A Survey on the Maintenance Demand of Nuclear Power Plants in Korea

Jun Seok LEE, Center for Advanced Reactor Research, Korea Advanced Institute of Science and Technology, Member
Poong Hyun SEONG, Department of Nuclear and Quantum Engineering, Korea Advanced Institute of Science and Technology, Member
Chang Heui JANG, Department of Nuclear and Quantum Engineering, Korea Advanced Institute of Science and Technology, Non Member
Hyuk Soon LIM, Operation and Maintenance Support Group, Korea Hydro & Nuclear Power Co., LTD., Non Member
Jang Hwan NA, Operation and Maintenance Support Group, Korea Hydro & Nuclear Power Co., LTD., Non Member
Seong Jong OH, Operation and Maintenance Support Group, Korea Hydro & Nuclear Power Co., LTD., Non Member

This work presents the maintenance demand of nuclear power plants (NPPs) in Korea. The NPP companies have been targeting to the improvement of their productivity and they have considered the maintenance technology development. For the development, a survey on the maintenance demand is important. In this work, a questionnaire method is employed to know the operator and staff's opinions who involve in maintenance works in NPPs. The contents of the questionnaire are the present state of the maintenance in Korean NPPs, the present state of preventive maintenance, the development of maintenance technology, and the demand for specific equipment maintenance technology. Also, the necessity of the predictive maintenance technology is investigated with the questionnaire as a part of the maintenance technology development. From the work, it is possible to know the problem in the maintenance work and the technology to solve the problem.

Keywords: Nuclear power plant maintenance, questionnaire, pressurized water reactor, pressurized heavy water reactor, condition monitoring, on-line maintenance, preventive maintenance, predictive maintenance, overhaul

1. Introduction

Recently, most of NPP companies have been targeting several areas to improve their productivity actively. Improving availability of the plant, shorter outages and a significantly lower reactor trip had all contributed to higher output of the plant. However, there is a limit in the improvement to gain higher output. For that reason, they have been considering the improvement of maintenance work [1], [2].

The object of this research is to do preliminary investigation of the NPP maintenance technology development. For the work, it is necessary to know the current maintenance environment in Korean NPPs. Also, it is very important to get the plant operators and staffs' opinions for the research. To get their opinion, we carried out the questionnaire investigation.

The structure of this paper is as follows. In Section 2, we introduce the present state of Korean NPPs. The questionnaire contents are introduced in Section 3. The result of the questionnaire is presented in Section 4. In Section 5, we present summary and conclusion from the questionnaire result.

POC: 373-1 Guseong-Dong, Yuseong-Gu, Daejeon, Korea 305-701, Center for Advanced Reactor Research, Korea Advanced Institute of Science and Technology,
Tel: +82-42-869-3860, Fax: +82-42-869-3849,
e-mail: wahrheit@kaist.ac.kr

2. Nuclear power plants in Korea

Table 1 shows the NPP sites in South Korea [3].

South Korea has 4 sites and 20 commercial nuclear power plants. The first three commercial units - Kori 1 & 2 and Wolsong-1, were bought as turnkey projects. The next six, Kori 3 & 4, Yonggwang 1 & 2, Ulchin 1 & 2, comprised the country's second generation of plants and involved local contractors and manufacturers. At that stage the country had six Pressurized Water Reactor (PWR) units derived from Combustion Engineering in USA, two from Framatome in Europe and one from AECL in Canada of radically different design.

Then, in the mid 1980s, the Korean nuclear industry begins a plan to standardize the design of NPPs and to achieve much greater self-sufficiency in building. In 1987, the industry entered a ten-year technology transfer program with Combustion Engineering (now Westinghouse) to achieve technical self-reliance, and this was extended in 1997.

A sidetrack from this was the ordering of three more CANDU-6 Pressurized Heavy Water Reactor (PHWR)

Table 1. Power reactors operating in Korea

Name	Reactor	Type	Operation
Kori	1	PWR	4/78
	2	PWR	7/83
	3	PWR	9/85
	4	PWR	4/86
Ulchin	1	PWR	9/88
	2	PWR	9/89
	3	PWR (KSNP)	6/98
	4	PWR (KSNP)	6/99
	5	PWR (KSNP)	1/04
	6	PWR (KSNP)	12/04
Wolsong	1	PHWR	4/83
	2	PHWR	6/97
	3	PHWR	6/98
	4	PHWR	6/99
Yonggwang	1	PWR	8/86
	2	PWR	6/87
	3	PWR (Syst 80)	12/95
	4	PWR (Syst 80)	3/96
	5	PWR (KSNP)	5/02
	6	PWR (KSNP)	12/02

units from AECL in Canada, to complete the Wolsong power plant. These units were built with substantial local input and were commissioned from 1997 to 1999.
In 1987 the industry selected the CE System 80 steam supply system as the basis of standardization. Yonggwang 3&4 were the first to use this, with great success. A further step in standardization was the Korean Standard Nuclear Plant (KSNP), which from 1984 brought in some further CE System 80 features and incorporated many of the US Advanced Light Water Reactor design requirements.

