Establishment and Pilot Implementation of Screening Criteria for On-Line Maintenance

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1. Introduction

In utilities in the USA and Europe, maintenance activities are typically done during power operation to improve the availability of the safety system during refueling outages and reduce the outage duration. In the case of US utilities, preventive maintenance (PM) has been done for about 50 % of the total equipment in the plant, and 72 % of this preventive maintenance is done during power operation as known as On-Line Maintenance (OLM) [1].

The Korea Hydro & Nuclear Power Co. (KHNP) has developed and implemented several programs which have been utilized for OLM, such as a Probabilistic Safety Analysis (PSA), a Maintenance Rule Program and a Risk Monitoring System (RIMS). Recently, OLM has become a favorite topic in Korea, but it has not been used thus far. Moreover, the screening criteria of OLM have not been established.

In this paper, the screening criteria adjusted to KHNP and the results of the screening of the pilot plant according to the criteria are discussed. It was found that nearly 30% of outage work activities can be done during power operation.

2. Status of OLM in USA and Europe

OLM is a type of maintenance strategy used to improve the reliability of equipment by performing preventive maintenance during power operation in advance, although its function is out of service during maintenance periods [2].

The United States issued the Maintenance Rule in 1991 to ensure the intended function of safety systems and require performance criteria for the acceptance of functional failures and unavailability over certain periods. In 1999, paragraph (a)(4) was added to the Rule stating that licensees shall assess and manage increases in risk that may result from proposed maintenance activities [3]. Since then, OLM for multiple safety systems has been actively done with on-line risk assessments.

From the survey of the EPRI and INPO Equipment Reliability Working Group in 2008, several trends at nuclear power plants in the USA were found. Nearly one-half of plant equipment required preventive maintenance, in which maintenance is performed before a break down, and all plants applied some form of OLM. Approximately 45 % of the safety-significant equipment and most of the non-safety equipment in a plant have been undergone maintenance during power operation, as depicted in Figure 1 [2].

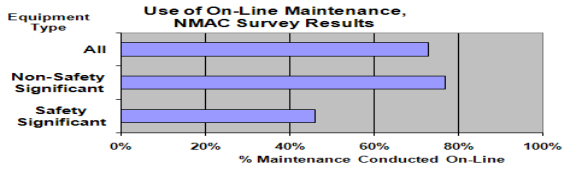

Fig.1. Status of OLM among preventive maintenance equipment in US utilities.

OLM is widely used in utilities in Switzerland, France and Spain as well. However, the scope and strategies are slightly different according to regulatory environment and plant policy. European utilities also perform preventive maintenance for safety systems during power operation, as shown on the Table 1.

Table 1: OLM status used in several European utilities compared to those of the USA

	Switzerland	France	Spain	USA
Scope of Safety System	System has redundancy	Safety support systems	One system per year	All systems
Multiple Safety Systems	Shortened AOT	Shortened AOT	Not permitted	Risk-informed evaluation
OLM scope related to AOT	Pre-defined in Tech. Spec.	95% of AOT	AOT>72hrs	AOT extension possible
Nuclear Safety Risk Evaluation	Trip potential	PRA	Un-availability Assessment	PRA

The benefits of OLM described in US Nuclear Regulatory Commission (NRC) Reg. Guide 1.182 are as follows: 1) Increasing system and plant reliability by reducing the potential of random and time-related failures. 2) Reduction of plant equipment and system material condition deficiencies that could adversely impact plant operation. 3) Reduction of the work scope during plant refueling outages, which is a benefit that increases the availability of safety system, reduces the outage length and stabilizes the work force employment [4]. The contributions of OLM to increase the availability and improve plant safety were reported, as illustrated in Figure 2.

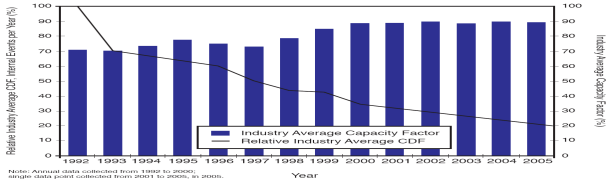

Fig.2. The relative industry average CDF was remarkably reduced by a factor of four and the average capacity factor of

US nuclear power plants increased from roughly 70% to nearly 90% between 1992 and 2002.

