High Power, High Pressure Electrical Connectors

EuALF 2014

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Contents

• Technical overview
• Industry Standards
• Practical Applications
• Summary
What do we mean by high power and high pressure?

<table>
<thead>
<tr>
<th>Time</th>
<th>Voltage (kV)</th>
<th>Current (A)</th>
<th>Pressure (psi)</th>
<th>Motor Size (~hp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980s – 2000s</td>
<td>3</td>
<td>125</td>
<td>3000</td>
<td>~250</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>140–160</td>
<td>5000</td>
<td>~1200</td>
</tr>
<tr>
<td>2007+</td>
<td>8</td>
<td>250</td>
<td>13000</td>
<td></td>
</tr>
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</table>

Motor Size
• What does this mean in practice? – size.
High power – Unbalanced Working

• Increased demand for the ability to work with a single phase failure.

• This has the effect to increase the voltage of the remaining 2 working phases:

• Therefore the design of the connectors has to be sufficiently robust to withstand this operational mode.

• Also – especially Surface Cable – has to be specified to cover this application.
High power – Electrical Stress Relief

- With increased voltage (above 5kV) there has to be additional attention to electrical stress raisers
- Occur at termination of cable layers
- Within general electrical industry there are standard techniques for stress relief
- Issues to be considered for downhole – size constraints, materials – temperature rating and chemical attack.
- Failures tend to occur at ‘discontinuities’.
High power – Induced Voltages during AC testing

- With increased Voltage there has to be additional attention to secondary voltage induction in surrounding materials.
- Voltage build up can be sufficiently high to cause discharge to the nearest Earth point.
- Good Earth connections must be maintained to reduce effect (single bonded or dual / multiple bonded.)
High power – Induced Heating

• With increased current there has to be additional attention to secondary heating induction in surrounding materials.
• Increased electrical field strength can induce currents in surrounding metalwork.
• Good earth connections must be maintained to reduce effect.
• Heating can be sufficient to cause problems.
High pressure – considerations

- Housings - increased thickness to withstand mechanical loads

- Hence – copper section increased to carry higher amperage, insulation has increased to withstand higher voltage, housing increases due to larger bore and higher pressure.

- Elastomer materials - higher bulk compression – e.g. seals.

Comparison of 5kV, 140A, 5000 psi to 8 kV, 250A, 13000 psi
High Power – Applicable Standards

There is no single particular standard which is applicable for connectors rated above 5kV (except hazardous area).

Standards such as IEC 60502-2, IEC 60502-4, API 11S6, IEEE 1018, IEEE 1017, ISO 10423 (API 6A), etc. can be used for guidance.

Hence the first high power connector qualified – Shell Perdido – qualification was established with client using IEC60502-2 and ISO 10423 (API 6A), as guidance
• Production spar in GoM, using high power ESPs.
• Connector specification is: 5.5 kV, 250 A, 250 deg F, 5525 psi
• 3 single phases through the Flow Control Assembly (wellhead)
Established a baseline high power connector test regime within RMSpumptools

Shell Perdido –GoM – Qualification (2)

Qualification included:

Pressure cycles

Rapid Gas Decompression Test

PR2 test per ISO 10423 (API 6A)

Hazardous Area Certification

Temperature Rise Test

Electrical Integrity Test

Established a baseline high power connector test regime within RMSpumptools
Shell Perdido – GoM – Lessons Learnt

- Electrical stress control.

- Working envelope within the FCA (wellhead) allows for a robust electrical design.

- Electrical hysteresis within the FCA can be ignored due to high cooling effect of production flow.

- Good high integrity electrical earth points - for all metallic elements near to cores.

- Exact application of IEC 60502-2 cannot be applied due to restrictions of connector current carrying ability.
• Design and qualification of both wellhead and packer equipment for a dual completion.
• Test regime established for Shell Perdido used as basis for qualification.
• Lessons learnt from Perdido resulted in successful qualification
• Design and qualification of wellhead and packer equipment based on SFLL
• Single Mandrel Wellhead Right Angle Connector
• Increased requirement on the packer from V3 (SFLL) to V0 test (to ISO 14310)
• Increased pressure to 13,500 / 7,500 psi (abs / diff) downhole, and 7500 psi Wellhead
• High pressure application – extension of the Bigfoot design.
• Main challenges are the high temperature and high pressure.
• Early focus on pressure barrier – ability to withstand high pressure differential.
• Important to note differential pressure vs. absolute pressure.
• First application of Single Phase Right Angle Connector.
• Closely based on SFLL design.
• Specifically used IEC 60502-4 for qualification.
• Use of large diameter dual armoured cable.
• Dual armour cable construction needs careful consideration during testing.
<table>
<thead>
<tr>
<th>Title</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>FAT</td>
<td>Confirms prototype suitable for qualification testing</td>
</tr>
<tr>
<td>Overpressure Test</td>
<td>5 off 1.5 hydrostatic pressure ambient temp cycles</td>
</tr>
<tr>
<td>Thermal Test</td>
<td>Confirms product carries rated current</td>
</tr>
<tr>
<td>Electrical Integrity</td>
<td>IEC 60502-2 as guidance – heat age cycles, power frequency test, AC breakdown test</td>
</tr>
<tr>
<td>Endurance Test</td>
<td>7 temperature cycles with downhole pressure applied</td>
</tr>
<tr>
<td>Hazardous Area Test</td>
<td>ATEX / FM (other) approval – EEExd - Wellhead</td>
</tr>
<tr>
<td>Title</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>ISO 10423 (API 6A)</td>
<td>PR2 test – pressure + temperature cycles – wellhead</td>
</tr>
<tr>
<td>ISO 14310</td>
<td>V3, V0 test – pressure + temperature cycles – packer</td>
</tr>
<tr>
<td>Pressure and Temp</td>
<td>Cycles applied depending on project / product requirements</td>
</tr>
<tr>
<td>Pressure Barrier Creep</td>
<td>Temperature and pressure applied to pressure barrier insulator(s)</td>
</tr>
<tr>
<td>Other</td>
<td>Project specific test requirements.</td>
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</table>
The Future…

- Collaboration to extend current industry standards to cover high power applications.

Applications / markets
- Increased depth of completions
- Increased use of aquifer applications
- Geothermal, seabed booster and other ‘non traditional’ applications
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Thank you for your attention