FEA OF REQUIRED CONDITIONING TIME FOR CABLE INSULATION AHEAD OF ACCELERATED WET AGEING

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- Study: Conditioning Time Needed Before The Wet Ageing Test
  - Ageing Test and Mechanism
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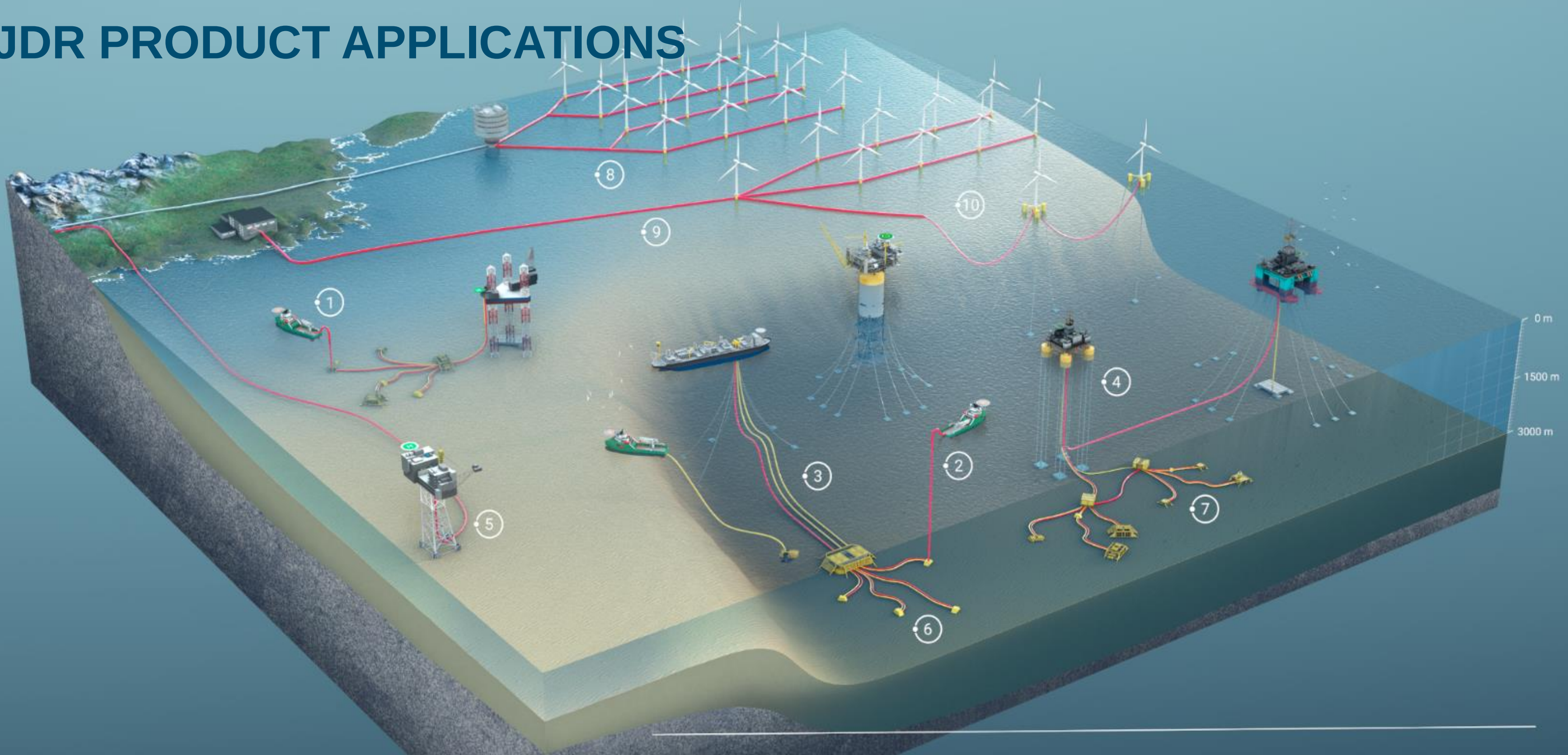
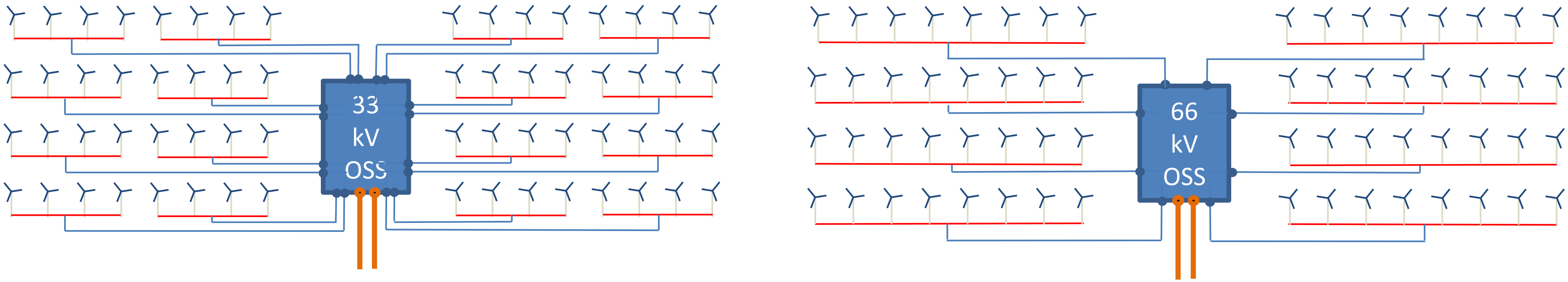
JDR PRODUCT APPLICATIONS



