PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

Establishing a draft roadmap for meshed HVDC offshore grids

Pierre Henneaux (Tractebel) – June 7, 2017

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

Objectives of the draft roadmap

- Derivation of a draft offshore grid development roadmap for the evacuation of offshore wind energy during the decade 2020-2030
  - Optimization of the grid topology
  - 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 Deployment Plan at the end of the project
    - “Pave the way” for the Deployment Plan
- Not a “complete” draft roadmap
  - Several aspects ignored (technological, financial, regulatory)
  - They are currently under study within the PROMOTioN’s project

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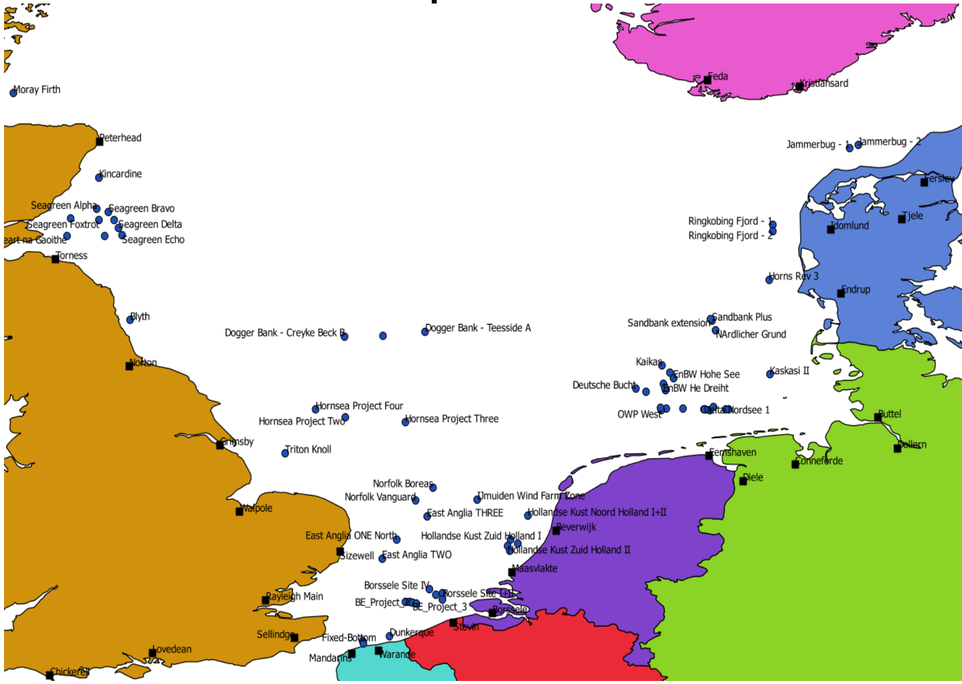
Introduction

Scope and main assumptions

- Geographical scope: North Sea
- 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 the final Deployment Plan
- Reference scenario for potential installed wind capacities in the North Sea: Vision
  - 2020-2030: +37 GW

COUNTRY	ADDITIONAL OFFSHORE WIND GENERATION
Belgium	+1,700 MW
The Netherlands	+4,444 MW
France	+3,005 MW
Germany	+7,389 MW
Denmark	+1,310 MW
United Kingdom	+19,360 MW



