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

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JDR Cable Systems Ltd
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
OFFSHORE WIND: INTRA-ARRAY CABLE VOLTAGE INCREASING 33 TO 66 kV

500MW Windfarm with 7 or 8MW turbines

- 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 through innovative cables
- Benefits to include reduced cable congestion at OSS, and a reduced total length of cabling
MEDIUM VOLTAGE AC SUBSEA POWER CORES TO UM=36 KV

Conductor
- Stranded Copper
- Water-blocked
- 50mm² to 800mm²

Triple Extruded Insulation
- Conductor Screen
- Insulation, typically XLPe, EPR
  - Water Tree Retardant at MV
- Insulation Screen
- MV = 6.6 kV to 30 kV (UM=36 kV)
- Standard IEC60502-2

Semi-Con water blocking tape

Copper Tape / Wire Screen

Sheathed Core

Screened & Insulated Phase Core

Electrical Stress at Conductor:

\[
E_{\text{cond}} = \frac{2 \cdot K_{2s} \cdot V}{d \cdot \ln \left( \frac{D}{K_1 \cdot d} \right)}
\]

- \(E_{\text{cond}}\) = Conductor stress (r.m.s) (V/mm)
- \(V\) = Voltage between conductor and screen (r.m.s)(volts)
- \(d\) = Conductor diameter (mm)
- \(D\) = Insulation diameter (mm)
- \(K_1, K_2\) = Electric field factors for strands

Typical tree growth in XLPe at 50 Hz, resulting from partial discharge from gas filled voids in insulation and under high electrical stresses.
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

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<thead>
<tr>
<th></th>
<th>Dynamic</th>
<th>Deep Water</th>
<th>Hermetic</th>
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<tbody>
<tr>
<td>Lead Radial Water Barrier</td>
<td><img src="image1.png" alt="Diagram" /></td>
<td><img src="image2.png" alt="Diagram" /></td>
<td><img src="image3.png" alt="Diagram" /></td>
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<td>Proven and easy but costly to apply</td>
<td>Permits high stress dry polymers</td>
<td>Limitations for lead layer under dynamic flexing</td>
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<tr>
<td>Corrugated Radial Water Barrier</td>
<td><img src="image4.png" alt="Diagram" /></td>
<td><img src="image5.png" alt="Diagram" /></td>
<td><img src="image6.png" alt="Diagram" /></td>
</tr>
<tr>
<td></td>
<td>Good fatigue performance for barrier layer</td>
<td>Proven but complex and costly to apply</td>
<td>Permits high stress dry polymers</td>
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<tr>
<td>Foil Laminate</td>
<td><img src="image7.png" alt="Diagram" /></td>
<td><img src="image8.png" alt="Diagram" /></td>
<td><img src="image9.png" alt="Diagram" /></td>
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<td>Known and low cost and easy to apply</td>
<td>Smallest Diameter Core Option</td>
<td>Tests for water vapor transmission showed reduced but still finite rate, hence not a hermetic water barrier layer.</td>
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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 proven for dynamic and deepwater applications
- JDR Conclusion: best development path at 66kV is to qualify semi-wet XLPE-WTR design with HDPE sheath
**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 3U0 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)
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 wet-design 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
CASE STUDY: 72 kV DEEPWATER POWER UMBILICAL – DYNAMIC SECTION

### 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

### 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

**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)

**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 wet-design 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, step-breakdown 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
Thank you

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