

The Investigation on Cable Aging Condition Monitoring Technology Trends and Findings

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1. Introduction

The typical environmental qualification is to ensure that equipment will operate to meet system performance requirements during normal and accident conditions. Various environmentally qualified cables made by polymer insulating materials are subjected to high temperature, radiation, chemical materials, mechanical stress, or other stresses. They are expected to be deteriorated from the first properties, it is called aging, critically influences its qualified life. Therefore, it is important to predict, evaluate and monitor the cable aging trends, and these series of activities are called ‘cable aging condition monitoring’.

In this paper, I’d like to introduce the technology trends and findings of cable aging condition monitoring by domestic and foreign literatures, and discuss the needs and further researches in this field.

2. Methods and Results

2.1. Background and definition of cable aging condition monitoring

The qualified life of cable may change depending on various environmental parameters. The purpose of cable aging condition monitoring is to prevent the cable errors by monitoring the change of cable aging condition due to unexpected aging stressors. Particularly, by aging condition monitoring for cables in nuclear power plant, the remained qualified life can be predicted, its original qualified life can be extended by aging condition indicator trending and the replacement intervals can be optimized.

2.2 Domestic technology and research trends

Some studies related to cable condition monitoring have been conducted in Korea, the investigation results are as follows;

The useful cable condition monitoring techniques are classified as 3 kinds, which are chemical, mechanical and electrical properties evaluations. Chemical properties evaluation methods are known as Oxidation Induction Time Test, Thermogravitic Analysis and Fourier Transform Infrared Spectrum Analysis. Well-known mechanical properties evaluation methods are Elongation-At-Break Test, Indenter Modulus Test and rarely used

methods are Infrared Temperature Measurement, Visual Inspection, Density Variation Measurement, Flexibility Test, and Dynamic Mechanical Analysis. Electric properties evaluation methods are DC test, AC impedance test, voltage withstand test, partial discharge test, time domain reflectometry, dielectric loss measurement and electromotive force(EMF) measurement.

Among these methods, Elongation-At-Break Test, Indenter Modulus Test and Oxidation Induction Time Measurement are very famous and frequently used. The Elongation-At-Break Test is an internationally standardized method based on tensile testing, but requires a lot of tensile specimens, is destructive and difficult to collect specimens from operating nuclear power plants. The Indenter Modulus Test method is good for field applications, can be quickly inspected and obtained the results immediately in the field. But changes in jacket or insulator thickness may affect the test results. In case only cable jacket tested, it is necessary to correlate with the insulation material and the elongation at break test results if possible. The Oxidation Induction Time Test method can be tested only with a small amount of non-destructive sampling, but can be applied only to antioxidant materials and difficult to apply to PVC material. This method also necessary to correlate the cable jacket and insulation, correlate with the elongation at break or other cable aging condition indicator if possible.

2.3 Foreign research trends

I could easily find a lot of research results have been published and current researches are ongoing in various countries.

US NRC supported the research of cable aging condition monitoring used in NPPs. These results described in NUREG/CR-7000, provides, they expect, guidance on practical cable aging condition techniques.

Based on the research results, The US NRC published Regulatory Guide 1.218, emphasizes the necessity to monitor the condition of cables throughout their installed life by the use of cable condition-monitoring techniques. This guide introduces 12 different methods for cable condition monitoring as follows;

- HPT, Direct Current High-Potential Test (dc High Voltage)
- SVT, Step Voltage Test (dc High Voltage)
- VLF, Very Low Frequency Test
- IB, Illuminated Borescope

- Visual Inspection
- Compressive Modulus (Polymer Indenter)
- $\tan\delta$ test, Dielectric Loss-Dissipation Factor (Power Factor)
- IR, Insulation Resistance
- PDT, Partial Discharge Test
- TDR, Time Domain Reflectometry
- FDR, Frequency Domain Reflectometry
- Infrared Imaging Thermography

The IAEA conducted a Coordinated Research Project(CRP) to monitor the performance of cable insulation and jacket materials and provide information and guidance on how to set up a cable condition monitoring program. In this project, global experts group was made to provide information on cable condition monitoring and aging management. Totally, about 100 engineers, scientists, regulators, suppliers and utilities participated in the project including experts of KHNP CRI.

Based on the results of joint research, the IAEA categorized the methods into four types(visual/ tactile, electrical, mechanical, and chemical) shows test results and special features of each method. Figure 1 shows the cable condition monitoring techniques classification.

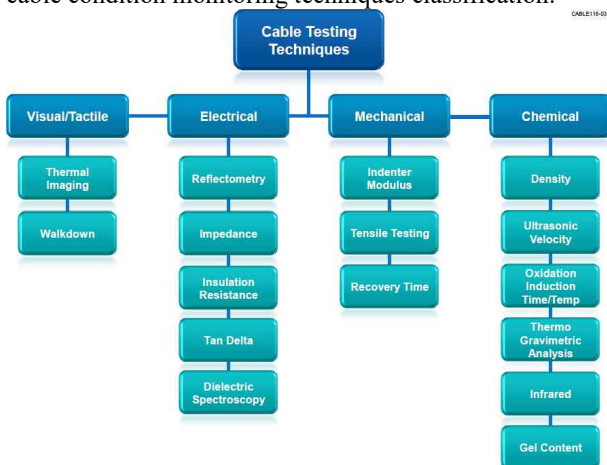


Figure 1. Cable condition monitoring techniques classification

The IAEA Nuclear Energy Series Report NP-T-3.6 also recommends how to select the appropriate cable condition monitoring method. The recommended consideration are as follows;

- Easy sample acquisition
- Clear safety functions in structural and electrical
- Can be tested without dismantling the device
- (if possible) Can be tested during normal operation
- Can be tested for all kinds of materials
- Can be correlate with the EAB test results
- Available in limited areas
- Cheap test cost than the cable replacement

2.4 Discussion of further research

There are many research results for various types of cables, mainly about the OIT, TGA, FTIR, EAB and Indenter Test. However, there are few studies on the electrical properties evaluation method like partial discharge test, time domain reflectometry and dielectric loss measurement in Korea.

On the other hand, based on worldwide experimental results, aging tendency and effective method for cable aging condition monitoring is recommended. For example, the dielectric spectroscopy and FDR tests showed good aging tendency and the IR and reflected wave measurement tests can be applied to all kinds of cables. Lessons learned from research results around the world, it is necessary to develop electric cable aging condition monitoring method such as VLF, PDT, $\tan\delta$, IR, TDR and FDR for various cable materials can be applied to domestic NPPs.

3. Conclusions

The importance of cable aging condition monitoring was discussed, it is important to prevent the cable errors because NPP operation can deteriorate its qualified life by exposing unexpected high temperatures or high radiation.

Various kinds of cable condition monitoring methods are tested and the results issued all over the world. This investigation shows the strengths and weaknesses for each methods and some meaningful results like aging tendency as cable aging indicator.

Reg. Guide 1.218 has been published, provides 12 test methods and special features of each methods based on their research. IAEA CRP on cable aging and condition monitoring test results shows important results and suggests further research directions.

The methods like OIT, TGA, FTIR, EAB and Indenter have many experimental results and good procedure in Korea. On the other hand, electrical properties evaluation method for cable aging condition monitoring is not common.

As IAEA recommended the dielectric spectroscopy and FDR for good aging tendency, IR and reflectometry for all kinds of cables, we need a lot of experimentations and researches on electrical properties evaluation methods like VLF, PDT, $\tan\delta$, IR, TDR and FDR as cable aging condition monitoring method.

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