Aging management for XLPE and EPR medium voltage cables in nuclear plant environments

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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, the regulators and operators are increasingly focused on the implementation of aging management of low and medium voltage cables in the nuclear environment - especially when one considers 60 year and possibly even 80 year plant life extensions.

In US MV Cable Aging Management (AM) programs, Very Low Frequency (VLF) tan delta testing and VLF withstand testing are the most commonly applied field diagnostic techniques, relying on test methods and assessment criteria guidance from the Electric Power Research Institute (Technical Report 3002000557) and IEEE 400.2-2013. Such programs have been successful in identifying cable system defects, particularly those related to bulk water-tree related degradation. In Canadian CANDU (Canada Deuterium Uranium) plants in Ontario, since 1981 a combination of AC withstand and partial discharge (PD) diagnostic methods have been most often applied, for commissioning generating station cable circuits as well as routine maintenance of aged cables at every outage. Such testing has been extremely effective in identifying both gross (bulk) defects as well as localized workmanship related flaws particularly in cable accessories.

This paper presents a summary of test statistics and key experiences from 30+ years of non-destructive shielded MV plant electrical cable diagnostics in CANDU plants, and approximately 5+ years in US nuclear stations by Kinectrics and its predecessor (Ontario Hydro Research Division). The contribution also describes an established technical approach for MV cable aging management consisting of:

1. Off-line AC (50 or 60 Hz) over-voltage or withstand testing
2. Off-line Partial Discharge testing using electrical and acoustic methods, including pulse injection measurements to confirm PD sensitivity at terminal ends
3. VLF (0.1 Hz) Tangent Delta Testing
4. Dielectric Spectroscopy Testing - typically obtaining frequency response from 0.01 or 0.1 - 10 Hz at variable voltages (0.5 U_o - 2 U_o)

By combining the approaches above, a number of benefits are realized as follows:

1. Technical merits of both power frequency and low frequency methods can be realized
2. Diagnostic measurements can be sensitive to localized latent electrical defects, distributed (bulk) water-treeing related degradation and, in the case of dielectric spectroscopy, to distributed (bulk) thermal aging related degradation.

In addition to the above approach, the benefits and limitations of additional evolving diagnostics such as travelling wave based methods (i.e. Frequency Domain Reflectometry (FDR), Frequency Response Analysis (FRA), etc.) will be discussed. These methods are unique in their applicability to electrical diagnostic field terminal measurements on unshielded and shielded, MV and LV cables. However, at the current time there is a lack of research on the fundamental technical basis and acceptance criterion for such techniques.