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Development of EDG Engine Condition Diagnosis Logic in Korean Nuclear Power Plants

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1. Introduction

Through benchmarking using the excellent record of the nuclear power plants under operation in the United States and Europe and with the continuous development of nuclear-related technology, the Korea Hydro & Nuclear Power Co., LTD (KHNP) reached an average planned preventive maintenance period of 29.6 days in 2009.

In addition, KHNP plans to reduce the planned preventive maintenance period at Korea standard nuclear plants (KSNPs) from 29.6 days to less than 21 days by 2014 through a combination of domestic research and development (R&D) and the introduction of the technical know-how applied in the very best overseas nuclear power plants (NPPs) [1].

Accordingly, it is necessary to reduce the inspection and maintenance periods of an emergency diesel generator (EDG), which are currently set in the planned preventive maintenance period.

If the condition-based predictive maintenance (CBM) technology is applied to EDG engines, the maintenance period of an EDG will be shortened because engine maintenance is accomplished according to the engine condition under this plan [2,3].

In this study, in the series of CBM program developments which will be applied to EDG engines, the development results of condition diagnosis logic to be applied to EDG engines for exiting domestic NPPs are introduced.

2. Engine Condition Diagnosis Logic

The problems associated with exiting maintenance method of EDG engines and the current developments in CBM logic which could serve as a solution are described.

2.1 Problem with the current maintenance method

The exiting maintenance program for EDG engines follows a time-based preventive maintenance (TBM) technology, which is a second-generation maintenance method. It involves periodic inspections and maintenance according to the engine manufacture's recommendations.

According to the TBM method, the EDG engine must be disassembled and inspected regardless of the EDG engine's condition. Also, engine components must be reinstalled or the entire engine replaced regardless of conditions.

This can lead to surplus repair work with the replacement of perfectly operable engine components, incurring a great expense due to the need for many spare parts.

Industry experience with EDGs and other plant components has shown that when components are disassembled, the potential for component failure or malfunction increases immediately after reassembly. Failures are typically "maintenance-induced" due to reassembly error (e.g., a failure to torque fasteners and/or incorrect component alignment). This can degrade the reliability of EDG.

2.2 Necessity of CBM technology

In accordance with the reduction of the length of maintenance service period for the planned preventive maintenance of NPPs, the maintenance period of EDGs must be reduced as well. As a solution to this problem, only the CBM technology as a third-generation maintenance method can meet the reduction requirements pertaining to the planned preventive maintenance of NPPs.

The CBM method as a predictive maintenance technology makes up for the faults in current TBM method.

The CBM method, which takes into consideration the condition of the engine and each engine part, can effectively mitigate excessive repairs by optimizing the required time and maintenance procedures of EDG engines and only replacing parts when necessary.

The CBM method is based on an analysis of the condition of the EDG engine as it operates. This type of surveillance of the condition provides a variety of facts and information related to the condition of the engine to operations and maintenance (O&M) personnel. The O&M staff can then decide whether or not to repair the EDG engine based on the data related to the engine's condition.

2.3 Development of engine condition diagnosis logic

The development of EDG engine condition diagnosis logic should be done before applying CBM program to an EDG engine maintenance plan.

Fig. 1 shows the process of the development of condition diagnosis logic related to an EDG engine under operation.

As shown in Fig. 1, on the basis of reviews of foreign and domestic maintenance case histories, different reference materials, and the initial technical consultation with EDG engine experts, evaluation items and the type of condition diagnosis methodology, which are essential for the proper organization of the engine condition diagnosis logic, are determined.

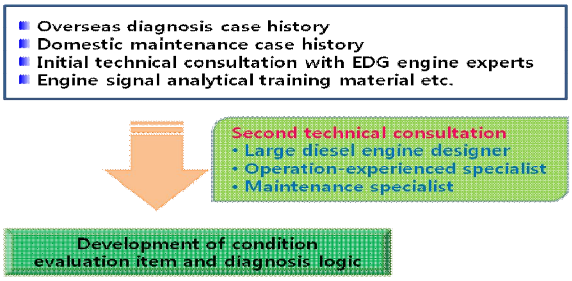

Fig. 1 The process of developing the EDG engine condition diagnosis logic

The evaluation items which identify any abnormal condition of an engine consist of measured data such as the temperature and pressure.

A second technical consultation with experts from academic circles and industrial working groups related to EDG engines was also undertaken to verify the suitability and on-the-site applicability of the evaluation items and the chosen condition diagnosis technology. Via these processes, the condition diagnosis logic was completed.

Table 1 shows the main contents of the evaluation items and the second technical consultation pertaining to the engine condition diagnosis logic.

Table 1 Main contents of evaluation items and the second technical consultation

Division	Main content
Evaluation items	○ Diagnosis data related to pressure ○ Diagnosis data related to vibration/ultrasonic ○ Diagnosis data related to the exhaust gas temperature, turbocharger and generator etc.
Second technical consultation	○ Selection of key factors related to the composition of the engine condition diagnosis logic and compatibility of this logic ○ Compatibility of condition evaluation questions related to the engine and attached components ○ Applicability and compatibility of failure causes associated with engine diagnosis phenomena ○ Compatibility of failure cause associated with operation variables

Fig. 2 shows EDG engine condition diagnosis logic, showing the different variables leading to primary engine failure and abnormal diagnosis symptoms. As shown in Fig. 2, the cause of a possible failure and the type of defect can be identified through a combination of various abnormal signals as measured by instruments in advance.

The primary causes of engine failure include 30 items divided into six system categories considering the feasibility of maintenance. The six system categories include the fuel injection system and the intake valve system, as shown in the Fig. 2.

The diagnosis symptoms include 68 items grouped into five processes according to combustion occurrence stages. Also as shown in Fig. 2, the processes include the air supply state and the fuel supply state.

Diagnosis Symptom \ Root Cause		Feul injection system		Intake valve system		Exhaust valve system		Engine body system		Turbocharger system		Generator system	
		Insufficient fuel pump performance	. . .	Excess intake valve clearance	. . .	Exhaust valve rocker bearing failure	. . .	Piston ring Blow-by event	. . .	Carbon deposit of turbocharger rotor	. . .	Generator bearing failure	. . .
Air delivery state	Is the closing of intake valve late (vibration and ultrasonic signal)?												
	......										○		
Fuel delivery state	Is the position of fuel rack high?		○										
	......	○											
In-cylinder pressure state	Is the peak firing pressure angle of in-cylinder low?	○											
	......		○										
Exhaust emission state	Is exhaust gas temp. of in-cylinder low?	○		○		○							
	......												
others	Is the outlet temp. of main bearing lubricating oil high?								○				
	......							○					

Fig. 2 Schematic diagram of the engine condition diagnosis logic

3. Conclusions

During the development of a CBM program for EDG engines, a useful engine condition diagnosis logic process that rectifies current problems associated with existing maintenance practices related to EDG engines was developed. The results of this study are as follows:

1. The current EDG maintenance practices are based largely on TBM activities recommended by the vendor. These practices are outdated, unnecessarily intrusive, and costly.
2. As part of the reduction program of the maintenance periods of the planned preventive maintenance of NPPs, the application of CBM technology based on the EDG engine condition is necessary.
3. To realize the CBM method as a predictive maintenance technology, a diagnosis logic process that takes into consideration the engine condition is developed.
4. The engine condition diagnosis logic will be updated by conducting additional engine condition diagnosis tests, after which it will be used as the fundamental data during the development of the engine CBM program.

REFERENCES

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