Offshore Transmission Systems

Working Group 5 Progress Report

9 April 2010

Contents

1 Background

The Government plans to facilitate investment in approximately 35 GW of new renewable generation plant in the UK between now and 2020 to allow the UK to meet its climate change targets and ensure security of supply. A large percentage of this 35GW of renewable is anticipated to be offshore wind generation, which will place different demands on the power system, requiring changes to the NETS SQSS.

As part of the development process, offshore wind projects require The Crown Estate's permission, as landowner of the seabed and areas of foreshore. The Crown Estate has granted leases for Round 1, Round 2 and, most recently, Round 3 offshore windfarm development programmes.

Offshore generation connection criteria have already been developed and implemented, suitable for Round 1 and Round 2 offshore developments, comprising offshore power park modules up to 1500MW of capacity and located up to 100km from shore. These criteria were based on a series of cost benefit analyses (CBA) conducted by The Centre for Sustainable Electricity and Distributed Generation (SEDG), and are now included in the new NETS Security and Quality of Supply Standard (Issue 2 - 24 June 2009).

Leases have been awarded in Round 3 for developments that will exceed the capacity and distance from shore assumed during the development of the existing offshore criteria. Additionally, given the location and scale of Round 3 developments there has been discussion within the industry about the possibility of incorporating interconnections to External Systems into the design of the offshore network for these developments.

Distance from shore	0 to 100km	100km to 300km
>1500MW to 10GW	✓ Round 3	✓ Round 3
0 to 1500MW	Round 1 & 2	✓ Round 3

2 Scope of Work

WG5 has been requested to analyse and define the basis of a security standard for offshore transmission networks suitable for the scale and location of Round 3 projects and the incorporation of Interconnectors to External Systems.

When considering the Round 1 and Round 2 offshore developments it was assumed that the offshore transmission systems would consist of radial connections rather than interconnected mesh systems. However, given the scale and distance from shore of some Round 3 developments:

- the additional cost of interconnecting multiple generation sites is more likely to be offset by the reduced severity of an outage (either planned or due to a fault) in an interconnected system – especially when a windfarm is not generating at full capacity
- incorporating interconnectors to External systems could bring additional benefits and be more efficient and economic than building dedicated interconnectors

Therefore, interconnected designs and connection to External systems are being considered by WG5, as well as radial connections.

As for the previous analysis for Round 1 and Round 2, both AC and HVDC transmission technologies are being considered.

For reference, an extract from the WG5 Terms of Reference is provided in Annex A.

3 Approach

To meet the terms of reference WG5 is using Cost Benefit Analysis (CBA) as a basis for determining appropriate recommendations for:

- the generation connection criteria appropriate for offshore power park modules between 1.5 – 10 GW of capacity and/or between 100 – 300 km offshore;
- the generation connection criteria applicable to External Interconnections;
- the generation connection criteria for offshore gas turbines located between 100km and 300km from shore; and
- the demand connection criteria applicable to an offshore transmission system (given the potential for higher levels of offshore power station demand for Round 3 projects).

The CBA will consider the lifetime costs (both construction and operational costs throughout the infrastructure's lifetime) to identify the overall most cost efficient solutions.

Key assumptions include that:

- there are no plans for supplying demand customers from offshore transmission systems other than offshore power stations who may wish for demand to be supplied (e.g. for station auxiliaries when the power station is off load)
- the criteria for offshore transmission systems will be designed to ensure that their application does not allow the security of supply for onshore users of the GB transmission system to be lowered
- this work does not include a review of other sections of the GB SQSS e.g. operation of an offshore transmission system or voltage limits in planning and operating an offshore transmission system

4 Working Group Progress

Before the actual CBA can commence, a wide range of inputs must be determined, the range of design options identified, and the necessary tools developed to enable the cost effectiveness of different design options to be assessed.

