HALF YEARLY MEETING
UNIVERSITY OF ABERDEEN, ABERDEEN, UK
31 MAY until 2 JUNE 2017

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 691714.
AGENDA for PROMOTioN, half-yearly meeting Aberdeen

Date : Wednesday 31 May – Friday 2 June 2017
Venue : Fraser Nobel Building & Meston building – please see campus map

University of Aberdeen
Elphinstone Road
Aberdeen, AB24 3UE

AGENDA

Wednesday 31 May, Work package meetings

- Presentation of results so far
- Discussion of the results
- Plan for future work

<table>
<thead>
<tr>
<th>Meeting</th>
<th>Time</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>WP1 and WP12 (combined)</td>
<td>09:00 – 17:00</td>
<td>Fraser Noble building, room FN114</td>
</tr>
<tr>
<td>WP2</td>
<td>09:00 – 17:00</td>
<td>Fraser Noble building, room FN113</td>
</tr>
<tr>
<td>WP3</td>
<td>10:00 – 16:30</td>
<td>Fraser Noble building, room FN115</td>
</tr>
<tr>
<td>WP4</td>
<td>09:00 – 17:00</td>
<td>Fraser Noble building, room FN116</td>
</tr>
<tr>
<td>WP5 and WP6 (combined)</td>
<td>09:00 – 17:00</td>
<td>Fraser Noble building, room FN110</td>
</tr>
<tr>
<td>WP7</td>
<td>10:00 – 16:30</td>
<td>Meston building, room G05</td>
</tr>
<tr>
<td>WP13 and WP14 (combined)</td>
<td>17:30 – 18:00</td>
<td>Fraser Noble building, room FN110</td>
</tr>
<tr>
<td>Lunch time</td>
<td>12:30 – 13:30</td>
<td>Building ‘The Hub’</td>
</tr>
</tbody>
</table>

Thursday 1st of June, Plenary meeting, Fraser Noble building, room FN1

Presentation of results and deliverables from work packages (15 min presentation 15 min discussion)

09:00 – 09:20    Opening and welcome (Prof J. Kilburn, vice principal, University of Aberdeen)
09:20 – 09:30    Introduction (DNV GL)
09:30 – 10:00    WP1 (TenneT)
10:00 – 10:30    WP2 (RWTH)
10:30 – 11:00    Coffee break
11:00 – 11:30    WP3 (DTU)
11:30 – 12:00    WP4 (KUL)
12:00 – 12:30    WP5 (DNV GL)
12:30 – 13:30    Lunch (building ‘The Hub’)  
13:30 - 14:00    WP6 (UniAbdn)
14:00 - 14:30    WP7 (TenneT)
14:30 - 15:00    WP8 (Siemens)
15:00 - 15:30    Tea break
15:30 - 16:00    WP12 (TenneT)
16:00 - 16:30    WP13 (SOW)
16:30 – 17:00  Day closing
18:00  Dinner  (building Elphinstone hall)

The dinner will be held in ‘Elphinstone Hall’ (building number 25 on the campus map).

Friday 2nd of June, General Assembly, Fraser Noble building, room FN1**
09:00 – 09:30  General project & consortium issues
09:30 – 10:40  Update about upcoming amendments & status WP8
10:40 – 11:00  Wrap up & Closing
11:00 – 14:30  PMG Meeting (room FN110 for WPL’s)
12:00 – 13:00  Lunch (building ‘The Hub’)

** General Assembly: every beneficiary should be represented by one representative with right to vote; more representatives allowed
WP1 Update Aberdeen

June 1, 2017
CONTENT

• Wrap-up of our achievements in WP1 so far
• Presentation of our plan for task 1.5, D1.7; Review of requirements (M20-24)
• Presentation of results from D1.6; the draft roadmap
• Room for questions
Wrap-up of achievements
WP1
WorkPackage 1 – Within the PROMOTioN project
WP1 Update Aberdeen

WorkPackage 1 – Tasks and Deliverables
WP1 update Aberdeen

Task 1.1 Deliverables

<table>
<thead>
<tr>
<th>D1.1</th>
<th>• Qualitative set of requirements. Delivered in April 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1.2</td>
<td>• Questionnaire and Workshops. Delivered beginning of 2017</td>
</tr>
<tr>
<td>D1.3</td>
<td>• Literature review. Delivered in September 2016. Please take the effort to read the executive summary!</td>
</tr>
<tr>
<td>D1.4</td>
<td>• Reference scenario’s. Delivered in beginning of 2017</td>
</tr>
<tr>
<td>D1.5</td>
<td>• Quantitative set of requirements. Delivered in beginning of 2017</td>
</tr>
<tr>
<td>D1.6</td>
<td>• Draft Roadmap. Almost finalized</td>
</tr>
<tr>
<td>D1.7</td>
<td>• Re-evaluation of the requirements. Starts in June</td>
</tr>
</tbody>
</table>
Task 1.5, D1.7; Review of requirements
WP1 update Aberdeen; Task 1.5

**Context of Task 1.5; D1.7**

An opportunity to review requirements from WP1 with the knowledge and experience gained in the rest of the project, and to develop requirements further where most valuable!
Approach task 1.5

2 Workstreams

• Split workload
  • Stream 1: Evaluate quantification of requirements from D1.5
  • Stream 2: Evaluate and complement non-quantified requirements from D1.1

• Determine relevant partners for each stream
  • Execution of both streams in parallel > in the end only one document!

M17-M19 M20-M22 M23-M24
Preparation Execution Completion

We will reach out to you during the summer to discuss your involvement, and discuss where you think an update of the requirements is most valuable.

• Proactive input is much appreciated!
## WP1 Update Aberdeen

### Contributors

**Task 1.5 members:**
- TenneT (Task Lead)
- EIRGRID
- Energinet
- RTE
- Statoil
- SOW
- Tractebel

**Other contributors (WP1):**
- ABB
- Alstom
- Carbon Trust
- DNV-GL
- DONG
- DTU
- DWG
- FGH
- RWTH Aachen
- SGI
- SHE Trans
- Siemens
- TU Delft
- T&D Europe
- USTRAT

**AND:**
- WP2
- WP3
- WP4
- WP5
- WP6
- WP7
Introduction

Objective of the task

• Derivation of a draft offshore grid development roadmap for the evacuation of offshore wind energy during the decade 2020-2030
  • Identification of factors impacting the grid topology
  • Analysis of the economic viability
  • Identification of the main questions that must be solved to provide a comprehensive study

• Not a “complete” draft roadmap
  • Several aspects ignored
    • Because they are being considered in other WPs
    • Or not fully developed yet
Introduction

Scope and main assumptions

• Geographical scope: North Sea
  • Scope of PROMOTioN: North Seas

• Temporal scope: 2020-2030
  • Need for an offshore grid is expected to begin in that decade, but should increase after → the period 2020-2050 will be considered in WP12

• Reference scenario for potential installed wind capacities in the North Sea: D1.4
  • 2020-2030: +37 GW

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>OFFSHORE WIND GENERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>1,700 MW</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>4,444 MW</td>
</tr>
<tr>
<td>France</td>
<td>3,005 MW</td>
</tr>
<tr>
<td>Germany</td>
<td>7,389 MW</td>
</tr>
<tr>
<td>Denmark</td>
<td>1,310 MW</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>19,360 MW</td>
</tr>
</tbody>
</table>

• Voltage level
  • 320kV xor 525kV
Approach for a reference offshore grid expansion plan

Main steps

1. Planning criteria
2. Optimization of the global topology (OTEP)
3. More detailed design based on a technical analysis
4. Analysis of the economic viability based on market simulations
Main results

Main cost assumptions

• Cost components considered: cables, converters (incl. platforms), DCCBs

• But the optimization optimizes only the topology and considers thus only the cables (and the additional platforms), and not converters and DCCBs

• Needs to be improved, and take into account learning and scale

<table>
<thead>
<tr>
<th>VOLTAGE (KV)</th>
<th>RATING (MW)</th>
<th>COST (M€/KM) – INCLUDING INSTALLATION, FOR TWO POLES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>UNDERSEA CABLES</td>
</tr>
<tr>
<td>320</td>
<td></td>
<td></td>
</tr>
<tr>
<td>600</td>
<td>1.08</td>
<td></td>
</tr>
<tr>
<td>800</td>
<td>1.23</td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td>1.38</td>
<td></td>
</tr>
<tr>
<td>1200</td>
<td>1.53</td>
<td></td>
</tr>
<tr>
<td>525</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td>1.48</td>
<td></td>
</tr>
<tr>
<td>1300</td>
<td>1.63</td>
<td></td>
</tr>
<tr>
<td>1600</td>
<td>1.78</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>1.93</td>
<td></td>
</tr>
</tbody>
</table>

### Main cost assumptions

- **Cost components considered**: cables, converters (incl. platforms), DCCBs.
- **But the optimization optimizes only the topology** and considers only the cables (and the additional platforms), and not converters and DCCBs.
- **Needs to be improved**, and take into account learning and scale.

<table>
<thead>
<tr>
<th>Voltage (KV)</th>
<th>Rating (MW)</th>
<th>Cost (M€/KM)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>Offshore VSC (incl. Platform)</strong></td>
</tr>
<tr>
<td>320</td>
<td>600</td>
<td>140</td>
</tr>
<tr>
<td></td>
<td>800</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>220</td>
</tr>
<tr>
<td></td>
<td>1200</td>
<td>260</td>
</tr>
<tr>
<td>525</td>
<td>1000</td>
<td>220</td>
</tr>
<tr>
<td></td>
<td>1300</td>
<td>280</td>
</tr>
<tr>
<td></td>
<td>1600</td>
<td>340</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>420</td>
</tr>
</tbody>
</table>
Main results

Four cases are studied

• One base case and three variants
  • Changes in cost estimation, but topologies are the same

<table>
<thead>
<tr>
<th>#</th>
<th>Hypothesis</th>
<th>Base Case</th>
<th>Variant 1</th>
<th>Variant 2</th>
<th>Variant 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Commercial availability of DRU converters (but only for radial, point-to-point connections)</td>
<td>✗</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>2</td>
<td>Commercial availability of Mechanical DCCBs</td>
<td>✗</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Main results

Resulting draft topologies

• Reference radial solution in 2030 (for comparison)
  • 525kV
Main results

Resulting draft topologies

- Reference coordinated solution in 2030
  - 525kV
## Main results

### Resulting draft topologies

- **Reference radial solutions:** total investment costs in 2030

<table>
<thead>
<tr>
<th>Equipment Cost [M€]</th>
<th>Base Case</th>
<th>Variant 1</th>
<th>Variant 2</th>
<th>Variant 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Radial Solution 320 kV</td>
<td>Radial Solution 525 kV</td>
<td>Radial Solution 320 kV</td>
<td>Radial Solution 525 kV</td>
</tr>
<tr>
<td>Offshore VSC Converters</td>
<td>11,880</td>
<td>0</td>
<td>11,880</td>
<td>0</td>
</tr>
<tr>
<td>Offshore DRU Converters</td>
<td>0</td>
<td>7,901</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Onshore VSC Converters</td>
<td>6,160</td>
<td>6,160</td>
<td>6,160</td>
<td>6,160</td>
</tr>
<tr>
<td>Submarine HVDC Cables</td>
<td>9,122</td>
<td>9,122</td>
<td>9,122</td>
<td>9,122</td>
</tr>
<tr>
<td>Offshore platform extensions</td>
<td>120</td>
<td>0</td>
<td>120</td>
<td>0</td>
</tr>
<tr>
<td>DC Circuit Breakers</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total CAPEX</strong></td>
<td><strong>27,282</strong></td>
<td><strong>29,122</strong></td>
<td><strong>23,303</strong></td>
<td><strong>25,108</strong></td>
</tr>
</tbody>
</table>
Main results

