Wet designs for HV submarine power cables

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ABSTRACT

This paper presents an evaluation and results from a water aging test performed at 10 kV/mm - 500 Hz of a HV 52 kV XLPE core. Water permeation tests and associated modelling have been performed on power cores with a PE-sheath only and a non-impervious water barrier to evaluate the effect of the "semi-wet" barrier. The cable is installed as part of an HV dynamic power umbilical in Åsgard Subsea Compression Project in Norwegian Sea. The estimated lifetime of high voltage (HV) XLPE cables having such a "semi-wet" design is discussed on basis of test results and diffusion models. It is shown that for example swelling tapes, overlapping Cu-tapes and PE-sheath in combination may increase the time to reach critical relative humidity levels significantly in cable insulation. Water treeing does occur but will terminate at a level which could be acceptable at voltage levels higher than traditionally limited to medium voltage (MV). HV cables for oil/gas industry, HV dynamic cables, HV array cables for wind farms, may be applications of interest for this design. However, even if results seem to be safe for many types of applications, caution has to be taken to the conditions needed to such a market introduction; i.e. good and robust material selection, material cleanliness and process technologies are vital.

KEYWORDS

XLPE HV cable, wet design, moisture barrier, 500 Hz, wet ageing

INTRODUCTION

Historically, HV cables have normally been applied with impervious moisture barriers in order to prevent any risk of degradation, e.g. water treeing. MV cables have on the other hand mostly been applied without moisture barriers. In the past, water treeing was a major factor for early breakdowns in MV cable networks but given considerable improvements in insulation material cleanliness, screening layer smoothness and cleanliness, processing, etc., the phenomenon of water treeing, though present in many cables today, cannot be considered to have the same detrimental consequences as it sometimes had 25 - 30 years ago.

There are three conditions that must be fulfilled simultaneously for a water tree to be initiated and/or grow:

1. Electrical field
2. Supply of water
3. An initiation point - impurities and lack of smoothness of screening layers

Item 1) is always valid for both MV and HV cables. Item 2) will be insignificant for dry designs but a wet design using some kind of "retardation" mechanism will decrease the supply of water significantly. Item 3) is the most pronounced improvement over the last decades and has therefore a positive effect for both dry, semi-wet and wet designs.

This paper presents results and analysis from water diffusion and 500 Hz long term ageing tests in water on HV cables using a "semi-wet" design, i.e. a design including swelling tapes, Cu-tapes and PE-sheath. The test is a modification of the test used for MV in ref [1]. It is shown that such a "semi-wet" design will increase the time to reach critical RH-levels [4] in the cable, significantly. Ross and Guerts have earlier shown that swelling tapes and PE-sheath reduce water migration properties, significantly [8]. The lifetime and possible arguments to introduce such cables for different HV applications is therefore discussed and outlined, in light of modern cable materials and processing techniques as well as modelling tools.

All materials used in this design have been characterized with regards to diffusion, saturation and permeability constants and activation energies. A model calibration check of the water permeability properties based on water diffusion measurements on reference cable samples at varying temperatures have been performed, giving good agreement.

The tests described herein are related to the Dynamic Power Umbilical as part of the Åsgard Sub Compression Project. The application of the power umbilical and power cable system is shown in Figure 1. The complete system was recently installed in Norwegian Sea.

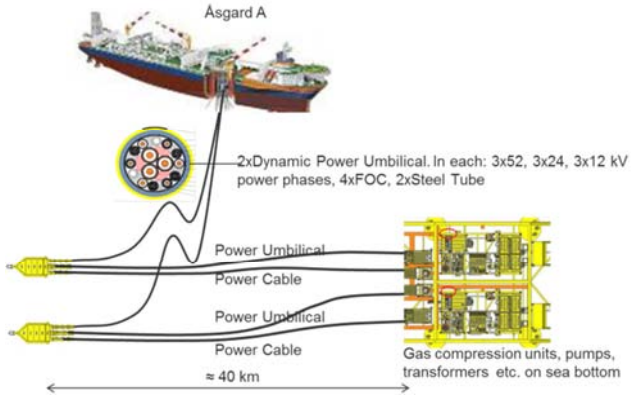

Figure 1. Åsgard Sub compression project installed in Norwegian Sea

TEST AND MODELLING CONDITIONS

To evaluate the performance of HV wet and semi-wet cable designs, a test and modelling program was set up, containing tests and models on one reference cable (Design 1: Wet design including XLPE core and PE sheath) and one power core design (Design 2: Semi-wet