AWARD WINNING PRODUCTS AND SERVICES TAKING OUT COST AND INCREASING OPERATING EFFICIENCY

The consequences of electrical insulation failures in ageing umbilicals: copper loss and hydrogen generation.
Power Distribution Systems

- Three main considerations

**AC or DC**

**Single or Multi Phase**

**Earthing**

- Most subsea control systems utilise:
  Single phase, AC, ungrounded IT systems operating at <1000V

- Three phase systems have been used for long offset subsea controls
  Always ungrounded IT systems

- DC supplies are predominantly used in Subsea Controls by Schlumberger/OneSubsea
Earthing Arrangements

- IEC has standardised on three families of earthing – TN, TT, IT
- 1st Letter is connection between earth and supply
- 2nd Letter is connection between earth and device being supplied
IT (Isolation Terra) Systems

- IT systems have no deliberate electrical connection to earth
- Continued supply on 1st ground fault
  - Could be down to Insulation resistance
  - Ground current on first fault is very small
  - Effectively grounds one side to turn IT system into a TT system
- If a 2nd ground fault occurs
  - Can lead to dangerous body currents lacking protection
  - Other phase(s) rise to phase-to-phase voltage – impressed on conductor. Increases electrical stress.
- 1st fault must be fixed ASAP
Insulation Monitoring Devices

Bender

Schneider

Viper Innovations

Megacon

Hakel

Irelec

Confidential & Proprietary Information

Copyright © 2018 Viper Innovations Ltd, All Rights Reserved
Leakage current $f$ of 3 sub-currents

Where:

- $V$: Applied Auxiliary Voltage
- $R$: Internal Current Limiting Resistance
- $R_i$: Insulation Resistance
- $C_i$: Insulation Capacitance
- $R_a$: Dielectric Absorption Effective Resistance
- $C_a$: Dielectric Absorption Effective Capacitance
Leakage Currents

The magnitude of the dc leakage current from the conductors to ground is a function of the IMD activation voltage and the insulation resistance of the cable. Simply by Ohm's law.

<table>
<thead>
<tr>
<th>Insulation Resistance</th>
<th>Leakage Current</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Competitor’s IMD</td>
</tr>
<tr>
<td>30kΩ</td>
<td>190μA</td>
</tr>
<tr>
<td>100kΩ</td>
<td>142μA</td>
</tr>
</tbody>
</table>

Where:

- $V$ = Applied Auxiliary Voltage
- $R$ = Internal Current Limiting Resistance
- $R_i$ = Insulation Resistance
- $I_i$ = Leakage Current
Experimental Set-Up
The IMD two-week effect

Single point damage to insulation equivalent to an insulation resistance of 30kΩ
The IMD Electrochemical Cell

- **H₂(g):** 2H⁺(aq) + 2e⁻ → H₂(g)
- **H₂(g) + 2OH⁻(aq):** 2H₂O(l) + 2e⁻ → H₂(g) + 2OH⁻(aq)
- **Cu²⁺(aq):** Cu²⁺ + 2e⁻ → Cu(s)

**Negative electrode (Steel):**
- Hydrogen gas (H₂) is produced at the cathode.
- Positive ions (Cu²⁺) are attracted to the negative electrode and deposit as copper (Cu(s)).

**Positive electrode (Copper):**
- Electrolyte of sea water.
- Negative ions are attracted to the positive electrode.
- Copper atoms lose electrons and move into solution.

**Electrons:**
- Flow through the external circuit.
- Powered by the IMD.
IMD Experimentation

After the experiment concluded, the wire insulation was stripped back to expose any damage to the conductor.

The corrosion affects a wide area as a result of water penetration of the wire interstices.

The copper corrosion has resulted in strands breaking.
AC Power Experimentation

At the negative surface:

\[ \text{Cu}^{2+}(aq) + e^- \rightarrow \text{Cu}(s) \]

\[ 2\text{H}_2\text{O}(l) + 2e^- \rightarrow \text{H}_2(g) + 2\text{OH}^- \]

Hydrogen evolution
AC Power Experimentation
The two conductors after AC power applied

Tarnishing of copper: \[ 2 \text{Cu(s)} + \text{O}_2(g) \rightarrow 2 \text{CuO(s)} \]
Major Industry Problem: Water ingress into electrical cables

The cost of subsea electrical failures is significant and includes:

- Marine intervention costs
- Replacement hardware costs
- Unplanned lost production
IT (Isolation Terra) Systems

Single Fault

or Multiple Faults
Extending System Life with V-LIFE
Example of restorative effect
V-LIFE & passivation
Increase the insulation resistance to 3.5MΩ then the rate of copper loss will be reduced by more than 4 times over the rate of loss due to the standard third party IMD.

If the insulation resistance is increased to 30MΩ, then the factor increases to almost 15 times less copper loss.

Copper loss due to V-LIFE is never as high as that which would be experienced by connection of a standard third party IMD.
Summary

- Low IR and use of a LIM results in copper loss
- Applying voltage to subsea lines with two earth faults can create significant conductor damage
- Hydrogen generation is a by-product of low IR in sea water on energised cables.
- Few subsea engineers understand the possible consequences of operating with low IR.
- V-LIFE results in less copper loss than systems without V-LIFE.
Questions?

ARE THERE ANY QUESTIONS? FEEL FREE TO ASK ANYTHING AT ALL.

WHY DO GHOSTS HAVE CLOTHES?

IF SOMEONE GIVES YOU A WEDGIE AT THE MOMENT YOU DIE, WILL YOU HAVE IT FOR ETERNITY?