is essential for the efficient monitoring of large-scale plant, but it has been challenged by issues such as: 1) difficulty in noticing signs that do not exceed the thresholds; 2) differences in the capabilities of recognizing alarms and abnormal values and in applying proper measures after confirming an abnormality and until estimating the cause (time, etc.).

We have solved these issues with the introduction of our Failure Sign Monitoring System that employs the System Invariant Analysis Technology (SIAT), one of NEC's unique big data technologies. After the demonstration test for verifying the effect in collaboration with the Chugoku Electric Power Co., Inc. and IIU Corp., the first system was delivered to Chugoku Electric Power Co., Inc.'s Shimane Nuclear Power Plant Unit 2 in July 2014. We outline system details below.

2. Basic Principles of the System Invariant Analysis Technology (SIAT)

At a large-scale plant a very large number of plant parameters, such as temperatures, pressures, flow rates and vibrations etc., are measured continuously. For example, Chugoku Electric Power Co., Inc.'s Shimane Nuclear Power Plant Unit 2 measures a total of 2500 parameters at 3,500 points.

When a plant maintains a stable operating status, there are certain correlations between plant parameters (for example increasing the generated power increases the pump pressures).

However, when an abnormality occurs, the correlations between the plant parameters under the stable operating status begin to collapse (e.g., the pump pressure drops even when the generated power is increased).

The System Invariant Analysis Technology monitors all of the sensors continuously in order to see if "the correlations with other sensors are the same as usual." This procedure aims at the detection of any sign of abnormality before the values of individual sensors exceed the threshold values. This NEC-original big data analysis engine enables the invariants between plant parameters to be deduced automatically by inputting historic operational data. This feature enables the system introduction without investing high costs.

By adopting this type of big data approach, the system detects at an early stage any minor "unusual" signs that even an experienced operator might overlook, and these are then notified to the operators. A database of the huge amount of accumulated plant parameters is compiled and a more accurate notification of "the causes of abnormalities" is enabled by making use of the past data.

3. Functions of the Failure Sign Monitoring System

3.1 Failure Sign Monitoring System during Normal Operation

Fig. 1 shows the operations under normal status of the failure sign monitoring system.

The system first develops a "normal operations model (= routine status)." This model represents the relationships between sensors derived by the SIAT and is based on the time-series data of the sensors installed at the nuclear power plant. Normal model operation is defined as "the model developed based on the sensor information during the previous normal operation of the nuclear power plant."

Setting the values of "the normal operation model (herein after referred to as the "model")" and configuring the failure sign monitoring system allows it to start the status of "capable of predicting sensor behavior during normal prediction (prediction of the operation of sensor x in the example)".

The failure sign monitoring system judges the operational status by comparing the predicted value based on the "model" with the actual measured value (prediction y* and measurement value y in Fig. 1) in real time. When the measured values change in the same way as the predicted values, the system judges that the normal operation is continuously maintained without trouble. If the measured values deviate from the predicted values, the system is judged to be in "unusual status" and a failure sign is identified if the deviation continues or increases as time passes. An example of the system display is shown in **Fig. 2**.

In order to utilize the acquired data effectively, the failure sign monitoring system packages various display and analysis functions, aiming at efficient abnormality cause analysis. In our verification demonstration, we were even able to detect a sign of an abnormality by approximately seven hours before the operator (results differs according to the operational conditions). We believe therefore that introduction of the system will improve the quality of management of the plant operation.

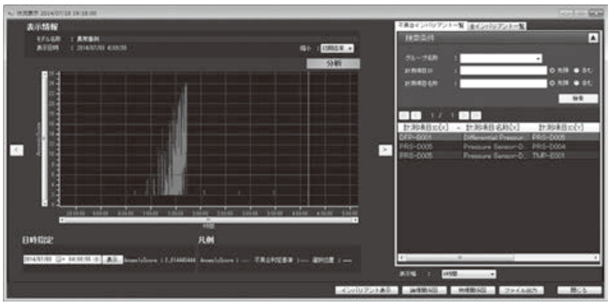

Fig. 2 Example of a failure sign detection monitoring screen.
(The X-axis of the graph represents the time and the Y-axis represents the abnormality value.)

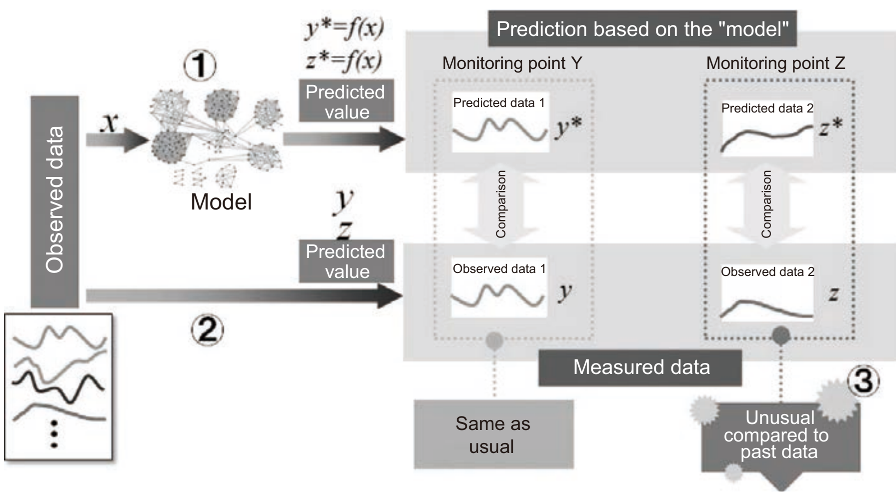

Fig. 1 Monitoring of normal operation using SIAT.

