

# **Subsea power, processing and boosting**

**Increased oil recovery solutions**

### Vision becomes reality

With the Åsgard subsea compression project subsea processing is becoming a reality. It will be the first compression system working subsea in a commercial application. The project encompasses the combined excellence in all areas of subsea processing technology in the world today.

Artist impression of the Åsgard subsea compression station installed subsea



**As the oil and gas industry speculates just how long worldwide oil supplies will keep up with the growing demand, operators are faced with two challenges: How to get more out of their reservoirs and how to manage deepwater developments and long step-outs.**

Aker Solutions is continuously pushing the boundaries of subsea technology to address these challenges. Our power, processing and boosting solutions aim to optimise both new and existing subsea developments in a safer and more profitable way.

Aker Solutions is uniquely positioned in the subsea processing and boosting market:

- We started long before anyone else – the Kvaerner Booster Station (KBS) was launched in 1985 and tested in 1991
- Extensive product knowledge – we have delivered hundreds of separators and pumps to the offshore industry
- Complete range of products and solutions – we are the only company providing both subsea pumps and subsea process systems
- Deepwater and HP/HT technology expert – we are the only subsea pump provider that also delivers deepwater and HP/HT solutions such as subsea trees, manifolds and control systems
- Unrivalled system design experience
- Ability to execute large and complex projects – we are the only company in the subsea processing and boosting business that also delivers complete topside and onshore process plants

Aker Solutions has experience with the most complex subsea projects ever, including Statoil's Ormen Lange subsea compression station pilot and the world's first subsea compression system for Statoil's Åsgard field.

Aker Solutions was also awarded a contract from Statoil for a subsea raw seawater injection (SRSWI) system for the Tyrihans field. With a record power rating of 2.5 MW for each pump and a record 31 kilometre (19 mile) step-out from the host facility we broke new boundaries.

Our expertise will help our customers meet their future needs in even deeper waters, with higher pressure and increasing complexity.

# From concept to realisation



“boosting  
production  
made easy”

## Benefits and capabilities

The benefits of our processing and boosting systems are as diverse as they are effective. We deploy innovative technology to address greenfield development, subsea debottlenecking, tail-end production, long step-out, hydrate and slug prevention, split flow to different receiving facilities and single flowline solution for deepwater fields.

Our technologies are qualified for a variety of conditions:

- Deepwater - Qualifying motor-pump system including electrical power supply for water depths down to 3 000 metres and high shut-in pressure
- Extensive monitoring - Accelerometers monitoring vibrations. Monitoring of transformers secondary side, both current and voltage as well as general insulation level
- Long step-outs – system designed for up to 120 km with subsea variable speed drives, transformers and circuit breakers
- All electric control solutions – Aker Solutions will deliver the first subsea separation and compression pilot for the Ormen Lange pilot and the Åsgard subsea compression system with electric control systems

These solutions give us, and our customers, the competitive edge.

### Tyrhans, North Sea

Award-winning water injection technology for Increased Oil Recovery (IOR).

The worlds largest subsea seawater injection pump system with 5 MW installed power.

- Up to 150 000 bbl/day
- Certified for 3 000 meters water depth
- Expected to increase oil recovery by ten percent



Passive cooling system qualified for the inlet and antisurge cooling of the process stream for the Ormen Lange Pilot compressor system



## Qualified technology

We are proud of our technology. Not only is it innovative, it is also proven. For more than 15 years we have worked to develop, test and qualify our subsea processing and boosting solutions. Research and development work is one of our key priorities. It helps us identify and deliver smarter ways to meet customer needs in an ever-changing market.

We carefully manage the risks involved with developing new technology through:

- Structured methods of assessing and qualifying technology
- High pressure casings according to ASME VIII at 13 500 psi
- In-house full scale test facilities
- Use of DNV-RP-A203 and similar methodology
- Extensive testing of all critical components
- Comprehensive operability testing on every complete system, which includes testing every possible operating condition and all key fluids

Final proof lies in our project execution model. It helps us deliver enhanced efficiency and best quality.

Aker Solutions provides a variety of service solutions for maximised recovery: from subsea condition monitoring and equipment maintenance programmes to full subsea system reconfiguration to accommodate changes in reservoir behaviour. This coupled with the competencies in the wider Aker family, including light well intervention, provides our customers with the most comprehensive offering of any provider in today's market.

