Aging Management for XLPE and EPR Medium Voltage Cables in Nuclear Plant Environments

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ABSTRACT

This paper presents a summary of key experiences and electrical testing statistics from 30+ years of non-destructive shielded MV plant electrical cable diagnostics in CANDU nuclear plants, and approximately 5+ years in US nuclear stations. The contribution also describes an established technical approach for MV cable aging management consisting of off-line AC (50/60Hz or Near Power Frequency) over-voltage testing, off-line partial discharge testing and dielectric spectroscopy, including VLF (0.1Hz) Tan δ testing. By combining the approaches above, technical merits of both AC and low frequency methods can be realized. Furthermore, the combined diagnostic approach can be sensitive to localized (latent) electrical defects, distributed moisture induced degradation and, potentially, bulk thermal aging.

KEYWORDS

Aging Management, Medium Voltage Nuclear Cable, AC Withstand, Partial Discharge (PD), Dielectric Spectroscopy (DS), VLF Tangent Delta (Tan δ)

INTRODUCTION

Currently, in North America, significant attention is being paid to the condition of cable systems in nuclear generating stations with respect to re-licensing and life extension, including recognition that low voltage (LV) and medium voltage (MV) plant cables are critical to the safe, reliable and economic operation of nuclear power plants. Consequently, plant operators and regulators such as the US Nuclear Regulatory Council (NRC) and the Canadian Nuclear Safety Commission (CNSC) are focused on the implementation of aging management of low and medium voltage cables in the nuclear environment. This focus on aging management increases when one considers plans for 60 year and possibly even 80 year plant life extensions, as well as the fact that an unplanned cable system failure in a nuclear environment can have serious consequences for plant safety and reliability.

In CANDU (Canada Deuterium Uranium) plants in Ontario, since 1983 Ontario Hydro and its successor companies have applied a combination of AC (50/60Hz) withstand and partial discharge (PD) diagnostic methods to test generating station components including shielded medium voltage cables [1]. This development was driven by the relatively high post-test failure rate of DC tested cable systems, combined with the need for high reliability in critical station service systems. While this test methodology was originally used to commission MV cables to ensure that cable and terminations were installed correctly, as the plants have aged, these test techniques are now employed for routine maintenance of aged cables at every outage to provide assurance of continued safe and reliable operation.

While the adverse consequences for solid extruded polymer cables operating long term in wet environments (i.e. water treeing) has long been recognized by distribution utilities, only recently has this issue of 'wet aging' gained profile in the nuclear industry in North America. In US MV Cable Aging Management programs, low frequency or VLF (typically 0.1Hz), variable voltage dielectric loss measurements are now the most commonly applied field diagnostic technique, relying on test methods and assessment criteria guidance from the Electric Power Research Institute [2] and IEEE 400.2-2013 [3]. Such programs have been successful in identifying cable system defects, particularly those related to bulk water-tree related degradation. Frequency domain dielectric spectroscopy (variable frequency, variable voltage dielectric loss measurement) has been applied in US nuclear plants on a more limited basis since around 2007. Dielectric spectroscopy (DS) features the same sensitivity to bulk water-tree related degradation as 0.1Hz dielectric loss, but features some advantages which will be discussed in this paper.

This paper discusses a technical basis for, and field experience from, a combined technical approach of AC withstand, partial discharge (PD) and dielectric spectroscopy (DS), including VLF tangent delta (Tan δ) electrical testing of in-service MV cables in nuclear plants.

POWER FREQUENCY AND VLF TESTING

The discussion in this section focuses on a comparison of sinusoidal (0.1Hz) VLF versus AC stress in a combined test methodology (i.e. a monitored withstand and/or diagnostic test). For a practical discussion on AC versus DC test stress and field experience, refer to [2].

Basis for Power Frequency Testing

The application of AC test voltage in a MV cable aging management program is based on the following technical principles:

- Medium voltage cables in the vast majority of operational environments actually experience 50/60Hz voltage stress in service. An AC test thus stresses all portions of the cable insulation and accessories in exactly the same manner as encountered in normal service, except at a higher level.

- 50/60Hz is stipulated for factory testing in international and North American MV cable testing standards such as IEC 60502, IEEE 48/404, and ICEA S-93-649. 'Near Power Frequency' (NPF) test voltages between 20 - 300Hz are stipulated for after-installation acceptance testing of MV, HV and EHV cables in IEC 60502, 60840 and 62067 respectively. The introduction of VLF (0.1Hz) testing into standards is