Considerations of On-Line Maintenance for Essential Chilled Water System in a Westinghouse Plant

Hee Seung Chang[a*], Sang Young Moh[a], Sung Mok Min[b]
[a] *Nuclear Engineering & Technology Institute (NETEC), Korea Hydro & Nuclear Power Co. (KHNP), 508 Geumbyung-ro, Yuseong-gu, Daejeon, 305-343 KOREA*
[b] *Kori 2nd plant , Korea Hydro & Nuclear Power Co. (KHNP), 216 Kori Jangan, Gijang, Busan 619-711 KOREA*
[*] *Corresponding author: daniel@khnp.co.kr*

1. Introduction

On-Line Maintenance (OLM), meaning preventive maintenance of safety systems while a nuclear power plant is in normal power operation, is widely used in many countries to improve equipment reliability, reduce outage work activities, and improve the availability of safety systems during outages [1].

In Korea, however, on line preventive maintenance for safety systems has not been experienced, because the voluntary entering Limited Condition Operation (LCO) of Technical Specifications (TS) has not been allowed practically, despite that maintenance of non-safety systems and corrective maintenance for safety systems during power operation is performed. OLM has been actively discussed and studied at the Korea Hydro & Nuclear Power Company (KHNP) in efforts to establish a strategy to implement OLM in a phased manner. The regulatory body is also making preparations to establish guidelines of OLM [2].

This paper proposes a pilot implementation of OLM for the Essential Chilled Water System (ECWS) in a Westinghouse reactor type plant. This ECWS has adequate Allowable Outage Time (AOT) and minor safety impact. The considerations and some review results of the systems are included in this paper.

2. Description of Essential Chilled Water System in a Westinghouse Plant

The ECWS supplies chilled water to the Main Control Room (MCR) HVAC, and to the HVAC for the Engineered Safety Feature pump rooms and breaker rooms in the case of a Design Basis Accident (DBA). It maintains the temperature of the MCR between 22.2 ℃ and 25.6 ℃ in emergency conditions, and requires sufficient redundancy and a separate system in the event of a single failure. During normal power operation, the Central Chilled Water System is operated while the ECWS is in standby mode for emergency situations.

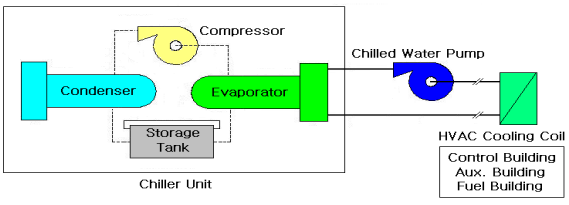

Fig. 1. Simplified diagram of ECWS.

The ECWS is composed of two trains with a 100% capacity essential chiller and a chilled water pump per train. The chiller consists of a compressor, condenser, evaporator, and storage tank, as shown in Fig. 1.

While there are not specific requirements in the TS for the ECWS, the Control Room Emergency Air Temperature Control System (CREATCS), one of the supplied loads of the system, should meet the following requirements:

1) LCO: two CREATCS trains shall be operable at all operation modes.
2) Actions required: If one CREATCS train is inoperable, the CREATCS train should be restored to operable status within 30 days. If two CREATCS trains are inoperable in modes 1, 2, 3, and 4, the plant should be in mode 3 within 7 hours.

3. Considerations for On-Line Maintenance

The ECWS is a suitable safety related system for pilot on-line maintenance, because it has little impact on plant safety and has a sufficient AOT (30 days). For performing OLM, several items should be considered in order to minimize the impact on plant safety and operations. Some considerations are identified and reviewed for the ECWS in this section.

3.1Risk Assessment and Management

A risk assessment should be carried out before performing maintenance so as to manage the increased risk that may result from the proposed maintenance activities of the safety system [3]. A Risk Monitoring System (RiMS) was developed as a plant specific real time analysis tool to determine the instantaneous risk based on the actual status of the systems and components during power operation. Table 1 shows the color code risk criteria defined in terms of multiples of the baseline risk.