1 Conventional IWOCS umbilical and reeler
2 Self-supporting open-water IWOCS umbilical and winch
3 Dynamic subsea production umbilical (SPU)
4 Dynamic subsea power cable (SPC)
5 Shore-to-platform subsea power cable (SPC).
6 Thermoplastic Hydraulic Flying Lead (HFL)
7 Steel Tube Flying Lead (STFL)
8 33 kV Static Intra-Array Cable
9 72 kV Export & Intra-Array Cable
10 72 kV Dynamic Export and Dynamic Intra-Array Cable

66 kV Array Cable

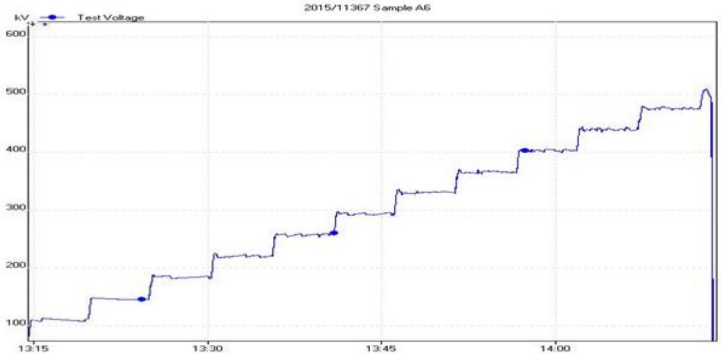
- 33 kV historically (maximum for European MV standards)
- Extend MV philosophy to 66 kV(i.e. without Lead sheath to reduce the cost)
- Mirrors trend in turbine capacity (3 to 4 MW → 7 to 8 MW)
- Example – 64 wind farm 500MW



