Field Application of Advanced Low Voltage Cables Electrical Condition Assessment Techniques

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ABSTRACT

Previous research conducted between 2015 and 2021 has clearly indicated the sensitivity of advanced, non-destructive electrical testing to condition assess thermally aged low voltage cables located in nuclear power plants. From this research, a field-testing protocol and provisional assessment framework was proposed which combines both globally sensitive and locally sensitive test techniques to properly assess results, allowing for targeted and prioritized plant actions. This paper presents the results of applying these advanced techniques Peach Bottom Atomic Power Station test and assess 70 cables from 2018 to 2022. The impact of these techniques over more industry techniques such as DC insulation resistance testing is also discussed.

KEYWORDS

Low Voltage Cables; Cross-linked Polyethylene (XLPE); Condition Assessment; Field Testing; Dielectric Spectroscopy, Insulation Resistance, Time Domain Reflectometry (TDR), Frequency Domain Reflectometry)

INTRODUCTION

Background

In-situ identification of Low Voltage (LV) cable degradation from long term exposure to environmental stressors, such as elevated temperature or radiation fields, or from discrete events, such as a fluid leaks, is of increasing interest to aging nuclear plants worldwide. Field deployable material-based techniques, including indenter modulus or near infrared spectroscopy, have been used successfully in the last few decades to determine the local condition of cable materials. However, their discrete nature combined with the lack of access to cables in most areas of the plants restrict their use to very specific issues where the precise location of degradation is known. In addition, these techniques typically only assess the jacket material whereas the primary concern in terms of the cable operability lies with the insulation.

The need for innovative electrical based methods to monitor the condition of LV cables from their terminal ends led EPRI to initiate research in 2017 on the applicability of Low Frequency Dielectric Spectroscopy (LFDS) and Polarization / Depolarization Current (PDC) methods to identify and quantify the level of degradation of thermally aged LV cables. This project demonstrated that LFDS and PDC test methods can track thermally induced insulation degradation and that key preliminary metrics correlated well with established material test results [1][2][3]. These initial findings were further supported by additional laboratory data from Phase II of this project which expanded the investigation to additional insulation materials [4]. This work, concluded in 2021, also established the sensitivity of these techniques to the effects of long-term water exposure. Key findings from this laboratory research work, including the development of preliminary guidance and diagnostic metrics for the condition assessment of cables, are presented in a related paper at this conference.

In recent years other research groups (especially in Europe) have also published promising results supporting the use of Dielectric Spectroscopy (DS) to test LV cables in nuclear plants [5][6][7]. The collected data showed good correlation between electrical permittivity responses measured in the higher frequency range (up to 1 MHz) with changes in mechanical and physio-chemical responses. While these techniques have shown great potential in the laboratory, as just discussed, there has been very little experience of their use in the field to determine the condition of LV cables. Suraci et al. did limited but promising trials in the field on coaxial and shielded twisted pair designs [8][9]. Reflectometry based techniques such as Frequency Domain Reflectometry (FDR) or Time Domain Reflectometry (TDR) have been more extensively used in the last few years in nuclear plants to identify degraded areas in LV cables [8][10]. However, these techniques lack the ability to accurately discriminate between different levels of aging, especially if the aging affects a significant portion of the cable.

One of the key outcomes of the EPRI research recently concluded was the development of a procedure for the deployment of LFDS and PDC methods in parallel with reflectometry techniques in the field. This procedure was used to benchmark the technologies and the laboratory-based assessment guidance in the field during a large-scale trial and follow up campaigns conducted at Peach Bottom Atomic Power Station (PBAPS) in the US on LV cables of various designs and known to be subjected to thermal aging. This paper presents the main results for this in-situ investigation along with important lessons learned.

Objectives

The field work is motivated and guided by three main objectives:

1. **Condition Assessment**: Provide an overall condition assessment rating of the global and/or local degradation condition of each tested cable, through quantitative analysis and qualitative comparison between the samples.
2. **Fault Localization**: Where adverse operating history/previous faults have been identified, undertake localization activities to identify the location of the faults.
3. **Future Trending**: Establish a baseline set of data which can be applied in future testing to identify deteriorating trends in cable test results.