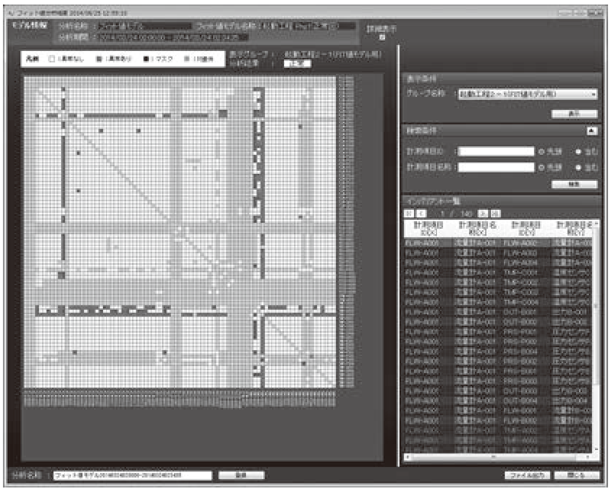

Fig. 3 Results of data comparison between the “model” data and the data of the startup process.

3.2 Validity Check at Plant Startup

This is another major function of the system.

The startup of a plant such as a nuclear power plant involves multiple processes. One process is advanced to the next process while checking the plant parameters carefully for each process in order to confirm the absence of malfunction. In each process, the failure sign monitoring system analyses the acquired data and confirms if there is any deviation in the data by comparing them to data acquired previously via the same process, and notifies the result. The operator can perform the startup procedure securely by checking if the plant performance is identical to previously.

Fig. 3 shows the comparison results between the “model” and the data acquired in the startup process.

Sensors are positioned in both the X and Y axis in the graph and the data comparison results are shown in the table. Any items that indicate deviations between the “model” data and the measured data are represented in red in the table.

On the other hand, an item in white represents “data without deviation.” This coloring method allows the operator to identify at a glance whether or not the startup procedure is advancing smoothly. Analyzing if red data occurs frequently with specific sensors enables a quick detection of any issues during the startup procedure.

- **Supplementary information**

1) After performing the above described check items for each process, the validity of the entire startup procedure is confirmed.
2) The accuracy of the validity checks will be improved when more “model” data are accumulated and available for the comparison.

4. Configuration of Failure Sign Monitoring System

Fig. 4 shows the configuration of the failure sign monitoring system.

The failure sign monitoring system acquires data from the existing operation monitoring system and performs analyses based on the acquired data to detect whether an abnormality is present. The system can be installed additionally to an existing operation monitoring system without interfering with its operation. Some of the advantages of the system are that it can use the existing sensors and operation monitoring units of the system and thereby cope flexibly with adding to or removing from the system.

The system adopts the server-client configuration by using multiple clients so that multiple operators can check the status simultaneously. The servers are categorized roughly into “analysis servers” and “storage servers.” The acquired data is analyzed by analysis servers incorporating the SIAT engines

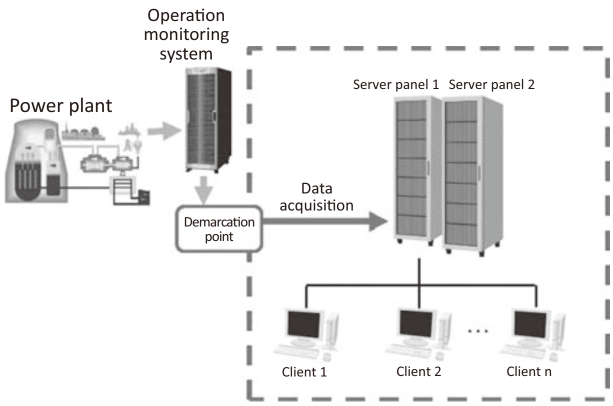

Fig. 4 Configuration of the failure sign monitoring system.

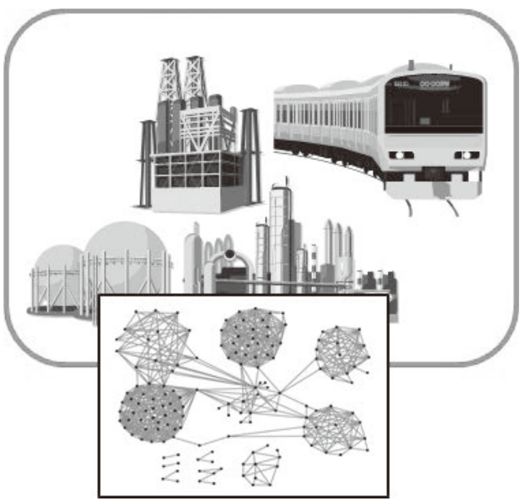

Fig. 5 Deployment in other commercial industries.

and the results are saved in the storage servers.

The clients can be used to check the results or to set the monitoring method, etc.

5. Future Challenges

We plan to enhance the system functionality in the future by improving the accuracy and speed of identifying abnormalities and estimating the causes. We are also investigating the possibility of expanding the application of the system in other commercial industries (**Fig. 5**).

6. Conclusion

In the present paper the NEC's failure sign monitoring system is introduced by discussing an example of its application in a nuclear power plant. We intend to contribute to the security and safety of the system infrastructures by improving the monitoring accuracy and also by applying technical level improvements. We are aiming thereby to deploy the system in a wider range of commercial activities.

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