Resulting draft topologies

- Reference coordinated solutions: total investment costs in 2030

<table>
<thead>
<tr>
<th>Equipment Cost [M€]</th>
<th>Base Case</th>
<th>Variant 1</th>
<th>Variant 2</th>
<th>Variant 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore VSC Converters</td>
<td>11,880</td>
<td>3,260</td>
<td>11,880</td>
<td>3,260</td>
</tr>
<tr>
<td>Offshore DRU Converters</td>
<td>0</td>
<td>5,732</td>
<td>0</td>
<td>5,732</td>
</tr>
<tr>
<td>Offshore VSC Converters</td>
<td>5,160</td>
<td>5,160</td>
<td>5,160</td>
<td>5,160</td>
</tr>
<tr>
<td>Submarine HVDC Cable</td>
<td>8,318</td>
<td>8,318</td>
<td>8,318</td>
<td>8,318</td>
</tr>
<tr>
<td>Offshore platform extensions</td>
<td>510</td>
<td>510</td>
<td>510</td>
<td>510</td>
</tr>
<tr>
<td>DC Circuit Breakers</td>
<td>5,616</td>
<td>5,616</td>
<td>127</td>
<td>127</td>
</tr>
<tr>
<td>Total CAPEX</td>
<td>31,484</td>
<td>28,596</td>
<td>25,994</td>
<td>23,107</td>
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</tbody>
</table>
Main results

Results of the CBA

• Comparison of the CAPEX (costs) and the Generation Cost Savings (benefits) of the coordinated solutions versus the radial solutions

<table>
<thead>
<tr>
<th>Meshed – Radial 320 kV</th>
<th>ΔCAPEX (M€)</th>
<th>Actualized GCS¹⁴ (M€)</th>
<th>NPV (M€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Case [M€]</td>
<td>4,202</td>
<td>-2,867</td>
<td>-1,335</td>
</tr>
<tr>
<td>Variant 1 [M€]</td>
<td>5,293</td>
<td>-2,867</td>
<td>-2,426</td>
</tr>
<tr>
<td>Variant 2 [M€]</td>
<td>-1,287</td>
<td>-2,867</td>
<td>4,154</td>
</tr>
<tr>
<td>Variant 3 [M€]</td>
<td>-196</td>
<td>-2,867</td>
<td>3,063</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Meshed – Radial 525 kV</th>
<th>ΔCAPEX (M€)</th>
<th>Actualized GCS (M€)</th>
<th>NPV (M€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Case [M€]</td>
<td>4,878</td>
<td>-2,211</td>
<td>-2,667</td>
</tr>
<tr>
<td>Variant 1 [M€]</td>
<td>5,981</td>
<td>-2,211</td>
<td>-3,770</td>
</tr>
<tr>
<td>Variant 2 [M€]</td>
<td>-3,308</td>
<td>-2,211</td>
<td>5,519</td>
</tr>
<tr>
<td>Variant 3 [M€]</td>
<td>-2,206</td>
<td>-2,211</td>
<td>4,417</td>
</tr>
</tbody>
</table>
Conclusions & Perspectives

Conclusions

• Main deductions from this first approach
  • The DCCBs capabilities and costs will drastically impact the business case of coordinated solutions such as meshed grids
    • If need of expensive DCCBs, only offshore wind farms far from the shore will be part of the offshore grid
  • The DRUs capabilities and costs will drastically impact the business case of coordinated solutions such as meshed grids
    • If they can be used only for radial point-to-point connections and if they are cheap, only the cost of radial solutions decrease
  • The hosting capacity of the onshore grid could strongly impact the grid topology, but possible onshore grid reinforcements
    • Importance of coordinated planning
  • Uncertainties about the way the grid will be operated (e.g. security rules, market rules) – they also impact the business case
Conclusions & Perspectives

To be developed further in WP12

• Limitations in the current approach that will have to be overcome within WP12 (development of an “optimal scenario”)
  • Only HVDC connections considered in the OTEP problem, but importance of HVAC connections
  • Offshore wind farms separated by short distances are connected individually, but in reality they could be clustered to be connected together
  • Need for DCCBs not considered in the OTEP problem, but could impact drastically the topology
  • Exchanges of energy between different market areas should be considered in the sizing of the grid
  • The N-1 security criterion is not considered in the OTEP problem, but should be
  • Countries might require that wind generated in their economic zone is connected to their onshore grid
Main open questions

• Planning criteria
  • Requirements on the system reliability (adequacy & security)?
  • Will be discussed within Task 1.5

• Technical capabilities of the DRU
  • Purely radial point-to-point or coordinated structures?
  • Feedback expected from WP2

• Short-circuit constraints
  • Impact on the topology?
  • Feedback on DCCBs capabilities expected from WPs 5, 6, 10

• Market organization
  • Organization of market areas and transfer between areas?
  • Could impact significantly the CBA
  • Where do we discuss/study that?
The end.

• Questions?
Approach for a reference offshore grid expansion plan
Planning criteria for an offshore grid
Planning criteria for an offshore grid

What are planning criteria?

• In a nutshell: reliability (adequacy & security) requirements
  • The power system must be able to accommodate power flows and endure contingencies while staying within acceptable working conditions

• Transmission planning criteria typically cover
  • The system states and the contingencies (including faults) to study
  • The acceptable system operating limits in normal operation (pre-contingency) and post-contingency states
  • The acceptable response of the system to outages and to fault disturbances

• The choice of planning criteria impacts the CBA
  • They must be discussed with all partners
  • In D1.6: provisional planning criteria
Categorization of planning criteria for an offshore HVDC grid

• Requirements on the system performance under normal conditions

• Requirements on the system performance following a single contingency (N-1 security criteria)

• Requirements on the system performance following several or extreme contingencies
Planning criteria for an offshore grid

System performance under normal conditions

• Requirements
  • When all HVDC transmission elements are available and all offshore wind generators are at their maximum (nominal) power output, it must be possible to set the onshore converters such that
    • Power flows within HVDC transmission elements are below the normal (continuous) ratings
    • Voltage at all nodes of the offshore HVDC grid are between 0.95 pu and 1.05 pu

• Comments
  • Voltage range: from D1.5
  • “European approach”: we do not impose a national evacuation of offshore power
    • It might change within WP12
  • Only offshore peak generation analysed
Planning criteria for an offshore grid

System performance following a single contingency

• Requirements
  • Following a single (N-1) contingency,
    • The system must stay electrically stable
    • No uncontrolled cascading outage is allowed (but the disconnection of an offshore wind farm radially connected, or an action of an automatic RAS is allowed)
    • Electrical variables (e.g. power flows, voltages) must be within emergency operating limits just after the contingency, once the automatic voltage droops of converter controllers have stabilized the system, and they should go back to normal (continuous) operating limits after system adjustments
    • The permanent loss of power infeed into the onshore grids must be below 3 GW for CE, 1.35 GW for Nordic countries, 1.8 GW for GB and 0.5 GW for Ireland
  • Pre-contingency state: same as under normal conditions, i.e. peak generation
  • Single contingencies: loss of a converter, loss of a cable with/without a fault, loss of an overhead line with/without a fault
    • Faults: pole-to-ground cable faults (permanent), pole-to-ground OHL faults (transient and permanent), pole-to-pole OHL fault (transient)
Planning criteria for an offshore grid

System performance following a single contingency

• Comments
  • Permanent loss of power infeed: values from D1.5
  • No criteria (for the moment) on the transient loss of power infeed
  • Faults considered: from D2.1
  • System electrically stable
    • Onshore AC grid: standard criteria
    • Offshore HVDC grid: criteria?
      • Some parts of the HVDC grid could be fully disconnected after the fault occurrence and re-energized after the fault clearing
Main results
Conclusions & Perspectives
Conclusions & Perspectives

Conclusions

- Main deductions from this first approach
  - The DCCBs capabilities and costs will drastically impact the business case of coordinated solutions such as meshed grids
    - If need of expensive DCCBs, only offshore wind farms far from the shore will be part of the offshore grid
  - The DRUs capabilities and costs will drastically impact the business case of coordinated solutions such as meshed grids
    - If they can be used only for radial point-to-point connections and if they are cheap, only the cost of radial solutions decrease
  - The hosting capacity of the onshore grid could strongly impact the grid topology, but possible onshore grid reinforcements
    - Importance of coordinated planning
  - Uncertainties about the way the grid will be operated (e.g. security rules, market rules) – they also impact the business case
Status – WP 2
Grid Topology & Converters
Objectives of WP2

• Identification of minimum requirements for offshore grids
  • Multiterminal grids
  • Meshed grids

• Feasibility assessment
  • Interoperability of different converter types (DRU/ MMC-HB/ MMC-FB/ others)
  • Meshed offshore grids
  • Analysis of steady state, dynamic and transient behaviour of offshore grids
    • Characteristics of grid topologies

• Analysis of grid code compliance

• Recommendation of requirements for standardization of HVDC (offshore) grids
Status WP 2

Timeline WP 2

2.1 Definition of model parameters, control objectives and operational assumptions for the meshed HVDC offshore topologies
   ✓ D 2.1: Grid topology and model specification

2.2 Adaptation of simulation models for the meshed HVDC offshore topologies
   → D 2.2: Scenario and test case specification

2.3 Simulative investigation and functionality demonstration of the meshed HVDC offshore topology system interoperability
   → D 2.3: Simulation results and benchmark

2.4 Define recommendations for minimum requirements on onshore and offshore power systems
   → D 2.4: Requirements for grid code extension
Model implementation progress

Detailed EMT Model set-up in PSCAD
- Based on Cigré working group B4.69
- Adaptation to parameter settings from D2.1
- Implementation of network structure
- Library created

RMS model set-up in various tools
- Based on parameters and control structure of EMT model
- Level of detail according to research scope

Quasi-stationary model set-up in Integral
- Based on data from TYNDP
Status WP 2

Timeline Task 2.2

Kick-off 09.01. – 10.01.17 at Tractebel, Brussels
- Discussion research aims
- Existing model presentation
- Identification of needed model development
- Draft test cases

Several Webmeetings and Telcos
- Regularly presentation on Model Status
- Presentation and Discussion Grid controller
- Discussion and Finalization of model validation procedure
- Definition of KPI
- Presentation of first test results
Status WP 2

Timeline Task 2.2

Work Meeting 31.05.2017, Aberdeen

- Presentation and discussions of developed building block models
- Discussion of results of validation procedure
- Review procedure for upcoming deliverable
- Transition from task 2.2 to task 2.3

D2.2 : Scenario and test case specification (M18)

- Specification list of investigated scenarios with exact nomenclature and report on test case simulation results
- Main deliverable: model
  → Review includes model review
Status WP2

Developed EMT Models

Overlaying system control

Strathclyde

VSC WPP-Model provided by WP3

VSC-Model based on Cigré, prepared by RWTH

Cable models based on Prysmian’s parameters, prepared by RWTH

VSC Model based on Cigré, prepared by RWTH

Offshore Wind

Offshore Converter

DRU WPP-Model provided by WP3 (M24)

DRU-Model prepared by UPV & Siemens

DC CB Model provided by WP 6

HVDC Grid Protection system by WP 4 (on-going work)

Strong, moderate and weak AC grid representation (RWTH)

Onshore Converter

AC Grid

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 691714.
Status WP2

Validation

• Validation of model behaviours by previously defined test cases with the test model (steady state, set point changes, faults)
• Curve comparison (general behaviour)
• Assessment of possible deviations in p.u. or statement
## Status WP2

