ÅSC – Operational experience
NTNU 140218 – Petter Harstad

Asgard Subsea Compression
The world’s first subsea compression system!
Midgard and Mikkel

**Midgard;**
- Production start up 01.10.2000
- 3 templates
- 10 wells

**Mikkel;**
- Production start up 01.08.2003
- 2 templates
- 3 wells
- Tie in Field to Åsgard
- Both Migard and Mikkel have very good reservoir properties, and are produced by pressure depletion
- Well completions:
  - Gravel pack with screens
  - Stand alone screens (SAS)

<table>
<thead>
<tr>
<th>Partners</th>
<th>Åsgard</th>
<th>Mikkel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statoil ASA (operator)</td>
<td>34,57%</td>
<td>43,97%</td>
</tr>
<tr>
<td>Eni Norge AS</td>
<td>14,82%</td>
<td>14,90%</td>
</tr>
<tr>
<td>Exxon Mobil E&amp;P Norway AS</td>
<td>7,24%</td>
<td>33,48%</td>
</tr>
<tr>
<td>Petoro AS</td>
<td>35,69%</td>
<td>0%</td>
</tr>
<tr>
<td>Total E&amp;P Norge AS</td>
<td>7,68%</td>
<td>7,65%</td>
</tr>
</tbody>
</table>

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Old Midgard and Mikkel Production System

- Long flowlines with large dimension (ID ~ 20”)
- Continuous MEG injection at wellheads to prevent hydrates in the flowlines
- At Åsgard B the produced MEG is regenerated and the MEG is then injected at the wells again
- A certain concentration of MEG is needed to keep the flowlines protected from hydrates
Minimum Flow Challenge

- A certain gas velocity is needed to be able to transport the injected MEG together with condensed water to Åsgard B.
- With time the gas velocity becomes too low to maintain stable production.
- MEG accumulates in the flowlines and will be produced to Åsgard B in slugs.
- Minimum flow rate; rate at which the largest liquid slug Åsgard B can handle occurs.

\[ \text{Gas velocity} = f(\text{pressure and flow rate}) \]

Time for minimum flow

Corrective measures

Lower limit for stable flow

Year
The SOLUTION:
Åsgard Subsea Compression

- Design gas flow rate: **21 MSm3/d**
- Pressure boost: **52 bar**
- Power: 2 x 11.5 MW centrifugal compressors
- 40 km step out
- Water depth 265 meters

- Additional reserves:
  - **306 Mboe**
System overview
Main components:
- Inlet cooler
- Scrubber
- Liquid pump
- Wet gas compressor
- Outlet cooler
The Gas Compression Process
New Field Layout

ÅSC Pipeline scope:

- Hot Tap into Y-101
- 60 km of new pipelines
- 12 PLEMS
- 2x dynamic integrated power/umilical risers
- 4x40km power cables and umbilicals
- 18 spools
- ++

- Last part of pipeline scope finished in August 2015
Discovery Channel – Mighty Ships

- Discovery Channel followed the installation of the last compressor module and made a program for their series «Mighty Ships»!

- Season 9, episode 1!

- [https://www.youtube.com/watch?v=WMNz7jE4yBQ](https://www.youtube.com/watch?v=WMNz7jE4yBQ)
Operational experience
ÅSC operation support group

- ÅSC operation support is run from Statoil office in Stjørdal
  - Day-to-day follow up of ÅSC related tasks and production optimization

- Spare train stored @ Vestbase:
  - Storage hall
  - Workshop hall
  - Washing hall
  - Test pit
  - Office building
Operational experience - MID/MIK gas production

- T#1 start-up 16.09.15
- T#2 start-up 28.02.16
- Increased production by approx. ~8 MSm3/d
- Producing above design rates since start-up
- Most production shut-downs caused by loss of power from Åsgard A
- Only minor technical issues prior to breakdown of T1 pump in July 2017
Daily run hours – T#1 since start-up

- T#1 start-up 16.09.15
- T#2 start-up 28.02.16
- Increased production by approx ~8 MSm3/d
- Producing above design rates since start-up
- Most production shut-downs caused by loss of power from Åsgard A
- Only minor technical issues prior to breakdown of T1 pump in July 2017

Updated 08.02.18
Daily run hours – T#2 since start-up

- T#1 start-up 16.09.15
- T#2 start-up 28.02.16
- Increased production by approx ~8 MSm3/d
- Producing above design rates since start-up
- Most production shut-downs caused by loss of power from Åsgard A
- Only minor technical issues prior to breakdown of T1 pump in July 2017

Updated 08.02.18
Operational experience – Production Efficiency

- Project system target / design: 96%
- Most production shut-downs caused by loss of power from Åsgard A
  - Increased robustness from 2017
- Very few unplanned losses related to subsea system:
  - Most of them related to pump regulation issues
  - Compressor: 100% PE
- Loss of redundancy not captured in PE

<table>
<thead>
<tr>
<th>Year / Cat</th>
<th>Entire system incl. power generation Åsgard A</th>
<th>System 17 (subsea + topside)</th>
<th>Subsea station</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PE loss (%)</td>
<td>Total PE (%)</td>
<td>PE loss (%)</td>
</tr>
<tr>
<td>2015</td>
<td>2.78</td>
<td>97.22</td>
<td>0.73</td>
</tr>
<tr>
<td>2016</td>
<td>2.70</td>
<td>97.30</td>
<td>2.05</td>
</tr>
<tr>
<td>2017</td>
<td>3.08</td>
<td>96.92</td>
<td>2.78</td>
</tr>
</tbody>
</table>
Crucial factors for success