### Life of field support

We have a long term commitment to our customers, from beginning to end. Aker Solutions has dedicated manufacturing and testing facilities, project management services and life-of-field service professionals with bases worldwide

Qualified atmospheric enclosure for power electronics



## Why subsea boosting?

- Increases production and recovery
- Prolongs the economic lifetime of a field
- Faster and safer start-up of low energy wells
- Enables a different production strategy ('inverse choking')

## Why subsea separation?

- Increases production and recovery
- Prolongs the economic lifetime of a field
- Debottlenecking: flowlines, risers and topsides
- Optimises the use of existing infrastructure
- Solutions to flow assurance challenges
- Safe and environmentally friendly operation

## Industrialising subsea compression ...

**Aker Solutions is continuously pushing the boundaries for subsea processing solutions and the Ormen Lange subsea compression pilot was the world's first full scale subsea wetgas compression system.**

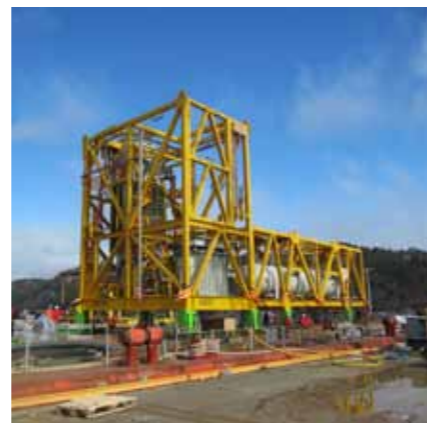
The pilot project comprises; qualification, delivery and testing of a complete subsea compression system including separator, compressor, condensate pump, variable speed drive (VSD), circuit breaker and all electric control system.

Aker Solutions has 25 years of technology development experience and the Ormen Lange pilot has industrialised the complete subsea processing system.

- System design for a 12.5 MW compression train
- Qualified technical solutions
- Technical specifications
- Resources and competence
- Execution and safety procedures
- Purpose built assembly and test hall
- Operational data from extensive test programmes
- HSE in design, testing and execution



Testing at our specialised Egersund yard



Ormen Lange subsea compression station power module during lead-out

## Why subsea compression?

- Cost effective way to maintain plateau production
- Avoids water accumulation in the flowline by boosting flow
- More effective by compressing closer to the wells
- Safe and environmentally friendly operation
- Gas fields require boosting of the reservoir flow as reservoir pressure depletes
- Subsea gas compression replaces the need for an offshore platform or onshore compression facility
- Cost-effective development solution (CAPEX)
- Reduced operational costs (OPEX)
- Advantageous to place the compressor close to the well
- Increased and accelerated production
- Reducing CO<sub>2</sub> emissions through lower energy consumption
- No emissions or disposals to sea
- Safer due to unmanned operation

## for the Åsgard field

**The combined industrial experience from the Ormen Lange pilot and other subsea projects goes into the design and development of the Åsgard subsea compression system.**

### The subsea processing system comprises:

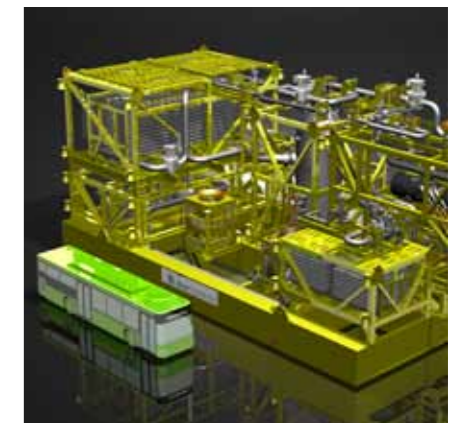
- Subsea compressor station
- Two compressor trains
- All electric control systems
- HV electrical power distribution system
- Topside control and power equipment
- Tooling, transport and installation equipment
- Manifold station

### Main design data:

- Flow rate 21 MSm<sup>3</sup>/d (total)
- Gas and liquid separation
- High power compressors – 2 x 10 MW
- Liquid pumps – 2 x 400 kW
- 50 km tie back
- 250 m water depth



Subsea compression station with two compressor trains



Subsea compression train (shown next to a bus for scale)

# “robust design”

## System engineering capabilities

Subsea power and processing solutions require intimate knowledge of all areas of a system in order to determine the best system design for your project.

Our engineers have worked with and are involved in the most advanced subsea projects in the world today. They are all experienced and well versed with company specifications, industry standards, available technology and are dedicated to ensure the most optimal design and execution of a project.

The most important requirements and philosophies are related to:

- General design basis parameters
- Technology qualifications (TQP) and synergies flexibility
- SAS philosophy
- SIL requirements
- Reliability/Maintainability/Operability
- Modularisation
- Installation philosophy
- Inspection, maintenance and repair philosophy
- Flushing and purging philosophy
- Conditioning monitoring philosophy
- Test philosophy
- Material selection



## Process design

Through our experience and tested process simulation tools we ensure reliable, robust and compact processing solutions.

