Prerequisite Conditions to Apply On-Line Maintenance (OLM) for Emergency Diesel Generator in Domestic Nuclear Power Plants

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1. Introduction

On-Line Maintenance (OLM) means intentionally entering the Limited Condition of Operation (LCO) Technical Specification (TS) for safety-related systems and equipment during the power operation of a nuclear power plant, accepting the inoperability of the facility and performing preventive maintenance within the specified allowable shutdown time. While overseas nuclear power plants such as the U.S. are actively performing OLM by utilizing risk information, domestic nuclear power plants are currently performing preventive maintenance of all safety-related facilities during the planned outage period because it is a violation of the operating TS to intentionally enter the LCO for preventive maintenance. In 2010, KHNP was approved by the regulatory body to conduct a pilot OLM for the essential chilled water system of the Kori 3 unit, and at that time, the regulatory agency also developed regulatory technical requirements [1] related to OLM, and changes in the regulatory environment were expected, but this discussion was completely suspended due to the Fukushima nuclear accident in 2011. However, in recently, KHNP has established an implementation plan of OLM to improve the safety and capacity factor of nuclear power plants. This paper analyzes the prerequisites for the introduction of OLM for Emergency Diesel Generator (EDG) in domestic nuclear power plants.

2. Methods and Results

2.1 Implementation of OLM

Nuclear power plant in the U.S. have been performing OLM for more than 70% of all facilities and more than 40% of safety facilities since the enactment of the Maintenance Rule (MR, 10CFR50.65) in 1996, and since 1999, the MR (a)(4) has been established to perform risk assessment before maintenance work [2]. In Korea, when it is necessary to repair (replace) safety-related structures, systems, and components, a repair plan must be established and submitted to the regulatory body for approval [3], but no regulatory system for preventive maintenance has been introduced. However, MR program has been implemented in domestic nuclear power plants since 2008. Probabilistic Safety Assessment (PSA) has been developed for all operating nuclear power plants in Korea since the announcement of the Severe Accident Policy Statement in 2001, and the status of As-built and As-Operated is maintained through periodic safety assessment. Since the enactment of the Accident Management Plan Act in 2016, a PSA for accident management plans has been developed and approved by regulatory body. Currently, the LCO 3.0.2 from the TS bases for Domestic Nuclear Power Plants states, "Do not intentionally enter the unsatisfactory required actions for the purpose of preventive inspection (preventive maintenance) or operation convenience." This was revised in 2014 in response to regulatory planned inspection result (Table 1).

Table 1. Planed Inspection Results by Regulator

Inspection Result	Since the exceptions specified in LCO 3.0.1 are "malfunction (LCO 3.0.2) and special test (LCO 3.0.7)", it is inconsistent with LCO 3.0.1 to state that it is possible to intentionally deviate from the LCO for preventive maintenance in LCO 3.0.2 from the TS bases.
Corrective action required	Delete the reference to "preventive maintenance" in the text of paragraph LCO 3.0.2 of the TS bases.

However, NUREG-1432 "Standard Technical Specification", the TS reference document for CE type nuclear power plants, states in Section LCO 3.0.2 that the required actions of the associated conditions shall be met upon discovery of a failure to meet an LCO, and LCO 3.0.2 from the TS bases states that intentional entry to LCO for preventive maintenance is permitted [4]. The NRC Inspection Guidance [5] also indicates that it is not a violation of the TS to intentionally enter the LCO for preventive maintenance. However, in this case, the preventive maintenance must be completed within the Allowable Outage Time (AOT), and it is not allowed to intentionally cause a loss of function or enter an intentionally LCO for operational convenience. On the other hand, the Korean NPPs referenced in NUREG-1432 translated the original "Upon discovery of a failure to meet an LCO" in LCO 3.0.2 from TS as "Upon discovery of a malfunction to meet an LCO," which was based on the regulatory body's inspection result in 2014 and is believed to reflect the regulatory body's regulatory intent for OLM.