20-30% reduction in array cable length

Wet Ageing Test

DEMONSTRATING LIFE WITH ACCELERATED AGEING & BREAKDOWN TESTS



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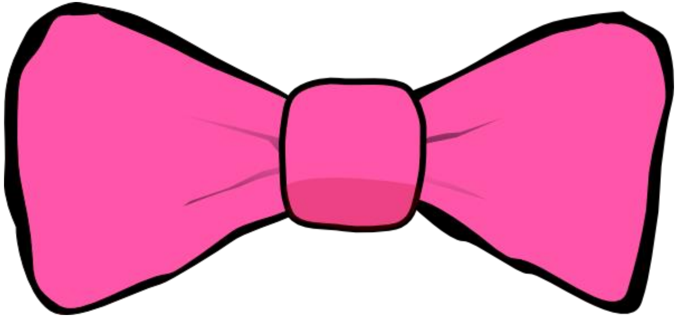
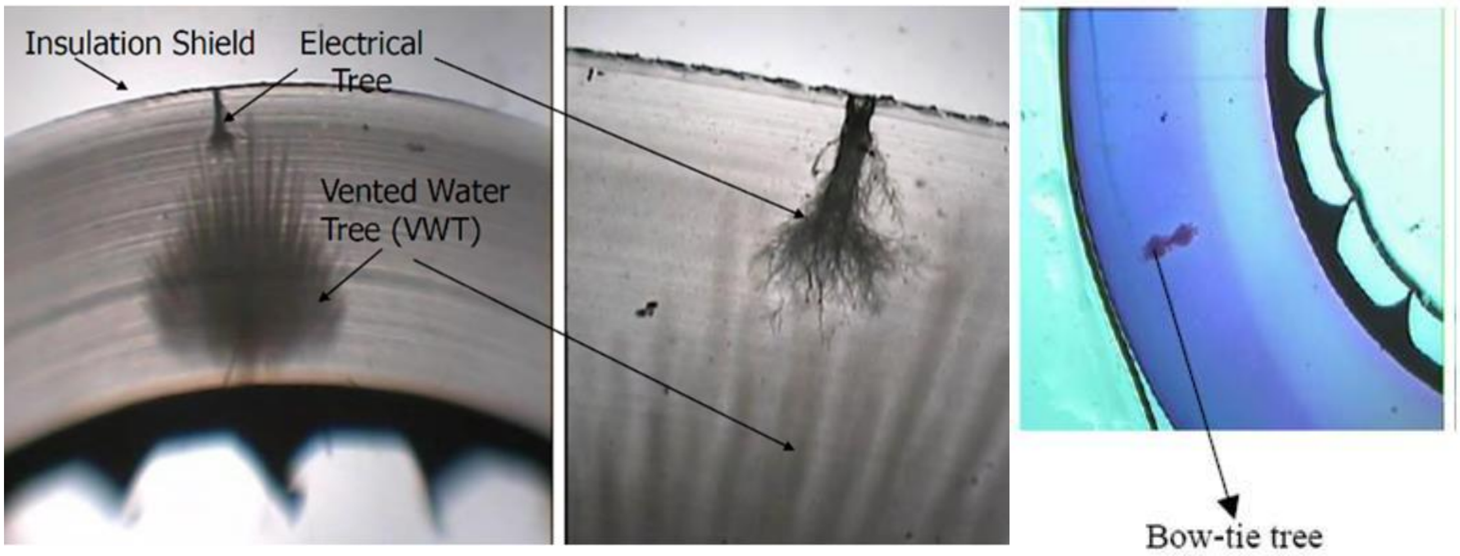
Ageing Mechanism

- Treeing (vented tree and bow-tie tree)



Mechanism



- Water Tree and Relative Humidity (RH)

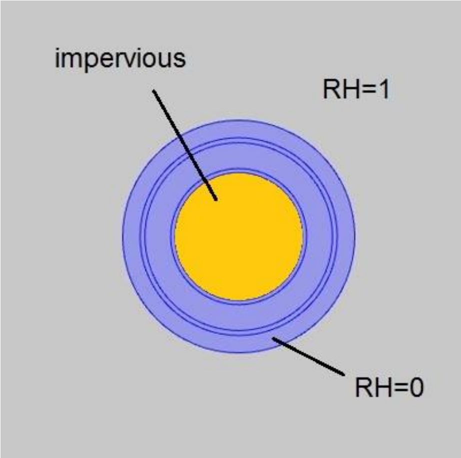
Finite Element Model- Physical Theory

- Governing Equations

  Henry's Law: $C = S \cdot p$ where S is solubility

  Fick's second law: $\frac{\partial C}{\partial t} = \nabla \cdot (D \nabla C)$ where D is diffusion coefficient

- Boundary Conditions



- Material Properties

TABLE II
Diffusion and Solubility Data

	Arrhenius parameters			
	D_0	E_D	S_0	E_S
Material	[m^2/s]	[kJ/(mol K)]	[kg/(m^3 Pa)]	[kJ/(mol K)]
XLPE	3.30×10^{-1}	55.7	1.80×10^{-7}	−9.90
SC	2.55×10^{-2}	58.0	9.75×10^{-11}	−42.15
HS	2.77×10^{-6}	28.7	4.34×10^{-11}	−37.1
LP	1.40×10^{2}	81.37	7.21×10^{-11}	−35.92

