Potential Use of New Water Tree Retardant Insulation in Offshore Wind Farm Array Cables.

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ABSTRACT

The off-shore wind farm industry is facing challenges to reduce the cost of renewable energy. In an effort to make the power from offshore wind farm generation more cost effective, wind farm developers and cable makers are evaluating the impact of increasing the array cable operating voltage from 33kV to 66kV. Cable design (wet or dry) and choice of insulation are also critical factors affecting the cost and performance of the wind farm array cable. In this paper we present the most recent data from long term wet aging of a new enhanced water tree retardant XLPE insulation compound and begin to explore the potential of this material as an insulation solution for 66kV wind farm array cables.

KEYWORDS

XLPE, water tree retardant, wind farm array cable

INTRODUCTION

The current high cost of offshore wind power is one of the main challenges facing this industry. As a result, efforts are underway to evaluate a range of options to increase the competitiveness of this form of renewable energy [1,2] Larger wind turbines and more turbines per array are being proposed [3]. Currently wind farm array cables operate at 33kV but a move to 66kV has been identified as having the potential to deliver significant cost savings [4,5]. “Wet design” cables without a metallic moisture barrier such as a lead sheath are also a lower cost solution for wind farm array cables and it is the intention of some cable manufacturers to evaluate the performance of these cables at the higher voltage of 66kV [6,7,8] . In a wet environment, cables under electrical stress which are devoid of a metal barrier, can be susceptible to the formation of water trees in the insulation. As a result, insulation systems such as clay filled ethylene-propylene rubber (EPR) and water tree-retardant crosslinked polyethylene (TR-XLPE) are usually selected to limit the impact of water treeing on cable breakdown performance. However EPR and TR-XLPE insulations exhibit a higher dielectric loss (increased dissipation factor) than standard XLPE, this is especially true as the electrical stress on the cable increases.
This paper looks at the potential option of using additive water tree retardant crosslinked polyethylene as the insulation material of choice for offshore wind farm array cables. In addition to limiting the growth of water trees, this insulation has a relatively low loss factor and maintains a high dielectric breakdown strength even after ageing in a wet environment.

Tree Retardant Insulation

In the 1970s, underground cables in a wet environment and insulated with crosslinked polyethylene began failing prematurely due to the phenomena known as water treeing [9,10] Water trees in insulation are generally considered to be degraded, chemically oxidised structures which are observed as a dendrite pattern of water filled micro and sub-micro 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.
In order to avoid or minimize this phenomenon, two different approaches are taken. One option is to modify the design of the cable to eliminate the possibility of water or moisture ingression. This is done by the use of a metal sheath resulting in a so-called “dry design” cable. Although successful, this is a relatively expensive solution, especially for a medium voltage cable installation. It can also impact cable bending and the cable installation process.The alternative is to use a more cost effective “wet design”, whereby the moisture-impervious metal sheath is eliminated and replaced by diffusion resistant polyethylene jackets, water absorbing tapes and conductor strand filling compound. However in this case, the cable insulation needs to be more robust towards the growth of water trees. As a result, the wet design cable preferably employs a water tree retardant insulation. The vast majority of wet cable designs are used in the manufacture of medium voltage (6-46kV) cables. However as offshore wind farm developers and cable makers look at ways to reduce the overall cost of renewable energy, “wet design” inter-array cables operating at higher (66kV) voltages are being evaluated as they have the potential to bring significant cost savings to the wind farm operation [4]. However we should also keep in mind that due to the variation in wind power generation, the current loading of a wind farm distribution network is very different from that of a traditional underground system which can lead to a higher temperature gradient in wind farm cables and a greater degree of thermo-mechanical stress during heating and cooling cycles.

Evaluation of TR-XLPE Insulation Solutions

TR-XLPE technology, introduced more than 30 years ago, is based upon the incorporation of a water tree retardant additive system in a very clean low density polyethylene. This technology ensures that water ingress into the cable insulation does not concentrate into regions of high permittivity relative to the polyethylene matrix and thereby lead to weakened “water-treed” areas of the insulation. In one theory the hydrophilic technology prevents condensation of the water in the electro-oxidised regions near it, thus retarding tree propagation and ultimately preventing early dielectric breakdown of the cable. In a related concept, the water tree retardant additive is water soluble and is able to reduce the permittivity difference relative to the polyethylene insulation.
Figure 1 compares results from laboratory studies of water tree growth in standard XLPE and TR-XLPE insulation samples in which the length of water trees is