### Defined Key Performance Indicators (KPI) for different studies

1. **Steady State**
2. **Set Point Changes**
3. **Fault analysis**

<table>
<thead>
<tr>
<th>Key Performance Indicators</th>
<th>Validation by</th>
<th>Comments/Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC voltage ripple at DC terminals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC current ripple at DC terminals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>THD of the AC networks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arm current peak and RMS values</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg. Capacitor voltage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circulating currents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC active/reactive power</td>
<td>Curve comparison/Statement</td>
<td></td>
</tr>
<tr>
<td>AC grid voltage/currents</td>
<td>Curve comparison/Statement</td>
<td></td>
</tr>
<tr>
<td>DC power</td>
<td>Curve comparison/Statement</td>
<td></td>
</tr>
<tr>
<td>DC voltages/currents</td>
<td>Curve comparison/Statement</td>
<td></td>
</tr>
<tr>
<td>Arm currents</td>
<td>Curve comparison/Statement</td>
<td></td>
</tr>
<tr>
<td>Capacitor voltage (min, max, avg.)</td>
<td>Curve comparison/Statement</td>
<td></td>
</tr>
<tr>
<td>Absorbed energy of surge arresters</td>
<td>Curve comparison/Statement</td>
<td></td>
</tr>
</tbody>
</table>
## Defined Test Cases for Validation

### Set Point Changes

<table>
<thead>
<tr>
<th>Test cases</th>
<th>LF Scenario</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step of demanded active power for AC onshore grid</td>
<td>Scenario 1</td>
<td>$P_{set_rate} = 4\ p.u/s$</td>
</tr>
<tr>
<td>$P_{C2}(t_0) = 1\ p.u. \rightarrow P_{C2}(t_1) = -1\ p.u.$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_{C2}(t_0) = -1\ p.u. \rightarrow P_{C2}(t_1) = 1\ p.u.$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 p. u. = 1200 MW</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step of demanded reactive power for AC onshore grid</th>
<th>LF Scenario</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Q_{C2}(t_0) = 1\ p.u. \rightarrow Q_{C2}(t_0) = -1\ p.u.$</td>
<td>Scenario 1</td>
<td>$Q_{set_rate} = 4\ p.u/s$</td>
</tr>
<tr>
<td>$Q_{C2}(t_0) = -1\ p.u. \rightarrow Q_{C2}(t_0) = 1\ p.u.$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 p. u. = 400 MVAr</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Fault analysis

<table>
<thead>
<tr>
<th>Test cases</th>
<th>LF Scenario</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC line fault for HB+CB</td>
<td>Scenario 1</td>
<td>Fault: P-G, P-P-G</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Location: 0%, 50%, 100%</td>
</tr>
<tr>
<td>DC line fault for FB + blocking</td>
<td>Scenario 1</td>
<td>Fault: P-G, P-P-G</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Location: 0%, 50%, 100%</td>
</tr>
<tr>
<td>HB Converter AC fault</td>
<td>Scenario 1</td>
<td>Fault: P-G</td>
</tr>
<tr>
<td>FB Converter AC fault</td>
<td>Scenario 1</td>
<td>Fault: P-G</td>
</tr>
<tr>
<td>AC Faults</td>
<td>Scenario 1</td>
<td></td>
</tr>
</tbody>
</table>
• Presentation, discussion and approval of developed models
• Presentation of DC Grid EMT and RMS model status
  • VSC: presentation and discussion of all building blocks including controls
  • DRU: presentation and discussion of all building blocks including windfarm
• Presentation of DC grid controller
  • Sets power and voltage references
  • Overall control of the DC grid during normal and abnormal operation
• Presentation of WPP models for RMS and EMT analyses
  • Comparison of RMS and EMT model
  • WTG and OWF control developed in WP3
• Presentation of AC grid model
  • Included grid models: UK, Continental Europe, Nordic 32, (different) MOG structures
  • Validation procedure in last steps
Status WP2

Work Meeting Aberdeen 31.05.2017 (2/2)

• Presentation of DRU model (EMT and RMS)
• Presentation of DC Grid steady state model status
  • Presentation of SCOPF method for integration of MOG in grid analysis
  • Modeling of operational strategies
  • Task 2.2 deadline cannot be kept for the steady state model in INTEGRAL but implementation of SCOPF ahead of schedule (Task 2.3)
  • Steady state model validation in EUROSTAG in last steps
• Planning of Kick-Off for Task 2.3

• EMT Model will be shared to be used in other WPs
Status WP 2

Next Period

9.-10.01.2017
Kick-Off Task 2.2 Brussels

31.05.2017
Aberdeen

July 2017
Kick-off Task 2.3

On going- preparations for task 2.3:
• Detailed specification of research questions
• Set-up of simulation plan
• Close collaboration with task leaders

30.06.2017
Finalization Deliverable 2.2
MS10 : Simulation models are set up

January 2019
WP 3
Wind Turbine – Converter Interaction

Ömer Göksu
DTU Wind Energy

01 June 2017, Aberdeen, 3rd Half-Yearly Meeting, Plenary Session
WP3 Objectives

1. define functional requirements to OWFs, focusing on DR-HVDC case
2. develop general control algorithms for OWFs, focusing on DR-HVDC case
3. define and apply compliance evaluation procedures for OWFs by simulations

verify interoperability of the WT and OWF controls by simulations

generate grid code recommendations for DR-HVDC connection of OWFs
WP3 Timeline

Functional requirements to WPPs

- **March’16**: T3.1
- **December’16**: D3.1
  - (WP1 & WP2) MS16, MS17 (input from WP1 & WP2 / models to WP2)

General control algorithms

- **September’16**: T3.2
- **December’17**: D3.2
  - D3.3 & D3.4 & D3.5

Compliance evaluation procedure

- **September’17**: T3.3
- **March’18**: D3.6
  - MS19 (approval)

Compliance evaluations based on detailed numerical simulations

- **December’17**: T3.4
- **June’19**: D3.7 & D3.8
  - MS20 (input to WP11)
Progress in T3.2

**DTU: D3.3 Models for control of WT/WPP connected to DR- HVDC [M24]**

Confidential, only for members of the consortium (including the Commission Services)

- Initializing to steady-state (no start-up, no auxiliary or umbilical)
- **DR** Mode (Diode Rectifier)
- **ISL** Mode (Island Operation)
- Normal Operation, Response to Faults, Ancillary Services
Progress in T3.2

**DTU:** Ancillary Services to onshore grid via DRU:
- Frequency support
- Power oscillation damping by active power modulation
Progress in T3.2

**Universitat Politècnica de València:** Offshore grid control with DRU connected WT

150x8MW wind turbines: 2450 nodes
3x400MW aggregated wind power plants: 174 nodes
Progress in T3.2

Universitat Politècnica de València:

Power transients (WPP disconnection)
Red: 3x400MW  Green:150x8MW

PCC voltages

PCC currents
Progress in T3.2

Universitat Politècnica de València:

PCC quantities show a very small error between detailed and aggregated models.

More than 350 times faster using aggregated models.

<table>
<thead>
<tr>
<th></th>
<th>WTs</th>
<th>nodes</th>
<th>Simulation time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detailed</td>
<td>150</td>
<td>2450</td>
<td>117 minutes</td>
</tr>
<tr>
<td>Aggregated</td>
<td>3</td>
<td>174</td>
<td>20 seconds</td>
</tr>
</tbody>
</table>
Progress in T3.2

University of Strathclyde: Focus on Faults

Accomplished Fault Cases: Offshore AC (symm. & asymm.), DRU, DC, Onshore AC
Future Cases: Umbilical Cable, Pole-to-Ground, Onshore Asymmetrical AC
University of Strathclyde: Offshore AC fault

Waveforms of WT converter: (a) AC voltages, (b) AC currents, (c) d- and q-axis currents, and (d) active and reactive power
Technical Review – WP3

WP3 Next Period (M18-M24)

T3.2 General control algorithms [M09-M24]

D3.2 (submitted M15)
Specifications of the control strategies and the simulations test cases

D3.3
Models for control of WT/WPP connected to DR- HVDC

D3.4
Operation of WPPs connected to DR- HVDC

D3.5
Performance of ancillary services provision from WPPs connected to DR-HVDC

M24

T3.3 Compliance evaluation procedure [M21-M27]
(kick off September 2017)

T3.4 Compliance evaluations based on detailed numerical simulations [M24-M42]
(kick off December 2017)
Promotion: WP4 report
Aberdeen meeting

Dirk Van Hertem, KU Leuven
June 1, 2017
Objectives

This WP aims to develop multivendor DC grid protection system. The goal is:

▸ to develop a set of functional requirements for various DC grids: from small scale to large overlay grids and for a variety of system configurations and converter topologies

▸ to analyse a wide range of DC grid protection philosophies on a common set of metrics

▸ to identify the best performing methods for the systems under study

▸ to develop detailed protection methodologies for the selected methods

▸ to develop configurable multi-purpose HVDC protection IEDs to enable testing of the methodologies

▸ to investigate the key influencing parameters of protection systems on the cost-benefit evaluation
Why WP4?

- AC protection is well known: AC Breaker at each line end, good redundancy
- AC protection is moderate expense in total system cost
- DC system protection (VSC): currently at the AC side
- For DC grids: We don’t know?
- Several option exist:
  - Opening AC breakers (disconnecting the entire DC grid)
  - Having DC breakers as in AC systems
  - New concepts:
    - Using fault current limiting converters
    - Fault current limiters in the grid (potentially superconducting)
    - ... 
  - What is the optimal solution?
    - Technically
    - Economically
## WP4 worktable

<table>
<thead>
<tr>
<th>Task</th>
<th>LEAD</th>
<th>Description</th>
<th>Start</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>WP4</td>
<td>KUL</td>
<td>DC Grid protection system development</td>
<td>3</td>
<td>42</td>
</tr>
<tr>
<td>4.1</td>
<td>Statoil</td>
<td>Investigation and evaluation of fault detection and selectivity methods, towards functional requirements</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>4.2</td>
<td>KUL</td>
<td>Screening analysis of various protection methods for different topologies</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>4.3</td>
<td>KUL</td>
<td>In depth study of selected protection methods towards practical implementation</td>
<td>18</td>
<td>42</td>
</tr>
<tr>
<td>4.4</td>
<td>KTH</td>
<td>Development of configurable HVDC protection IEDs for multi-purpose and multi-vendor grid protection 0)</td>
<td>22</td>
<td>40</td>
</tr>
<tr>
<td>4.5</td>
<td>SGI</td>
<td>Preparation of cost/benefit analysis of studied protection solutions</td>
<td>3</td>
<td>42</td>
</tr>
</tbody>
</table>

- Large WP: 362 PM (in 2016 75.6 PM used)
- 18 partners
- Set up a core group to streamline efforts (bi-weekly meetings/telco)
Basic flows within Promotion related to WP4

4.1 Functional requirements + tests (Statoil)

4.2 Benchmarking algorithms (KUL)

4.3 Industrializing protection methods (KUL)

4.4 IED Development (KTH)

4.5 Cost benefit analysis protection (SGI)

9 Validation in RTDS (SSE)

12 Roadmap for HVDC Grids (TenneT)
Basic flows within Promotion related to WP4

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4.2 Benchmarking algorithms (KUL)

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4.4 IED Development (KTH)

4.5 Cost benefit analysis protection (SGI)

9 Validation in RTDS (SSE)

12 Roadmap for HVDC Grids (TenneT)
Promotion: WP4 report

Deliverables

- D4.1: Definition of representative test cases for DC grid protection and functional requirements for DC grid protection methodologies (M12)
- D4.2: Report on the broad comparison of protection philosophies for the identified grid topologies (M18)
- D4.3: Report on performance, interoperability and failure modes of selected protection methods (M36)
- D4.4: Preparation of protection methodologies for testing in the MTTE environment (M30)
- D4.5: Requirements for DC switchgear [joint deliverable with WP5] (M42)
- D4.6: Functional HVDC protection IED including documentation (M36)
- D4.7: Preparation of cost-benefit analysis from a protection point of view (M42)
Goal of D4.1