Finite Element Model- Model Validation

- Study of Two Cases (Hellesø et al. published paper*)

TABLE I
Cable Dimensions and Materials

Cable layer	Material	Code	Thickness [mm]
Conductor	Copper	–	22.7
Conductor screen	Polymer with carbon black filler	SC	1.5
Electrical insulation	Cross-linked polyethylene	XLPE	9.2
Insulation screen	Polymer with carbon black filler	SC	1.75
Outer jacket (combined)	Jacket no. 1 (J1) Jacket no. 2 (J2)	LP/HS[a]	6.2

[a] LP: Low water permeability material, HS: High water solubility material.

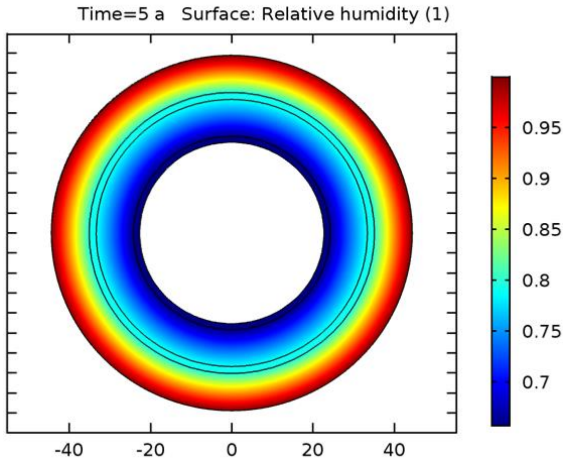
TABLE III
Simulation Cases

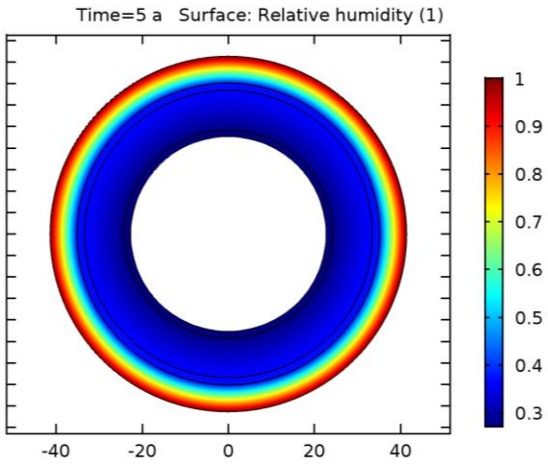
Case	Inner jacket no. 1 material (thickness) (mm)	Outer jacket No. 2 material (thickness) (mm)
1	–	XLPE (6.2)
2	–	LP (6.2)

*S.M.Hellesø, S. Hvidsten, G. Balog and K.M.Furuheim, "Calculation of Water Ingress in a HV Subsea XLPE Cable with A Layered Water Barrier Sheath System," Journal of Applied Polymer Science, vol. 121, pp. 2127-2133, 2011.

