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Study for Environmental Qualification of 60 Years Life Cable

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1. Introduction

Class 1E cables in nuclear power plant have been regarded as not replaceable since it was qualified for 40 years. Most of cable companies have completed qualification test of class 1E cable for 40 years. Because of energy crisis, most of countries are willing to apply plant lifetime extension to 60 years. Consequently, concern of cable life extension has been raised greatly. IEEE383 suggests several methods for life extension of cable if cable life was underestimated during qualification process.

APR1400, AP1000 and EPR, new design NPPs of 60 years life, require qualification of class 1E cable for 60 years. Since most of existing materials for cable insulation and jacket are not strong enough for 60 years aging, some improvement of cable material or environmental condition is required.

We have investigated several ways of supplying 60 years cable life not only for operating NPPs of 40 years design life but also for new design NPPs of 60 years design life. The result of investigation is herein described.

2. Methods and Results

2.1 Demand of 60years life cable

AP1000 of Westinghouse, US-APWR of Mitsubishi, EPR of Areva and APR1400 of KHNP are designed for 60years plant life. Cables of these NPPs are also designed for 60years life.

In the domestic NPP construction market, Shinulchin 1,2, APR1400 NPP, is required to construct with 60years life cables by regulatory body. Shinkori 3,4 has to make a plan of life extension of 40 years life cable to 60 years life before 40years operation. In the export market, ENEC(Emirates Nuclear Energy Corp.) requested Kepco to supply 60years life cable for UAE 1,2.

EPRI has made a study plan of long term operation as show on table 1. These studies are focused on the life extension over 60 years. Consideration and further study for cable aging and potential aging limit is herein addressed.

Table I: EPRI LTO issues tracking table

Issue	Project	Discussion	EPRI Status/ Priority
Identification of potential life-limiting issues	Analysis for life beyond 60years	Rx vessel, internal, concrete structure, **cables**	Planned work. High priority
Cable Aging	Testing and aging management of **cable**	Cables including submerged, wetted cable	No planned work. Medium Priority

2.2 Manufacturing status of 60 years cable

2.2.1 HABIA

HABIA is Sweden cable manufacturer which supplied 40years life cable to Yongkwang 5,6 and Shinkori 3,4. This 40years life cable is composed of HFI260 insulation and HFS105XL jacket. They insist that HABIA cables can be regarded as 60years life by changing the activation energy from 0.8 ev to 1.2 ev. Any detail background of changing the activation energy is not open to public yet. They insist that synergy effects of the cable materials are unknown. No detail evidence of denying synergy effect is open to public yet. Habia cable is qualified in accordance with IEEE383.

2.2.2 NEXANS

Nexans is brand name of french cable manufacturer. The cable from Nexans is known as EPR insulation qualified for 60 years life at the environmental condition of 90℃ and 2E+06 Gy radiation exposure. This cable is known as qualified in accordance with IEC standards. Careful comparison of qualification factors between IEC and IEEE standards is required.

2.2.3 Domestic cable manufacturer

LS cable, JS cable and Daehan electric cable have a experience of manufacturing 40 years cable. LS cable has been developing 60 years cable for nuclear power plant in accordance with IEEE383.

2.3 Obstacles for 60 years life cable

2.3.1 Conservative design of cable requirement

Environmental design requirement of power, control and I&C cable is 90℃ in OPR1000/APR1400. According to the operating experience of cable temperature monitoring, the worst case of power cable operating temperature was below 80℃. Operating temperatures of control and I&C cable were below 50℃. Beta ray has been regarded as same intensity of gamma ray even the beta ray can be protected by thin aluminum plate fabricated between cable jacket and insulation.

2.3.2 Conservative requirement of cable test standard

According to IEEE383-2003 6.4.2, Upon completion of the DBE simulation, the samples shall be straighten (if bent) and coiled around a mandrel with a diameter of approximately 40 times the overall cable diameter and immersed in tap water at room temperature for a period of one hour. While still immersed, the specimens shall pass voltage withstand test. Bending test requirement after DBE can give severe damage to cable insulation survived from the condition of DBE condition. The bending test requirement is too conservative to demonstrate retention of a degree of flexibility, margin in electrical performance and ability to withstand some movement and vibration.

2.4 Life extension solution of IEEE383

For extending qualified life of cable, IEEE383-2003 '5.4 extending qualified life' recommends three ways such as below[1].

a) Place same type cable in a natural or accelerated aging environment and perform type test. Fig. 1 shows a picture of cable depot installation.
b) Aging deterioration of cable will be monitored at specific intervals and compared with specified acceptance criteria. Fig. 2 shows cable aging monitor[2].
c) Perform environmental condition monitoring of plant cable to judge that originally assumed were overly conservative. Fig. 3 shows temperature monitor

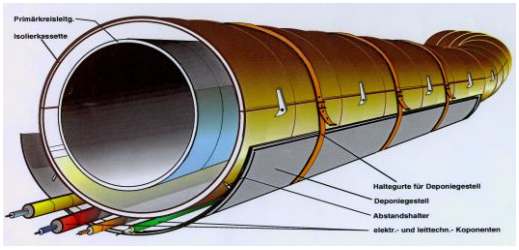

Fig. 1 Installation of cable depot

Fig. 2 Cable aging monitor

Fig. 3 Temperature monitor

2.5 Other solutions

There are several other tasks that we have to overcome for qualification of 60 years life cable.

The first one is bending test requirement after DBE described in IEEE383. According to NUREG/CR-6384, The post LOCA mandrel bend test, removing cable from a mandrel, straightening and recoiling on a mandrel of 40X diameter, imparts an unrealistic stress on the cable which induces failures of good cables[3]. They recommend 20X diameter coiling and post LOCA dielectric testing in tap water instead of 40X diameter recoiling and straightening.

The second solution is excluding of beta radiation in the total integrated radiation exposure. If the cable can be fabricated with aluminum sheet between cable jacket and insulation, TID is not necessary to include beta radiation which is almost 50~75% of TID. Reduding of TID can give benefit for extending cable life to 60 years.

The third solution is installation of air circulation system in the cable tray. By installing insulated cable duct and air culculation system instead of cable tray, normal operating temperature and DBE peak temperature can be considerably reduced .

3. Conclusions

There are several ways to extend cable life to 60years. For the operating plants, exemption of post LOCA bend requirement, aging condition monitoring of cable, environment monitoring of temperature and radiation in the operating plant are recommended. For the construction plant, development of beta ration free cable and cable tray duct with cooling system are recommended.

REFERENCES

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