- Definition of representative test cases for DC grid protection and functional requirements for DC grid protection methodologies (M12)

- Objectives:
  - agree on how to design a protection system for DC systems, based on functional requirements
  - understand and agree about the interactions in AC/DC grids for protection purposes
  - understand and agree on the main parameters which need to be analysed
  - define benchmark networks and test cases to be able to create consistent benchmarks
  - agree on a common vocabulary
  - Very hard task (many opinions/stakeholders)
Some results from 4.1

- Defined functional requirements
  - for components
  - for subsystems
- DC side limitations need to be defined
- Loss of infeed to a node/zone/system is variable over time
- Defined small, medium and large impact systems + benchmark systems with potential faults
- Risk based assessment of protection
  - Zone 1: out of norm
  - Zone 2: unacceptable consequences
  - Zone 3: unacceptable risk
  - Zone 4: acceptable risk
- Identified faults in DC systems in these zones (preliminary assessment)
WP4.2: Screening analysis for various protection methods for different topologies

- Step 1: a literature study of fault identification methodologies and protection philosophies
- Step 2: qualitative assessment of fault clearing strategies. Linking protection with specific systems (protection matrix concept)
- Step 3: quantitative (high level) assessment of fault clearing strategies using selected simulation tests
- Develop a **benchmarking** tool/approach for different protection methods
- Comparative study and analysis of different approaches, with different breaker technologies using protection matrices
- Robustness of schemes
- Backup approach
- Effect of inductors, OHL/Cable, grounding,... Cost elements? ⇒ nr breakers needed, max operating speed allowed,... (input from WP4.5)
- Started September 2016, Deliverable 4.2 by M18 (now)
- Task Leader: Willem Letterme (KU Leuven)
WP4.5: Preparation of cost-benefit analysis for studied protection methods

- Provide initial indicators to evaluation done in 4.2
- Preparation towards delivery to WP12
- Initial indicators: nr of breakers, EENS, system losses? Volume of breakers offshore, ...
- Goal: CBA of protection methods
- Tool developed by SGI, focusing on the reliability/protection aspects of HVDC grid protection strategies
- Methodology is described in an internal report
- In order to have realistic results, realistic data is necessary
- Cost data is very tricky to obtain
- Reliability data is very tricky to obtain
- Task Leader: Serge Poullain (SGI)
Fault clearing strategies under investigation

- Selective fault clearing strategies
  - Selective with breakers (different opening times, unidirectional - directional)
  - Different backup options (e.g. breaker between busbar and converter)
  - Superconductive fault current limiters
- Non-selective fault clearing strategies
  - Non-selective with AC breakers
  - Open Grid
  - Non-selective with full bridge MMC
  - Non-selective with DCCB at converter terminals
- Partially selective fault clearing strategies
  - Grid splitting using DCCB
  - Grid splitting using fault current limiters
  - Grid splitting using DCDC converter
Promotion: WP4 report

Performed studies

- Feasibility of fault clearing strategy considering AC network constraints (yes/no)
- Component requirements (investment cost)
- Achieved reliability (risk analysis)
- Extensibility (investment cost/feasibility)
- Multivendor/Multi-TSO (discussion)
Promotion: WP4 report

Developing timing diagrams for each strategy

- Setting up timing diagrams for primary protection
- And backup protection
Protection matrix approach

- Matrix setup to evaluate how different faults in the system will affect the system
- Different faults in the system
  - Those the primary protection should cover
  - Other faults
- Influence on the connecting system
- Each combination is investigated to see whether there will be:
  - Continuous operation
  - Temporary stop
  - Permanent stop
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- Each combination is investigated to see whether there will be:
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  - Permanent stop
Promotion: WP4 report

Detailed analysis on parameters

- A number of parameters/configurations is investigated with each strategy to assure robustness of solutions
Risk assessment

- Contribution of WP4.5 to D4.2
- Based on a Monte Carlo Petri Net methodology (MCPN). Petri Net representation allows a quite easy modelling of the protection system dynamics (succession of events) on the basis of both flowchart and time chart descriptions
- Also allows to describe, on the same base support, the protection system architecture including physical links between the different components (relays, DC CBB, High speed switch,...)
## Benchmark table

<table>
<thead>
<tr>
<th>MAIN COST DRIVER</th>
<th>RISK CATEGORY</th>
<th>EXTENSIBILITY</th>
<th>FEASIBILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Primary</td>
<td>PS→TS</td>
<td>Small impact</td>
</tr>
<tr>
<td></td>
<td>Backup</td>
<td>TS→CO</td>
<td></td>
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<tr>
<td>FS DCCB Option 1</td>
<td>DCCB</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>DCCB and Converters</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>FS DCCB Option 2</td>
<td>DCCB</td>
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</tr>
<tr>
<td>FS DCCB Option 3</td>
<td>DCCB</td>
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<td>✓</td>
</tr>
<tr>
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<td>✗</td>
</tr>
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<td>NS FB</td>
<td>FB</td>
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<td>✓</td>
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<tr>
<td>NS ACCB</td>
<td>DCCB</td>
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<tr>
<td>ParS ACCB/DCCB</td>
<td>DCCB</td>
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<td>✓</td>
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<tr>
<td>ParS FB/DCCB</td>
<td>DCCB/FB</td>
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<td>✓</td>
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<td>✓</td>
</tr>
<tr>
<td>PARS ACCB/DCDC</td>
<td>DCDC Conv</td>
<td>✗</td>
<td>✗</td>
</tr>
</tbody>
</table>

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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.
Costs in the benchmarking

5 options were considered:

1. Yes, we include (weighted) cost data in our deliverable and show details. Cost data is based on partner input (possibly not all partners). Disclaimers are added

2. We calculate the numbers, but only put figures and aggregated results in the document. Disclaimers are added. Potentially there is an appendix which is not published

3. We only give high level outcomes (option A is high, B is very high except if technology X is comparable in cost to technology Y in which case it is medium, and option C is low). Disclaimers are added

4. Only write what the anticipated main cost driver is (component count)

5. We do not use anything cost related
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5. We do not use anything cost related
Cost modeling of DCCB

- new task within WP4(.5)
- Ongoing effort

Breakdown of DC CB costs

Total Systems Costs (Purchase Price)

- Installation and Commissioning costs
- Indirect costs
- Direct costs

Total Component Costs (Purchase Price)

- Development Costs
- Margin
- SG&A - Overhead
- Manufacturing Costs % (uplift)
- Cost of (specific) Components: Materials; Other costs for specific components
- Standard Components; Price

31 May 2017
Next steps

- Delivery of D4.2 should be soon (likely small delay for delivery, before holidays)
- Followed by a milestone: MS21: Identified list of top candidate protection philosophies for the proposed grid topologies (M18)
- WP4.3 is starting soon
- WP4.4 starts later this year
- WP4.5 continues to work
WP4: summary

- Working hard to finalize D4.2
- Performed extensive analysis on disjoint fault clearing strategies
- Benchmarking being done on different aspects, including sensitivity analysis, extensibility and risk analysis
- Performance differs → unfortunately a nuanced conclusion is likely
Questions?

Dirk Van Hertem
Dirk.VanHertem@esat.kuleuven.be
WP5 – Test Environment for HVDC Circuit Breakers

Nadew Belda, Cornelis Plet

01-June-2017, Aberdeen, UK
CONTENT

- Objective
- Deliverables
- Discussion
- Future plan
WP 5 – Test environment for HVDC circuit breakers

**Partners:** DNV GL (WP Leader), ABB, MEU, UniAbdn, TU Delft

**Objectives:**

- Fault analysis
- Produce dynamic, **black-box models** of HVDC circuit breakers of various technologies
- Stress analysis of HVDC circuit breakers
  - Produce documents on **test requirements and procedures** for HVDC circuit breakers
  - Compare different test circuits for HVDC circuit breaker testing
  - Realize **high-power test-circuits** including the necessary equipment (components) specifically needed for HVDC testing.
WP 5 – Test environment for HVDC circuit breakers

Milestones:

- Transient fault stresses on HVDC circuit breakers
- Test requirements formulated and test procedures documented
- Test circuit for HVDC circuit breaker based on AC power supply designed

2016
- M9
  - HVDC Network fault analysis
  - PSCAD models of HVDC CBs

2017
- M11
- M16
- M18
  - Candidate test-circuits and their effectiveness identified

2018
- M24
  - Test-circuits and installation ready for use
Objective: Identifying the tests applicable to HVDC circuit breaker

- Terms and Definitions related to HVDC circuit breaker and its operation
- Service conditions
- Ratings
- Test requirements
Service conditions & Rating

- Service conditions have to be specified
  - Temperature range, pollution level, humidity, etc.

- Ratings
  - Rated voltage
  - Rated insulation level
  - Rated normal current
  - Rated short-time withstand currents
  - Rated temperature rise, etc.
  - Rated power losses
    - Rated breaking/making current
    - Rated breaker operation time
    - Rated maximum transient interruption voltage (TIV)
    - Rated energy absorption
PROMOTioN – Work Package 5

Terminology, Design and construction

Series inductor
Residual current breaker
Control & Protection
Module

DCCB

Breaker unit

Functional unit

Component
Normal current path
Commutation path
Energy absorption path

Normal current path
Commutation path
Energy absorption path

Normal current path
Commutation path
Energy absorption path

Multiple breaker units

Control & Protection system
PROMOTioN – Work Package 5

Test Requirements

HVDC Circuit breaker tests

Dielectric Tests
- Lightning impulse
- DC voltage withstand

Operational tests
- Temperature rise test
- Short-time current withstand
- Current let-through

Breaking/Making
- Breaking/making current
- Maximum TIV withstand
- Energy absorption

Endurance tests
- Electrical Endurance
- Mechanical Endurance
How to execute the tests on HVDC circuit breaker (tests identified in D5.4)

- Number of test repetitions
- Test duties
- Duration between tests
- Sequence of tests
- Success criteria
  - Pass/fail criteria for test object
  - Tolerance (validity of test)
- Measurements needed
- Number of test specimen (for type test qualification)
Tests in PROMOTioN

- General list of tests that are included in a type test program are considered in D5.4 and D5.5
- In PROMOTioN in DC current interruption will be performed
  - Rated normal current: ≈ 2 kA
  - Rated breaking current: 15-20 kA
  - Rated operation voltage: 70-100 kV
  - Rated energy: to be defined upon discussion with manufacturers
A test circuit need to produce the necessary stresses to the test breaker

- Current
- Energy
- Voltage

Test circuit shall withstand the stress from the circuit breaker (Transient Interruption Voltage)

Handle the stresses in case of failure of the test breaker
D5.6: Software analysis of Candidate test circuits and their effectiveness

Rectifier with controllable parameters

Charged capacitor

Charged reactor

AC short-circuit generator

© PROMOTioN – Progress on Meshed HVDC Offshore Transmission Networks
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 691714.
### Charged Capacitor

- Large capacitors need to be charged to a high voltage
- Space
Larger reactors are required for sufficient energy stress
- Reactors with high quality factors
- Simultaneous switching of several switching elements
AC short-circuit generators

[Diagram of AC short-circuit generators with labels for R, L, Making switch, and HVDC CB.]
AC short-circuit generator

- Already in use for AC switchgear testing
- Offers flexibility in achieving test parameters (di/dt, energy)
  - Frequency
  - Voltage magnitude
  - Making angle
  - Rate of rise of current

- Limitations
  - Require availability of high power
  - Number of short circuit generators and step-up transformers
  - Needs another source for dielectric stress after current interruption
  - Require additional circuit to avoid damage to the test object
Test circuit comparison

Circuit parameters

- Circuit inductance 20 mH
- Source/charging voltage 80 kV
- Breaking current 9 kA
- Capacitance 506 µF (for charged capacitor circuit)
- Breaker operation time of 2 ms

Main differences

- The total interruption time
  - Fault current suppression
- Total energy absorbed
  - Due to difference in driving voltage magnitude during energy absorption phase
PROMOTioN – WP5

Dielectric stress after current interruption

TRV of AB1 = TIV + $V_{gen,peak}$
Overcurrent mitigation in case the test breaker fails

- To avoid long arcing of AB and overcurrent on test breaker
- Use triggered spark gap
  - The spark gap can also be designed for over voltage protection

To the test breaker
- Could damage some components

To the test installation
- The Auxiliary breaker AB1 will be subjected to long arcing
- Transient pressure of Master Breaker
D5.7: Realization of test circuit based on AC power supply

- Design of test circuit for HVDC circuit breakers based on AC short circuit generators
  - Determine circuit parameters at different frequencies
  - Test duties could be T10, T30, T60 and T100 (for 18 Hz)
- Test report on validation and verification of test circuit
  - Control interface, capacitor charging/discharging circuits/components
  - Safety to the test breaker in case of failure
  - Safety for the test installation (both in case of failure and success)
- Specification document on circuit components
- Specification of measurement equipment
  - e.g. measurement of current in each branch of circuit breaker
Thank you for your attention!