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Methodology

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Methodology

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

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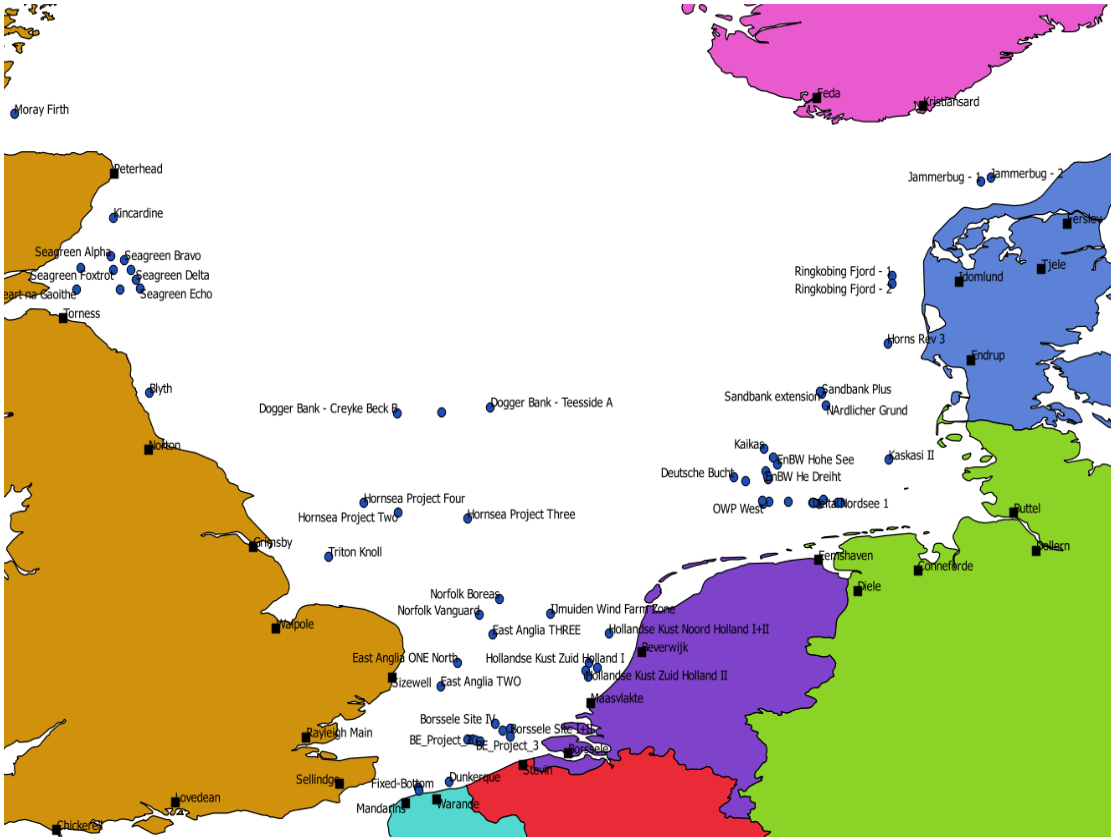
Methodology

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
  - E.g. N-1 security (and its exact definition)

Optimization of the global topology

- Optimization of the connections of offshore wind farms to the shores such that
  - The cost of cables (and offshore platform extensions) is minimal
  - All the offshore wind energy can be evacuated



Methodology

More detailed design

- The optimization of the global topology
  - Does not optimize
    - The placement of HVDC circuit breakers
    - The use of DRU/VSC converters for offshore wind farms
  - Model the offshore grid in a simplified way
- Need of a technical analysis
  - Determine where HVDC circuit breakers are needed, using a very simple policy
    - Smarter strategies are analysed within the PROMOTioN's project
  - Other adaptations
  - Guarantee the technical viability

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Analysis of the economic viability

- Purposes of an offshore meshed grid
  - Not only to evacuate offshore wind energy
  - But also to exchange energy between countries
- Additional benefits brought by the offshore grid
  - Increase of the Socio-Economic Welfare (SEW)
  - Integration of Renewable Energy Sources in the North Sea countries (possibility to exchange RES surplus)
  - …
- Economic viability: linked to the SEW increase
- Estimation of the SEW increase
  - “Market simulation”: estimation of the hourly dispatch of generating units for an entire year in the North Sea countries
  - SEW increase = Reduction of the generation cost with the meshed grid compared to a purely radial solution

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Methodology

Different sets of assumptions

- Main sources of uncertainties
  - Technical capabilities of Diode Rectifier Units (DRUs)
  - Technical capabilities of HVDC Circuit Breakers (DCCBs)
- Four different sets of assumptions

	Availability of DRUs, but only for radial, point-to-point connections	Possibility to use “cheap” DCCBs (cost of a DCCB negligible compared to the cost of a converter)
Base case	✗	✗
Variant 1	✓	✗
Variant 2	✗	✓
Variant 3	✓	✓

