CONDITION OF SHIELDED 5 KV AND 8 KV PINK ETHYLENE PROPYLENE RUBBER (EPR) INSULATED CABLES AFTER 25 YEARS OF SERVICE IN WET ENVIRONMENT

Bogdan **Fryszczyn**, Cable Technology Laboratories (USA) bogdanf@cabtl.com and Andrew **Mantey**, Electric Power Research Institute (USA), amantey@epri.com

ABSTRACT

There are 99 nuclear power reactors generating about 20% of total U.S. electric energy. The average nuclear reactor is about 33 years old. Shielded medium voltage (5 kV, 8 kV and 15 kV) cables in these plants are insulated with butyl rubber, black EPR, cross-linked polyethylene (XLPE), brown EPR and pink EPR which was introduced commercially in 1974.

The pink EPR insulation has given much more reliable service than the butyl rubber, black EPR, and XLPE insulations that preceded. However, as with other polymeric insulation, pink EPR is not immune to aging in wet environments.

Medium Voltage (MV) cable failures are of great concern, as such events quite often lead to unplanned, costly plant outages and lost revenues. Much of the past research on water related cable failures focused on XLPE insulations, but EPR's comprise the majority of medium voltage cables in U.S. nuclear power plants and the cables recovered from these plants have been the focus of EPRI sponsored research at Cable Technology Laboratories (CTL) since 2006.

The paper will describe the condition of two 3/C cables (cable 1 and cable 2) removed from nuclear plants because of high and unstable values of 0.1 Hz dissipation factor (tan delta) of one of their phases. The cables were replaced and the removed cables were subjected to laboratory forensic evaluation.

It will be shown, in the case of cable 2, that water treeing is responsible for the substantially decreased cable insulation strength as determined by the five-minute ac step voltage test. The results obtained on this cable also show that very advanced water trees, spanning nearly the entire insulation wall are detected by 0.1 Hz tangent delta measurements.

KEYWORDS

Electrical cable aging

Submergence

Water treeing

Wet aging

AUTHOR NAMES & AFFILIATIONS

Bogdan Fryszczyn, Cable Technology Laboratories, bogdanf@cabtl.com and Andrew Mantey, Electric Power Research Institute (USA), amantey@epri.com

INTRODUCTION

A major focus area of cable research at EPRI since 2006 has been on wet (including submerged) EPR insulated cables. This research area's scope includes the forensic analysis of medium voltage cables operating in wet environment, evaluation of tan delta test data, and attempt to establish a protocol for accelerated wet aging and an environmental qualification for wet cables. Also, a more recent effort is an investigation if four frequently used low voltage cable insulations degrade in wet conditions.

Medium voltage cable failure mechanism research focuses on forensically evaluating cables that failed in service or were removed and replaced due to poor electrical tan delta test results. The research goal is to identify how and why the cable insulation degrades in wet conditions. EPRI has partnered with Cable Technology Laboratories (CTL) on seven reports that have been issued to-date [1-7]. Forensic studies have been done on butyl rubber and different insulation formulations of ethylene propylene rubber (EPR). Research findings include establishing a correlation between tan delta test values and reduced insulation dielectric strength as measured by ac voltage breakdown testing.

This paper will discuss some past wet aging studies on pink EPR. The cases of two pink EPR cables that were replaced by plant operators due to poor results of diagnostic testing, provided to EPRI for forensic analysis and forensically examined by CTL will be described.

BACKGROUND

Extensive prior studies of medium-voltage polymeric insulated cables operating in wet environment has established that water-treeing type of insulation degradation is the main degradation mechanisms responsible for the loss of electrical insulation strength and in-service failures [8,9]. This type of degradation is common to all types of polymeric insulation like polyethylene, ethylene-propylene rubber, butyl-rubber, etc. [4, 8, 9].

EPRI research has shown that 0.1 Hz tangent delta/dissipation factor testing can be used to identify degraded insulation and assess the degree of insulation degradation. Previous forensic work by CTL has established a correlation of field-measured tan delta values [10] with laboratory established breakdown strength [6].

Past Wet Electrical Aging Studies

A past EPRI study [11] on wet electrical aging of medium voltage insulated cables shows how pink EPR initially loses its electric strength in a wet environment. A pink 15 kV EPR cable of the same manufacturer, as those discussed later in this report, were electrically aged in the laboratory at room temperature in water filled tanks. Voltage continuously applied to the cable conductor was 2.5 x U_0 (23 kV rms to ground). Identical cables, in parallel, were installed in underground ducts at a utility and subjected to aging under normal field conditions.