Ageing behaviour analysis of different cores of multicore nuclear power plant instrumentation and control cables by dielectric spectroscopy

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ABSTRACT

The instrumentation and control cables play a key role in the safe operation of nuclear power plants. Regular condition monitoring can help to maintain the cables' qualified condition. In the case of multicore cables, the question is which core is appropriate for carrying out the condition monitoring measurement. In this study, the tan δ of different cores of gamma-irradiated multicore EPR-insulated I&C cable samples was measured in the 0.5 mHz...5 kHz range and the results were analysed. The results show that the difference between the tan δ values is relatively high, only at 4.4 kHz, and 5.0 kHz frequencies and in the 40-110 Hz frequency range, lesser than 25%. The tan δ values of each core correlate with ageing in mHz range. While by averaging the tan δ values of the cores, a good correlation was also experienced in the kHz range. The results show that in the mHz frequency range, the condition monitoring measurements should always be performed on the same core, whereas it is advisable to average the measurement results of more cores in the kHz frequency range.

KEYWORDS

nuclear power plant cable; EPR insulation; tan δ; FDS measurement

INTRODUCTION

In the long run, the safe operation of nuclear facilities relies on safety-related equipment, including cables. These cables need to perform their intended function during normal operation and all postulated events throughout their expected lifespan. The cables in nuclear facilities are exposed to multiple stressors (as shown in Figure 1) that trigger chemical reactions like oxidation, cross-linking, and chain scission in their insulation and jacket materials made of polymers, leading to the deterioration of the chemical, mechanical, and electrical properties of the cable's polymeric components [1, 2]. If the critical properties decay below a critical value, it ultimately causes a loss of functionality. Therefore the measurement of material parameters Traditionally, in the nuclear industry, the 50% value of elongation at break (EaB) is considered the end-of-life criterion for insulating polymers [3]. However, despite being a destructive technique, measuring EaB is widely used to estimate the remaining lifespan [4,5].

Intensive research has recently been done about applying dielectric measurements for condition monitoring for NPP cables worldwide [6-9]. These techniques are based on measuring dielectric properties in the time or frequency domain (dielectric spectroscopy). These techniques are non-destructive because the measurements are carried out at lower voltages than the nominal voltage of these cables. Nevertheless, in many cases, the measurement time requires a long time, especially if the lower frequency or longer time dielectric responses are the reliable markers used in condition monitoring. The cables used in nuclear power plants have various structures, especially the I&C cables containing multiple cores. Therefore, dielectric testing measures the resultant dielectric properties of the materials inside the cable; hence, the measurements' results can differ from core to core [10, 11]. Nevertheless, the measurement time for one cable is limited, so measuring all cores in a given cable is impossible.

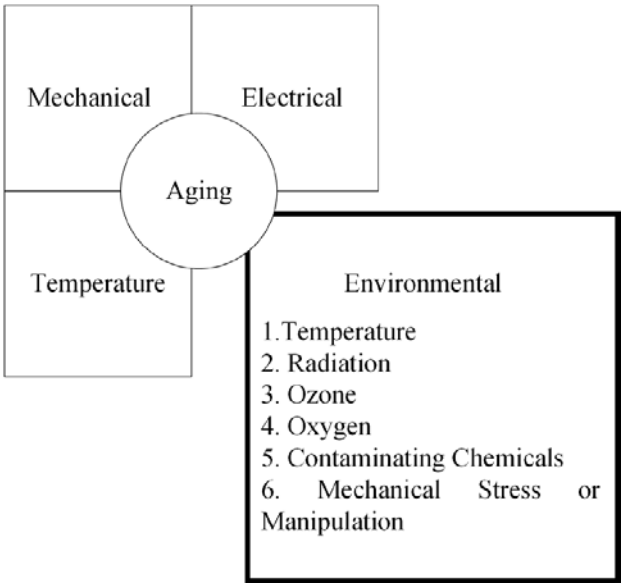

Fig. 1: Stressors and ageing of cable insulations in NPP [1, 2]

This paper is intended to show the differences between the dielectric properties depending on the connection of testing equipment to a multicore cable. For this purpose, a multicore I&C cable exposed to irradiation ageing and more cores were measured using frequency domain spectroscopy. The results were analysed and discussed, showing which core measurement is suggested for condition monitoring.

MATERIALS AND METHODS

In this study, the dielectric responses in the frequency domain were measured on a multicore cable with two usual connections. In the first case, the equipment measures the centre core, while in the second case, the outer one.

Samples

The subject of the investigation is an ethylene propylene rubber (EPR) insulated and cross-linked polyolefin (XLPO) jacketed, 7Cx14 AWG (7x2.08 mm2) shielded, Class 1E nuclear power plant instrumentation and control (I&C) cable, manufactured by LS Cable, Seoul, Korea (Fig. 2). The structure and nominal data of the tested cable are the following: