Ultra-long Subsea Power Transmission Using Frequency Step-up Equipment

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Subsea Power – Enabling Increased Oil & Gas Recovery

Type 1
- Topside VSDs

Type 2
- Topside VSDs
- Subsea transformers

Type 3
- Subsea VSDs
- Subsea Switchgear

Type 4
- Low Frequency AC
- 4a – Topside VSDs
- 4b – Subsea VSDs

HVDC not covered
- No connectors
- No switchgear
- Too large subsea
- N/A next 5-10 years
  - High power
  - Exists for < 10kV / <10kW
Power System Type 1

Supply: 4160V / 60Hz

Topside

Subsea

24km

28km

1600m and 1700m

BP King MultiBooster

- 2x 1MW 6.6kV
- 2x 2.5MVA VSDs
- 24km & 28km
- 1600m and 1700m

Qualified for 3000m
**Power System Type 2**

Supply: 11kV / 50Hz

- **18MVA 6.6kV**
- **VSD**
- **33kV**
- **13kV**
- **33km**

Qualified for 300m & 3000m

- **Compressor Trafo**
- **Pump & CPDU Trafo**
- **CPDU** (control power distribution unit)

**Åsgard Subsea Compression**

VSD Building 40MVA total

- **Compressor Station**
- **Pump** 6.6kV 750kW

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**Power System Type 3**

- Supply: 132kV / 50Hz
- Topside
- Subsea
- 125km 76/132(145)kV 3x1x240mm²
- 90kV
- 40MVA 90/20kV

**Ormen Lange Pilot**

- 30MW / 22kV Circuit Breaker Module
- 16MVA Compressor VSD Module

- Prototypes Qualified for 900m

- 16MVA UPS Modules A & B
- 500kVA Pump VSD Module

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**Low Frequency AC Transmission Stability**

Graphs showing voltage (Vr) vs. cable length (km) for 100Hz and 50Hz transmission.

100Hz:
- No-load voltage increases with cable length.
- Rated load voltage decreases with cable length.

50Hz:
- No-load voltage increases with cable length.
- Rated load voltage decreases with cable length.

**Low Frequency AC Power Transfer Capability**

**Maximum Power Transfer at 16.7Hz & 50Hz**

Graph showing cable capacity (MW) vs. cable length (km) for different voltage frequencies and cable types.

- 3x1x240mm² cables

**Solution:**
- Reduce transmission frequency
  → Less charging currents
  → Longer step-out
RotoConverter™ - Low Frequency AC for Long Step-out

Power System Type 4

Patented RotoConverter™

- Electrical gear
  - 10-20Hz transmission
  - 50-200Hz generator
- Reduces cable ageing due to low frequency
- More MW, longer step-out
- Works as harmonic filter (due to mass) and phase compensator
- Low weight/size
- Pressure compensated
- Robust due to low mech. speed

Supply: 132kV / 50Hz

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LFAC RotoConverter™ for Subsea Control Systems

Control Power Supply
- LFAC
  - 3-ph or single phase
  - More power
  - Longer step-out
  - Smaller cables
  - An alternative to DC
- Lower transmission voltage
  - Less cable / connector stresses
RotoConverter™ 70kVA/50kW Prototype

70kVA/50kW RotoConverter™
- For Subsea Control Systems
- Permanent Magnet Motor
- 16.7Hz input / transmission frequency
- Permanent Magnet Generator
- 50Hz 50kW output / load motor

Conventional industry / Railway rotating converter design
70kVA/50kW Subsea RotoConverter™ during FAT

Subsea RotoConverter™ during MC checks

Subsea RotoConverter™ during high voltage testing
RotoConverter™ – Prototype Design and Analysis

- Analytically proven:
  - Load flow and short circuit
  - Start-up
  - Harmonics
  - Dynamic load changes

- Verified by:
  - Sintef Energy Research (3rd party)
  - Aker Solutions
  - PMSM - PMSG Supplier / Smart Motor

- 70kVA/50 kW unit test will lift the technology readiness level to:
  - TRL to 4 for small units (<100kVA)
  - TRL to 2 for large units (>10MVA)
Example 1: Subsea Pump Test Set-up and Model

- Scale model with 200km step-out cable simulator
  - 16.7Hz transmission frequency
- 50kW output PMSM-PMSG RotoConverter™
  - 50Hz / 50kW pump load / static control load
Example 1: Start-up Simulations – Results 200km

Proof: Works well at 16.7Hz and not at 50Hz!
70kVA/50kW Prototype FAT completed
- System test to start Q2 2014
- Test with cable simulator H2 2014

Joint Industry Project (JIP) planning for launch on-going
- Identify business case / test field application
- 8MVA/6MW prototype design, construction and qualification test

8MVA/6MW Prototype qualification planned to be completed 1.5-2 years after JIP start
8MVA RotoConverter™ for 6MW Compressors / Pumps

Key data:

- **RotoConverter™ Unit**
  - Weight = 35T
  - LxD = 3.5m x 2.3m

- **Module:**
  - Weight = 50T
  - LxWxH = 5.0 x 4.0 x 6.5 m
    - HV jumper routing decides height

- **Power for 6MW Compressor (example)**
  - **Input:**
    - 8MVA / 6.5MW
    - 19Hz
    - 6.6kV (can be higher / “RotoTransformer”)
  - **Output:**
    - 7MVA / 6MW
    - 210Hz
    - 6.6kV
    - RotoConverter™ shaft speed
      - Approx 300 rpm
      - Oil-filled
      - Low losses due to speed
LFAC / RotoConverter™ – Summary of Subsea Advantages

1. More power / MW @ longer distances
   - Eliminates need for subsea VSD for more prospects
   - Subsea HV and high power up to 50MW and beyond
   - Subsea LV and control power typically <100kW
   - Reduced subsea modules and equipment CAPEX

2. Reduced transmission frequency
   - Smaller cables → less copper
   - Increased transmission cable robustness / lifetime
   - Ultra-long step-out
   - Reduced cable CAPEX

3. Better power system stability
   - Less charging currents and power losses
   - Less voltage variations
   - Works as phase compensator and harmonic filter
Thank you for your attention!

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