= MCE Deepwater Development 2017 💳

Innovative 72 kV Wet-Design Cables for Dynamic Deepwater Power Umbilicals

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OFFSHORE WIND: INTRA-ARRAY CABLE VOLTAGE INCREASING 33 TO 66 kV



- 66 kV (UM=72 kV) cable development project initiated, supported by DECC(UK) and Carbon Trust Offshore Wind Accelerator (OWA)
- Objective to double the power transmitted for the same conductor size, lowering cost though innovative cables
- Benefits to include reduced cable congestion at OSS, and a reduced total length of cabling



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resulting from partial discharge from gas filled voins in insulation and under high electrical stresses

MEDIUM VOLTAGE AC SUBSEA POWER CORES TO UM=36 KV





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EXISTING HIGH VOLTAGE INSULATION CORE SOLUTIONS

- HV cores above 36 kV are designed to IEC60840 using "Dry" type insulation
- Typically these HV cores operate at higher electrical stress > 6 kV/mm
- To do so a radial water barrier is needed to avoid water-tree growth







Lead Radial Water Barrier

- Proven and easy but costly to apply
- Permits high stress dry polymers
- Limitations for lead layer under dynamic flexing

Corrugated Radial Water Barrier

- Good fatigue performance for barrier layer
- Proven but complex and costly to apply
- Permits high stress dry polymers
- Largest Diameter Core Option

Foil Laminate

- Known and low cost and easy to apply
- Smallest Diameter Core Option
- Tests for water vapor transmission showed reduced but still finite rate, hence not a hermetic water barrier layer.



72 kV AC WET-DESIGN CABLES



No Radial Water Barrier

- WTR-XLPE insulation system
- Materials rated to 72.5kV
- Widely proven at MV (e.g. 33kV, with typical electrical stress 3kV/mm, max 4kV/mm)
- Extension to 66kV (72kV max)
- Cable insulation is required to operate at a higher electrical stress than standard MV designs, e.g. 5 kV/mm
- This results in a lighter weight, lower cost cable •
- Semi-wet design power cables are already mechanical ٠ proven for dynamic and deepwater applications
- JDR Conclusion: best development path at 66kV is to • qualify semi-wet XLPE-WTR design with HDPE sheath









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3-Core 72 kV AC Cable

LONG DURATION WET AGE & BREAKDOWN TESTING





- Full-scale accelerated ageing tests performed on 150mm2 36/66(72.5)kV core
- Two ageing test runs conducted in 40°C saline water for 3000hrs at 108 kV (3xUo) and 500Hz
- Aged cable cut into 19 m lengths, with 4 m at each end for water terminations
- Step voltage applied, starting at 108 kV, rising in steps of 36 kV with 5 minutes at each step
- Scaled Acceptance Criteria from HD620: 5kV/mm / 3 kV/mm x 18 = 30kV/mm
- All breakdown data points from both test runs are well above the 30 kV/mm acceptance criteria: a large 'safety factor' exists







72 kV AC CABLE & SYSTEM ELECTRICAL TYPE TESTING

- Extension to higher electrical stress at 72 kV demonstrated in cable type testing
- 72 kV cable type test to IEC60502-2, CIGRE TB 171, 189, 490 completed, including compliance with Statoil TR3127 for factory flexible joints
- 72 kV system type testing included coilable cable, factory flexible joint, connectors and repair joints, all successfully completed.
- Full-scale 72 kV accelerated wet-age testing performed in saline conditions at 3Uo 500 Hz for 3000 hrs
- Weibull assessment of step-break down results gives a lifetime prediction of > 40 years at operating stress
- CIGRE B1.55 committee are now writing the technical brochure for:

RECOMMENDATIONS FOR ADDITIONAL TESTING FOR SUBMARINE CABLES FROM 6KV (UM = 7.2 KV) UP TO 60 KV (UM= 72.5KV)