Questions?
D5.6: Software analysis of Candidate test circuits and their effectiveness
WP6 Characterisation of DC Circuit Breakers

May 2017
Dragan Jovicic, University of Aberdeen

PROgress on Meshed HVDC Offshore Transmission Networks
CONTENT

- Overview
- WP6 amendment,
- WP6.9 Develop standard DC CB verification plan and RTDS models,
- WP6.3 Develop component-level model for hybrid DC CB,
- WP6.4 Develop component-level model for mechanical DC CB,
- WP6.5 Develop kW-size hardware prototypes for hybrid and mechanical DC CBs,
### PROMOTioN – WP6 -ammendment

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WP6 Deliverables

- D6.1: Offline models for hybrid DC CBs (UniAbdn, M11)
- D6.2: Offline models for mechanical DC CBs (TU Delft, M11)
- D6.3: Detailed component-level model for hybrid DCCBs (UniAbdn, M30)
- D6.4: Detailed component-level model for mechanical DCCBs (TU Delft, M30)
- D6.5: Hardware prototypes of DC CBs (200V, 400A) at Uni. laboratory (UniAbdn, M36)
- D6.6: Demonstration and report on DC CB failure modes study (UniAbdn, M48)
- D6.7: Techno-economic roadmap for hybrid DC CB scaling to EHV DC voltage (UniAbdn, M48)
- D6.8: Techno-economic roadmap for mechanical DC CB scaling to EHV voltage (TU Delft, M48)
- D6.9: Standard DC CB verification plan and RTDS models (UniAbdn, M24)

WP6 contributes to:
- WP4, WP5, WP9, and also WP1, Wp12
- Increases understanding and confidence in DC CBs

WP6 Amendment rationale

- 4 different DC CB technologies (includes SciBreak)
- Common terminology, labelling of components and variables (internal and external),
- Common model verification plan,
- System-level models demonstrated for all 4 technologies
Meetings
1. Meeting 1: Arnhem, January 2016, 9 participants in person and 3 over phone
2. Meeting 2: Aberdeen, 03 June 2016, 15 Participants
3. Meeting 3: Teleconference, 24 November 2016, 8 Participants
4. Meeting 4: Berlin, 29 November 2016, 17 Participants
5. Meeting 5: DELFT, 23rd February 2017, 15 participants

Deliverables completed:
• D6.1 Develop system-level model for hybrid DC CB, December 2016,
• D6.2 Develop system-level model for mechanical DC CB, December 2016,

Technical papers:
1. D Jovcic and M.H. Hedayati “DC Chopper based test circuit for high voltage DC circuit breakers” IET ACDC Power transmission, Manchester, February 2017,
5. A. Jamshidifar and D Jovcic Design, Modeling and Control of Hybrid DC Circuit Breaker Based on Fast Thyristors, IEEE Transactions on power Delivery, January 2017 – in review
PROMOTioN – WP6.9 Develop standard DC CB verification plan and RTDS models

1. General DC CB model verification plan,

2. Verification of IGBT-based hybrid IGBT DC CB model,

3. Verification of thyristor-based hybrid DC CB model,

4. Verification of mechanical DC CB model,

5. Verification of SciBreak DC CB model,

6. RTDS modelling and verification of IGBT DC CB model,

7. RTDS modelling and verification of mechanical DC CB model,
General DC CB model verification plan,

1. Test circuit

2. Model testing with external trip signal
   a. Opening on rated interrupting current,
   b. Opening on low fault current,
   c. Opening on low load current (0.01kA-0.2kA),
   d. Closing on load current,
   e. Reclosing in fault,
   f. Repeated open-close (close-open-close-open-close),
   a. Reverse current direction (all the above),

3. Model testing with no external trip signal (self protection)
   a. Low impedance fault,
   b. High-impedance fault,

4. Model testing with different parameters
   a. Different Ldc,
   b. Different cable parameters,
Simulation verification of IGBT-based DC CB model

Figure 3. Verification of IGBT-based DC CB model for repeated open-close cycle.
Simulation verification of mechanical DC CB model

Figure 4. Verification of mechanical DC CB model for repeated open-close cycle.
PROMOTioN – WP6.3 Component level model of hybrid DC CB

Proactive breaking and fault current limiting
• Each cell is 80kV, 2kA,
• Surge arrester is 120kV, 6MJ,
• Energy balancing between cells is essential,

Entering current limiting mode
• On DC CB internal decision (current over 1.5pu)
• On external command,

Exiting current limiting mode
• On receiving external trip signal - move to open state
• On receiving self protection signal (temperature rise) - move to open state,
• On clearing fault (voltage rise) – move to closed state

Figure 4. IGBT-base hybrid DC CB model.
Figure 5. Simulation of fault current limiting mode.
Modelling ultrafast disconnector

1. Charging circuit,
2. Electrical driver circuit,
3. Electro-mechanical system,
4. Mechanical system (force-acceleration-friction)

Figure 6. UFD model structure.

Figure 7. UFD electrical schematic.
Modelling ultrafast disconnector

1. Model shows good accuracy,
2. Model enables research on UFD enhancements

Figure 8. UFD model comparison against laboratory prototype.
1. Detailed modelling of energy absorber,
2. Detailed modelling of current injection circuit,
3. Contact separation and arc modelling,
4. Failure modes and interaction between components,

Figure 9. Energy absorber.
Test circuit for DC CBs
- Current pulse over 500A
- Voltage control,
- Safety features

Figure 10. Test circuit for DC CB.
Test circuit for DC CBs

- tests without DC CB,
- self protection works well,
- voltage control works well,
Ultrafast disconnector – research on reducing bounce
Thomson coil is used for magnetic breaking

Figure 12. Ultrafast disconnector contact position:
left no magnetic breaking and right with magnetic breaking.
Ultrafast disconnector – research on voltage control
Active voltage control reduces peak fault current and reduces DC CB energy dissipation

Figure 13. Ultrafast disconnector active voltage control.
CONCLUSIONS

• Deliverables D6.1 and D6.2 completed in December 2016
• 5 technical papers prepared
• Task 6.9 introduced to standardise DCCB model verification
  • Limitations of DC CB technologies
  • Self protection is important and it is different for each DC CB technology
• Task 6.3:
  • UFD modeling,
  • Current limiting,
• Task 6.4:
  • Energy absorber modeling,
  • Arc chamber modeling,
• Task 6.5:
  • DC CB test circuit close to completion,
  • Advancing DC CB technology
  • UFD magnetic breaking
  • UFD voltage control
Workpackage 7
Regulation & Financing

Progress update, 1 June 2017, Berlin
Berlin November 2016 Status

11 Apr 2016
1st WP session

29 Jun 2016
Stakeholder meeting
Brussels

14 June
2nd WP session

30 Sep 2016
1st deliverable

31 Jan 2017
2nd deliverable

30 Apr 2017
Internal deadline
report

30 Sep 2016
1st deliverable

31 Mar 2017
3rd deliverable

30 June 2017
EC deadline
report

Task 7.1
Leader: RUG
Legal framework
- Analysis offshore competences
- Analysis EU legislation

Analysis legal regimes
Overview main barriers

Public intermediate report (D7.1)

Task 7.2
Leader: EUI
Economic framework
CBA methods
- Coordinated planning
- Grid user participation

- Support scheme
- Investment incentives
- Revenue model/tariff design

Public intermediate report (D7.3)

Task 7.3
Leader: DWG
Financial framework
Analysis financing model
(onshore and offshore)

Analysis financing models
wind farm connections &
interconnectors

Analysis alternative
ownership and
governance models
(worldwide)

Public intermediate report (D7.5)

Task 7.4
Leader: SOW
Stakeholder workshops

Stakeholder kick-off (MS34)

Public intermediate report (D7.7)

December 2017: Intermediate report on policy recommendations (D7.8)
Timeline: Current status

- **21 Jan 2016**: Project Kick-off
- **29 Jun 2016**: Stakeholder meeting in Brussels
- **11 Apr 2016**: 1st WP session
- **14 June**: 2nd WP session
- **29 Jun 2016**: Stakeholder meeting
- **30 Sep 2016**: 1st deliverable
- **31 Mar 2017**: 3rd deliverable
- **31 Jan 2017**: 2nd deliverable
- **30 June 2017**: EC deadline report
- **Jun/Aug 2016**: Start PhD's

**Task 7.1**
- Leader: RUG
- Legal framework
- **Analysis offshore competences**
- Analysis EU legislation
- Overview main barriers
- Public intermediate report (D7.1)

**Task 7.2**
- Leader: EUI
- Economic framework
- CBA methods
- Coordinated planning
- Grid user participation
- Support scheme
- Revenue model/tariff design
- Public intermediate report (D7.3)

**Task 7.3**
- Leader: DWG
- Financial framework
- Analysis current financing model onshore
- Analysis current financing models OWF connections
- Analysis current financing models offshore interconnectors
- Public intermediate report (D7.5)

**Task 7.4**
- Leader: SOW
- Stakeholder workshops
- Stakeholder kick-off (MS34)
- Public intermediate report (D7.7)

**December 2017**: Intermediate report on policy recommendations (D7.8)
Analysis of existing financing models of transmission grids in EU; offshore

WP 7.1: Legal framework for offshore grids


International and European: already in internal deliverable 7.1.1 (October 2016)

National = comparison and analysis of 8 coastal States: Belgium, Denmark, France, Germany, Netherlands, Norway, Sweden, UK

Main result: analysis of legal framework leads to pinpointing the legal barriers.

= input for further work in WP7.1

Structure: according to PROMOTioN building blocks:

- offshore grid planning,
- offshore grid construction,
- offshore grid operation
Analysis of existing financing models of transmission grids in EU; offshore

WP 7.1: Legal framework on a national level

**Offshore Grid Planning**
- Maritime spatial planning
- Permits & Licenses
- Support Schemes

**Offshore Grid Construction**
- Legal classification of different (hybrid) grid components
- Clustering of OWFs

**Decommissioning**
- Difference in decommissioning obligations OWFs and grid

**Offshore Grid Operation**
- Based on EU Network Codes
WP 7.2: Economic framework for offshore grids

**Planning**
- CBA Assessment
- Offshore-Onshore Coordination
- Participation of grid users

**Investment**
- Support schemes
- Transmission tariff designs
- CBCA methods
- Investment and efficiency incentives

**Operation**
- Rules on ancillary services
- Compensation scheme and liability
- Capacity allocation

Intermediate Deliverable

Planned 2017-2019
Analysis of existing financing models of transmission grids in EU; offshore

WP 7.3: Financial framework for offshore grids

1. Overall objective

- Analysis of the current financial strategies for OWF grid connections and offshore interconnectors.