This is possible in the U.S. because maintenance regulations are legally institutionalized to monitor the performance of the system or equipment to ensure the

reliability of the facility and to monitor and manage the risks associated with configuration changes. A study on "Development of Safety Impact Assessment Technology for OLM [6]" conducted by the Korean regulatory body in 2012 also suggests that OLM is beneficial in terms of nuclear power plant safety and economy, and that legislation of MR along with regulatory technology requirements for maintenance risk management is a prerequisite for the establishment of OLM. In addition, in relation to the implementation of OLM, the evaluation of KHNP's work control system, MR, and in-service risk monitoring program concluded that it has the capability to perform OLM. However, in 2014, the TS bases were revised by the regulator, and it is currently impossible to perform OLM at domestic nuclear power plants. Even if the TS states that it is possible to intentionally enter the LCO for preventive maintenance, it is necessary to secure sufficient maintenance time for preventive maintenance for OLM.

Table 2 shows the AOT and maintenance time for the major safety-related systems of the APR1400, Saeul 1. The maintenance times presented are for the most time-consuming preventive maintenance items for each system. As shown in Table 2, OLM requires an extension of the AOT in the TS, except for the auxiliary feed water system.

Table 2. AOT for 1 train inoperable and expected maintenance time

System (PBS)	AOT (hr)	Expected maintenance time(hr)
SI (441)	72	126
CS (442)	72	98
CCW (461)	72	110
ESW (462)	72	84
AF (542)	72	36
EDG (591)	72	177
ECW (633)	168	97

2.2 Extension of AOT

The EDG of a nuclear power plant is an essential safety facility that automatically starts up in the event of a Loss of Off-site Power (LOOP) or an Engineered Safety Features Actuation System (ESFAS) signal to enable the safe shutdown of the reactor and to provide emergency power to safety-rated essential equipment and facilities to keep radiation emission below the reference value even in the event of a loss of reactor coolant. An Alternate Altering Current (AAC) DG is installed for common use of Saeul Units 1 and 2 to prepare for Station Black Out (SBO) accident in which all EDGs lose function under the condition of LOOP.

As shown in Table 3, about 77% of the total preventive maintenance items are performed during outage period, and the maintenance time for EDG disassembly inspection is 177 hours, which requires an extension of the AOT to perform OLM.

Table 3. Percentage of PM01/02 respectively

Maintenance type	PM01	PM02
Status Check	15	0
Test	7	8
General Inspection	4	4
Disassemble Inspection	0	67
Calibration	0	6
Sum	26(28%)	85(77%)

PM01: Preventive Maintenance at power
PM02: Preventive Maintenance during outage

To extend the EDG AOT, quantitative risk must be evaluated according to the KINS regulatory guidelines [7], [8] and approved by the regulator through the licensing process. In domestic nuclear power plants, there have been many cases of extensions such as extending the Integrated Leakage Rate Testing (ILRT) cycle and extending the inverter AOT by utilizing risk information since 1999, and there are still cases under review.

In addition, the requirements of the Light Water Reactor Safety Review Guidance "Appendix 8-9, Extension of the Allowable Outage Time (AOT) for onsite (Emergency Diesel Generators) and offsite Power Sources" [9] must be met. This guidance is based on the U.S. Standard Review Plan(BTP 8-8), "Onsite (Emergency Diesel Generators) and Offsite Power Sources Allowed Outage Time Extensions" [10], which suggests that if a multi-unit nuclear power plant with one AAC installed under the SBO requirement wishes to extend the EDG AOT to 14 days, the AAC must serve the LOOP load of the EDG replacing the AOT-extended unit and all SBO load of the remaining units without load shedding. In other words, in the event of a LOOP while AOT is extended, one AAC source for SBO should be used in the non-AOT extended reactor to satisfy the SBO requirement. For AOT extended reactors, the utility should provide a permanent or temporary source to replace the EDG to maintain the same level of depth of protection for the safe shutdown of the reactor.

Recent AOT extensions of EDG at U.S. nuclear power plants have demonstrated the need for additional power sources to satisfy this regulation. Catawba NPP, which consists of two reactors and has two 7,000 kW EDG for each unit and one on-site Standby Shutdown Facility (SSF) diesel generator, applied for a 14-day extension of the AOT and met the requirements by installing two diesel generators with a capacity of 3,150 kW as a shared non-safety emergency power source on the site [11]. In addition, Wolf Creek is a single-unit nuclear power plant and had already received a 7-day extension to the AOT in 2003 based on two 6,201 kW EDGs and two offsite diesel generators located approximately 3.2 kilometers from the plant. In 2021, the AOT was extended to 14 days with the removal of these offsite diesel generator conditions and installation of three 3,150 kW SBO diesel generators [12].

