Progress On Meshed Offshore HVDC Transmission Networks

Cornelis Plet, DNV GL Energy
Content

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- HVDC Circuit Breaker Testing
  - HVDC circuit breaker technology
  - Test circuit requirements
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  - Test results – mechanical circuit breaker with active current injection
By 2030.....

- 40% cut in greenhouse gas emissions compared to 1990 levels
- 27% share of renewable energy consumption
- 27% energy savings compared with the business-as-usual scenario
- 15% electricity interconnection target
Offshore meshed HVDC transmission network

Need

- Different types of offshore users
- Traditionally connected point-to-point
- Interconnector function
- Dedicated connection, lower utilisation
- Reliability offshore
- Mesh offers benefit
Offshore meshed HVDC transmission network

Challenges

- Offshore requires cables
- Long cables require HVDC
- HVDC requires converters
- HVDC network requires HVDC protection system
- Protection system requires HVDC switchgear / circuit breakers
- Transnational network
PROMOTioN

Objectives

1. Identify technical requirements and investigate possible topologies for meshed HVDC offshore grids
2. Develop protection schemes and components for HVDC grids
3. Establish components’ interoperability and initiate standardisation
4. Demonstrate cost-effective offshore HVDC equipment
5. Develop recommendations for a coherent EU and national regulatory framework for HVDC offshore grids
6. Develop recommendations for financing mechanisms for offshore grid infrastructure deployment
7. Develop a deployment plan for HVDC grid implementation
8. Disseminate results
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Partners

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Test environment for HVDC circuit breakers
Test environment for HVDC circuit breakers

HVDC circuit breaker principle

\[ \frac{d i_{SC}}{d t} = \frac{V_{DC}}{L} > 0 \]
Test environment for HVDC circuit breakers

HVDC circuit breaker principle – current suppression by counter voltage

\[
\frac{di_{SC}}{dt} = \frac{V_{DC} - 1.5V_{DC}}{L} < 0
\]
Test environment for HVDC circuit breakers

HVDC circuit breaker principle

\[ V_{DC} = 0 \]
Test environment for HVDC circuit breakers

HVDC circuit breaker principle
Test environment for HVDC circuit breakers

HVDC circuit breaker principle
Test environment for HVDC circuit breakers

HVDC circuit breaker principle

DC circuit breaker

V_{DC}
Test environment for HVDC circuit breakers

HVDC circuit breaker principle - modularity
Test environment for HVDC circuit breakers

HVDC circuit breaker topologies

- **Mechanical circuit breakers**
  - Active current injection
  - Passive resonance
  - Active resonance

- **Hybrid circuit breakers**
  - Thyristor based
  - IGBT based

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Test environment for HVDC circuit breakers

Current interruption test circuit requirements

1. Normal operation
   - Apply heating – Pre-condition
   - Supply power to auxiliary systems

2. Current commutation time
   - Supply sufficient $\frac{di}{dt}$
   - Bidirectional

3. Fault suppression time
   - Supply sufficient energy
   - Withstand Transient Interruption Voltage

4. Post suppression
   - Apply DC voltage stress

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Test environment for HVDC circuit breakers

Reduced frequency AC short-circuit generator based test circuit

- Test circuit parameters
  - Generator frequency
  - Circuit inductance
  - Magnitude of source voltage
  - Making angle
Test environment for HVDC circuit breakers

Realizing test duties

\[ t_1 = \text{short circuit making moment} \]
\[ t_2 = \text{send trip signal to the test breaker} \]
Test environment for HVDC circuit breakers

Implementation with mechanical circuit breaker with active current injection

Frequency: 16.7 Hz
Interrupting current: ±2 kA - ±16 kA
Breaker operation time: 8 ms
Voltage rating: 72.5 kV / 108 kV
Energy dissipation: 1 - 4 MJ

- VI: Vacuum Interrupter
- HSMS: High Speed Making Switch
- \( C_p \): Capacitor
- \( L_p \): Reactor
Test environment for HVDC circuit breakers

**KEMA Laboratory set-up**

- Triggered making gap
- DCCB Control Panel
- Reactors
- Counter current injection capacitors
- Auxiliary SF$_6$ AC CB
- HV and making vacuum interrupter switch
- Energy absorbing MOSA

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Test environment for HVDC circuit breakers

**Test results – 16 kA positive & 3.6 MJ**

Energy absorbed by HVDC CB

- **Prospective current**
- **Interrupted current**

- **Current through MOSA**

- **Counter voltage generated by HVDC CB**

- **Dielectric stress**

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Conclusions

- HVDC technology required to enable development of large scale offshore wind and interconnection capacity in Northern Seas
- Meshed grids potentially offer advantages over radial connections
- PROMOTioN addresses technical, regulatory, economical and legal challenges to the implementation of a meshed HVDC network
- HVDC circuit breaker technology still immature but developing quickly
- Reduced frequency AC short-circuit generators can be used to test DC circuit breakers’ current interruption performance
- Current interruption of Mitsubishi Electric mechanical circuit breaker with active current injection successfully demonstrated in KEMA Laboratories