INNOVATIVE ENGINEERING PRODUCTS AND SERVICES FOR THE INTERNATIONAL SUBSEA OIL, GAS AND OFFSHORE RENEWABLES INDUSTRIES.

V-IR: Technological Advancements in Subsea Electrical Integrity Management

Steve Simpson
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“Insanity: Doing the same thing over and over again and expecting different results”

Albert Einstein

Applicable to subsea electrical distribution system designs?

Ever since the first subsea installed electro-hydraulic control system, the industry has suffered from electrical system failures

It is ‘when’ ... not ‘if’ ... we lose control and/or monitoring of the subsea system
Electrical Failures

Electrical Failures in connectors and cables can result in one of three failure modes:

- Short Circuit
- Open Circuit
- Line Insulation Failure – current leakage to earth

Fault types can be classified as either:

- Intrinsic – the fault relates to design, materials or hardware assembly
- Extrinsic – the fault relates to handling, installation, environment, mechanical stressing and/or misapplication
Intrinsic Failures

- Elastomeric failures (including bellows)
- Polyethylene moulding failures (cathodic disbondment)
- Nascent Hydrogen in Umbilicals and gassing
- Poor soldering (flux, excessive quantity, sharp edges)
- Use of incorrect crimping tools
- Cracks in epoxy in connectors
- Shuttle pin assembly failure
Extrinsic Failures

- Calcareous and/or marine deposit around compensation and pin shrouds
- Lateral mechanical stresses placed on connectors when cables are installed on structures
- ROV impact damage
- Connectors left exposed subsea for too long (not properly parked or protected)
- Cable sheath damage
- Fishing/trawl board impact
- Water trees/Electric trees
- Water permeation into insulation
Subsea electrical failures in ageing systems

Subsea electrical failures* are caused by:

- Tin Whiskers $\approx 2\%$ of all subsea electrical failures
- Dendrites in electrical connectors $\approx 5\%$
- Electrical component failures in Subsea Electronic Modules $\approx 20\%$
- Water ingress into umbilicals, cables and connectors $\approx 73\%$

* % figures are subjective from Viper Subsea experience
Tin Whiskers

- Hair-like crystal structures that may grow from surfaces coated by Tin (or Zinc or Cadmium) finishes
- Length is typically <1mm but can be up to 10mm
- Only mitigation is addition of 3% or more of Pb by weight
- Growth mechanism is currently UNKNOWN
  - No theories for prediction
  - Known about since 1940’s
Tin Whiskers

- Transient short circuit until whisker fuses
  - Under certain electrical and atmospheric conditions vaporized tin may initiate a plasma that can conduct over 200 amps
- May grow in hours, days, weeks or years (can start growing after years of dormancy)
- $\approx 2\%$ of all subsea electrical failures
Dendrites

- Dendrites are tree-like growths of conductive metal filaments
Dendrites

- Conditions required for dendrite growth:
  1. Moisture (i.e. high relative humidity)
  2. Contamination on the insulator surface
  3. Voltage difference between conductors
  4. Narrow spacing widths

- Metal ions can migrate to a cathodically (negatively) charged surface and plate out, forming dendrites.

- The dendrites grow and eventually bridge the gap between the contacts, causing an electric short and, possibly, arcing

- ≈ 5% of all subsea electrical failures
Water ingress into electrical cables

Moisture ingress can occur in long-term wetted cables and results in:

- Decrease in dielectric strength
- Increase in leakage currents
- Continual degradation leading to eventual failure
- $\approx 73\%$ of all subsea electrical failures
Water ingress into electrical cables

The cost of subsea electrical failures is significant and includes:

- Marine intervention costs
- Replacement hardware costs
- Lost production
Fault Location & Prediction: The Problem

Either Single Fault or Multiple Faults

How can we identify Insulation Resistance degradation & location?
Fault Location & Prediction: The Problem

What is the lowest operating level of IR that the system can withstand?

How long do we have? ...1 month or 5 years?
V-IR : Subsea Insulation Resistance Monitoring

- Monitoring of the Subsea electrical distribution network
- JIP established with TOTAL, Shell, BP and Chevron as sponsors
- 22 month project
- Field trial planned Q4 2015
- Development of key V-IR system components:
  - V-SLIM Subsea Line Insulation Monitor
  - V-NET Subsea-to-surface communications system
Electrical Distribution Network Monitoring System

V-LIM
Topside Line Insulation Monitor electronics

V-SLIM
Subsea Line Insulation Monitor electronics
Electrical Distribution Network Monitoring System

V-LIM
Topside Line Insulation Monitor electronics

V-SLIM
Subsea Line Insulation Monitor electronics
Subsea-to-Surface Communications

V-NET

V-SLIM to V-LIM communications system
V-SLIM Subsea Monitoring Electronics

- Located in Electrical Flying Leads
- Suitable for both green field and brown field applications
V-SLIM Subsea Monitoring Electronics

- Lines taken straight through for reliability (no electronics in-line)
Integrated into an Active EDU

- Replaces conventional Electrical Distribution Units
- Houses multiple V-SLIMs in one deployable and recoverable unit
- Optional automatic fault isolation
V-IR System Features

- V-SLIM measures IR both upstream and downstream of its location
- Also measures capacitance, voltage, current, power-factor
- Can be used on transformer coupled and bus-bar systems (AC or DC)
- Communicates directly back to the surface
- Fail safe: designed so that V-SLIM failures do not impact on overall system integrity and reliability
- Extensive use of digital signal processing techniques for high resolution / accuracy measurements with simple electronics
- Typically better than 5% measurement accuracy
Conclusion

- Subsea electrical failures have been in existence for many years

- Numerous different failure modes exist

- Design improvements should improve reliability

- Legacy systems continue to present electrical integrity challenges

- New fields will only add to this problem

- V-IR provides high reliability integrity monitoring for brown-field and green-field systems

- V-IR facilitates planned maintenance

- V-IR mitigates repair costs and unplanned production loss
V-IR
A VIPER SUBSEA SOLUTION

LOCATES ELECTRICAL FAULTS

FACILITATES PLANNED MAINTENANCE

MITIGATES REPAIR COSTS AND UNPLANNED PRODUCTION LOSS

COMPATIBLE WITH ALL SUBSEA CONTROL SYSTEMS

SUITABLE FOR BROWNFIELD & GREENFIELD APPLICATIONS

SUBSEA LINE INTEGRITY MONITOR
LINE INTEGRITY MONITOR
INNOVATIVE COMMUNICATION SOLUTION