Development of RCPs Predictive Diagnosis System

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1. Introduction

The Reactor Coolant Pump (hereinafter referred to as "RCP") predictive diagnosis system targets RCPs, which are among the primary core devices operated in domestic standard nuclear power plants (OPR). To prevent unexpected failures of core equipment (RCPs) during power plant operation, we plan to build a machine learning-based predictive diagnosis system to constantly monitor and diagnose equipment status from a remote location. Each power plant is operating RCPVMS and PMS (PI System) to monitor the status of RCP. RCP VMS uses vibration data collected from real-time pumps to monitor vibration magnitude and frequency component change information and generates an alarm when the set range is exceeded. PMS mainly monitors the status of various operating variables such as temperature and pressure related to the pump. However, the existing systems do not share collected data with each other, making it difficult to comprehensively analyze pump vibration and operating performance. Additionally, since a monitoring system is operated for each power plant, comparative analysis is not possible, making it difficult to perform an accurate diagnosis. In particular, it is difficult to respond quickly because it does not provide the precise diagnosis information necessary for managers to take risk measures, such as the type and cause of the defect.

2. System configuration and functions

The RCP predictive diagnosis system configures the system as follows and connects the network to accurately diagnose the health of the pumps (4 units per unit) in operation at the OPR nuclear power plant in real-time from a remote location.

2.1 Data Communication

The data communication of the RCP predictive diagnosis system is intended to secure real-time input data necessary for monitoring the equipment status and machine learning diagnosis of the monitoring system (RCPVMS, PMS, PI System, OPMS) operated at the power plant and headquarters and the AIMD Center operation server. To collect RCP vibration measurement data, communication with the RCPVMS system operated at each power plant is required, and a network connection was made with the CMD HMI Prosy server of the PI System (provided by PMS) to collect operation data related to the pump. The data transmitted through the external monitoring system was implemented so that all data was received from the preprocessing server of the RCP predictive diagnosis system.

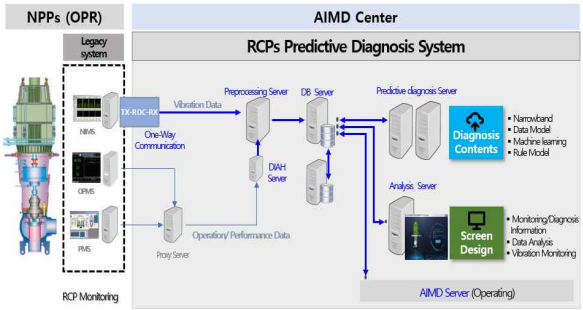

Fig. 1. Configuration diagram of RCPs predictive diagnosis system.

2.2 Data collection and standardization preprocessing

Data collection and standardization preprocessing are performed through the periodic/non-periodic communication from each RCP monitoring system operating at the six target nuclear power plants. The transmitted data is collected comprehensively from the preprocessing server of the RCP predictive diagnosis system, the transmission data protocol is standardized and classified, and grouped data files are created to be provided to the big data DB.

2.3 Big data DB

Big data DB stores and manages pre-processed surveillance system data in a large-capacity database (NoSQL, RDBMS) and converts it into a database to provide collected data to the linked machine learning server, vibration analysis server, and visualization server. For efficient operation of the big data DB, the raw data provided by the monitoring system is stored and managed in the NoSQL DB, and the operation and diagnosis result data required for system operation are mainly managed in the RDBMS. In addition, a redundant configuration (Main DB, Backup DB) was established to provide stable data to the linked server without data loss even when the server or program is shut down due to the irregular operation of the big data DB.

2.4 Machine Learning Diagnosis

Machine learning diagnostic technology is intended to detect defects occurring due to any cause during normal operation of the RCP pump early and to precisely predict the type and cause of the defect in advance. Algorithm models applied for machine learning diagnosis include data model, rule model, narrowband parameter model, and SVM (Support Vector Merger) model. The data model is intended to detect abnormalities in RCP-related operating variables early, and the AAKR algorithm was used. The rule model is intended to diagnose defects in pump components and equipment. A number of rule-sets based on pump operation variables reflecting expert experience and information were created and Bayesian inference techniques were applied. The narrow-band parameter model is intended to diagnose defects in rotating parts. It is intended to monitor the occurrence of abnormalities in each narrow-band section based on the order and phase parameter components extracted from vibration data, and perform rule-set and Bayesian diagnosis for fault diagnosis. After learning the defect identification features extracted from vibration data, an SVM algorithm with excellent identification ability was applied. Accordingly, a machine-learning diagnosis process was configured as shown in the figure below.

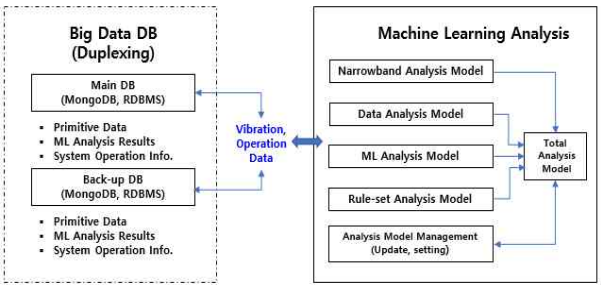

Fig. 2. Machine learning diagnosis and data processing process structure.

2.5 Vibration analysis program

The vibration analysis program is designed to analyze the cause when a defect occurs due to any cause during RCP pump transients (starting, stopping) and normal operation, and to monitor the vibration condition during normal operation. The RCPVMS system operated in existing power plants does not provide the various analysis functions required by the ASME OM CODE PART-24 international standard, and only provides simple monitoring and alarm functions that monitor only changes in vibration magnitude and frequency. For this reason, when abnormal pump vibration occurs, a precise cause analysis must be performed using separate equipment and programs. In this study, to solve these problems, we developed and applied various condition monitoring and cause analysis functions required by ASME OM CODE PART-24.

2.6 Visualization HMI

Visualization HMI is a user interface screen that provides visualization services to users for status monitoring and diagnosis results of RCP pumps operating in six OPR power plants. HMI screen information is data that receives monitoring and diagnosis results provided by the big data DB from the visualization platform and then preprocesses them into the form required for visualization services. The screen configuration consists of a screen for monitoring the real-time monitoring and diagnosis status of the RCP pump and a screen for recalling and analyzing past data. Additionally, there are other management function screens to support and operate it.

3. Conclusions

The RCP automatic predictive diagnosis system aims to prevent unexpected failures of RCP and improve operational efficiency through real-time monitoring and diagnosis of equipment status from a remote location. To this end, RCP vibration data was linked in real-time to the network, a big data DB was built, and various diagnostic contents were developed and applied to the system. Accordingly, we plan to build a big data DB that collects and shares RCP data and build a predictive diagnosis system using the latest machine learning diagnosis technology.

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