Development of Artificial Intelligence Monitoring & Diagnosis (AIMD) System

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1. Introduction

Since 2017, KHNP has been developing an artificial intelligence monitoring and diagnosis (AIMD) system for NPP equipment based on big data and AI in order to detect signs of failure and predict conditions of essential equipment. In Step 1 (Dec. 2017 – Dec. 2018), a pilot project was carried out to develop a predictive diagnosis system for 300 equipment of five types rotating equipment. In Step 2 (Jan. 2019 – Dec. 2022), which is currently in progress, an automatic predictive diagnostic model and analysis algorithm are under development targeting 12,000 equipment of 675types rotating equipment (turbines, generators, pumps, etc.) and power equipment (of transformers, breakers, etc.) of the 26 units in KHNP's fleet. In addition, an AIMD Center has been set up and the automatic predictive diagnosis system will start operation in July 2022 covering the entire fleet (26 units) and thereby provide real-time diagnosis and prediction of conditions for major equipment at NPPs in service. This is expected to reinforce safety, operation, monitoring, and maintenance of NPP operation by minimizing failures and/or unplanned trips of major equipment.

2. Applied Technologies

The AIMD System based on big data and AI facilitates an on-line network integration among the plant monitoring system (PMS), vibration monitoring system (VMS), and predictive maintenance system (PdM). In addition, the AIMD System is an innovative technology which monitors and diagnoses equipment conditions addressing shortcomings of the existing equipment monitoring system by applying key technologies of the Fourth Industrial Revolution (big data, AI, IoT, wireless, etc.)

2.1 Network connectivity & optimization of diagnostic big data

To enhance equipment reliability and availability, various equipment monitoring systems (PMS, VMS, and PdM system) are connected to the network and a big data platform has been established. To optimize the integrated big data, KHNP has collected and standardized NPP equipment data, selected faulty parameters, and standardized diagnosis results, points of measurement, and measured values. In addition, world's largest NPP equipment diagnosis big data platform (675 types of equipment, about 12,000 equipment) has been completed.

2.2 Automatic diagnosis of equipment failure using various diagnosis techniques

To enhance accuracy of the automatic diagnosis of defects on rotating equipment (turbines, pumps, etc.), the AIMD System enables concurrent execution of rule-based diagnosis, narrowband frequency diagnosis, and machine learning diagnosis. Equipment defects are automatically diagnosed following a series of process; trend monitoring, narrowband monitoring, diagnosing symptoms, and a processing algorithm. Machine learning is a technology which learns important patterns and rules from accumulated big data and when new data are entered they are classified according to criteria generated by machine learning. As part of machine learning, Support Vector Machine method was applied in diagnosing imbalance, misalignment, and bearing damages of rotating equipment. Support Vector Machine method is widely used in diagnosing defects, since it determines classification criteria by learning from existing data and has very high accuracy in classifying new data.

2.3 Thermal image deep learning

Thermal image deep learning is applied to power equipment (transformers, breakers, etc.) and rotating motors. The quality of existing thermal image data widely varies since personnel measuring the thermal image data have different levels of technology and expertise. Against this backdrop, in order to secure high-quality data, KHNP has standardized components used for thermal image data and provided training across the fleet on how and where to measure thermal image data. A ResNet-based algorithm was applied to the thermal image deep learning since the algorithm recognizes objects with complex structures due to multiple characteristic extraction layers.

2.4 Wireless vibration sensors

Hanbit Unit 6 was selected as a pilot plant for the AIMD project. Wireless sensors were installed on 24 rotating equipment and equipment conditions are monitored and diagnosed by collecting vibration data. Wireless sensors are planned to be installed in other plants as well.

2.5 Comparative diagnosis of same-kind equipment

Comparative diagnosis of same-kind equipment refers to conducting diagnosis by comparing with same-kind equipment in other nuclear power plants and thereby enhance diagnostic accuracy and take pre-emptive measures by detecting microdefects at an early stage. Same-kind equipment are classified in the order of reactor type → equipment type → operating speed → bearing type → manufacturer → particular issues. In addition, defects with high frequency can be detected by standardizing diagnostic alarm values and by compiling statistics of diagnosis results. Furthermore, in connection with previous maintenance records, major failures and defects can be predicted in advance. Comparative diagnosis of same-kind equipment is a technology which is realized by integrating data of all equipment in 26 different units into the AIMD Center.

2.6 Visualization of diagnosis results (where the defects are found) using 3D virtual modeling

Visualization of diagnosis results (where the defects are found) refers to 3D virtual modeling and interconnecting data from the PMS, VMS, and IoT with plant equipment. Equipment defects detected by the AIMD System are visualized in a 3D virtual model enabling early identification of exact locations of defects and prompt decision making to resolve the problems.

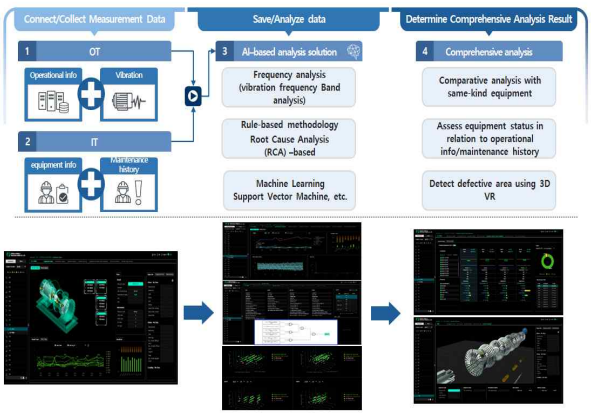

Fig. 1. The Diagnosis Process of AIMD System

3. Conclusions

The purpose of the AIMD System is to minimize unplanned shutdown of a nuclear power plant due to equipment failure by monitoring, in real time, conditions of 12,000 major equipment (rotating equipment, electric power equipment) in 26 units in service, identifying abnormal symptoms in advance and taking preventive measures. AIMD Center was established (Sep. 2020) and activities are under way to optimize systems and operating processes of the center.

Manual diagnosis of major NPP equipment depends on experience and knowledge of personnel and diagnosis results vary depending on individual capabilities and reliability of the diagnosis results is low. In order to resolve these problems, diagnosis systems in each plant were interconnected into the network, acquired data are standardized, a big data platform has been established, and key features of the Fourth Industrial Revolution (AI, VR, thermal imaging, wireless sensors, etc.) were applied. As a result, the AIMD System enables prompt and highly accurate diagnosis, prevents similar failures in advance, and contributes to enhancing productivity and efficiency of plant diagnosis and maintenance since the system is relatively easy to understand even for beginners.

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