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Main results

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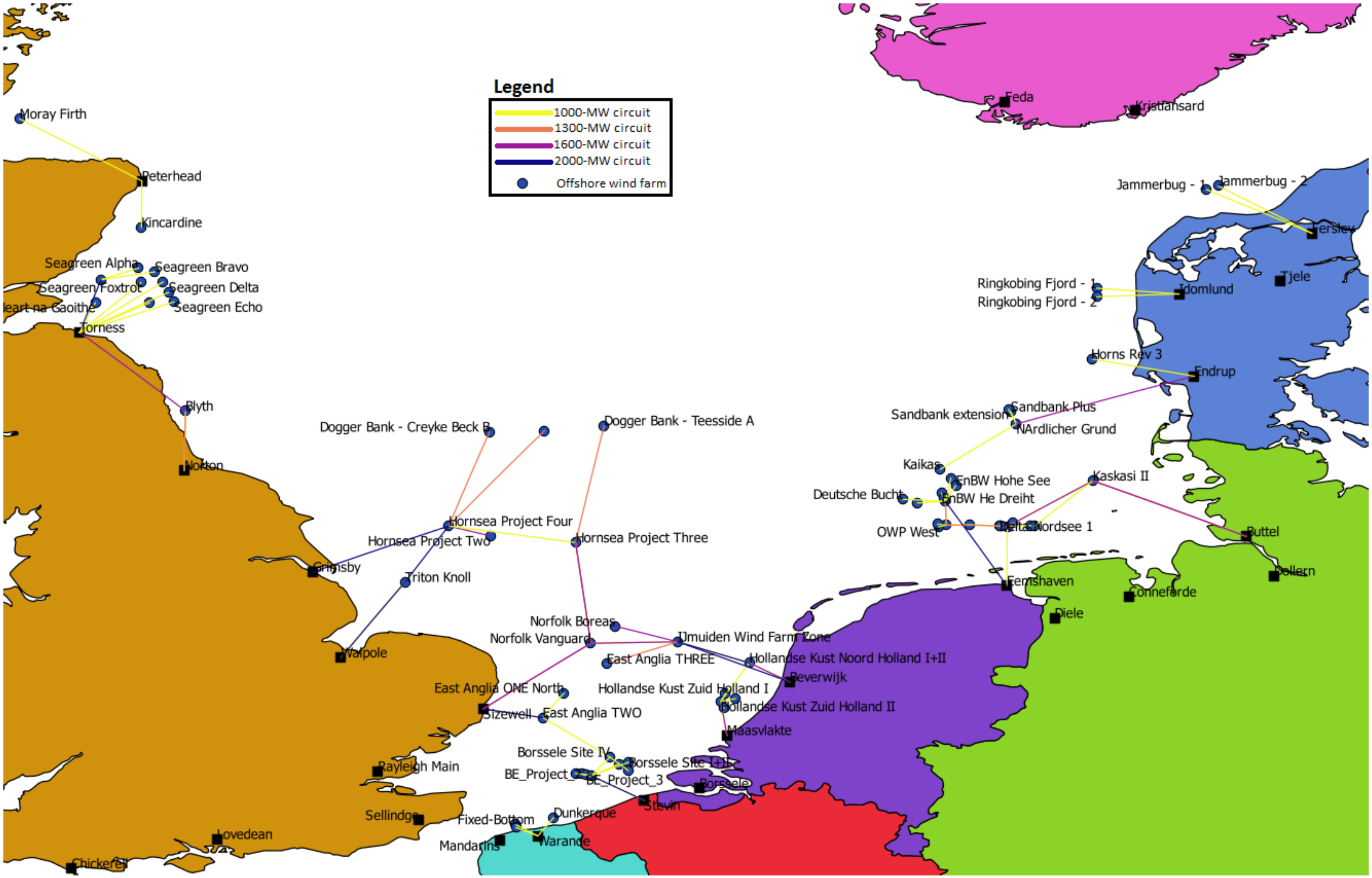
Main results

