ADVANCEMENTS IN TR-XLPE INSULATION TECHNOLOGY TO ENABLE USE IN HIGH VOLTAGE CABLE APPLICATIONS

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ABSTRACT

A third generation TRXLPE insulation material has been introduced that incorporates technology that leads to a dramatic increase in wet cable life performance in addition to maintaining an improved electrical loss characteristic. Wet third generation TRXLPE insulated cables have been assessed under high voltage stress conditions that demonstrate high breakdown strength retention. Recent developments in TRXLPE technology have identified pathways to continue providing excellent wet electrical performance while achieving an electrical loss characteristic comparable to non-tree retardant XLPE under extra high voltage stresses.

KEYWORDS

XLPE, water tree retardant, high voltage cable

INTRODUCTION

The use of paper insulated lead sheathed (PILC) cable technology for underground high voltage cable applications started in the early twentieth century. High voltage cables are considered to be those rated over 30 kV. Currently, many high voltage cables being installed are extruded dielectric insulated cables versus the older PILC cable technology. Extruded dielectric high voltage cables are typically insulated with crosslinked polyethylene (XLPE). The use of XLPE for high voltage cables up to 138 kV began in the 1970s. The application of XLPE insulated cables to ever higher voltages progressed in the 1990s with expansion to extra high voltage cables (cables rated over 345 kV).[1] In 2001, industrial specifications for XLPE insulated cables up to 500 kV were issued.[2] Expansion of the applications for extruded dielectric XLPE high voltage cables including for installation in wet environments under harsh environmental conditions, such as in 66 kV array cables for off shore wind farms, continues.[3] In addition to having very low dielectric losses and high dielectric strength, a XLPE insulated cable has an advantage over older PILC cable technology in that it does not use oil. Therefore, oil leakage to the environment is not a concern with XLPE insulated cables.

To obtain a long cable service life, it is important to keep moisture out of an XLPE cable. When exposed to moisture, electrical and mechanical stress, XLPE insulation is susceptible to water treeing, which has been associated with cable failures.[4,5,6,7] Water trees in the XLPE insulation are generally considered to be degraded, chemically oxidised structures that are observed as a dendritic pattern of water filled micron and sub-micron sized cavities. As water trees grow, the electrical stress on the insulation can increase to the point where an electrical tree initiates at the tip. Once initiated, electrical trees grow rapidly and lead to catastrophic failure of the cable.

To exclude water from the cable, high voltage XLPE cables typically use a “dry cable design” that involves water swellable tapes, a (metallic) moisture barrier layer as well as other water blocking components. Additionally, to avoid ingress of water, the installation of a high voltage cable requires appropriate precautions to ensure the outer layers of the cable are not damaged during transport and installation. These additional precautionary steps to exclude water from an extruded dielectric high voltage cable lead to extra effort and cost in cable installation.

Water tree retardant crosslinked polyethylene (TRXLPE) has demonstrated 35 years of excellent field performance under medium voltage electrical stresses in harsh, wet environments. TRXLPE is globally accepted as the medium voltage power cable insulation material of choice due to its superior long-life performance and excellent value. Since the introduction of the first generation TRXLPE over 35 years ago, there have been significant improvements in the TRXLPE formulation technology leading to further enhanced cable performance and even greater value to the power industry. These improvements have contributed to longer life cables as demonstrated in accelerated wet electrical cable tests and field experience.

TRXLPE insulated cables have achieved this outstanding long life performance in “wet design” cables. A “wet design” cable does not have a metallic moisture barrier such as a lead sheath and it is replaced by diffusion resistant polyethylene jacket. Though a “wet design” cable may also contain water absorbing tapes and conductor strand filling compound, these are not required for TRXLPE insulated cables. These cable design changes are also a lower cost solution.

This paper reviews the history of TRXLPE advancements and the potential of using a third generation TRXLPE as the insulation of choice for “wet” high voltage cable designs.

FIRST GENERATION TRXLPE

The first generation TRXLPE insulation achieved a dramatic improvement in medium voltage cable life performance in wet environments. The lifetimes of cables insulated with the first generation TRXLPE and conventional XLPE were compared in the accelerated cable life test (ACLT).[8,9] The ACLT utilizes accelerating factors such as temperature, water, electrical and mechanical stress. The ACLT measures the time to cable failure. The test is generally performed on a 15kV cable core with 4.4 mm thick insulation. A continuously applied test voltage of 4Vo (4 times rated voltage to ground of a