Rejuvenation of EPR-insulated medium voltage underground cables

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ABSTRACT

Underground cable rejuvenation fluids retard further growth of water trees and enhance dielectric strength by reducing the amount of water in medium voltage insulation. A review of 10 years of rejuvenation experience on field-aged polyethylene and EPR-insulated medium voltage cables shows that the post rejuvenation failure rates of both insulation types are low (0.4%) - suggesting that rejuvenation benefits both insulation types.

KEYWORDS

underground cable rejuvenation; ethylene propylene rubber

INTRODUCTION

Shortly after being introduced into widespread field use medium-voltage high molecular weight polyethylene (HMWPE) and cross-linked polyethylene (XLPE) insulated cables began experiencing electrical failures at an alarming rate. The failure mechanism was ascribed to water tree formation – bushy structures left behind after polymer degradation due to the formation of powerful oxidants from water by the medium voltage electric field.(1,2) The voids resulting from oxidation of the polymer create paths for partial discharge followed by an electrical fault.

Once the failure mechanism was identified, several strategies emerged including drying the insulation by injecting nitrogen or air into the core conductor or injecting compounds such as acetophenone.(3) These approaches were short-lived unless the treatment was regularly repeated. This proved impractical.

Ultimately underground cable rejuvenation using a class of materials classified as di-alkoxysilanes emerged to be the dominant commercial treatment fluid. (3-7) Di-alkoxysilanes work by reacting with water and forming a liquid oligomer. The fluid raises the dielectric strength of the cable shortly after treatment. Due to its large size and low diffusion coefficient, the oligomer remains in the cable for several decades after initial treatment. Over 30 million meters of HMWPE and XLPE underground cables have been treated with di-alkoxysilanes in the last 25 years by the authors' firm.

A second type of medium-voltage solid core insulation, ethylene-propylene rubber (EPR) is also available. The failure mechanism of EPR insulation is less well defined because: (3)

- EPR–insulated cables generally have enjoyed a higher in-service reliability compared to vintage PE cables
- Water trees are fewer in number and/or more difficult to detect than those in PE cables
- The paucity of water trees in EPR insulation makes their role in electrical failures more controversial
- EPR is a complex, composite material whose composition varies widely by manufacturer and vintage.

These factors make it difficult to relate laboratory results to field experience and to apply laboratory results commonly to the entire population of EPR cables.

The purpose of this paper is to propose a circumstantial case for chemical rejuvenation of medium voltage EPR electrical cables based on recent findings in other laboratories plus analysis of 10 years of results from commercial rejuvenation of EPR cables in the field.

Ingredient	Description	Purpose	Loading, parts per hundred
Elastomer	EPM/EPDM	Base polymer	100
Translink 37	Surface treated Kaolin clay	Reduces water transmission	60
Agerite Resin D	Antioxidant	hydroquinoline	1.5
DrimixSilane A-172	Vinylsilane	Improves wet electrical properties	1
Kadox 911	Heat stabilizer	Zinc oxide Improves electrical breakdown strength	5
ERD90	Red lead	Neutralizes catalyst residues EPR Cable 2	5
Paraffin Wax	Wax	Processing aid	5
Escorene LDPE	Low density polyethylene	Cross-linkable resin	5
Di-Cup 40KE	Dicumyl peroxide on clay (40% active)	Catalyst Curing or vulcanizing agent	6.5
Total pph			189

Table 1. Commercial EPR Insulation Formulation (8)