4.1 Selection of CBA Input Parameters

There are a wide variety of input parameters to a CBA which must be defined, including:

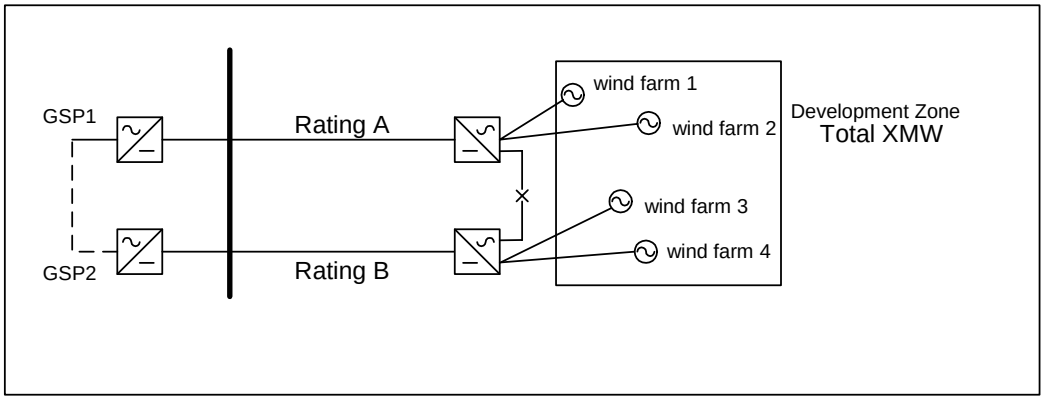
- the capacity and output profile of the generation
- the configuration of the network (including any redundancy)
- the cost and capacity (electrical and physical), and parameters of equipment
- reliability parameters: fault rate and mean time to repair
- construction costs
- value of constrained energy and lost load
- maintenance requirements and costs
- ability to carry out post fault corrective actions

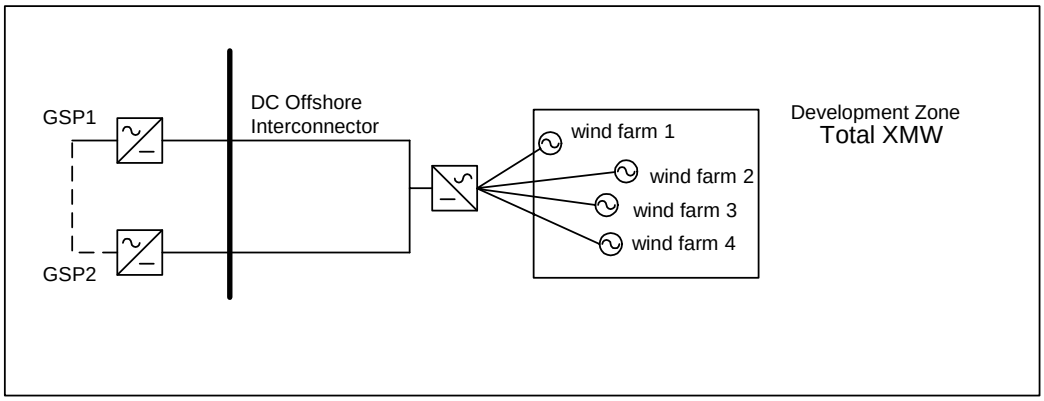
WG5 has put considerable effort into defining these parameters. The interactive nature of network design makes this process more involved. For example, the reactive requirements of an AC network are a non-linear function of the electrical parameters of the cable, the length of the circuit, and the power flowing through the circuit. Changing one parameter can therefore affect the suitable choice of other parameters. Therefore, the working group has also invested considerable time identifying the relationships between all of the various parameters. A questionnaire has been sent out to industry and responses received. This activity is almost complete.

