Visualization of Electrical Facility Conditions by Monitoring Data-Analysis

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Abstract

We provide a cloud-based maintenance service of electric facilities for the purpose of shifting to Condition Based Maintenance (CBM). As a function of this service, we developed a visualization function of electric facilities using monitoring data. Specific examples of visualization include: (1) the visualization of a wide-area status of the equipment using alarm logs, (2) the detection of failure signs of heat exchangers using monitoring data, and (3) the detection of rotating machinery errors. This function was developed based on monitoring data and does not limit target facilities. By utilizing the visualization function, it is possible to encourage a shift to CBM based on monitoring data.

1 Preface

We provide electrical equipment and systems to public and industrial sectors in Japan and abroad. In doing so, we have contributed in building social infrastructures. In order to maintain quality and performance of these electrical facilities, periodic inspection and maintenance, or Time-based Maintenance (TBM), is conducted. There is a growing trend of shifting to Condition-based Maintenance (CBM) for economic and management efficiency. To apply CBM to actual facilities, the technology and tools used to diagnose health with high accuracy are essential. For this reason, various sensors are installed in electrical facilities. The technical development for collection, storage, and analysis of various types and large volumes of measurement data is in progress. There are situations, however, where the modification of existing facilities is not as economical in terms of effectiveness by this introduction considering the capital costs. As a measure to solve this challenge, we consider the effective use of data (monitoring data) collected by control and monitoring systems such as the existing Programmable Logic Controller (PLC) and Supervisory Control And Data Acquisition (SCADA). If it is possible to analyze singularly by the monitoring data, can to expand the scope of our application to CBM of existing facilities.

We developed and constructed an analysis and management function (visualization) based on monitoring data[1][2] to implement CBM for existing facilities. Fig. 1 shows a data-driven visualization technology for the imaging of facility conditions. In this paper, we introduce our programs for advanced maintenance technologies for existing electrical facilities.

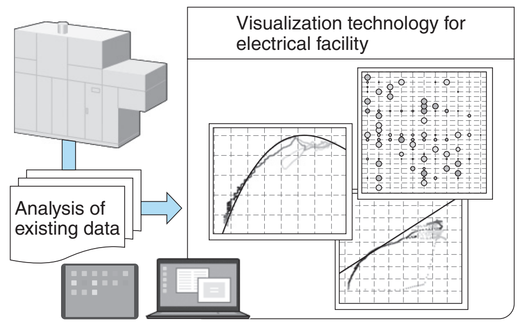

Fig. 1 Data-Driven Visualization Technology for Imaging of Facility Conditions

Data-driven visualization technology for imaging of facility conditions is shown.

2 Monitoring Target: Combined Heat & Power (CHP) System

Monitoring data from the CHP system operating at a particular facility is used as a verification test site. We utilized the monitoring data, "alarm logs" and "measurement data", used by the remote monitoring service from our customer center. We

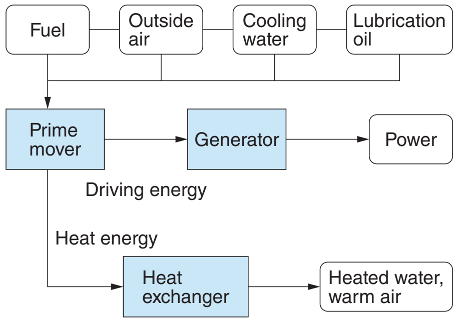

Fig. 2 Configuration of the Target CHP System

The CHP system is composed of multiple equipment units. A variety of matters (fuel, cooling energy, etc.) are transmitted among these machines. The measured values of these matters are used for the monitoring of conditions within the system and operation.

made a visualization of the monitoring data obtained in the past with the cooperation of the related facility management department. Fig. 2 shows the configuration of the target CHP system. The facility structure is shown below. This system mainly consists of multiple equipment, mostly our supplied diesel engine generator and heat exchanger. In the visualized design stage for this facility, there were already dozens of monitoring items (power, temperature, pressure, flow rate) installed and operated in the existing monitoring system. Although there are many monitoring items, under the CHP system where equipment is intricately interlinked in a complicated manner, it is difficult to evaluate status based on rule-based judgment. For the CBM based on monitoring data, high-precision visualization based on data- driven analysis is therefore required.

3 Visualization

The case study of analysis and visualization of monitoring data is shown below.

3.1 Visualization Using Alarm Logs

The alarm logs in the monitoring data store information of past anomalies that have occurred. Contents are varied and it is difficult to extract the regularity by visual inspection. By the overview showing of our accumulated alarm logs on the monitoring display, we focused on the visualization of the wide-area trend of abnormalities. This display function is effective in making the facility status visible by organizing and integrating data.