Finite Element Model- Model Validation

- Results and Comparison





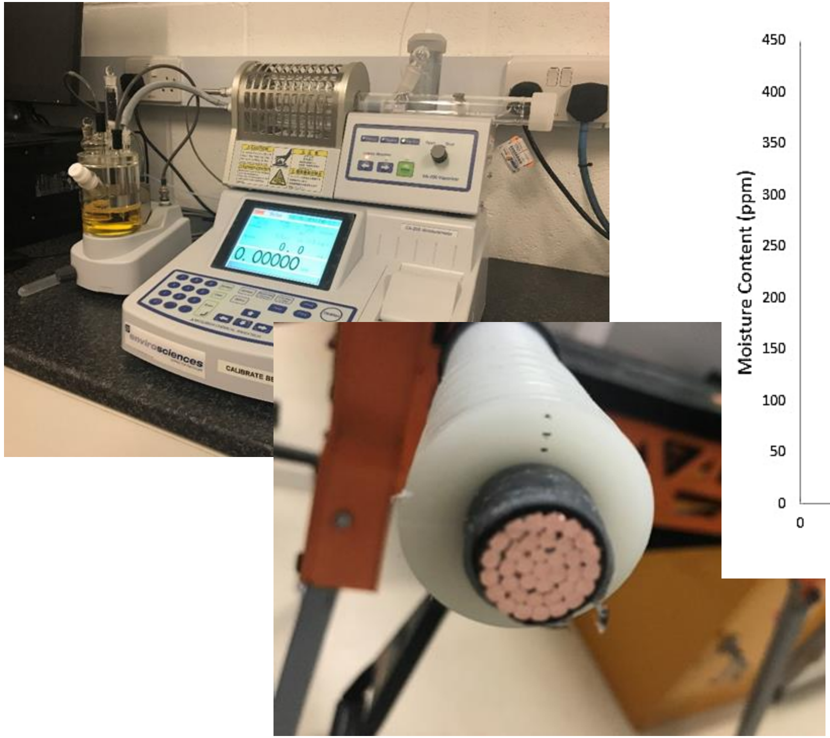
Case	Time to 70% RH [years]		Time to equilibrium [years]	
	From Hellesø Paper	From JDR Model	From Hellesø Paper	From JDR Model
1	2.4-4.4	3.5-5.5	13-15	15.5-16.5
2	14-16	14-16	54-57	54-60

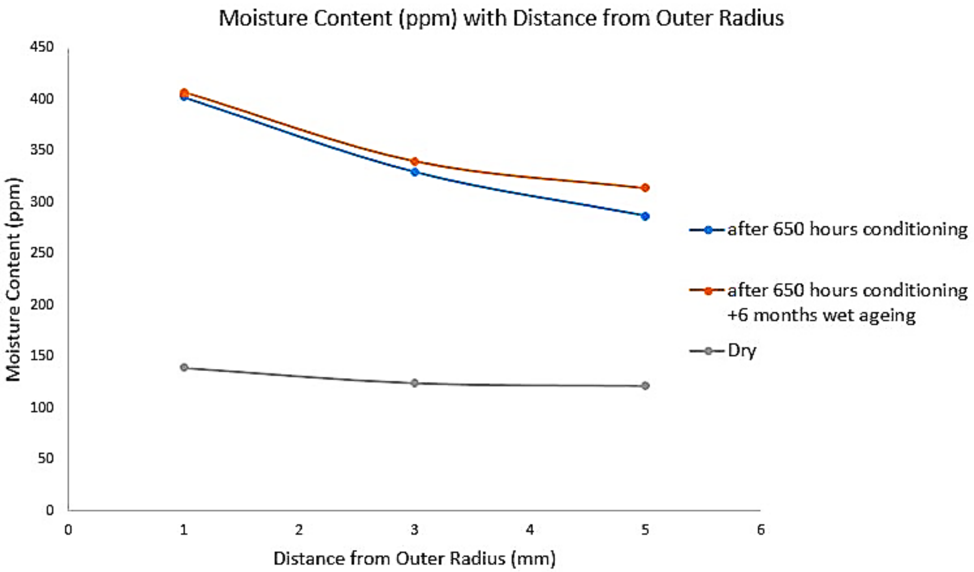
Finite Element Model- Equivalent Conditioning Time for 66kV

- FEA model was adapted to 33kV and 66kV cable design to identify RH.
- Conditioning Times from the CENELEC standard HD 605 is 500 hours for 8.8mm insulation thickness, 33kV cable.
- For thicker insulation to reach same RH, conditioning time found to have a linear relationship with the insulation thickness.
- This required conditioning time has been adapted in draft “recommendations for additional testing for submarine cables from 6kV up to 60kV” by Cigre WG B1.55.

Cable	Insulation thickness (mm)	Time (hours)	RH
33kV	8.8	500	0.89
66kV	>8.8	100+46* thickness	0.89

Water Content Test





Summary

- The FEA model and wet content test were designed and validated against previous published work.
- The relationship of conditioning time with thicker insulation (66kV) was defined.
- The finding has been adapted in draft recommendations produced by Cigre B1.55.

Thank you

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