MCE DD Madrid 2014

Performance and Condition Monitoring of Subsea Production Systems

- Functionality
- Interface
- Qualification
- Examples
GE Oil & Gas - Measurement & Control

Bently Nevada
- Monitors
- Field devices
- Tech support
- System 1® software
- Machinery diagnostics

Measurement & Sensing
Reuter Stokes
- Nuclear instrumentation
- Flame detectors
- He-3 detectors
- Scintillations sensors
- Mechanical assemblies

Measurement Solutions
- Flow meters
- Flare Gas
- Gas and Moisture
- Pressure
- Temperature

Wayne
- Fuel Dispensers
- Pay-at-the-Pump
- Aftermarket
- Compressed Natural Gas

Inspection Technologies
- Ultrasonic, Eddy current
- Remote Visual
- CR/DR, X-Ray, CT
- Software
- SubSea X-Ray

Control Solutions
- Retrofits and parts
- Woodward
- Mark IV, V, VI, Vle
- Software upgrades

Flow & Process Technologies
- Control Valves and Actuators
- Safety Relief Valves
- Blowers and Compressors

Sub-sea Integrity

PII Pipeline Solutions
- Robots “pigs” pipeline condition monitoring
- UltraScan Crack Detection Tool
- MagneScan Corrosion Management Tool

Healthcare for Industry
Principles
Technology principle

**Acoustic Leak Detection**
- Oil, Gas, Water, MEG, hydraulics

**Acoustic Condition Monitoring**
- Rotating machinery
- Valve and chokes
- Structural vibrations (incl. Risers)

**Electric Condition Monitoring**
- Electric power monitoring
- Ground faults, isolation faults
- VSD monitoring

**Centrally located monitoring unit**
- One unit
- Easy installation by ROV.
- Retrievable
- Low power requirement
- Interface to all ECM’s
- 25 years design life
- Qualified to ISO 13628-6

Non intrusive
Naxys Leak Detection & Condition Monitoring

**Naxys Acoustic Leak Detector**
- ROV Lifting Interface
- Protective Frame
  - Titanium Gr.2
- Hydrophone Array
  - Receiver of acoustic energy
  - Spatially distributed sensors
  - Successful Arrhenius life cycle testing
  - 25 years design life
  - Qualified according to ISO 13628-6
- Electronics Canister
  - Subsea processing
  - 1 atm. canister
  - Glass to metal penetrator
  - Oil filled chamber
  - Anguilla hose & wet mate-able connector

**Naxys Acoustic Condition Monitoring**
- Additional sensor array specially designed for condition monitoring:
  - ✓ Vibration Detection
  - ✓ Rotating Machinery
  - ✓ Valves, chokes
  - ✓ Diagnostics

**Naxys Electric Condition Monitoring**
- 3-axis underwater electrical potential (UEP) sensor
  - ✓ VSD monitoring
  - ✓ Ground faults
  - ✓ Isolation faults
  - ✓ Diagnostics
  - ✓ Electrical power monitoring

18-30V DC
15-25W
Naxys Leak Detection & Condition Monitoring

- User-friendly interface
- Status: OK, Warning, Alarm
- Trend values
- Ethernet
- Modbus
- CAN
- IWIS
- Modbus/TCP
- FTP
- UDPIP
- Download
- Calibration
- Configuration
- Software updates

Hydrophone receiver array

Status Message
- Ethernet
- Modbus
- CAN
- IWIS
- Modbus/TCP
- FTP
- UDPIP

SW update examples
- Sensor error detection
- ROV detector
- Storage of processed data
- Improved spatial accuracy

Naxys support

Transparent links

ringbuffer
Wide area coverage

- Infrastructure & machinery
- 500m detection range
Directional monitoring

- Spatial resolution
- Localize leaks, events & processes
Acoustic Condition Monitoring-event tracing

TROLL PILOT: Sequence of events during pump shut-in

Sound direction

Sound pressure

- Shut-down of water injection pump
- Operation of return valve
- Operation of needle valve

