BP King Subsea Pump Project

Record breaking subsea boosting project
Katrine Kierulf, UTC/Bergen, 5 June 2008
Aker Solutions – Who we are & what we do
Agenda

- Project Overview – Aker Solutions Scope of Work
- Technological challenges
- High pressure housing design
- Lube oil control system
- High voltage power supply system
- Control and monitoring system
- Deep water installation and retrieval methods
- Operational experience
Substantial IOR!

“The two pumps will enhance production from the King field by an average of 20 per cent. After its 2002 start-up, the King field reached peak production in 2004, with recent production averaging 27,000 barrels of oil equivalent a day. In addition to the increase in production, this project will allow a seven per cent increase in recovery factor, extending the economic life of the field by five years.”

Technological success! – bringing a prototype to a 1700 m commercial application

“At 5,500 feet below the sea’s surface, the King facilities are in water almost twice as deep as the previous deepest installation of multi-phase pumps. The pumps are also positioned over 15 miles from the Marlin tension leg platform – well over twice the previous record distance from a host platform of six miles.”

- BP press release 4 December 2007
King Subsea Pump Project

- Optimize Oil Recovery from the King Field Reservoirs
- New deep water enabling technology (deepest booster ever)
- Tied into the existing King subsea infrastructure (longest ever)
Project Overview – Aker Solutions Scope of Work

- Management & Engineering
- Performance and Stack-up testing
- Pump Modules, 2 off
  - 2 off subsea Pump Stations
- Pump Manifolds, 2 off
- Subsea Control System, SCM 2 off
  - +1 spare
- Topside Control System, MCS 1 off
- Topside Lube Oil HPU, 1 off
- VSD’s, 2 off
- HV Connectors & Jumpers
- SIT (limited to SCM vs umbilical)
Basic Design Data

- Water depth: 4900 ft to 5200 ft (1500 to 1700 m)
- Water Depth at Host: 3000 ft (1000 m)
- Tie back Distance: 18 miles (27 km)
- Design Pressure: 5000 psi
- Max Power: 1MW
- Max Delta Pressure: 50bars
- Speed: 800-1800rpm
- Ff: 6.6kV / 120A

<table>
<thead>
<tr>
<th></th>
<th>Length x Width x Height (ft):</th>
<th>Approx Weights</th>
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</thead>
<tbody>
<tr>
<td>PUMP MODULE</td>
<td>17 x 10 x 14</td>
<td>50 Te</td>
</tr>
<tr>
<td>PUMP MANIFOLD</td>
<td>27 x 12 x 20</td>
<td>40 Te</td>
</tr>
<tr>
<td>SCM (Control Module)</td>
<td>5 x 3.5 x 4</td>
<td>1 Te</td>
</tr>
<tr>
<td>COMPLETE PUMP STATION</td>
<td>27 x 12 x 23</td>
<td>91 Te</td>
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</table>
Pump in Pit for testing
Pump Unit

Extensive Design Work and Testing

- Pressure vessel design
- Seal design and testing
- Material selection
- Limited penetrations in pressure shell
- Internals are included as cartridges
Testing of Pump Unit Housings

Design Pressure $p_D = 345$ bar (5000 PSI)
Casing Test Pressure $p_T = 493$ bar ($1.43 \times p_D$)
Ambient temperature $20^\circ C$
Test Fluid Temperature $80^\circ C$
Lube Oil Control System

Lube Oil System Functions
- Lubricates bearings, timing gears and dynamic seals
- Provides cooling oil for motor (~400hp heat input)
- Pressure compensated dielectric oil for motor

Dedicated umbilical supply line for each pump
One shared spare line (stand-by)
Topside Lube Oil HPU

- 260 gal Inlet Tank
- 2x160 gal Supply Tanks
- N2 Blanketed Tanks
- Offline Oil Purifier
- Dual HP Pumps
- Div 2 Area Rated
- Operated by PLC in VSD Container
- All 316SS Skid Frame

L 8,3’ (2770 mm) x H 7,3’ (2440 mm) x W 6,0’ (1980 mm)

The Lube Oil System must be 100% operational for the life of the subsea pump. Lube Oil must be dry to less than 50 ppm water in oil content. Lube Oil must be clean to NAS class 6 maximum.
Power system overview
VSD Container

Siemens Perfect Harmony Drives
- 1 Drive per Pump
- 9 kV, 140 amp, 0-70Hz
- Air cooled with fans on the roof
- Low Harmonics
- Modular Construction
- Redundant Auto-Bypass

AKS Control System
- Surface Control Unit
- Electrical Power Unit
VSD Building onboard Marlin platform
Control and monitoring system

- Subsea part fairly standard compared to wellhead systems (few hydraulic functions, few sensors)
- Complexity is in
  - Topside part (complex logic)
  - Umbilical (noise from HV to LV wiring)
  - Operation with ground fault
- 10 Mbit/s fibreoptic communication used over 28 km (still somewhat novel for subsea use)
- All sensors duplicated (A / B network)
- All sensors connected via digital links
**Subsea Control Module**

- **Power / Comms. Connections**
- **Sensor Connections**
- **Hydraulic connections**

5 Hydraulic functions:
- 2 manifold valves XV1, XV2
- 2 pump module valves XV3, XV4
- 1 common hydraulic function for 6 PVR switching valves

- 2 Sensor connectors for A / B sensors
- 1 Sensor connector for "future" expansion

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**EPU**

- Provides power to subsea control system
- Dual redundant
- Oversized (each channel can drive appr 4 SCM’s, we have 2)

**iSCU**

- Fibre Optic modems (for comms with subsea SCMs)
- File server for data storage
- Allen Bradley PLC for logic (the ”Brain” of the system)
- IO cards for topside signals
- Local Operator Station with keyboard
OPDM

- The OPDM system analyses logged data, and estimates "time to service" to enable prediction of required intervention.

- Sensor data and calculated signals are captured offshore in the topside part of the control system and transferred for onshore processing and storage.
  - Suction pressure
  - Discharge Pressure
  - Lube Oil Supply pressure (topside)
  - Lube Oil Supply pressure (subsea)
  - Lube Oil system temperature (hot end)
  - Lube Oil system temperature (cold end)
  - VSD Output Power
  - VSD Output Frequency

- The database is then used for general visualization and analysis.
Deep water installation and retrieval methods

- Same pump station at both locations, fully assembled unit, 90 tons
- Hook-up by ROV connected flying leads:
  - HV and LV Power
  - Instruments
  - Hydraulic Supply
  - Lube Oil
  - Methanol
- Retrievable Modules:
  - Pump Module
  - PVR
  - Subsea Control Module
- Hook-up to Xmas Tree
  - DES MARS™ Choke Insert System
Installation
Operational experience

- Operational since late November 2007, the two pumps will enhance production for the King field by an average of 20 percent and allow a 7 percent increase in recovery, extending the economic life of the field by five years.

- The pump is designed for 3-5 years operation before intervention is required and can then be replaced with a spare pump.

- BOTH PUMPS ARE RUNNING STABLE

- The OPDM system is up and running, and weekly analyses of logged data is carried out to monitor performance.
Thank you for your attention!

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Thanks to everyone who contributed to this success!

Questions?

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