Table 1: Risk color codes and required actions

Colors	Criteria	Required Actions
Red	CDF>20 x CDF(b) LERF>20 x LERF(b)	Unacceptable to voluntarily enter
Orange	CDF>10 x CDF(b) LERF>10 x LERF(b)	Compensatory plans to minimize risk
Yellow	CDF>2 x CDF(b) LERF>2 x LERF(b)	Unavailability time is limited
Green	CDF<2 x CDF(b) LERF<2 x LERF(b)	No specific actions are required

From the assessment of ECWS with the RiMS, the Core Damage Frequency (CDF) of one train out-of-service (OOS) is 8.48E-06 while the base CDF is 6.20E-06, as depicted in Fig. 2. This falls in the green color area, and thus no additional action is required. If the two trains of the system are out of service, the CDF will be 2.65E-05 and thus yellow risk color. This could be manageable, but the TS require that the plant be shut down when two trains of the systems are inoperable.

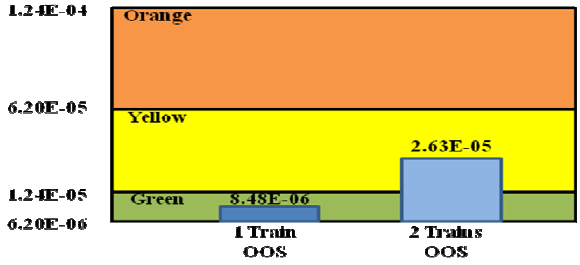

Fig. 2. Risk assessment results when the ECWS is out of service for maintenance during power operation.

3.2 Performance Monitoring

US Reg. Guide 1.174 stated that performance monitoring in conformance with the Maintenance Rule (MR) can be used when the monitoring performed under the MR is sufficient for the SSCs affected by the risk-informed application. The NRC Inspection Manual Part 9900 mandates that the requirements of MR be met when taking equipment out-of-service to perform preventive maintenance during power operation. MR stipulates performance criteria of reliability and availability, established to ensure the intended functions of safety systems. In particular, the maintenance should be considered in order not to exceed the availability performance criteria, and thereby prevent entering LCO unnecessarily.

The availability performance criterion of ECWS is 384 hours per 3 years. If there is any functional failure of the essential chiller, chilled water pumps, or valves, an evaluation should be performed to determine whether the failure is within the criteria.

3.3 Work Management

The maintenance activities have currently been issued on a weekly or monthly basis. A work order of each work activity is initiated with brief work plans and separate maintenance plans for each area. An integrated work plan and work packages are essential to minimize the impact on plant operation and increase the efficiency of the work, particular with regard to communication and cooperation among related departments.

The work plan for ECWS maintenance must display the sequential work activities and responsible departments. Individual work activities that take more than eight hours should be displayed.

A functional equipment group (FEG) will be developed to identify the components that will be out of service at a given time so as to minimize unavailable time of the system train. The motor, breakers, upstream and downstream valves, and some instrumentation and control should be included.

The work package for ECWS includes pre-job briefing, the procedures of maintenance work activities, a data sheet for as found conditions, an evaluation sheet for foreign material excursion prevention, operating experience, and related drawings other than the work order, including maintenance resources, tools, and spare parts.

2.4 Contingency Plan and Recovery Plan

In order to minimize additional risk increment during the maintenance of the safety system, a contingency plan and a recovery plan should be determined before starting the maintenance [4]. The equipment to be protected and monitored can be identified from the "remain in service" function in RiMS.

In the case of the ECWS, there is no specific equipment to be protected. However, protection for other train equipment should be carried out as a contingency action.

A recovery plan should be developed to ensure the standby train is activated when a DBA occurs, and to recover the maintenance activities quickly in case the standby train is not available.

3. Conclusions

OLM of safety systems can be performed if the proposed considerations are well prepared. No major problems or changes are involved in the maintenance of the ECWS during power operation as a pilot implementation. Detailed and systematic work management enables improved work quality and equipment reliability.

Further study for high safety significance systems such as the Emergency Diesel Generator and Safety Injection System is required for a full scope OLM so as to identify the considerations and necessary preparations in order to minimize the impact on safety and plant operation.

REFERENCES

[1] Hee Seung Chang et al., Establishment and Pilot Implementation of Screening Criteria for On-Line Maintenance, Transaction of the Korean Nuclear Society Spring Meeting, 2010.

[2] Sang-Kyu Ahn et al., Analysis of Worldwide Regulatory Framework for On-Line Maintenance, Transaction of the Korean Nuclear Society Spring Meeting, 2010.

[3] NEI, Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants, NUMARC 93-01, 2000

[4] EPRI, Guidance for Developing and Implementing an On-Line Maintenance Strategy, EPRI TR-1009708, 2004