3. Screening Criteria for OLM Scope

OLM screening criteria should be established to select work activities which can be done during power operation. The EPRI document described that equipment with redundancies and that are testable on-line can be considered for OLM.

KHNP performs maintenance on-line for some equipment that is not related to safety and power generation. Hence, a strategy of phased OLM should be considered based on safety and economic benefits upon initial implementation.

In accordance with this strategy, screening criteria were developed to be customized to KHNP, as shown in Figure 3.

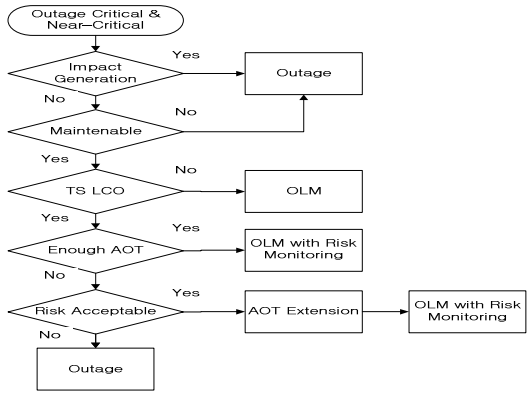

Fig.3. Flow chart of the screening criteria for OLM.

To select OLM work activities, the first step of the criteria is to select work activities related to a critical path or near critical paths of the outage. Questionnaires were developed, as shown below.

1) Is it possible to work without any load reduction or impact on power generation?
2) Is it possible to access the equipment for maintenance work on-line without high radiation exposure or risk to industrial safety?
3) Is it possible to do the maintenance without any impact on the requirements of the Technical Specifications when the equipment/system is out of service for maintenance?

Work activities with all "yes" answers on the questions above can be done during power operation. Additionally, previous work durations of activities related to the Technical Specifications were collected and analyzed in a comparison with the Allowable Outage Time (AOT) required in the Specifications. If the work can be done within the AOT, the maintenance activity may be performed on-line with an acceptable risk increase due to its being out of service. In some cases, activity which requires a longer duration than AOT may be acceptable to extend the AOT based on the PSA and defense-in-depth analyses, as done with US utilities.

4. Screening Results of OLM Activities for a Pilot Plant

The work activities during an outage of a Optimized Power Reactor (OPR) 1000 were reviewed and screened according to the proposed criteria. The outage was performed during approximately 25 days with a critical path of reactor shutdown, defueling, replacement of primary equipment, refueling and plant start up. A total of 1,688 work orders for the outage were issued.

Nearly 30% of them, 504 work orders, were accessible and done on-line, as presented in Figure 4. 231 work orders from these could be moved on-line based on the plant situation. The examples were the maintenance works of the pumps, motors and some equipment in the TBOCW, TBCCW, Instrument Air, Service Air and CVCS systems.

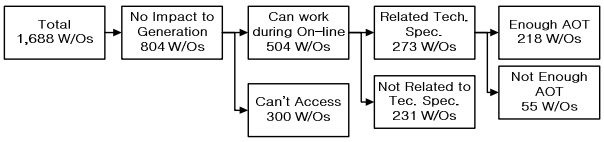

Fig.4. Screening results of work orders for a pilot plant.

The work orders related to Technical Specifications can be done on-line on condition of a risk assessment and acceptance of the risk increase. Fifty-five work orders were identified that the AOT was shorter than the previous work duration.

5. Conclusions

OLM has been rigorously performed in US and European utilities to improve the safety and availability with risk-informed application. In preparation for this, KHNP has implemented PSA, Maintenance Rule and risk monitoring tools as the basis for OLM.

The proposed screening criteria can be used to identify the on-line work activities in an outage. The work activities, nearly 30% of the outage work orders, can be maintained on-line according to the plant situation in a phased approach. Some activities related to the Technical Specifications can also be done if the risk increase is within an acceptable range. The analysis and study of safety and effective maintenance of those activities would be required in near future.

REFERENCES

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