Offshore Platform Powered With New Electrical Motor Drive System

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• Background
• The Application
• User Values
• The Technology
• Conclusion
The Application (1)
Boost the Gas Capacity Through the Pipelines to Mainland

A new type of compressor motor drive and electrical transmission system is installed.

- **AC to DC converter station**
- **Compressor Motor Drive**
- **Pressure**
- **Electrical Energy**
- **Gas to Mainland**

Distance: 70 km (43 miles)
The Technology (1)
Combining New Technologies

High Power IGBT

XLPE power cables
The Business Values (1)
User Values

A Cost Effective Solution Through:

• Substantially Higher System Efficiency
• Lower Energy Consumption by Means of Compressor Speed Control
• No emissions of environmentally harmful substances from the platform
The Case (2)
Typical Power System on Off-Shore Platforms

Loads up to 5-10 MW:

- Fuel Supply
- Exhaust Gases

Larger Loads:

- Fuel Supply
- Exhaust Gases
Mechanical Drives

Gas turbine driven compressors result in emissions. In this case:

- 230,000 tonnes (507,000,000 lbs) of CO$_2$
- 230 tonnes (507,000 lbs) of Nox

Heavy taxation in the North Sea

Troll emissions for turbine alternatives (SCGT/CCGT)

Electric motors: No Troll emissions to air
Mechanical Drives

Gas turbine driven compressors have limited speed control

- 90-100% speed at same efficiency
- 70-100% with lower efficiency
Selecting Concept
Evaluation of Gas Turbines vs. Electric Motors

**Gas turbines:**
- Lower investment cost

**Electric motors:**
- No emissions to air
- Secure regarding future environmental constraints
- Possible positive effect on environmental profile
- Confident regarding meeting start up date
- Better with regards to operations, working environment and safety
- Suitable for future low manning mode
Would it not be more cost efficient if...

...we just replaced the gas turbines with electrical motors?

Such large motors (2x40 MW) cannot be fed by the platform electrical system.
What if....

....we supply the motors from shore?

Such powers cannot be transmitted by AC such long distance.

2 x 40 MW (53 640 HP)

70 km/43 miles

NOT PASSED
What if...

....we used HVDC transmission?

Conventional HVDC transmission requires lots of space, is heavy, and requires a certain “short circuit capacity”.

NOT PASSED
But How About if ...

….we use the latest technology VSC based HVDC?

You still need bulky transformers on the platform.
Not if you use the latest technology VHV motors!
The Technology (2)
VSC Based HVDC for Variable Speed Motor Drive

- It is the world’s first VSC based HVDC transmission offshore
- It is the world’s first cable wound VHV motor offshore
- It is the world’s first electrical drive system at 56 kV AC without transformer between inverter and motor.
High Power Voltage Source Converter

Pulse Width Modulation (PWM) with Gate Bipolar Transistors (IGBT)
Higher Voltage Brings Electrical Motors to New Levels

- Experience with motors built for 42 kV and 56 kV.
Technical Highlights on The Motor
Custom Design for a Variable Speed Offshore Motor Installation

Shaft power vs. speed range 1260-1890 rpm
Rated power 40 MW (53640 hp) @ 1800 rpm

No critical speed within 1070-2160 rpm

Class 1, Zone 1, Group IIA, T3

Electrical supply in terms of voltage, current, and frequency
Mechanical Design

Special concerns:
- minimize weight on the platform
- weak foundation (skid) on the platform
- first bending mode need to be >2160 rpm

=>
- Skid dynamic requirements resulted in 15 tonnes increased weight.
The harmonics content has to be considered carefully in the motor electrical/thermal design.

Converter controller is made to minimize harmonic content.