Fig. 3 shows the visualization of the facility status in the bubble chart. The bubble chart shows

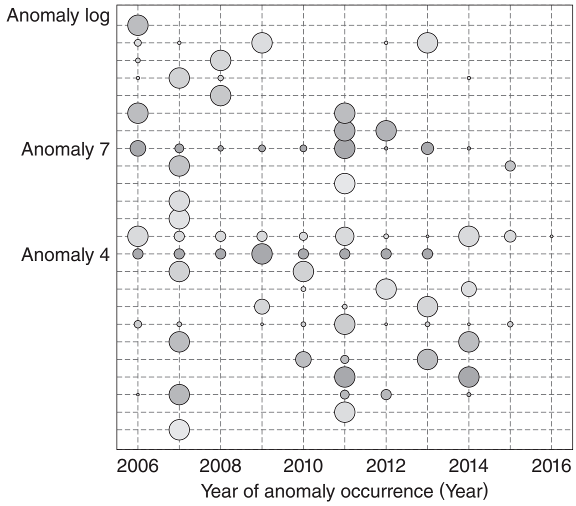

Fig. 3 Visualization of Facility Status in Bubble Chart

Anomaly logs are classified for each anomaly, year of anomaly occurrence, and frequency of occurrence so that the status of the monitoring target can be clarified.

the frequency of occurrence of each abnormal factor on one screen. The frequency of occurrence of each factor is expressed by the varying size of the bubble. Each event bubble is placed on a horizontal axis with time as the unit. This chart objectively visualizes the wide-area error factors (equipment conditions) inherent to the equipment. Focusing on the alarm logs, Abnormality 4 and 7 can be identified as chronic alarms. Focusing on the year of each alarm, it is discovered that many alarms were issued in 2007 and 2011. This is the result of the occurrence of sudden failures and special operation. In this way, this function can clearly show the “individual characteristics” of the equipment that were grasped by the maintenance staff through their experiences.

3.2 Early Sign of Failure in Heat Exchanger

Anomaly 4 and Anomaly 7 were revealed by log visualization, alarms related to the heat exchanger. We therefore, selected several measurement data related to the heat exchanger and tried to visualize them by analyzing the data and processing the signals.

Fig. 4 and 5 show the results of the visualization of the heat exchanger. The results of the analysis were visualized as a scatter plot diagram based on the daily monitoring data. The horizontal axis represents the exhaust gas and the vertical axis represents the feature values showing the state of the cooling system. Comparing the normal operation day in **Fig. 4** and the day before the failure in **Fig. 5**, the relationship between the characteristic values of the cooling system and the exhaust gas system is significantly different in the operation/stop process. It was, at this time, confirmed from the actual record of the equipment that a failure due to a malfunction of the cooling system had chronically occurred. Since the change started several weeks before the day before the failure, the failure can be predicted by daily comparative evaluation of the visualized results. This failure is difficult to detect by monitoring changes in a single sample of data. By combining and analyzing multiple existing monitoring data, we were able to visualize the equipment status based on the collapse of the relationships between items.

3.3 Detection of Rotor Malfunction

This method is a data-driven analysis and can be used for visualization of the state of different target machines. **Fig. 6** and **7** show the result of visualization of the rotating machine. This is a case

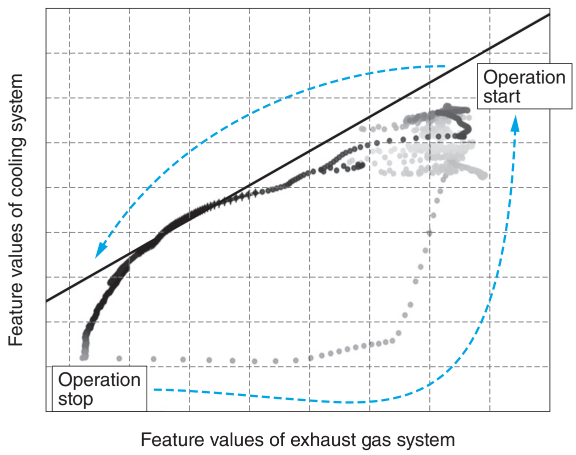

Fig. 4 Visualization of Heat Exchanger (Normal Operation Days)

Regarding the operating conditions, the feature values of both the cooling system and exhaust gas system are changed with time. As a result, the scatter plot diagram shows a circular locus.