**Sound pressure**

**Time**

**Bearing (Degrees)**

**SPL [dB rel uPa]**
Case study
Pazflor subsea separation unit

Detection of pump trip

Increased choking

Increased flow noise

Pump trips

Increased flow noise and pump trip detected by Naxys acoustic detector

Very rich sequence of acoustic signatures related to pump shut-down

Very rich sequence of sound features related to pump shut down
## Ormen Lange Subsea Compression Pilot

### Project description
- First ever wet-testing of 12MW subsea compressor
- Acoustic & Electric Condition Monitoring of Ormen Lange Subsea Compression Pilot
- Demonstration/evaluation of system capabilities and robustness

### Key Features
- Acoustic & Electric sensor arrays
- High speed synchronous sampling
- Real-time wide area data distribution
- Real-time control room acoustic feedback

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### Diagram
- **Topside process facility**
- **Separator tank**
- **Compressor**
- **Pump VSD**
- **Transformer 132kV**
- **Circuit breaker**
- **Condensate pump**
- **Electric & Acoustic Sensor Array**
- **UPS A&B**
- **5 x Satellite Acoustic Sensors**

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*Simultaneous monitoring of several components*
Nyhamna pit-monitoring

Richly featured Graphical User Interface
Real-time processing and automatic component detection

Automatically generated list of components
Green color indicates currently component running
Current measured values are presented along with statistics

Harmonic vibration actual value
Electric Power Spectrum
Real-time Acoustic Spectrogram
Minimum and Maximum measured values
High Frequency Vibrations in sector 1
Real-time Electric Spectrogram
Electric Power in low frequency band
Low Frequency Vibrations in sector 1
CASE EXAMPLE 1

START-UP OF SUBSEA TRANSFORMER

“Audio feedback when operating the pilot: gives a great ‘comfort feeling’ to operations, when you hear what you are doing actually happening.”

Jane B. Kendall, Shell
Case example 1: Start-up of Subsea Transformer

Subsea transformer @ 800m (2600ft) below sea level

Onshore control room

110km (68.4 miles)
Case example 1: Start-up of Subsea Transformer

Transformer is energized. Strong acoustic signature

Detection of two distinct sounds. Likely safety relay or contactor triggered.

✓ Detection and verification of important events
CASE EXAMPLE 2

CONDENSATE START-UP

I have been impressed by the accuracy of the analysis performed by Frank on several occasions

Thomas Blanchin, Aker Solutions
Case example 2: Start-up of Condensate Pump

**Start attempt**
Dec. 10th 2011

Attempt to start-up detected by electrical sensors
Observes VSD control signal (227 Hz) and ... ...

... electric ramp from 0 to 10 Hz (0-600 RPM)
Case example 2: Start-up of Condensate Pump

Electric

Successful start
Dec. 12th 2011

Attempt to start-up detected by electrical sensors
Observed VSD control signal (227 Hz) and...

..... electric ramp from 0 to 17 Hz (0-1000 RPM)

√ Payback through mechanical validation
CASE EXAMPLE 3

SHAFT VIBRATION & MAGNETIC BEARING CONFIGURATION
Case example 3: Shaft Vibrations & Magnetic Bearing Configuration

“Independent validation of events in the pit:
Location of magnetic bearing system instabilities when tuning......audio signals matched very well the signals from the bearing control system”

Jane B. Kendall, Shell

✓ Payback through protecting the asset
Case example 3: Shaft Vibrations & Magnetic Bearing Configuration

Harmonic vibration of 543 Hz and broad band vibrations around 1000 Hz

Strong shaft vibrations (2nd bending mode) around 543 Hz identified by acoustic system

Broad band vibrational noise

Detection of Shaft Vibrations
Oct. 12th 2011

Ramp-up of Adaptive Magnetic Bearing (AMB), 2-1600Hz

After reconfiguring AMBs the ramp-up is smooth. Less vibrations along excitation axis, less overall noise. No 543 Hz signal present.
CASE EXAMPLE 4

