Providing a Compact Cost Effective 3kV Electrical Connector

Long Step Out, Single Phase
Subsea Wet-Mate Connectors
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What is the intended use?

Siemens Subsea identified the need for a single phase compact cost effective connector for long step out applications.

Continuous dialogue with customers and logging of requests lead to the following understanding:

• Primarily single phase AC for controls.
• Space constraints and the associated costs are of upmost importance.
• Usually long step outs.
• Require higher voltage ratings due to the increase in distance travelled (power losses).
• Specifically 1.8kV Uo, 3.6kV Um.
• Future for DC voltages.
What does DigiTRON3 do?

- The connectors role is to supply power from the main umbilical to the relevant subsea architecture or to infield umbilical's.
- It needs to operate over a 30 year design life.
- Withstand general use, misuse and abuse!
- To do so with the upmost reliability.
- Meet amalgamated specification of TR2390/SEAFOM TQP-02 and SEPS SP-1001
Reliability
Knowing our materials

- Advanced material data has been collected, both lab based and operational, for over 38 years.
- Elastomeric, polymeric insulation and dielectric oils.
- Virgin and aged.
- This information is utilised in calculations and simulation tools in designing connectors.
- This body of data leads to a reduction in development timelines.
Reliability
The importance of qualification

- Statoil TR2390/SEAFOM TQP-02 and SEPS SP-1001.
- To prove the design.
- To qualify way in excess of the operating conditions to confirm safety factors.
- Conform to industry standards.
- Confirm repeatability of the manufacturing process and design.
- The results of the tests are a critical factor in assessing the system’s readiness for production.
- Find your breaking point!

Gives real values to design too!
Understanding the fundamentals

**Complexity:** Simply a build up of the basics.

- **Paschen**
- **Insulation Resistance**
- **Band Theory**
- **Partial Discharge**
- **High Voltage Breakdown**
- **Townsend**
- **Ohm**
- **High Voltage Holds**

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Liam Widdrington/ New Product Development, Subsea Products (Connectors)
Knowing where to improve
Data Gathering

- Calculations showed that the DigiTRON+ connector would be suitable for a 1.8kV Uo system.
- DigiTRON+ was tested unmodified in order to see which areas needed optimisation to allow operation at higher voltages.
- Small incremental steps were taken during testing.
- Repeated.
- Analysed.
- Compared to calculations.
Knowing where to improve
Data Gathering

- Understanding the full system.
- Highlighted areas which could be optimised.
- Monitoring PD continually.

<table>
<thead>
<tr>
<th>Step</th>
<th>Test</th>
<th>Test level</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Helium leak test</td>
<td>See test method</td>
<td>7.4.1</td>
</tr>
<tr>
<td>2</td>
<td>Static pressure test - penetrations</td>
<td>See test method</td>
<td>7.4.16</td>
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<tr>
<td>3</td>
<td>Contact resistance</td>
<td>See test method</td>
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<td>4</td>
<td>Insulation resistance</td>
<td>See test method</td>
<td>7.4.8</td>
</tr>
<tr>
<td>5</td>
<td>PD test</td>
<td>1.73 x Uₐ (10 pC)</td>
<td>7.4.5</td>
</tr>
<tr>
<td>6</td>
<td>PD test</td>
<td>2.50 x Uₐ (200 pC)</td>
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</tr>
<tr>
<td>7</td>
<td>High voltage AC test</td>
<td>4 x Uₐ (1 hour)</td>
<td>7.4.6</td>
</tr>
<tr>
<td>8</td>
<td>PD test</td>
<td>1.73 x Uₐ (10 pC)</td>
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<tr>
<td>9</td>
<td>PD test</td>
<td>2.5 x Uₐ (200 pC)</td>
<td>7.4.5</td>
</tr>
</tbody>
</table>
Knowing where to improve Validation

\[ E = \frac{2.4kV}{(2.92/2) \cdot \ln\left(\frac{4.65/2}{1.85/2}\right)} = 1.78kV/mm \]

PD inception point

Optimising the Future Designs

- Design Engineering
- Validation of analysis
- Analysis
- Functional Testing
Within any electrical system insulation is required. More insulation does not necessarily mean a better design. It matters less about the amount of insulation and more about the quality and the position of said insulation.

\[ E = \frac{V_o}{r_1 \cdot \ln\left(\frac{r_2}{r_1}\right)} \]

\[ E = \frac{V_o}{r_2 \cdot \ln\left(\frac{r_2}{r_1}\right)} \]

\[ E_1 = \frac{V}{d_1 + d_2 \cdot \left(\frac{\varepsilon_1}{\varepsilon_2}\right)} \]

Design and Analysis

Functional Testing

Validation of analysis

Analysis

Functional Testing
• Electrical stress controls can be used to re-position high stress points.
• Doing so can increase the average stress but decrease the peak electrical stresses.
• Doing so in areas where air entrapment or contamination are possible is critical.
“Testing, 1, 2, 3”

- Over 5 months of testing.
- 3 full sets of connectors used for each of the 15 electrical integrity qualifications.
- Monitored electrical values continuously rather than pre and post.
Conclusions

- One of the most challenging parts of any development is understanding the needs of our customers.
- Understanding the fundamentals and proving these through functional testing enabled a focused development.
- Following a structured design processes and utilising our extensive materials data reduces development lead-times.
- Continuously building our material properties data drives development efficiency and engineering knowledge.
- The advantage of following this methodology is that developments become pro-active rather than re-active.
The future...

- Reduction in operational costs
- EPC standardisation
- DC
- DCFO
- Long step outs
- Voltage ratings
- Uo/U (Um)
Thank you for your time
Any questions?

Liam Widdrington
Design Engineer

Siemens Subsea
Subsea Excellence Centre
Ulverston
LA12 9EE
United Kingdom

Phone: +44 1229 485130

E-mail: liam.widdrington@siemens.com

www.siemens.com