3. Conclusions

This paper analyzed the prerequisites for implementing EDG OLM in domestic nuclear power plants. At the time of the pilot OLM demonstration of the essential chilled water system of the Kori 3 unit in 2010, regulatory body was positive about implementing the OLM developing related regulatory requirements. However, following the Fukushima nuclear accident in 2011 and the revision of the TS bases in 2014 in response to regulatory inspection result, OLM is now essentially impossible. Currently, it is necessary to extend the AOT for major safety-related facilities such as disassembly inspection of EDG. In particular, to extend the AOT of EDG, the utility must provide a permanent or temporary power source to replace the EDG, so that the same level of in-depth protection related to the safety shutdown of the nuclear power plant can be maintained. In other words, if AAC DGs are used for two reactors, such as Saeul 1, additional power sources for EDGs are required in addition to the AAC DGs. KHNP is currently trying to revise its TS bases, and in the short term, it plans to prioritize maintenance that can be performed within the AOT and apply for an extension of the AOT to perform OLM of EDG. Starting in 2024, regulators will implement a year-round inspection system that will allow regular inspections, which were previously performed only during planned preventive maintenance periods, to be conducted even while the plant is in operation. In addition, in-depth inspections will be added so that regulators can monitor abnormal state in the plant in advance and identify problems before they occur. As this new system is being implemented to improve the safety of nuclear power plants, it is hoped that the regulatory system for OLM will be established and OLM will be implemented at domestic nuclear power plants in the near feature.

REFERENCES

[1] Jin Woo Hyun et al, A study of the Effectiveness on Online Maintenance for Nuclear Power Plant, Journal of Energy Engineering, Vol. 29, No. 1, p. 52-57, 2020.
[2] EPRI, On-Line Maintenance at Nuclear Power Plants: History, Implementation, and Benefits, TR-1018422, 2009.
[3] Nuclear Safety and Security Commission (NSSC), Regulation on In-service Inspection of Nuclear Reactor Facilities, NSSC notification No.2023-2.
[4] U.S. Nuclear Regulatory Commission (NRC), Standard Technical Specifications Combustion Engineering Plants, NUREG-1432 Vol. 1~2(Rev.1~4)
[5] U.S. Nuclear Regulatory Commission (NRC), Inspection Manual PART 9900: Technical Guidance, Maintenance – Voluntary Entry into Limiting Conditions for Operation Action Statements to Perform Preventive Maintenance, 2002
[6] Korea Institute of Nuclear Safety (KINS), Development on Assessment Technology of Safety Effect for On-Line Maintenance, 2012
[7] Korea Institute of Nuclear Safety (KINS) Regulation Guide, A General Approach for Using in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis (Rev.02), KINS/RG-N16.09.
[8] Korea Institute of Nuclear Safety (KINS) Regulation Guide, Risk-Informed Decision Making for Plant-Specific Change of Technical Specifications (Rev.02), KINS/RG-N16.10.
[9] Korea Institute of Nuclear Safety (KINS), Light Water Reactor Safety Review Guidance "Appendix 8-9, Extension of the Allowable Outage Time (AOT) for onsite (Emergency Diesel Generators) and offsite Power Sources, KINS/GE-N001, 2014
[10] U.S. Nuclear Regulatory Commission (NRC), Standard Review Plan Branch Technical Position 8-8, Onsite (Emergency Diesel Generators) and Offsite Power Sources Allowed Outage Time Extensions, NUREG-0800, 2012.
[11] U.S. Nuclear Regulatory Commission (NRC), Safety Evaluation by the Office of Nuclear Reactor Regulation related to Amendment No. 304 to Renewed Facility Operating License No. NPF-35&52 Catawba Unit 1&2 Docket No. 50-413&414, 2019.
[12] Wolf Creek Unit 1, License Amendment Request − Diesel Generator Completion Time Extension for Technical Specification 3.8.1, “AC Sources − Operating”, Docket No. 50-482, 2021