Study Committee B1

Insulated Cables

10955_2022

Time to Failure Testing of Model HV XLPE Cables in Salt Water at High Electrical AC Stress and Temperature

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Motivation

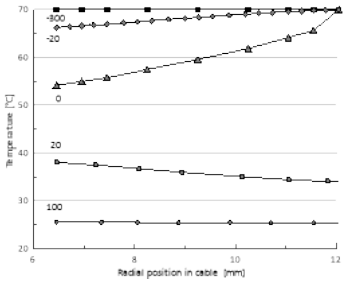
- Installation of high voltage cables (66 kV) replacing medium voltage (36 kV) inter-array cables for offshore wind installations
- "New" HV subsea cable designs: Wet designs allowing water molecules to enter the cable core during service.
- Time-to-failure (TTF) testing can provide data to empirically model the service lifetime of the cables at a lower service stress.
- Challenge: Premature breakdowns at the terminations, ageing anomalies at the air-water surface, or in the insulation (due to accelerated electrical stress).
- This paper presents initial results to facilitate a TTF test set-up and program to model high voltage cable cores soaked in salt water and subjected to 70 °C and 30 kV/mm with water from outside only.

Objects of Investigation

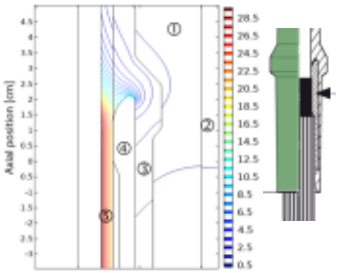
- Temperature and electrical field distribution
- 12 kV XLPE model cables and terminations
- AC breakdown testing (terminations)
- Time-to-failure testing (cable)
- Material analysis

Picture showing test set-up in the laboratory.

Results and Discussion

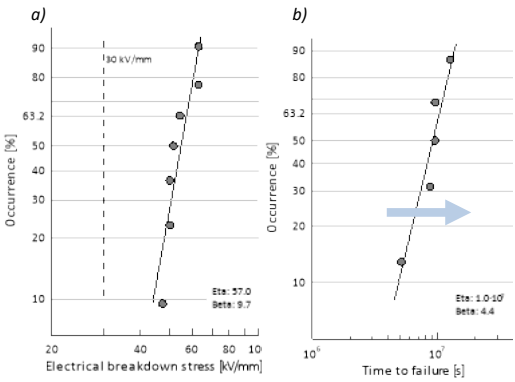


Radial temperature gradients at different locations along the cable: 0: At water surface, 20 or 100: 20 or 100 cm above water surface (in air), -20 or -300: 20 or 300 cm below water surface (in water). The radial positions are taken from the metallic conductor to the insulation screen surface.



Electrical field distribution in the 12 kV SOT termination during the TTF test (94 kV).

1: Synthetic ester, 2: PE tube wall, 3: SiR rubber, 4: Field grading, 5: XLPE insulation.



a) Results from AC breakdown testing of 12 kV slip-on terminations. b) Time to failure of 12 kV XLPE cables wet aged at 30 kV/mm.

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Results and Discussion cont.

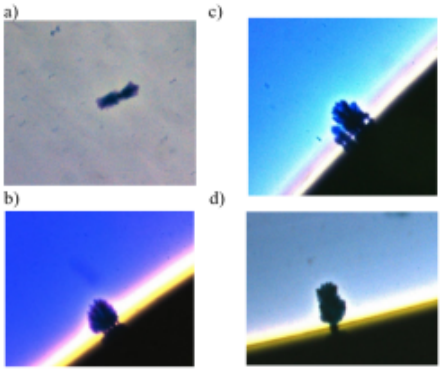

Figure 6: a) 138 µm long vented water tree growing from the conductor screen (Cable No. 2). b) 130 µm long vented water tree with inception site close to the end section for Cable 5. c) Bow-tie tree growing in the insulation of Cable No. 2 with a length of 123 µm. d) 140 µm long vented water tree growing from the insulation screen in Cable No. 4.

Cable No.	Length of trees [%]			Density of trees - CS [$\cdot 10^{-7}/\mu m^3$]	Density of trees - IS [$\cdot 10^{-7}/\mu m^3$]
	BT	V-CS	V-IS		
1	3.8	1.7	2.4	10,4	3,2
2	2.6	3.5	3.2	9,8	5,8
3	3.2	3.5	2.3	11,8	6,8
4	2.3	2.4	3.6	9,6	5,0
5	3.2	2.0	2.6	19,0	4,2
5*	7.1	3.3	2.6	15.1	- - -

Notes: BT: Bow-tie, V-CS: Vented water trees at Conductor Screen, V-IS: Vented water trees at Insulation Screen. Density of trees: Number of BT trees in a 160X160 μm^2 area close to the cable screens. *: Axial position at the water surface.

Conclusions

A TTF test of model HV subsea cables using 12 kV voltage XLPE cores with HV materials was undertaken at a high stress of 30 kV/mm at the conductor screen. From this test it is shown that:

- The modified 12 kV termination system had a high breakdown stress and inception voltage for partial discharges.
- The heated air system included in this work resulted in no anomaly temperature conditions nor any excess ageing phenomena at the water-air interface.
- All breakdowns occurred in wet sections of the cable, and the mean time to failure at 30 kV/mm was about 116 days.
- Short vented water trees of about 100 µm in length appeared both at the conductor and insulation screen with about the same length and appearance despite the higher electrical field at the conductor screen (30 vs 15 kV/mm).
- A significantly higher density of bow-tie trees was detected close to the conductor screen than close to the insulation screen.