3. Questionnaire for the research

The questionnaire for the survey is classified to 4 parts.

(1) Present state of the maintenance in Korean nuclear power plant
In this chapter, we survey on Korea Hydro & Nuclear Power Co., LTD. operators and staffs' opinion of the current state of maintenance. The contents for this chapter are the self-supporting level and the level of the maintenance technology in Korean NPPs in comparison with other countries. The maintenance technology items are classified into 5 items:

- Management technology: The technology related to the equipment failure prevention, and maintaining the equipment in optimum condition. For example, improvement of operating method, environment, etc.
- Prediction of the equipment failure and condition monitoring technology: The testing, diagnosis, and evaluation technology for the equipment failure prediction and detection.
- Repair technology: Equipment assembly, disassembly, and replacement technology.
- System engineering technology: The technology to improve existing equipment's performance, reliability, and safety.
- Integrated maintenance management technology: The management technology to reduce operation and maintenance cost and maximize its effect.

The answers for those questions are "very low", "low", "normal", "high", and "very high". The urgent needs to perform improvement of the equipment are inquired in the last of this chapter.

(2) Present state of the preventive maintenance
In this chapter, we want to know the obstacle of the overhaul period reduction. In the analysis, we divided the result into 2 cases; PWR case and PHWR case.

(3) Development maintenance technology
This chapter shows the technologies which are needed in the current maintenance work. The technologies are classified into 3 contents – maintenance planning, implementation, and equipment improvement. In the last part of this chapter, the degree of necessity of the predictive maintenance technology is inquired. Most of NPPs perform the preventive maintenance. However, it is found that many NPP maintenance staffs think that some maintenance resources are wasted and some activities are not needed. In addition, they think that some equipments can be in worse conditions after performing preventive maintenance. Therefore, equipment condition based predictive maintenance is needed to be considered in NPP industry to optimize the reliability and the availability of equipments.

(4) The demand for specific equipment maintenance technology
This chapter shows the specific system or components which are needed for the maintenance technology of the specific system, structure and component in NPPs in terms of the condition monitoring, on-line maintenance, and shortening of the overhaul.

4. Result

We carried out a survey on 86 operators and staffs in 8 units; 13 in Kori 2, 32 in Ulchin 1~3, 23 in Wolsung 1&2,

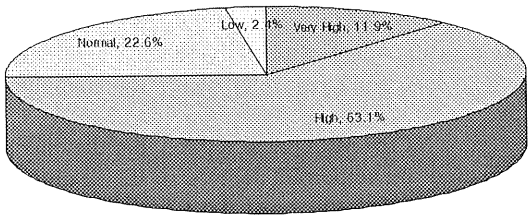

Fig. 1. Self-supporting level

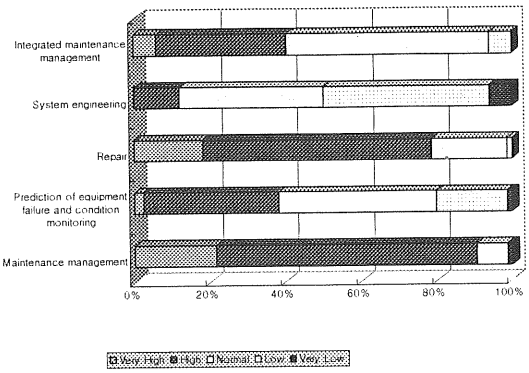

Fig. 2. Present state of nuclear power plant maintenance

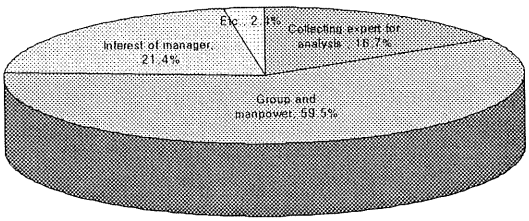

Fig. 3. The urgent needs to perform improvement of the equipment

and 16 in Younggwang 1&3. The selected departments in one NPP are engineering, operation, electrical, mechanical, and instrumentation and control departments.