Voltage waveform results in voltage transients on the insulation screen of the motor cable.
Cable Stator Winding

The stator winding consists of one continuous cable per phase, each 1.14 km (0.7 miles), without joints.
Cooling System

Two sub-systems:

- Fresh water circuit for stator core, end plates, and slot
- Water-to-air cooler for rotor, exciter, and stator winding ends (sea water)

- Separate fans to force the inner cooling airflow independently of rotor speed
Suitable Ex Design

Requirement: Class 1, Zone 1, Group IIA, T3

• The motor is of pressurized EEX (p) design with increased safety according to EN 50016

• Temperature class T3 requires that all, internal and external, parts of the machine have maximum surface temperatures of 200°C (392 F).
Motor Protection

All motor protection functions are implemented in the HVDC control and protection system.

**MOTOR PROTECTION**

<table>
<thead>
<tr>
<th>Description</th>
<th>ANSI code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Differential protection</td>
<td>87</td>
</tr>
<tr>
<td>Overload and over current</td>
<td>49 50/51</td>
</tr>
<tr>
<td>Negative sequence current</td>
<td>46</td>
</tr>
<tr>
<td>Harmonic overload</td>
<td>49 51</td>
</tr>
<tr>
<td>Voltage-frequency (U/f)</td>
<td>24</td>
</tr>
<tr>
<td>Over speed Over frequency</td>
<td>12 81H</td>
</tr>
<tr>
<td>Stator ground fault</td>
<td>51G</td>
</tr>
<tr>
<td>Locked rotor and long start</td>
<td>48</td>
</tr>
<tr>
<td>Over and under excitation</td>
<td>76 37</td>
</tr>
<tr>
<td>Diode fault</td>
<td>58</td>
</tr>
</tbody>
</table>
Motor Testing at Factory

- Dielectric testing (on cable, inbetween winding, and on complete motor)
- Electrical characteristics
  - No-load test up to 76 kV
  - Short-circuit test
  - Transient reactance, zero and negative sequence reactance, stator impedance
- Loss measurements
- Heat run tests comprising of three parts
  - No-load
  - Short-circuit
  - Friction
Test Result

The determined efficiency from test for sinusoidal feeding was 97.9%-98.1% for the speed range 70-105%

The balance quality grade of ISO G0.32 (according to ISO 1940) Standard requirements is ISO G2.5

Vibration velocity:

<table>
<thead>
<tr>
<th>Direction</th>
<th>Measured average values</th>
<th>Acceptance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[mm/s]</td>
<td>[in/s]</td>
</tr>
<tr>
<td>Horizontal</td>
<td>0.8</td>
<td>0.031</td>
</tr>
<tr>
<td>Vertical</td>
<td>0.3</td>
<td>0.012</td>
</tr>
<tr>
<td>Axial</td>
<td>0.6</td>
<td>0.024</td>
</tr>
<tr>
<td>Exciter</td>
<td>0.9</td>
<td>0.035</td>
</tr>
</tbody>
</table>

EEX (p) test was successfully completed.
Installation

- Weight: 3500 tonnes (3858 ton)
- Footprint: 300 m² (3229 ft²)

- Weight: 500 tonnes (551 ton)
- Footprint: 300 m² (3229 ft²)
The Offshore Platform

472 meters high (1549 ft)  Total weight: 678 500 tonnes
Water depth: 302 meters (991 ft) (747 918 ton)
<table>
<thead>
<tr>
<th>Event</th>
<th>Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Deliveries</td>
<td>January/March 2004</td>
</tr>
<tr>
<td>Modules Sail Away</td>
<td>May 2004</td>
</tr>
<tr>
<td>Cable Loadout and Installation</td>
<td>May-July 2004</td>
</tr>
<tr>
<td>Spin test</td>
<td>January-April 2005</td>
</tr>
<tr>
<td>Load testing starting</td>
<td>June 2005</td>
</tr>
<tr>
<td>Commercial operation</td>
<td>October 2005</td>
</tr>
</tbody>
</table>

System has been tested at 25 MW
Conclusion

• Offshore platform powered by VSC based HVDC
• Speed control 40 MW compressors with electrical motors at 56 kV
• Significantly higher system efficiency without emissions to air

Key project success factors
• Early selection of technical concept
• Sufficient time to study, mature and qualify selected technology
• Build trust through open, close and good cooperation between all parties
• Common and joint approach to problem solving
Thank you!

QUESTIONS?