Progress on Meshed HVDC Offshore Transmission Networks

WindEurope, 03-04-2019, Nicolaos A. Cutululis
PROMOTiOn Context

European Commission Energy Strategy 2030

40% Cut in greenhouse gas emissions compared to 1990 levels

32% Share of renewable energy consumption

27% Energy savings compared with the business-as-usual scenario

15% Electricity interconnection target
Go like the wind...

**EUROPE ELECTRICITY CAPACITY (FIGURE 3-5)**

- **Units:** TW
- **Energy source**
  - Geothermal
  - Offshore wind
  - Onshore wind
  - Solar thermal
  - Solar PV
  - Biomass-fired CHP
  - Biomass-fired
  - Hydro
  - Nuclear
  - Oil-fired
  - Gas-fired CHP
  - Gas-fired
  - Coal-fired CHP
  - Coal-fired

Source: DNV GL - Energy Transition Outlook

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This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 691714.
New Transmission Infrastructure

TYNDP 2016 Projects Map
Select a line, station or bubble for more information on that project.

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Why a meshed grid?

• Different types of offshore users
  • Consumers
  • Producers
  • Interconnectors
• Traditionally connected point-to-point, dedicated connection
  • Lower utilisation
  • Reliability offshore
• Mesh offers benefit
**PROMOTiON Context**

**Challenges**

- Offshore requires cables & platforms
- Long cables require HVDC
- HVDC requires converters
- HVDC network requires HVDC control & protection system
- HVDC protection system requires HVDC switchgear / circuit breakers
- Transnational network
  - Regulatory differences
  - Business models
  - Governance
  - Financing

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PROMOTioN Objectives

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
PROMOTioN Project organisation

Work packages

WP1 – Requirements for meshed offshore grids - TenneT

WP2 Grid topology & Converters
   RWTH Aachen

WP3 Grid topology & Converters interaction
   DTU

WP4 HVDC Grid Protection Systems
   KU Leuven

WP5 Test environment for HVDC CB
   DNV GL

WP6 HVDC CB performance characterisation
   UniAberdeen

WP15 HVDC GIS Demonstrator
   ABB

WP7 Regulation & Financing
   TenneT

WP13 Dissemination
   SOW

WP14 Project Management
   DNV GL

WP16 MMC Test bench demonstrator
   RWTH Aachen

WP9 Protection system demonstration
   SHE Transmission

WP10 HVDC Circuit Breaker demonstration
   DNV GL

WP11 – Harmonisation towards standardisation - DTU

WP12 - Deployment plan for future European offshore grid - TenneT

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Bilbao, 03-04-2019
PROMOTiON The Project

Demonstrators

**HVDC network control**
- MMC test bench
- RWTH Aachen
- Aachen, Germany

**HVDC network protection**
- Multi-terminal test centre
- SHE Transmission
- Glasgow, UK

**HVDC circuit breakers**
- KEMA High Power Lab
- DNV GL
- Arnhem, Netherlands

**HVDC gas insulated system**
- KEMA High Voltage Lab
- DNV GL
- Arnhem, Netherlands
Statistics

33 partners

11 countries

4 years

42 million EUR
WTG Control capability evolution

- **Grid Following**
  - P Control
  - Q Control
  - Require powered grid
  - High SCR
  - High Inertia

- **Grid Supporting**
  - ω Support
  - V Support
  - Require powered grid
  - Low SCR
  - Low Inertia

- **Grid Forming**
  - ω Control
  - V Control
  - Islanded operation SCR=0
  - Zero Inertia
  - Shared control effort

Increasing percentage of PE based renewable energy

Source: Prof. R. Blasco-Jimenez, UPV
rblasco@upv.es
WP3 WTG – Converter interaction

Diode Rectifier Units as offshore HVDC

Current VSC solution

New DRU solution

Key features of the Modular Diode Rectifier Unit:
- Encapsulated, rugged equipment
- Biodegradable and flame resistant insulation
- Simple and robust power electronics
- Small platforms with easy transport and installation
- High reliability, minimal maintenance
- No offshore DC converter as single point of failure
- Flexibility for installation options due to modular rectifier concept

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Grid Forming Wind Turbines

Grid forming wind turbines control
- dq current control based
- voltage/angle control based
- GPS synchronization based
- master/slave based
WP3 WTG – Converter interaction

Objectives

Objective 1
Define functional requirements to OWFs

Objective 2
Develop test cases & control algorithms

Objective 3
Define & apply compliance evaluation

Objective 4
Recommend grid code requirements

Objectives

Objectives

DRU
Diode Rectifier Unit

HVDC link

VSC onshore

Grid Forming WPP

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Offshore AC Grid Start-up Options

**Umbilical AC Cable**

**Nearby VSC-HVDC (or AC)**

**Local Energy Storage (e.g. battery, diesel)**

**Black-startable wind turbines**

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Some results – AC grid start-up (string connection)
Next steps - Demonstrator

• CHIL validation (WP16 – DNV-GL, RWTH Aachen, UPV):
  • DRU connected grid forming wind power plants
  • Black start for HVAC connected wind power plants
  • Black start for HVDC connected wind power plants
  • HVDC grid connected WPPs
WP3 WTG – Converter interaction

WP3 Preliminary list of Recommendations for Requirements
DRU-HVDC connected WPPs

- Grid forming WTs for DRU connection
  - Energization
  - Operational ranges (e.g. V, f, df/dt)
  - Control gains (e.g. droop, reserve)
  - Onshore and offshore FRT (100% Power-Electronics)

https://www.promotion-offshore.net/fileadmin/PDFs/D3.4_PROMOTioN_Results_on_control_strategies_of_WPPs_connected_to_DR-HVDC.pdf
WP3 WTG – Converter interaction

WP3 Preliminary list of Recommendations for Requirements
HVAC & VSC-HVDC connected WPPs

➢ Self-Energization and Black Start requirements for OWPPs

HVAC-connected OWPP

HVDC-connected OWPP(s) with AC collector substation(s)

HVDC-connected OWPP(s) directly (66kV) connected to the HVDC
APPENDIX

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