(1) Present state of the maintenance in Korean nuclear power plants

In Fig. 1, 75% of the respondents think that current self-supporting level of maintenance technology in Korean NPP is high or very high and 22.6% think that it is in normal level. Only 2.4% of the respondents think that the technology is in low level.
Fig. 2 shows the present state of maintenance in Korean NPP. In this figure, most of the maintenance related technologies are in high levels, except the system engineering. Most of the respondents think that the system engineering technology of Korean NPP is lower than other country.

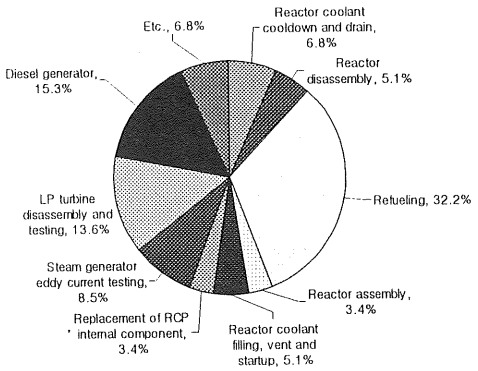

Fig. 4. Pressurized water reactor case

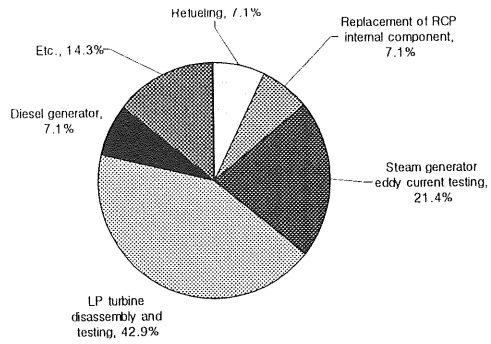

Fig. 5. Pressurized heavy water reactor case

Fig. 3 shows the urgent needs to perform improvement of the equipment. Most of the respondents replied that the group and manpower are very important for the equipment improvement. That is, the short of human resource is the most serious problem in the NPP maintenance work.

(2) Present state of the preventive maintenance

In this chapter, we investigate what is the problem to reduce the overhaul work during the overhaul. In the investigation, we divide the results into two cases; PWR case and PHWR case, because the type of nuclear power plant in Wolsung is PHWR from Canada, and the others are PWR from USA and France, and hence their operation environment and equipment are different.
In the PWR case, as shown in Fig. 4, about 32.2% of respondents replied that refueling is the obstacle of the overhaul reduction. The fuel rods have been replaced during the overhaul of the plant, and most of the preventive maintenance has been performed during that time. But the one by one fuel rods replacement has taken lots of time, so that it makes the delay of the maintenance. Therefore, improvement of the refueling method is required. Next to that, the diesel generator maintenance, the low pressure turbine disassembly and testing are the obstacles of the overhaul reduction.
Fig. 5 shows the PHWR case. In this figure, the low pressure turbine disassembly and testing, steam generator

eddy current testing are obstacle of the overhaul reduction. In comparison with PWR, PHWR can be refueled on-line; therefore refueling is not a serious problem in the reduction.

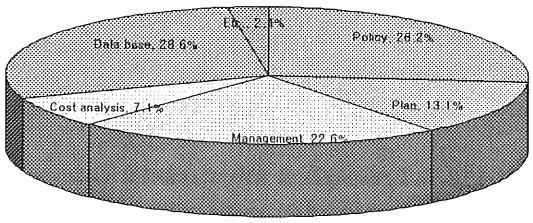

Fig. 6. Development of maintenance technology (Maintenance planning)

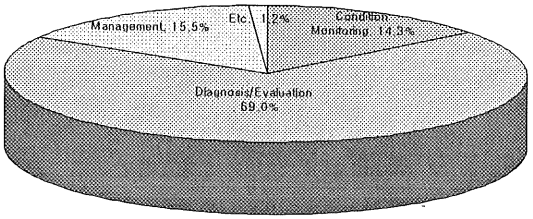

Fig. 7. Development of maintenance technology (Maintenance implementation)

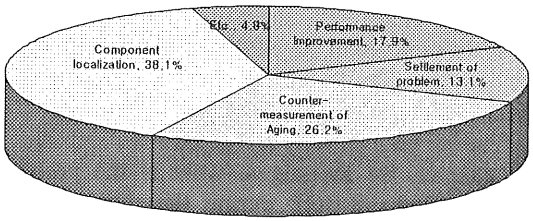

Fig. 8. Development of maintenance technology (Equipment improvement)

