Development of a Methodology for the Selection of Cable Priorities for Condition Evaluation in Nuclear Power Plants

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1. Introduction

Low voltage cables in nuclear power plants are components that play important roles such as mechanical operation control of safety facilities, transfer of safety-related signals, and operation of control equipments that mitigate accidents, which in the event of failure can cause plant transient conditions, unexpected shutdowns, and failure of multiple safety facilities. Despite this importance, cables are generally considered reliable components in accordance with design or environmental conditions, so little attention is paid to them. However, there have been about 20 accidents at the nuclear power plant due to abnormalities in the cable system, which have highlighted the need to diagnose the condition of cables and to predict their remaining life. To diagnose the condition of cables and predict the remaining life of cables, it is urgent to develop a method for selecting the monitoring cables with priority of managing the aging of the cables and securing safety of the plant. It takes a huge amount of time and money to perform a condition evaluation on all installed I&C cables in a nuclear power plant. Therefore, regulations and recommendations for monitoring cable conditions at domestic and abroad were analyzed to select the priority of cables based on safety and probability of failure and perform a condition evaluation of cables according to their ranking. U.S. NRC REG 1.218 includes regulatory recommendations for condition monitoring of cable status and those for cables subject to enhanced condition monitoring. According to U.S NRC REG 1.218, cables subject to condition monitoring are all cables included in the Maintenance Rule (MR). It is recommended that the environmental characteristics and the conditions of the cable be identified to perform test and inspection activities for periodic monitoring of the cable condition, and that the cables should be checked for deterioration and immediate maintenance if necessary.

IAEA-TECDOC-1188 mentioned the need for health monitoring and diagnosis of I&C cables that are important for safety in containment buildings. Of all cables in containment buildings, I&C cables that are important for safety are divided into high, intermediate, and low priority, and the contents and frequency of aging management activities, such as degree of condition monitoring or planned replacement, are different depending on their respective rankings. The initial scope could cover all cables within containment. Generally, those cables performing safety functions during and following an accident would be of most concern. Those cables that are important to continued operation may also be considered. In an initial evaluation of cable systems for ageing management, the scope should be wide to allow issues to arise for evaluation. It then presented a methodology that could narrow the scope as the issues was understood. It also includes that the functions and characteristics of cables can be used to prioritize condition monitoring because they can be affected by various factors such as radiation levels, chemical conditions, moisture and/or vibration, and so on.

NP-T-3.6 issued by the IAEA classifies the electrical cables into seven categories for each function, and refers to performance expectations for each classification. The following are the seven categories of cable function.

(1) Equipment relied on for mitigating the effects of an accident (safety systems) that are subjected to the accident environment.
(2) Equipment relied on for mitigating the effects of an accident (safety systems) that are not subjected to the accident environment.
(3) Equipment necessary to prevent the release of radiation.
(4) Equipment that supports the systems necessary for accident mitigation.
(5) Post-accident monitoring instruments.
(6) Equipment necessary for the normal operation of the plant.
(7) Equipment that can fail and mislead the operator during an accident.

This paper analyzes the regulation/recommendation of cable condition evaluation in domestic and foreign, selects the range of cable subject to condition evaluation among low voltage cable of nuclear power plant, and proposes a methodology to prioritize target cable.

2 Selection of cable priority for condition evaluation

2.1. Selection of cables subject to condition evaluation

Among the instrument & control cables and low-voltage cables used in nuclear power plants, the following cables are selected for condition evaluation

(1) Cables connected to equipment within the scope of the Maintenance Rule (MR)

(2) Cables connected to equipment within the scope of the EQ program.
(3) Cables connected to equipment subject to ISI or IST
(4) Safety-critical cables located in containment buildings

2.2. Condition evaluation priority selection program

Among the cables selected in 2.1., the priority shall be determined according to the degree of impact on the safety and economic feasibility of the nuclear power plant in the event of a cable failure, and the condition evaluation shall be performed gradually according to the priority. The priority criteria for cables subject to condition monitoring were developed by analyzing cable-related maintenance programs, preventive maintenance templates(PMT), and foreign research data to reduce unnecessary condition monitoring activities and at the same time increase the reliability of cables. The data from "Reg. 1.218, IAEA- ‐ OC-1188, NES-NP-T3.6" were used and the priority classification methodology of the cables was developed using the methodology in EPRI-TR-1018015 (Tiered valve generation). The six classification criteria developed for the low voltage cable priority of the nuclear power plant are as follows: the function, environmental conditions, remaining life of a cable, regulations, the history of a facility connected to a cable, and its effects on the plant; The number of items to be assessed on the criteria is as shown in Table I.