- **Testing, testing, testing!**
- Comprehensive onshore test program:
  - **K-lab**: Functional testing of compressor
  - **Tranby**: Functional testing of pump
  - **Egersund**: Site integration testing (SIT)
  - **Aberdeen**: Control system testing
Pump breakdown July 2017
July 2017 - T1 pump breakdown

- Occurred 18.07.17 02:09
- Increasing power consumption @ fixed speed prior to trip
- Indications of locked rotor when trying to restart – not able to spin pump
ÅSC Pump Module

- **Main purpose:**
  - Control level in scrubber
  - Recycle a continuous flow rate for sand
  - Supply liquid for compressor washing

- **Weight in air:** 57 T

- **Retrieval weight (water filled structure):** 64 T

- **Dimensions, incl. lift rigging:** 5621x4640x7865

- **Intervention by use of NSG MHS**
ÅSC Intervention challenge

- Requirement for year round intervention (Hs 4.5)
  - 400T modules
- Large volumes of HC
- Challenging pipe geometry
  - MEG and N2 needed to displace HC
- Complex single barriers
  - Difficult to do fault finding
Subsea Process Intervention System (SPIS)

- Allow safe and effective recovery and installation of ÅSC modules:
  - HC displacement
  - MEG
  - N2
  - Pressurization and depressurization
  - Leak testing
  - Seawater displacement
  - Service hub in every module
Subsea Process Intervention System (SPIS)

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Subsea Process Intervention System (SPIS)

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ÅSC T1 Pump replacement

- North Sea Giant in KSU 01.08.17 to start mobilize for pump replacement
  - Pump replacement finished by 10.08.17
  - Commissioning 09.08.17 - 10.08.17
  - Train #1 start-up 11.08.17 00:20
    - 24 days from trip
  - Pump #1 and T#1 in operation since
  - Very rapid operation without major issues
The future
ÅSC – Beyond 306 Mboe

- ÅSC enables future IOR possibilities in the Midgard / Mikkel area
- Infill wells
- Tie-in fields
- Built-in flexibility in current design
- Desired outcome:
  - Increase recovery!

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ÅSC – Phase II project

- Ongoing project
  - DG2 2018

- Qualify and modify existing compressor system for extended operational envelope
  - Increased speed
  - Wet gas compression

- Qualify new compressor solution for increased pressure ratio
Simplify, Standardize, and Industrialize (SSI)

Where are we after ÅSC?

• ÅSC was first of it’s kind and through ÅSC we have a unique opportunity towards the future:
  • Comprehensive technology tool-box available for reuse
  • Reuse of test and service facilities
  • Reuse of intervention system and tools

• From the different project stages and over two years in production a significant amount of learning's have been accumulated

• Ensure that further cost reductions are captured:
  • Simplification
  • Standardization on the simplified solution
  • Industrialization by repeating and re-use
Simplified Subsea Gas Compression System

From soccer field... to tennis court
Back-up
Installation and Intervention

- North Sea Giant
- DP Class III
- Size 161x30m
- Accommodation 120 person
- Main Deck area 2900m²
- WROV x2, Triton XLX and XLR
- SHS for large modules in fabrication
- Total weight of structure ~1000Te, height 30m
- Capacity 388 tons, 15x12 + 12 m, Hs 4.5m
- Moonpool Handling System 70 tons, 7.2 x 7.2m
- Subsea Process Intervention System
  - Handle residual hydrocarbons in modules
  - MEG displacement of modules
  - Nitrogen flushing
Control System

- All controls functionality integrated in SAS
- Power Supply
  - Topside UPS
  - Subsea Control Power Distribution Unit (CPDU)
- All electric system
- 3 segregated redundant systems
  - Process Control System (PCS)
  - Process Shutdown System (PSD)
  - Condition Monitoring System (CM)
- Subsea closed loop functionality
  - Active Magnetic Bearing System (AMB)
  - Anti Surge
- 100 Mb TCP/IP (Modbus/ModSafe) on separate fibers
- Subsea Control Modules:
  - 2 SCM per compressor train
  - 1 SCM on manifold station
- Hydrocarbon leak detection system
**Umbilical System**

- **Dynamic part < 1500m**
- **Static part ~42km**
- **Combined umbilical**
- **Fibre link**
- **Power cable**
- **Cable splice**
- **Umbilical**
  - Compressor Power
  - Pump Power
  - Control Power
  - Pump Barrier Fluid
  - Fibre Optic

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Asgard A

Asgard B

SCSt

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**Subsea Processing**

**Arctic: 2020+ ?**
Subsea processing
Large step-out, large duty

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**Snøhvit: 2017-2020 ?**
Subsea compression
140 km

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**Gullfaks: 2015**
Subsea compression
2x5 MW
17 km

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**Åsgard: 2015**
Subsea compression
2x11.5 MW
17 km

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**Tordis: 2007**
Subsea sep.
Sand handling
2x2.5 MW
43 km

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**Tyrihans: 2009**
Subsea raw seawater injection
2x2.5 MW
17 km

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**Troll: 2001**
Subsea sep.
1x1.6 MW
12 km

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**Lufeng: 1997**
Subsea pump
5x0.4 MW
4 km

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The Statoil Subsea Factory™

Main Subsea Factory technology elements ready for deployment
Large potential for reuse of technology and utility systems in new projects
Subsea compression importance for future

Subsea compression can be enabling technology to gain:

1. Profitable tie back of gas fields by
   • Accelerated production & Increased recovery

2. Operational flexibility compared to topside
   • To reduce impact on weight, space, HSE
   • Energy efficient & robust flow assurance
   • Act as hub for new tie backs, avoid new platform

3. Access deep water, environmentally sensitive locations