- Investigation of the financing needs in the case of hybrid solutions/combination of OWF connections and interconnectors (MOG)

- Deviation between the current financing practices and the financing needs of a MOG:
  - Limitations/financing challenges
  - Best practices

- Recommendations for a financial framework for meshed offshore grid investments
Analysis of existing financing models of transmission grids in EU; offshore

2. Work so far (2016-June 2017)

1. Investment volumes
   - EC estimations for a Northern Seas offshore grid: EUR 30 billion by 2020
   - EC estimated a financing gap of EUR 8 billion by 2020.
   - ENTSO-E Regional Investment Plan (2014) for North Sea Region (internal projects & interconnectors): EUR 100 billion by 2030

2. Financial structures
   - TSO
   - OFTO and merchant interconnectors
   - Debt financing
     - Impact of debt market fluctuations
   - Private equity injection could be a viable solution in the long run => hard to implement on state-owned TSOs
3. Regulatory framework for electricity transmission investments

- The same rate of return for onshore and offshore investments

- If the interest rates increase will the current regulatory framework still be sufficient?

- Merchant interconnectors is a possibility

- Cap and Floor regime: currently an attractive option for interconnector investment ensuring a min level of revenue ("floor").

- EU policy tools (e.g. PCIs) & funding instruments (CEF, EEPR etc.):
  - despite PCI status significant delays due to permitting procedures
  - funding instuments not sufficient to fill the investment gap when the market alone cannot deliver the required investments
Analysis of existing financing models of transmission grids in EU; offshore

3. Financial framework next deliverables:

- continue with interconnector examples, Nemo as pilot project for Cap and Floor regime and NordLink venture between Stattnet, TenneT TSO GmbH and KfW (promotion German bank)

- Listing and assessment of obstacles for investing in a MOG

- Investigation of financing models of electricity transmission internationally (e.g. China, USA, Brasil)

- Recommendations for a financial framework for MOG investments
END
Dissemination

Task 13.8
External communication activities

Testimonial Video Clips Launch:

• Project partners highlight relevant aspects/aims of PROMOTioN

• Embedded on project website and YouTube channel

• Finished and published on 22 December 2016

• Website Insight section: https://www.promotion-offshore.net/insight/detail/promotion-testimonials/

→ Dissemination / Testimonial clips
If you are giving a presentation on a PROMOTioN relevant topic?
Are you in a discussion on relevant PROMOTioN content?
Is the PROMOTioN website linked on your own website?

→ Please help us to create additional project awareness by mentioning the project and its website
→ Join our LinkedIn group and share contents
Dissemination

Task 13.2
Development and production of a newsletter

Third edition scheduled for 5 July 2017

\[ \rightarrow \text{295 active subscribers} \]

Please announce the newsletter via all your communication channels!
Dissemination

Newsletter #3 – draft content

1. Editorial (provided by DNV GL)

POLICY

1. North Sea Energy Forum Meeting in Brussels
2. Results of First Offshore Wind Energy Tender in Germany
3. Article about German BFO consultation and German O-NEP

PROMOTioN

1. Recap side-event London and InnoGrid 2020+
2. Deliverable 1.6 Report and computer demonstration with a draft roadmap and reference offshore grid expansion plan
3. Deliverable 1.4: Report with reference scenario and related offshore meshed HVDC grid topology
4. Deliverable 4.2: Report on the broad comparison of philosophies for the identified grid topologies
5. Combined article on deliverables 7.1/7.3/7.5
6. Combined article on Deliverables 5.4./5.5/5.6 DC circuit breaker test requirements and procedures

UPCOMING EVENTS
Online activities

Task 13.3
Website statistics

Website visits July 2016 – May 2017

User behaviour overall

Sessions
5,512

Pages/Session
3.06

% New Sessions
54.77%

Users
3,072

Avg. Session Duration
00:03:37

Bounce Rate
45.65%

Benchmark:
Above 2 min.
Below 60%
Task 13.3
Website: Search engine optimization (SEO)

- **Content Optimization:**
- Detection of relevant search requests
- How often do users search for certain terms
- Afterwards the contents of a website are optimized for relevant search inquiries

**What is SEO?**

“Search engine optimization or SEO is the process of affecting the visibility of a website or a web page in a web search engine's organic search results.”

- Wikipedia
Main keywords: HVDC, interconnected, grid connect, wind farm, submarine cable, network technology

• Creation of articles focused on the main keywords, but several sub-keywords should also be included:
  • Topic 1: „HVDC technology“ (Q3)
  • Topic 2: „Interconnection of offshore wind farms“ (Q2)
  • Topic 3: „Common electricity infrastructure for offshore wind farms“ (Q3)
  • Topic 4: „Wind energy in Europe“ (Q3)

• Drafted by agency – reviewed by project partners / PMG
Mailing list

Task 13.4
Development of a targeted mailing list

• For stakeholder interaction
• More than 1400 recipients
• Regularly updated
• Input from project partners

STAKEHOLDER CATEGORIES

1. European bodies
2. Policy institutions
3. Industry Stakeholders
4. Financing bodies
5. Academia & Consulting
6. Others
Dissemination

Task 13.5
Support WP14 in editing/layout of Executive Summary of Project Interim Report and Final Report

Deliverable 13.5
► submitted March 2017

• Last official deliverable for WP13
• Tasks are still ongoing
Dissemination

Task 13.6
Production of public reports, papers/articles, presentations

• **Keep us informed** about every publication/presentation
  Philipp Kalweit p.Kalweit@offshore-stiftung.de

• **Makes us aware** of all relevant events/conferences

• **Be aware of publication procedure**

• Ensure public accessibility (on PROMOTioN website)

→ Dissemination documents
Dissemination

Task 13.6
Production of public reports, papers/articles, presentations

• **Deliverable 13.6**
  - submitted December 2016

• 2016: 13 presentations  3 conference papers
• 2017: 9 presentations  8 conference papers

• Total amount of 25 journal articles and 50 conference papers is pursued
  (acc. to GA Annex 1B Communications Activities)
Dissemination

Task 13.6
Production of public reports, papers/articles, presentations

Urgent need to increase number of publications

→ Introduction of an reminder, to announce events/conferences separately

→ Self management of your subscription

→ Contact relevant project partner directly

Sign up: https://confirmsubscription.com/h/d/E8591FF1E9013748

• One responsible person per partner + WP leaders

• By 15 June
Dissemination

Conference outlook 2017 & 2018

2017

• Offshore Wind Energy 2017, 6 – 7 June, London
• InnoGrid2020+, 26 – 27 June, Brussels
• Wind Integration Workshop, 25 – 27 October, Berlin
• WindEurope Summit, 28 - 30 November, Amsterdam

  Deadline for abstracts: 18 June

2018

• WINDFORCE Conference, 15 – 17 May, Bremen
• CIGRE Technical Exhibition, 26 – 31 August, Paris
• WindEnergy Hamburg, 25 – 28 September, Hamburg
Dissemination

Task 13.7
Stakeholder interaction

External PROMOTioN events:

• Project booth at InnoGrid2020+, Brussels (26 – 27 June)

2nd Reference Group Meeting:

• Envisaged November 2017, Amsterdam

Intermediate conference

• May/June 2018
• Potentially connected with 2. North Sea Energy Forum
• Copenhagen, Amsterdam/Den Haag, Dublin or Berlin
Dissemination
PROMOTioN @ Offshore Wind Energy 2017

Event details:

- Time: 13:30 - 16.30
- ICC Capital Suite, Room 16, ExCeL – Exhibition Centre London
- Exhibition passes are necessary
Dissemination

Task 13.8
External communication activities

Press briefing:

• 7 June: 12:30 - 13.15
• Offshore Wind Energy 2017
• ICC Capital Suite, Room 16, ExCeL – Exhibition Centre London

Topics:

• General project progress overview – Cornelis Plet (Project coordinator, DNV GL)
• Presentation of Draft roadmap – Pierre Henneaux (Tractebel)
• Presentation of Report of the broad comparison of protection philosophies – Dirk van Hertem (KU Leuven)
Dissemination

Task 13.8

External communication activities

Press coverage:

- December 2016 “Energie und Management”
- January 2017 „Energie und Management“
- January 2017 „Magazin für Energiewirtschaft“
- January 2017 „Schiff und Hafen“
- February 2017 „Die WELT – N24“
- March 2017 „Energie Winde“
Dissemination

Task 13.8
External communication activities

**Media communication:**

- To **increase number** of press articles
- Inform us about PROMOTioN related **press articles**
- Makes suggestions for **newsworthy** topics
- **Update your press contact persons!**
- **By 15 June**
- Press and media contact: Sebastian Boie ([s.boie@offshore-stiftung.de](mailto:s.boie@offshore-stiftung.de))
North Sea Energy Forum in Brussels

- 23 March 2017
- 200 Participants
- Organized by EU Commission
- High level politicians from EC and CEOs
- MoU: “North Sea Wind Power Hub” (TenneT and Energinet.dk)
- Four thematic Support Group sessions
- PROMOTioN presented by Cornelis Plet (DNV GL) and Pradyumna Bhagwat (EUI) in SG2: Development and regulation of offshore grids and other offshore infrastructure
Policy – Backup WP14

Public consultation for “Federal Offshore Grid Plan”

(Bundesfachpläne Offshore – BFO – published by BSH)

• PROMOTioN consortium is officially requested to participate
• About 30 questions to grid connection concepts and standardized technical requirements
• Forwarded to relevant partners
• No joint PROMOTioN position
• but individual answers by ABB, Siemens, TenneT and DONG which have been already sent directly
Thank you for your attention!

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PROMOTioN - General Assembly

PROgress on Meshed HVDC Offshore Transmission Networks
CONTENT

• Update WP8

• General consortium issues

• Upcoming amendments
Update on WP8
Siemens opted for NO GO regarding the Klim DRU demonstrator
No proposal for an alternative DRU demonstrator was submitted by Siemens
Stand-alone cable demonstrator will not be accepted by EU
Option of combined DC GIS and cable demonstrator is being explored
WP8 will probably be terminated
Person-month budgets of WP8 participants (other than Siemens and Prysmian) will be transferred to other WPs
Budget of Prysmian and Siemens is returned to EU and can possibly be used by proposed new demonstrators (incl. cable)
‘Converters pillar’ looses demonstration element
Update on WP8: Impact on project objectives
Impact of WP8 termination on objectives

1. ‘To establish interoperability between different technologies and concepts by providing specific technical and operational requirements, behaviour patterns and standardization methods for different technologies’

> Analysis of behavioural patterns, development of technical and operational requirements for DRU based links and wind farms continues as planned in work packages 2 and 3.

> Results of work packages 2 & 3 will be used to contribute towards standardisation in WP11 as planned.

> Simulation results cannot be cross-validated using experimental data from a demonstrator which impacts the achieved TRL.

> This objective is slightly affected by the NO GO decision.
Impact of WP8 termination on objectives

2. ‘To develop interoperable, reliable and cost-effective technology of protection for meshed HVDC offshore grids and the new type of offshore converter for wind power integration’

Concerns the research & engineering and not demonstration work

Work on the development of protection systems for HVDC networks will go ahead as planned in work packages 4-6.

Work on developing control technology for the diode rectifier export link continues as planned in work packages 2 and 3.

The results of work packages 2-6 will be used to contribute towards standardisation in WP11 as planned.

Simulation results cannot be cross-validated using experimental data from a demonstrator which impacts the achieved TRL.