- Flow assurance
- Process design controls topology

## Controls system

All electric or conventional hydraulic systems are available with built in;

- High-speed communication
- Reliability
- Redundancies

## High voltage power systems

Many of today's subsea increased oil and gas recovery solutions rely on high voltage power supply through long step-out power umbilicals with wet mateable connection systems and subsea transformers, variable speed drives and switchgear.

Aker Solutions expertise in the design and delivery of complete power systems for high power subsea equipment is unrivalled through challenging power supply systems like the Ormen Lange and Åsgard Subsea Compression projects. This includes marination of power electronics for subsea compression together with key industry partners.

Aker Solutions can provide complete solutions for:

- 3 000 mwater depth
- 200 km step-out and beyond
- 50 MW and more

Ormen Lange 16 MW subsea compressor VSD module



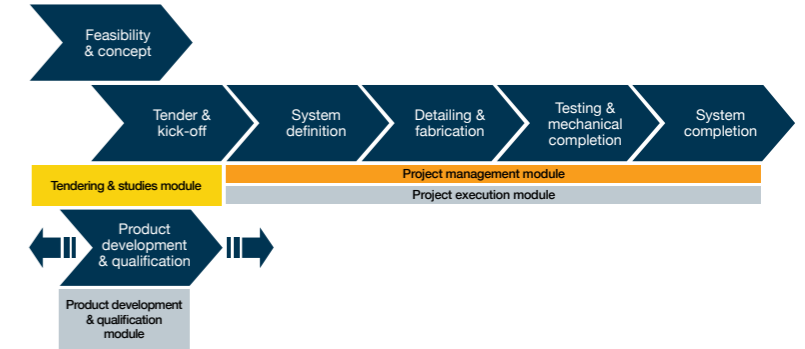
# “solid execution and support”

## Project execution model (PEM)

### Dedicated and experienced engineers

To deliver a complete, safe and cost efficient product to our customers without fatalities or injuries on the agreed delivery date, to the required quality and within the agreed budget is a challenge we take seriously.

The Aker Solutions PEM is a cornerstone in meeting this challenge, the foundation of the method has more than 30 years of experience with offshore oil and gas industry projects from all over the world and from the last decade experience from a number of major EPC(I) projects. A significant advantage in this context is the knowledge of the actual project costs, how these are distributed and relate to the various activities over time. The processes influencing the end cost of the product such as the need for “front end loading”, ensures sufficient concept definition prior to starting project execution.



Our purpose built hall at the Egersund yard for construction, assembly and testing of subsea processing modules.



## Subsea lifecycle services

Subsea lifecycle services is one of the most important areas for our customers, as uninterrupted installation and production results in financial gain.

In terms of support, Aker Solutions' ultimate goal is to continue to enhance the performance and reliability of our subsea equipment once installed and operational.

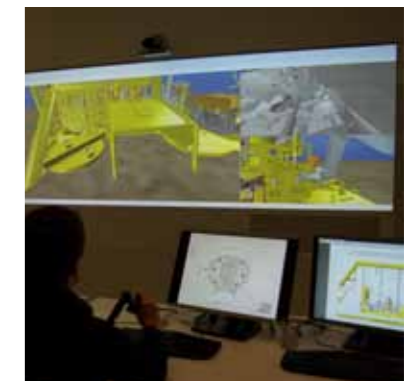
Services:

- Condition monitoring and remote support
- Production optimisation
- Installation support
- Start up and commissioning
- Rental of intervention tools
- Life-of-field and intervention support
- Tool maintenance, repair and upgrades
- Customer property management
- Storage
- Rental services

## Key elements of condition monitoring

- Key performance management
- Event management
- Security management
- Decision support
- Message and data management
- Repositories and databases

iPort control room



**Statoil - Tyrhans, North Sea**

The highest capacity subsea raw seawater injection system ever developed including the delivery of a complete pump system including three multistage centrifugal pumps (including one spare), manifold, template, subsea transformers and topside power and control system. When installed, the two pumps are expected to increase oil production by 10 percent.

# Subsea boosting solutions

**Multistage centrifugal pumps - the HybridBooster™**

The HybridBooster™ uses Aker Solutions' proven multistage centrifugal pump technology in combination with highly gas tolerant mixed-flow stages, assembled as one cartridge. The HybridBooster™ enables a high pressure increase with good gas handling capabilities.