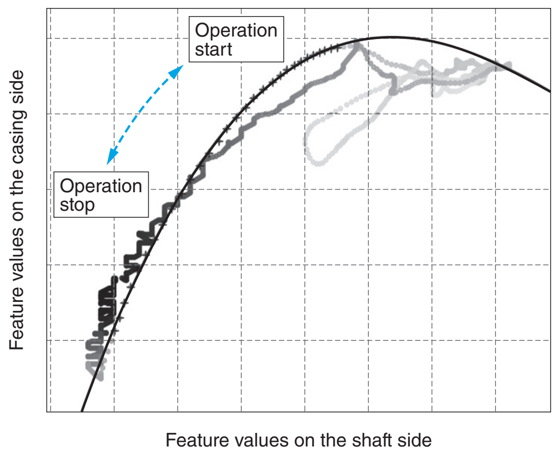

Fig. 6 Visualization of Rotating Machine (Normal Operation Days)

For a different monitor target system (rotating machine), the feature values of both the shaft side and the casing side are changed with time. The scatter plot diagram shows an arc-shaped locus.

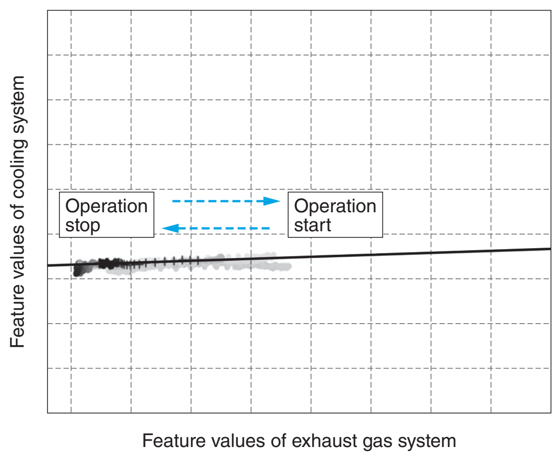

Fig. 5 Visualization of Heat Exchanger (Day before Failure)

On the previous day before a failure, feature values of the exhaust gas system were changed according to the status of operation. The feature values of the cooling system, however, did not change. For this reason, the scatter plot diagram shows a non-circular locus. Failure prediction is possible by comparing the data with the data record on a normal operation day.

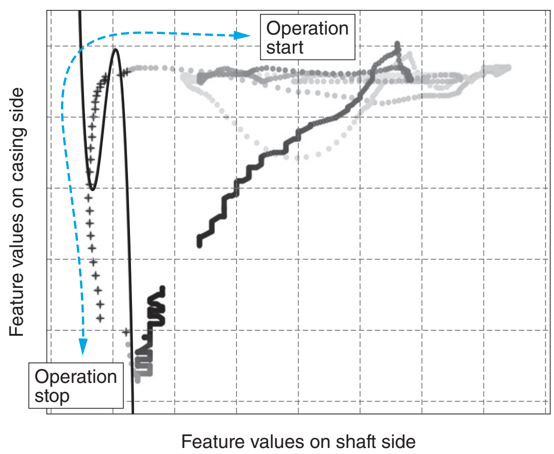

Fig. 7 Visualization of Rotating Machine (Day of Anomaly)

On the day of the anomaly, a change appeared in the feature values of the casing side. As a result, the scatter plot diagram does not show an arc-shaped locus, but a locus different from that of a normal operation day. In this manner, evaluation of a locus acquired from the scatter plot diagram is very effective and useful in monitoring the system conditions.

study of detection of an abnormality of a rotating machine. The horizontal axis is the feature value on the axis side and the vertical axis gives the feature value on the housing side. In **Fig. 6**, during the normal operation, on the day, the numerical value on both the shaft side and the housing side shows a gradual upward trend during starting and stopping time. **Fig. 7**, on the abnormal day, however, the response of the vertical axis to the ascending process is the axial direction, changed and behaved differently than usual. It was recorded in the alarm log that this anomaly occurred multiple times. In addition, even on a day when there was no record in the alarm log, similar behavior was detected by the visualization. This visualization suggests that it is possible to deal with abnormalities that were difficult to detect by already existing methods.

4 Postscript

We introduced a data-driven management function that visualizes equipment status, signs of failure, and detects abnormalities from monitoring data. This technology has been made into a service as part of our cloud-based maintenance service.

With the spread of CBM in social infrastructures, we will continue to develop technologies for advanced maintenance of equipment, improvement of operation efficiency, and reduction of on-site workloads.

《References》

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