COMPRESSOR TRIP

“Audio of compressor trips helped us (eventually) identify a non return valve opening and closure that we did not expect”

Jane B. Kendall, Shell
"Independent validation of events in the pit:
“Audio of compressor trips helped us (eventually) identify a non return valve opening and closure that we did not expect”

Jane B. Kendall, Shell

✓ Payback through mechanical validation
ORMEN LANGE PIT-MONITORING

Case example 4: Compressor trip

April 21st. 2012

Several impacts detected as Compressor trips

Compressor freewheels to a stop

Unrecognized signal with strong sidebands emerge

Speed Increasing

Discovery and warning of equipment misbehavior.

✓ Payback through predictive maintenance
SW Developments ongoing

<table>
<thead>
<tr>
<th>Module name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data processor and conditioner</td>
<td>Pre-conditioning and processing of raw-data</td>
</tr>
<tr>
<td>Statistics processor</td>
<td>Calculation of parameter statistics</td>
</tr>
<tr>
<td>Change detector</td>
<td>Sensing changes in processed data</td>
</tr>
<tr>
<td>Machine tracker</td>
<td>Calculate and track machine specific parameters</td>
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<tr>
<td>Signature detector</td>
<td>Recognize pre-recorded events</td>
</tr>
<tr>
<td>Trending tool</td>
<td>Characterize statistics information and generate trends</td>
</tr>
<tr>
<td>Topside communicator</td>
<td>Enable communication between modules</td>
</tr>
</tbody>
</table>
CASE EXAMPLE 6

Riser Vibration Monitoring
ÅSGARD EXPORT RISER BASE (2002)
FLEXIBLE RISER VIBRATION MONITORING

Åsgard ERB
• ERB—Export Riser Base
• Monitoring Objects:
  2 x 14” rough-bore risers
• Gas export 48 MSCMD

Project description
• Acoustic Noise and Vibration Monitoring
• Locate and Characterize Riser Vibrations
• Monitoring Campaign Initiated by Statoil
• Three measurement campaigns

Åsgard Export Riser Base

Acoustic Monitoring Module deployed to seabed by ROV

Riser Vibrations (frequency characteristics)

Rough-bore flexible riser construction
Based on acoustic monitoring, optimize flow velocity while minimizing damaging vibrations.

Excessive vibrations appear when flow velocity through riser B104 exceeds 3 m/s. Vibrations detected acoustically.
LEAK DETECTION
Commissioning
Qualification
Recommended Practice
Technology verification & qualification

- **Tank test**
  - Verified technology concept

- **Deepwater inshore tests**
  - Technology performance: ~500m detection range

- **SINTEF seawater basin tests**
  - Technology performance verified by SINTEF

- **Commissioning of systems**
  - Successful commissioning: Vega and Ormen Lange (2011)
Technology verification & qualification

Tank test
- Verified technology concept

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- Technology performance: ~500m detection range

SINTEF seawater basin tests
- Technology performance verified by SINTEF

Commissioning of systems
- Successful commissioning: Vega and Ormen Lange (2011)

Naxys deepwater station
- The Naxys deepwater station is located next to the offices and workshop outside Bergen, Norway
- The test station enables Naxys to offer subsea equipment testing services and also gives the company the opportunity to test own products

Technology verification & qualification

210 m (689 ft) Umbilical

Leakage nozzle
Commissioning of Naxys ALD

Successful commissioning at Ormen Lange (2011)

Subsea Template Dimensions: 45 x 33 x 15 meter

All simulated leak detected:
- Positive detection of leak and leak position
- Positive detection of leak, but not confirmed position

Courtesy PLEM
“During commissioning of the ALVD units on Ormen Lange template A and B we saw an impressive ability to detect and determine the direction of small and large simulated leakages.”

Lars Kristian Asbjørnsen, Subsea Control System Engineer, Shell
Way forward
Thank you for your attention!