This objective is slightly affected by the NO GO decision.
3. ‘To demonstrate different cost-effective key technologies for meshed HVDC offshore grids and to increase their technology readiness level by investigating and overcoming early adopter issues and pitfalls’

ediator actions such as proposals for new demonstrators will have to ensure that this objective will be met.

The remaining demonstrations of HVDC protection and of HVDC circuit breakers are not affected and continue as planned in work packages 9 and 10.

This objective is seriously affected by the NO GO decision.
Impact of WP8 termination on objectives

4. ‘To develop a new EU regulatory framework, both in accordance with EU wide energy policy objectives and those of the Member States, and to increase the economic viability of meshed HVDC projects by providing a suitable financial framework’

Work on regulatory, legal, economic and financial aspects continues as planned in work packages 1, 7 and 12.

DRU technology continuous to be considered in analysis in WP1 and WP12 as planned

This objective is not affected.
5. ‘To facilitating the harmonization of ongoing initiatives, common system interfaces and future standards by actively engaging with working groups and standardization bodies and actively using experience from the demonstrations’

Work on contributing to and harmonising standardisation has not started yet and will commence and take place in work package 11 as planned from month 25 onwards.

No experience from DRU demonstration can be used

This objective is slightly affected.
Impact of WP8 termination on objectives

6. ‘To provide concrete deployment plan for “phase two” in bringing key technologies for meshed HVDC offshore grids into commercial operation in Europe, taking into account technical, financial and regulatory aspects’

↗ Work on developing the deployment plan will continue as planned.

↗ The technology roadmap of the diode rectifier link concept will be adapted to take into account the delay in achieving TRL 8.

↗ This objective is not affected.
Update on WP8: Impact on work plan
Impact of WP8 termination on work plan

MS12 WP2 M20 Preliminary simulation results delivered to WP8

Work package 2 carries out steady-state and transient network simulations of HVDC networks with diode rectifier units connected to it in order to determine operational concepts and configurations.

The preliminary results of these studies were envisaged to be shared with work package 8 for future validation and possibly as useful input into the design of the demonstrator.

With the cancellation of work package 8, this is no longer necessary, but it will not impede the progress of work package 2.

This milestone will be removed from the work plan.
General Assembly

Impact of WP8 termination on work plan

MS18 WP3 M20 Preliminary general control algorithms simulation results and experiences transmitted to WP 8

In work package 3, control algorithms for wind turbines connected to a diode rectifier link are developed and tested according to a list of developed requirements and test simulation cases.

The pre-liminary results of these studies were envisaged to be shared with work package 8 for future validation and possibly as useful input into the design of the demonstrator.

With the cancellation of work package 8, this is no longer necessary, but it will not impede the progress of work package 3.

This milestone will be removed from the work plan.
Impact of WP8 termination on work plan

**MS41 WP8 M40 Feedback of test experience to WP 2 and WP 3**

- Operational experience from the Klim demonstrator was envisaged to be fed back to work packages 2 and 3 to cross-validate the developed control algorithms, operational concepts, system configurations and requirements.

- With the cancellation of the Klim demonstrator, no operational experience will be gained which can be used in work packages 2 and 3.

- This has an adverse impact on the technology readiness level of the technology and the results developed in work packages 2 and 3. Whereas the Klim demonstrator may have lifted the TRL to level 8, without it the technology will achieve a level 6.

- This milestone will be removed from the work plan.
Impact of WP8 termination on work plan

**MS51 WP11 M36 Recommendations received from WP 2-6**

- Operational experience was recognised as a ‘nice to have’ in work package 11 where outcomes of the technical and engineering work packages are used to provide reports on the harmonisation of standardisation activities and to ensure uptake of the PROMOTioN results. The demonstrator results would have been nice to include in this task but were already expected to be too late.

- The NO GO decision is not expected to have a major impact on the deliverables of work package 11.

- This milestone will be not removed from the work plan but the text will be adapted to reflect the cancellation of WP8.
General Assembly

Impact of WP8 cancellation on role of DRU technology in PROMOTioN

- The DRU technology continues to be a portfolio element of Siemens and as such is a potential cost-saving technology for future offshore wind farm export connections
- The DRU technology continues to be studied in work packages 2 and 3
- The cancellation of WP8 means a slowdown in the evolution of the DRU’s TRL
- The DRU technology continues to be considered as a potential technology candidate in the initial road map in WP1 and the final deployment plan in WP12
General consortium issues
Overall overview of the project activities was provided in the periodic report, and in particular on the results and progress of the activities.

A detailed report was provided with a strong focus on the overall economic and social impact of the project before and after the “NO-GO” Decision of project partner 17 (Siemens) and the resulting consequences for WP 8 (cable-demo by Prysmian).

The report does not yet include a proposal and the decision of the project management and Siemens how to proceed with WP 8 and a reflection of possible impact reductions of the whole project with regard to the scope for each of the expected impacts of the work programme. This is yet to be decided.
An actual Gant Chart was provided with the revised Periodic report - to provide an overview of the i) “NO-GO decision” within WP 8 and ii) corresponding content of the work package, respective tasks and expected deliverables.

Detailed information regarding liberated costs as a result of the NO-GO decision in WP 8 was included in the periodic report (especially regarding the two partners involved in the action – SIEMENS and Prysmian).

Explanation regarding the subcontracting costs claimed by partners was provided.
Identified risks and risk mitigation measures in the periodic report, Appendix II e.g. concerning WP 7 (e.g. concerning conducting a CBA for HVDC) and WP 8 (“NO-GO-Decision of Siemens”, probably cancellation of the cable-demo) are not accurate/partially not provided. Please re-assess risk management based on the no-go decision.
General Assembly

General consortium issues

↗PMG minutes are made available after approval to all General Assembly members on ProjectPlace

↗Siemens Wind Power was a linked third party to Siemens, now withdraws from the project after merger with Gamesa

↗Iberdrola has significantly reduced their contribution due to staffing issues

↗New R&D coordinator Dr. Ralf Puffer from RWTH Aachen

↗Reminder: half yearly reporting due at the end of June 2017
Mismatch exists in work plan between WP7 and WP12
- WP 7 will only deliver recommendations for a CBA method
- WP 12 needs to carry out a CBA and therefore requires a CBA method
- The work plan does not foresee in the step of developing a CBA method based on the WP7 recommendations

Task force set-up to create CBA method
- Participants: Tractebel, TenneT and DNV GL
- Probably a new task in WP7
- 6 person-months will be transferred from unused budget (not from WP8 budget)
Component cost data is required to enable meaningful CBAs. Cost data of existing components will be collected from existing sources by DNV GL (Yongtao Yang) into a database.

Cost data of HVDC circuit breakers does not exist. A dedicated subtask has been created in WP4.5 for the University of Aberdeen to model the costs of DCCBs based on their technical parameters. For this, and other additional work, 6 person-months have been transferred to University of Aberdeen from remnant budget of ABB in WP5.

DRU cost data still to be determined. Need input from Siemens?
Upcoming amendments
2nd amendment has been carried out to change DNV GL’s registered bank account number. No further action required

Two more amendments are planned:

3rd amendment will focus on project ‘hygiene’, separate from effects of Siemens NO GO decision

3rd amendment already complete and will be sent within one or two weeks of Aberdeen meeting

4th amendment will focus on including the proposals for new demonstrators

4th amendment in preparation. Will be sent as soon as 3rd amendment is agreed
General Assembly

3rd amendment

- Only changes to Grant Agreement Annex 1 part A
- Formalize person-month changes
- Formalise deliverable deadline shifts
- Formalise Scibreak’s entry as partner
- Formalise Siemens WindPower’s exit
- Amendment almost finished and will be sent within two weeks of Aberdeen meeting
- Amendment of WP6 (University of Aberdeen)
  - DCCB cost modelling
  - Additional system level modelling of DCCBs
  - Additional steps towards DCCB model verification
General Assembly

4th amendment

- Grant agreement Annex 1 part A & B will both have to be amended
- Termination of work package 8
- Development of CBA method (Tractebel/DNV GL)
- HVDC MMC benchtop demonstrator (Aachen)
- HVDC GIS demonstrator (ABB)
- Extension of visualization tool with web interface (TenneT)
- Budget for SCiBreak

Not included:
- Additional budget for ABB for HVDC circuit breaker logistics
- Desktop low voltage HVDC demonstrator, info graphic, road show
The opinions in this presentation are those of the author and do not commit in any way the European Commission

PARTNERS
Minutes of meeting: PROMOTioN general assembly – Aberdeen 01-06-2017

09:00 - Prof. Dragan Jovcic opens the meeting

Prof. Phil Hannaford makes welcome speech

09:15 - Cornelis Plet

WP1- Niek De Groot

Dirk van Hertem: DCCB pricing and cost effectiveness, is it decided that the DC grid will have DC breakers?

Niek De Groot: Draft roadmap is more of an exercise and WP12 will perform the analysis in more detail.

Pierre Henneaux: We put this as an if condition. That is if circuit breakers are to be used, draft roadmap aims to provide high level insight into ratio cost of DC CB, cable, etc. how does that ratio affect the overall goal? (the meshing). It is not having fixed value and to have relative value

Claudia Spallarossa— what is the status of CBA in WP1?

Niek De Groot—there are different CBAs out there at different WPs.

WP2- Cora Petino

Ali Jamshidifar — What is the performance criteria of your models? For example, do you consider junction temperatures?

Dirk van Hertem – Not all of the models are aimed to be detailed enough to include the junction temperatures IGBTs.

Cornelis Plet – the impact of DC fault on AC grid, are these addressed in your study? Are the models suitable for these studies?

Cora Petino— The EMT models do not have detail on AC side. The detailed model is only up to the point of common coupling (PCC). The RMS models could perform these studies.

Christina Brantl — We will have some partners which will try to study these impacts with RMS models. It will be tackled.

Cora Petino—RMS models could be altered for the analysis but the EMT may not be.
Dirk van Hertem—Licenses of open source model are rather important to ensure they comply with the terms and conditions of the software as well as the requirements of the EU

Pierre Henneaux—How do you define N-1 security in your work? How do you address it?

Core Petino—We do not yet have criteria set for N-1 security

Dragan Jovcic—Similar studies have been done in other European projects. What is your conclusion? Are we advancing the knowledge area? Is there any new conclusion so far?

Cora Petino—the level of detail is different than, for example, in BESTPATHS project. We are considering the entire grid. There are controller topologies which are studied which have not been addressed before.

Dragan Jovcic: For example, N-1 is quite interesting and it is new. That could be one of the results of PROMOTioN project.

Dirk van Hertem—We look at that a little bit in Task 4.5 of WP4.

WP3: Ömer Göksu

Dragan Jovcic: using detailed model did you observe any of the issues SIEMENS was mentioning in relation to its NO GO decision (for example stability issues)?

Ramon Blasco-Gimenez: The main goal is to study converter interactions especially during faults and provide the models that enable such investigations.

Dragan Jovcic: The issue was small signal stability. It would be interesting to see your opinion about this.

Ramon Blasco-Gimenez: We have several test cases to study that. It could be challenging to find fault responses especially when having different vendors. This is what we are going to study.

Pierre Henneaux: Does it make a big difference if you use full bridge concept?

Ömer Göksu: DRU is intended to be used with a full bridge converter.

Pierre Henneaux: Do we already know that we cannot use half bridge?

Alexander Broy: In principle, yes. However, half-bridge could also be used. In this case all the windfarms should be operating and the voltage should remain above certain values.
Dirk van Hertem: A half-bridge converter and a tap changer could be used instead of a full bridge converter.

Wei He: How detailed is the controller on the wind turbine side? Does it consider the changes in the wind speed?

Ömer Göksu: The controller can track active power changes. The maximum power is also considered. For changes in wind speed there are results from University of Valencia, however, not in terms of wind dynamics.