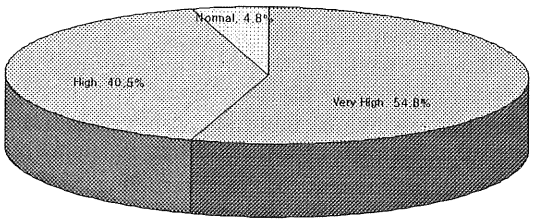

Fig. 9. Necessity of the predictive maintenance technology

(3) Development of maintenance technology

In Fig. 6, the respondents replied that database, policy, and management have to be developed for the maintenance planning.
In Fig. 7, most of the respondent replied that the diagnosis and evaluation are important factors in the maintenance implementation. In means the analysis from lots of data is necessary to know abnormality of equipment and to support maintenance work.
Fig. 8 shows that what is important in the equipment improvement. In the items, component localization is necessary for the improvement. As shown in Section 2, early Korean NPPs were imported from USA, France, and Canada. With the lapse of time, the components are no longer manufactured by original equipment manufacturers or provided for spare parts support. Moreover, some manufacturers are no longer in business. Those issues make the maintenance work very difficult to perform. Hence, the localization is very important in the development of maintenance technology. The next one is the counter-measurement of system or component aging. This means that aging management is important in the equipment improvement related technologies.
The result of the necessity of the predictive maintenance technology is shown in Fig 9. In this figure, most of the respondents are aware of the importance of the predictive maintenance technology. With Fig. 7, it is strongly requested that the diagnosis and evaluation from condition monitoring of the equipment are necessary for the operation and maintenance work in nuclear power plants.

(4) The demand for specific equipment maintenance technology

Table 2 shows the demand for specific equipment maintenance technology. In the condition monitoring results, main generator and turbine are necessary to monitor the abnormality by using vibration monitoring or oil analysis. In turbine, respondents replied that advanced non-destructive method is necessary to reduce the maintenance work. Condition monitoring is needed in the

Table 2. The demand for specific equipment maintenance technology

	Condition Monitoring	On-line maintenance
Equipment	Main generator, Turbine, Steam generator, Tube (PHWR) Transformer	Relay, Pump, Diesel generator, Reactor protection system
Technology	Non-destructive testing, Vibration monitoring, Oil analysis Thermography	Aging Management, Lifecycle Management, Monitoring

transformer abnormality such as thermal aging, dielectric breakdown, or short circuit. Advanced oil testing and thermography technology should be developed to detect abnormality. The tube maintenance in the steam generator is mentioned among respondents from PHWR.
In the on-line maintenance results, respondents replied that relay, pump, and diesel generator are necessary to perform the on-line maintenance. For that, advanced aging management and monitoring technologies should support the maintenance work. In the reactor protection system, drift prediction and life cycle management technologies are needed to perform the on-line maintenance.

5. Summary and Conclusion

In this study, we introduced the maintenance demand of NPP in Korea. To investigate the demand, a questionnaire method is employed for the research. The questionnaire consists of the present state of maintenance, the obstacles in overhaul period reduction, the needs for development of advanced maintenance technology, and the demand for specific equipment maintenance technology. The questionnaire results can be summarized as follows:

(1) Most of the respondents replied that current NPP maintenance technology is high except system engineering.
(2) Group and manpower are needed urgently to perform the equipment improvement.
(3) In PWR, the refueling, LP turbine disassembly and testing are obstacles in the NPP overhaul period reduction. In PHWR, LP turbine disassembly and testing and steam generator eddy current testing are obstacles in the reduction.
(4) Diagnosis, component localization, aging management are required in the development of maintenance technology.
(5) The condition monitoring is necessary for main generator, turbine, steam generator, and transformer. Relay, pump, diesel generator, and reactor protection system are needed to perform the on-line maintenance.

Acknowledgement

This work has been supported by Korea Hydro & Nuclear Power Co., LTD through research contract. Special thanks are given to Korea Hydro & Nuclear Power Co., LTD.

References

[1] L. Whistlecroft, D.J. Mallaburn, "Business improvement and maintenance optimisation in Nuclear Electric", Power Station Maintenance - Profitability Through Reliability, 1998. First IEE/IMechE International Conference on (Conf. Publ. No. 452), 30 March-1 April 1998, pp. 179-183.
[2] S.S. Darling, D.A. Army, T. P. Mairs, "Improving plant capacity by redefining the processes by which maintenance is planned, scheduled, and accomplished", Nuclear Science Symposium and Medical Imaging Conference, 1994 IEEE Conference Record Volume 3, 30 Oct.-5 Nov. 1994, pp. 1051-1055.
[3] "Nuclear Power in South Korea", World Nuclear Association, May 2005.