Conductor Joint and Insulation Reinstatement



Cable system and repair joint type testing



CASE STUDY: DYNAMIC DEEPWATER 72 kV AC POWER UMBILICAL

- A the SUT In-Depth 2013 conference delegates debated Subsea Power and Processing for requirements future O&G fields
- One option considered was to evaluate whether increasing the voltage to 66 kV (UM=72 kV) from 33 kV (UM=36 kV), using wetdesign solutions, and whether this would deliver more power to the seabed.
- Four case study umbilicals have been considered, manufactured in both dynamic & static configurations for deep waters:
 - 3 x 36/66(72.5) kV 150 mm² Copper XLPe Typical power 15-20 MVA, with line current typically 130-180 Amps
 - Case A Dynamic Copper Corrugated Core
 - Case B Dynamic Wet-Design Core
 - Case C Static Lead Sheathed Core
 - Case D Static Wet-Design Core
 - 3 x 12/20(24) kV 70 mm² Copper XLPe
 - 9 x 1" NB 5,000 psi Steel Tubes
 - 3 x 48 SM Fibre Optic Cable





Dynamic Deepwater Configuration



Steel Tube Power Umbilical Horizontal Lay-Up Machine

CASE STUDY: 72 kV DEEPWATER POWER UMBILICAL – DYNAMIC SECTION

Case A



72 kV Copper Corrugated Dry Cores				
Max. Electrical Stress	kV/ mm	~ 6.5		
Outer Diameter	(mm)	225		
Weight in air	(kg/m)	90.3		
Weight in sea water	(kg/m)	52.5		
Length, 9.2m Reel	(m)	2222		

Case B

72 kV Wet Design Cores			
Max. Electrical Stress	kV/ mm	~ 5	
Outer Diameter	(mm)	210	
Weight in air	(kg/m)	82.3	
Weight in sea water	(kg/m)	49.3	
Length, 9.2m Reel	(m)	2727	

CASE STUDY: 72 kV DEEPWATER POWER UMBILICAL – STATIC SECTION

Case C



72 kV Lead Sheathed Dry Cores					
Max. Electrical Stress	kV/ mm	~ 6.5			
Outer Diameter	mm	169			
Weight in air	kg/m	43.7			
Weight in sea water	kg/m	23.2			
Max Length (Carousel)	km (Te)	68 (2988)			

Case D



72 kV Wet Design Cores

Max. Electrical Stress	kV/ mm	~ 5	
Outer Diameter	mm	177	
Weight in air	kg/m	38.6	↓
Weight in sea water	kg/m	15.9	↓
Max Length (Carousel)	km (Te)	66 (2539)	

BENEFITS OF 72 kV WET-DESIGN CORES IN POWER UMBILICALS:

- Reduced diameter & weight for Dynamic sections of 72 kV Power umbilicals
- Reduced hang-off top tension and reduced sizing for dynamic BSR's and other hardware
- Longer lengths can be supplied on a 9.2 m Reel
- Significantly reduced umbilical weight for static sections, reducing installation tensions
- Longer length continuous umbilicals can be supplied in cases vessel carousel product weight is a limitation, avoiding a mid-line joint for longer step-out distances.
- Reduced cost over conventional metallic barrier layer solutions at 72 kV



SUMMARY

- With advances in water-tree retardant polymers and insulation extrusion processes the use of wetdesign insulation systems to 72 kV is now possible
- Following full scale accelerated ageing of core rated at 24/60~69(72.5) kV in saline conditions, stepbreakdown tests demonstrate good safety margin remaining at end of life scenario.
- 72 kV wet-design core technology can enable operators can benefit from
 - Reductions in dynamic umbilical weight
 - Increased lengths of dynamic power umbilicals on standard 9.2 m deployment reels.
 - Increased lengths of static umbilicals where carousel/turntables are the constraint
- The reduction in dynamic umbilical section weight offered by 72 kV wet-design insulations will
 reduce installation and operating tensions, thereby contributing to reduced umbilical and hardware
 costs



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PROVIDING THE VITAL CONNECTION