Cornelis Plet: Are you considering start-up and stop of the wind farms in your studies?

Ömer Göksu: we are considering it. It is there but the results are not showing this in the slide. Start-up and shut down are also considered by the industries.

Unknown: I have concern about by-pass switches in parallel with DRUs (referring to the figure in the slide). Have you studied any impact of these?

Ömer Göksu: The full bridge will be able to handle it. It will be challenging and we are considering it. We do not have the results yet.

Wei He: it is better if you consider, in the remaining time, the state-of-the art projects for higher power wind turbines.

Carbon Trust: considering the time span of 2025 onwards. It should be considered in the discussion chapter. The detail may not be observed from the models.

Ramon Blasco-Gimenez: Once we have the systems running, it is not difficult to change parameters to represent other bigger wind turbines.

WP4: Dirk van Hertem

Michiel de Schepper: do you identify the benchmarks against which you compare to say one method performs better than the other?

Dirk van Hertem: This comparison is initially based on technical criteria and not on cost.

Marjan Popov: Do you consider fault locator in HVDC grid, in your studies?

Dirk van Hertem: no we are not considering a fault locator. We are focusing on the design of protection system.

Marjan Popov: What is the purpose of IEDs? Is it the idea is to use back-up protection?
**Dirk van Hertem:** Measurement data from the DC side and fault detection algorithms are going to run on IEDs.

**Marjan Popov:** will it be open source?

**Dirk van Hertem:** Yes.

**Marjan Popov:** What is the algorithm for protection? Is it overcurrent based or impedance based? etc.

**Pierre Henneaux:** in WP12 we need involvement of all partners and WP4’s participation is limited so far. If we have cost, we will have agreement.

**Dirk van Hertem:** Getting numbers is difficult, even ranges are not easy.

**Cora Petino:** Are TSO involved in the presented classification of operation states after faults? (since there are very different opinions on the behavior of the system after a faults).

**Dirk van Hertem:** WP4 has three vendors and many TSO’s. Regarding terms and definitions, we are working on it. We are looking at the works in CENELEC and CIGRE.

**Dragan Jovcic:** Continuous operation is preferable for PROMOTioN. It would be nice to know the underlying margins. 4 kA is only if you use large reactors in the range of 500 mH which is too big.

**Dirk van Hertem:** I do not think it is 300 mH here. The definition of continuous operation needs to be modified. You can block and unblock the converter as long as it allows to do so without significant impact.

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**WP5: Nadew Belda**

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**WP6: Dragan Jovcic**

**Michiel de Schepper:** for WP12 from your DC CB modeling and CBA, do you foresee that you can provide cost estimate?

**Dragan Jovcic:** We can do component count and provide this to Task 4.5.

**Michiel de Schepper:** you are using self-developed components which are not standardized. This could have an impact on cost estimation. Do you use standardized components?
Dragan Jovic: ABB circuit breaker components are quite standardized. There will be no radically new technology that we do not understand. In CIGRE Technical brochure it is suggested that the cost can be estimated as one third of the valve and you can take this as a starting point.

Yongtao Yang: Where is thyristor based technology coming from? Is this new technology or your development?

Dragan Jovic: This is a breaker developed in Twenties project (Then by Alstom now GE).

Yongtao Yang: how is the scalability of the UFD in your lab? Is it scalable for high voltage?

Dragan Jovic: It is well understood and we will publish the results soon.

Cornelis Plet: modelling helps in understanding different functionalities and this will have an impact on cost analysis. For example, the impact on cost of reclosing functionality, or whether it is unidirectional or bidirectional. This could be a take away from this work.

Dirk van Hertem: reclosing could be necessary but the question is how quick? We do not know the number yet. But the models need to have that functionality.

Dragan Jovic: we show in the report what current technology can do.

Dirk van Hertem: joint deliverable from WP4, 5 and 6 could answer some of these questions. We are doing research. The market will decide what to choose.

WP7: Bryan Brard

Michiel de Schepper: if you look at international experiences, is there a difference between onshore or offshore in cost analysis?

Alexandra Armeni: This is just to serve as a starting point.

Michiel de Schepper: looking at Germany to rate of return, how are you picking this up in the report?

Alexandra Armeni: we have raised this in the report. This is of course one of the challenges. In the long run, we will investigate this further.

Niek de Groot: can you give examples of any legal barriers?

Ceciel Nieuwenhout: for example, what legal classification (interconnector, export cable, something else) of cable is used to interconnect two hubs. Asked some players and right now they do not know yet. Now, there are a lot of uncertain things.
Niek de Groot: I mean one or two examples

Ceciel Nieuwenhout: for example, support scheme. Many countries have different regulations regarding offshore.

Pierre Henneaux: Is this something you look at?

Bryan Brard: that is something that we will address in the future

Paul Neilson: Economic value of offshore windfarm is a complete construct.

Niek de Groot: stability of support schemes is important. However, it is not going to depend only on support schemes.

Michiel de Schepper: if you look at EU interconnections, in Germany and Netherlands, as the more countries interconnection, it may be creating more inconsistencies.

WP8: Alexander Broy

Michiel de Schepper: I did not understand the situation with Prysmian. The SIEMENS approach is clear. We are not sure if they stopped participating in project or still ...

Alexander Broy: each partner has the right to make their own decision. We informed them in advance so that they react to that in time. EU does not support testing of cables alone in WP8.

Michiel de Schepper: No support means no funding.

Alexander Broy: may be integrate it in other tasks e.g. DC GIS. However, their (Prysmian) cooperation is very little to make progress so far.

Dragan Jovcic: Technical question regarding seabed placement of DRUs. Is this a viable solution? Can you give us an update on this?

Alexander Broy: DRUs are very robust. You may not need expensive platforms and may be put in the seabed directly. At the moment, this is just an idea.

Dragan Jovcic: Any number in cost benefits, advantages, etc.

Alexander Broy. There is a public document on this.

WP12 – Michiel de Schepper, TenneT
Carbon trust: Look at each investment from margin. Initial links may not have economic benefits eventhough the complete grid may have benefit

Michiel: Look at different scenarios including central planning vs multiple actors making individual investment decisions. Make reasonable assumption about state of the world and investment structure in future.

Bruno Luscan, SGI: Will E-Highways output be interesting input including generation scenarios to WP12

Niek de Groot, TenneT: E-Highways is used in D1.4 and connection to TYNDP is made. However it does not fill in the North Sea, and that is what PROMOTioN is trying to do, so it is seen as a starting point.

Wei He, Statoil: What are the successful criteria for our deployment plan? These should be very clear, focus on TRL, and reduce investment risks and increase investor confidence.

Michiel: That is something that needs to be determined in WP12 although it will be hard to measure investor confidence, even though parameters or importance can be discussed with them.

Carbon Trust: We suggested three separate roadmaps; Regulatory, technical and financial roadmap to combine later into one final roadmap. How do you see this?

Michiel: This is a good suggestion and will be taken onboard.

WP13 - Philipp Kalweit, SOW

Niek de Groot, TenneT: Suggestion for website: very hard to find deliverables, it would be valuable to structure of deliverable according to topic or WP

Philipp: OK

Prad, FSR: Is there a Twitter account?

Philipp: Yes, there are Twitter and LinkedIn accounts

https://www.linkedin.com/groups/8527880

https://twitter.com/PROMOTioN_HVDC

Ceciel, RUG: 2nd Niek, order deliverables to find them easily. Also, would it be possible to build a search engine into the website to easily find deliverables and other documents.
Philipp: Option is already there, but still needs to be expanded with finding PDF file functionality

Cornelis Plet: Next proposes next general assembly meeting

Proposed time: Week 47, 22-24th of November, location, University of Valencia

Agreed by all.

17:05 Session closed
Friday 2 June, PROMOTioN, General Assembly, University of Aberdeen, Room FN1

9:10: Cornelis started to present the general issues and updates about upcoming amendments & WP8 status.

Michiel asked that how much CBA might be affected by the WP8 no go decision? Cornelis answered that WP8 was not supposed to provide cost data. Some person-months may be added to WP3 for cost analysis.

There was a discussion about TRL. Niek de Groot asked about the impact of Siemens decision on TRL. Alexander Broy tried to answer by explaining some works that have been done and should be done in WP8 subtasks. He also mentioned that they may have not similar definition of TRL in Siemens. It seems that Alexander Broy cannot say too much in this regards at this time and he is looking for getting advice and more information from Siemens. Michiel de Schepper said that it should be cleared soon and not delayed too long, for example one year.

The WP leaders have been asked to answer how much the Siemens NO GO decision had an impact on their WPs.

WP1: It has no impact
WP2: It has no direct impact, since control of the grid topologies is not possible to be verified by the Klim demonstrator anyway.
WP3: It has impact on control investigation and verification of simulation results.
WP4: It has no impact.
WP5: It has no impact.
WP6: It has no impact at all.
WP9: DRU could be included in WP9 but has not direct and significant impact.
WP11: It may have minor impact on standardization. Dragan Jovcic mentioned that it probably has significant impact on 11.4 and 11.5 because of its direct impact on DRU. WP11 (Poul Sorensen) replied that it might have impact on AC side and converters and we will find it later. However it has more impacts on WP3.
WP12: The TRL will not be lifted to 8 in PROMOTioN which will be reflected in the roadmap. Any increase in TRL outside PROMOTioN will be taken into account in WP12

Michiel de Schepper asked what the future role of Prysmian will be in project following the Siemens NO GO decision. Cornelis Plet replied that EU does not accept any stand-alone cable demonstration. The only way to keep Prysmian involved with a demonstrator is to combine it with another demo such as the DC GIS and cable together. ABB is reluctant but willing to discuss the possibility. No news has been received from Prysmian and they are also not present at the General Assembly despite a request to do so.
Dirk van Hertem asked about the impact of Siemens no go decision on their contribution in other WPs. He questioned will Siemens contribute in other WPs or not? Alexander Broy replied it seems that yes and they will contribute in other WPs after the no go decision. Cora Petino said Siemens was originally interested to contribute but after this decision she is not sure about the future cooperation.

Alexander Broy was asked to update the group about Siemens Wind Power decision and he answered that he has not much to say but he knows that it is because of staffing.

Cornelis Plet mentioned that it is needed to define CBA methods in WP7 & WP12. Dirk van Hertem asked that if it would be two methods or one merged method? Cornelis Plet replied it would be two methods. Frederick Page said that it was supposed to start 6 months ago according to the Berlin meeting. Cornelis Plet replied it could start sooner but that it has taken a while to define the scope of the CBA and to decide whether to apply for new budget or use existing budget. Michiel de Schepper mentioned that it is important to comment now without long delay.

Wei He asked if the wind turbine manufacturers are involved in this CBA task? Cornelis Plet replied that it is about creation of CBA methodology. It would be good to have the manufacturers’ view but it is not necessary. Dirk van Hertem asked what the CBA are applied to?

Michiel de Schepper asked how we can go from component level to manufacturer & system level cost data? Cornelis Plet replied the question by asking what is the difference between cost and price? He asked TSOs if they have any comments. Yash Audichya said cost depends on many parameters and may change with projects. He mentioned that final cost includes many parameters from components to manufacturing cost and margin. He agreed that the cost data and analysis would be very helpful for all including TSOs.

Stig Holm Sorensen mentioned that Energinet maintains a cost database which can be used for cost estimates.

Cornelis Plet reminds everyone to read and comment on deliverable D1.6 the draft roadmap.

There was a discussion about 4th amendment especially regarding the items that are not included.

Niek de Groot suggested to change the format of the work package reporting day in the half yearly meetings in order to improve the internal dissemination of the WPs results and outcomes.

The presentation and discussion was ended at 11 am.