Resulting coordinated topology in 2030



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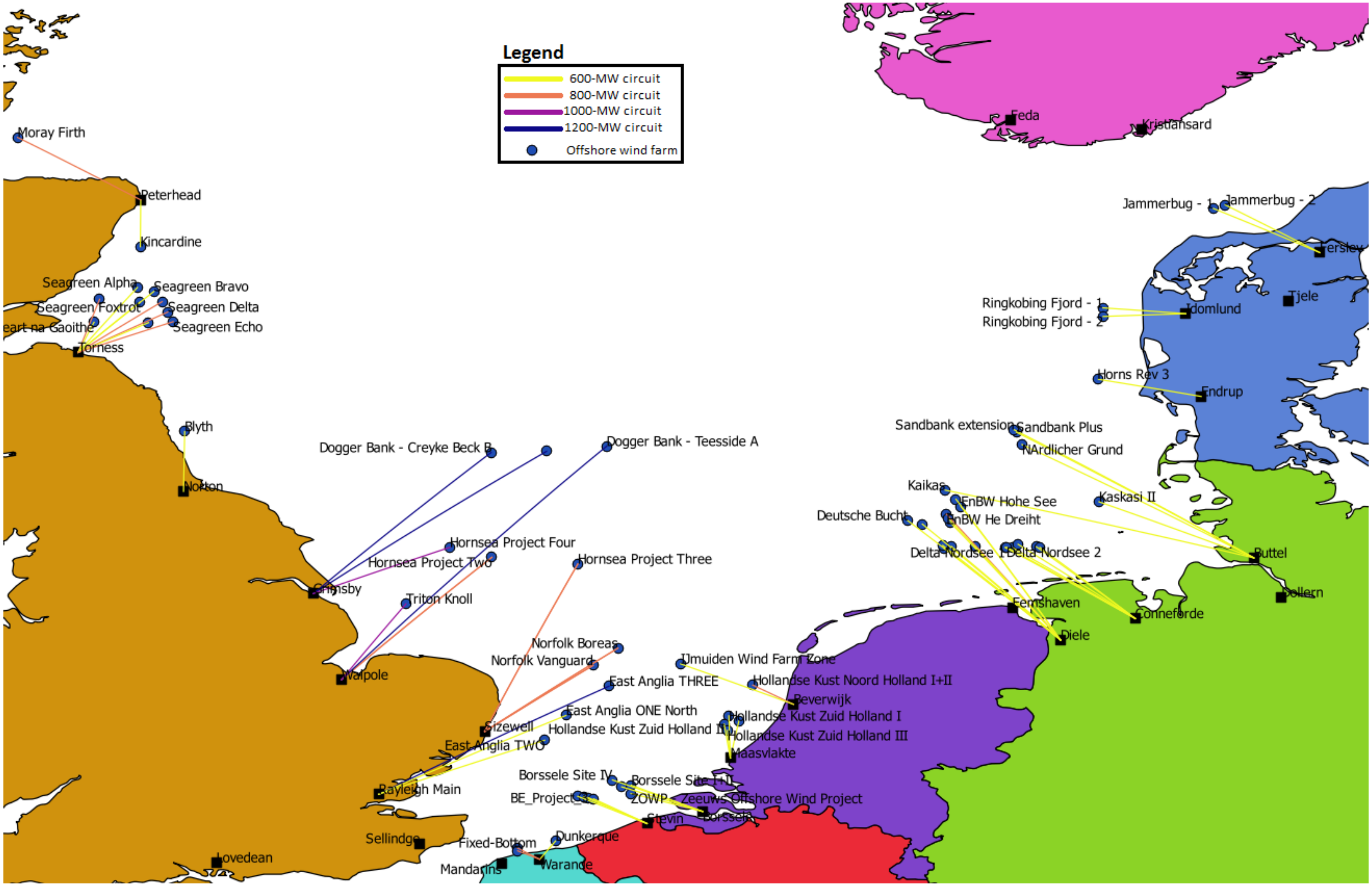
Main results

Resulting radial topology in 2030 (comparison)



Main results

Corresponding costs

Equipment Cost [M€]	Base Case		Variant 1		Variant 2		Variant 3	
	Radial solution	Coordinated solution	Radial solution	Coordinated solution	Radial solution	Coordinated solution	Radial solution	Coordinated solution
Offshore VSC Converters	12,000	12,000	0	3,300	12,000	12,000	0	3,300
Offshore DRU Converters	0	0	7,986	5,789	0	0	7,986	5,789
Onshore VSC Converters	6,160	4,870	6,160	4,870	6,160	4,870	6,160	4,870
Submarine HVDC Cables	10,962	8,194	10,962	8,194	10,962	8,194	10,962	8,194
Offshore platform extensions	0	570	0	570	0	570	0	570
HVDC Circuit Breakers	0	8,366	0	8,366	0	179	0	179
TOTAL COST	**29,122**	**34,000**	**25,108**	**31,089**	**29,122**	**25,813**	**25,108**	**22,902**

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Main results

Cost-Benefit Analysis

- The initial investment of the radial and the coordinated solutions can be different
- But the coordinated solution is expected to bring additional benefits
  - Exchange of energy between countries
- Benefits valued through the increase of the Socio-Economic Welfare (SEW)
  - Estimation of that increase through market simulations

	Additional investment compared to the radial solution (M€)	Actualized increase of the SEW over the lifetime (M€)	Net Present Value (M€)
Base case	4,878	-2,211	-2,667
Variant 1	5,981	-2,211	-3,770
Variant 2	-3,308	-2,211	5,519
Variant 3	-2,206	-2,211	4,417

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Conclusions & perspectives

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Conclusions

- 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

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Perspectives for the Deployment Plan

- Limitations in the current approach that will have to be overcome for the final Deployment Plan
  - Only HVDC connections considered in the optimization 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 optimization problem, but could impact drastically the topology
  - Exchanges of energy between different market areas should be considered in the sizing of the grid
  - Countries might require that wind generated in their economic zone is connected to their onshore grid

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APPENDIX

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