Table I: Cable priority assessment items to be evaluated

Classification	Evaluation item	Classification	Evaluation item
Functions of equipments	7	Regulations	3
Environmental conditions	6	History of equipments	3
Cable service life	1	Impact on the plants	3
Total evaluation item			23

2.2.1. Classification according to the function of the equipments

The classification of cables according to the functions of the equipment or equipment connected to the cables was selected by applying the classification methodology discussed in NP-T-3.6.

(1) Equipment relied on for mitigating the effects of an accident (safety systems) that are subjected to the accident environment.
(2) Equipment relied on for mitigating the effects of an accident (safety systems) that are not subjected to the accident environment.
(3) Equipment necessary to prevent the release of radiation.
(4) Equipment that supports the systems necessary for accident mitigation.
(5) Post-accident monitoring instruments.
(6) Equipment necessary for the normal operation of the plant.
(7) Equipment that can fail and mislead the operator during an accident.

2.2.2. Classification according to environmental conditions

Cables used in slightly worse environmental conditions than cables used in good conditions should be aged quickly, and these cables should be managed with higher priority. Therefore, the following six classification criteria are selected depending on the conditions of use.

(1) Does the cable's laying path include areas affected by temperature?
(2) Does the laying path of cables include areas affected by radiation?
(3) Does the laying path of cables cover areas with high humidity environments?
(4) Does the installation or device connected to the cable include areas with high vibration environments?
(5) Are there any abnormal symptoms in the laying path of the cable?
(6) Does the cable contain any specifics?

2.2.3. Classification according to cable service life

The priority was divided into three classes depending on the cable service life. (Begin: Within 15 years, Middle: Between 16 and 30 years, End: 31 years or more)

2.2.4. Classification according to regulations

Regulations requiring monitoring of structures, system, and equipment that could cause safety-related or plant shutdown are major considerations in determining maintenance activities and diagnostic priorities. The following items were selected for the classification cables or equipments are connected to cables according to regulations

(1) If the equipment connected to the cables fails, is it the operation limiting condition applied within 72 hours?
(2) Is the equipment connected to cables affected by other obligations (regulations)?
(3) Is the equipment connected to the cables part of the system performance mitigation or reactor monitoring process?

2.2.5. Classification according to history due to electrical problems in a equipments

Maintenance history of equipment due to electrical problems should be taken into account when prioritizing condition monitoring.

(1) Has the equipment connected to a cable failed in the past?
(2) Has the equipment connected to the cables been monitored based on the goals currently set in the plant and taking appropriate corrective action when they do not meet the goals established or have they been in the same state in the past five years?
(3) How was the operation history of the equipment?

2.2.6. The impact on the plant

Failure of the equipments or equipment connected to cables may result in reduced plant power and loss of plant operation. Therefore, the following items were selected for the criteria for classification of effects on the nuclear power plant.

(1) Does loss of function of an equipment or connected cable cause a plant to stop?
(2) Does loss of function of an equipment or connected cable cause power reduction of the plant power?
(3) Does loss of function of an equipment or connected cable affect the plant safety-related facilities?

2.2.7. Determining the priority of a condition evaluation.

The flow chart of cable classification subject to condition evaluation is as follows.

Selection of cables subject to condition evaluation

Evaluation based on the target cable priority classification criteria					
FCT (4)	HCT (6)	ICT (4)	RCT (6)	HCT (11)	PICT (7)
7 item (weighted value applied)	6 item (weighted value applied)	1 item (weighted value applied)	3 item (weighted value applied)	3 item (weighted value applied)	3 item (weighted value applied)

Fig. 1. Cable classification flow chart for condition evaluation

Figures quantified by each criterion from 0 to 7 (0: No impact, 7: large impact) are used to classify priorities, and the results of the evaluation for the priority classification criteria items are aggregated to determine the priority of the target cables. The priority evaluation formula is as follows

= Priority Evaluation
+ Score of classification according to equipment's function
+ Score of classification according to environmental condition
+ Score of classification according to the period of use of cable
+ Score of classification according to regulations
+ Score of classification according to history in an equipment
+ Score of classification according to effect in the plant

3. Conclusions

It takes a lot of time and money to perform a condition evaluation on all low voltage cables installed in the nuclear power plant. To ensure the safety and economic feasibility of the plant, the condition evaluation cables that should be applied first according to safety and failure probabilities should be selected and gradually expanded to all target cables. Cables selected for diagnostic cable priority classification are classified according to the six classification criteria. the function of the equipment, the use environment, the period of use, regulations, the history of the equipment, and its impact on the plant, and each item is evaluated by criteria. The weights are applied to each item and are digitized from 0 to 7 to be used to classify priorities. Determine the priority of the target cable by aggregating the assessment result figures for priority classification criteria.

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