Application areas:

- Pumping liquid from a gas/liquid separator where the risk for gas carry-under exists
- Pumping hydrocarbons from fields producing mainly liquid but with the risk of gas break-through over time

**Multistage centrifugal pumps – the LiquidBooster™**

The LiquidBooster™ uses Aker Solutions' proven multistage centrifugal pump technology for a wide range of subsea applications. The subsea pump has been extensively tested on fluids containing sand and high gas fractions to prove its efficiency. Application areas:

- Subsea raw or filtered seawater injection
- Subsea produced water re-injection
- Subsea crude oil / condensate boosting

**Raw seawater injection system – the SeaBooster™ system**

The system consists of a single retrievable liquid pump module (LiquidBooster™) with a filtration module that is separately retrievable from the pump module. The liquid pump is a centrifugal multistage type and is driven by a water-filled motor. The filter unit is self-cleaning with hydraulic actuator and a water purging system. The pump can be delivered horizontally for lower fishing friendly structures or vertically for reduced environmental footprint.





# Subsea processing solutions

## Gas and liquid separation with liquid boosting system – the DeepBooster™ system

The DeepBooster™ system is a subsea processing system for separating the gas and liquid phases of well fluid, followed by pressure boosting of the liquid phase. Each of the phases is transported to the host facility topside through separate risers.



## Oil, gas and water phase separation system – FlexSep™

Operational robustness is ensured through the combination of proven separator design optimised for subsea application, a sand handling system, a gas and sand tolerant pump, plus stable and rapid control systems.

The basic FlexSep™ system consists of a gravity separator and a produced water injection pump (the LiquidBooster™).



## Wetgas compression – the GasBooster™ system

The GasBooster™ system is a subsea process system incorporating a GasBooster™ centrifugal compressor module and other process stages such as scrubber and liquid pump (LiquidBooster™).



## Subsea power, processing and boosting

## Subsea HV power products

- Topside and subsea VSD and switchgear systems for supply to subsea rotating machinery like pumps and compressors
- Subsea variable speed drive (VSD) modules designed for 500 kW - 16 MW / 6.6 kV / 200 Hz



Subsea VSD module

## Subsea circuit breaker modules

- Complete power distribution module with UPS supply
- VSD pre-charge system and 36 kV switchgear



Subsea circuit breaker module

## Subsea uninterrupted power supply (UPS) modules

- Designed to provide uninterrupted power to production shut-down systems
- Power is ensured for active magnetic bearing systems and electric actuated valves



Subsea UPS module

## Subsea power, processing and boosting

“right tools for the job”

Skills and expertise acquired over many years, combined with the right tools, are used to optimise new and existing designs for power and process systems.

Separators and internals are designed with the aid of computational fluid dynamics (CFD) technology. CFD is used to simulate velocity and pressure fields under process conditions, which would be impossible to produce under laboratory conditions.



## Efficiency prediction

In addition, particle tracking, or full multiphase simulations are used to predict the efficiency of the equipment being modelled.



In-line gas liquid separator analysis

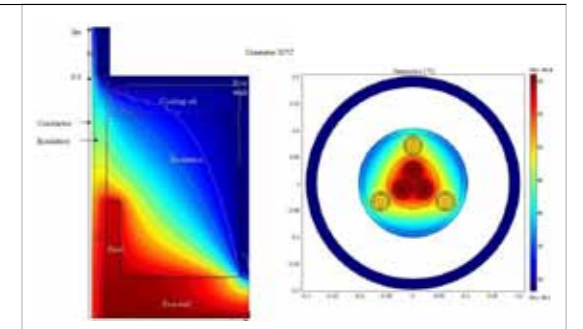
Within power, leading professional electrical system simulation software and 3D multi-physics tools are used, which simultaneously simulate thermal, electromagnetic and mechanical behaviour in real time.

## Complete power system analysis

- HVDC and AC studies done up to 500 km
- Load flow simulations for equipment sizing
- Earth fault and short-circuit calculations
- Transient studies
- Real time simulations for rotating machinery start-up, stop and trips
- Harmonics analysis and frequency response of long cables, umbilicals and transformers

## Electromagnetic finite element analysis (FEA)

- Electromagnetic FEA of induced currents and voltages in subsea power umbilical cable screens and umbilical steel tubes and control cables
- Design of how to avoid crosstalk between power cables in an umbilical and between power cables and LV control cables
- Thermal FEA of subsea power modules and high voltage connectors and penetrators
- Electrically induced corrosion protection



Left: HV Motor Penetrator thermal design verification  
Right: Power Umbilical inside a platform J-tube - thermal verification



**Contact Aker Solutions:**

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