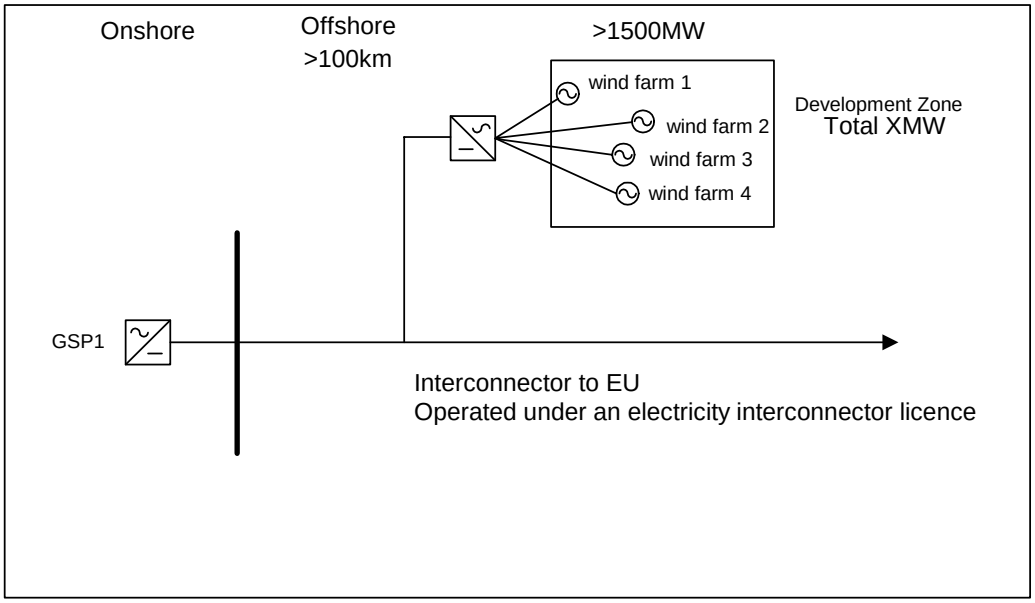
4.2 Identification of Offshore Network Configurations & Design Options

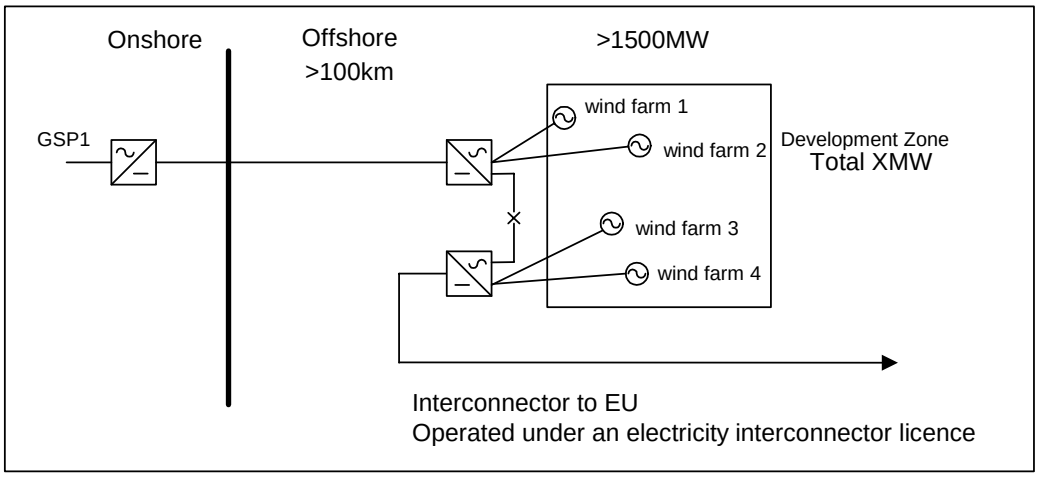
As previously indicated, interconnecting multiple links is more likely to be cost-effective for developments of the scale and location of some of the Round 3 projects. There are various ways in which links could be interconnected, and another early focus of the working group has been to identify a set of possible network configurations and the range of other design options.

Some example network configurations follow:




GSP1
GSP2
DC Offshore
Interconnector
wind farm 1
wind farm 2
wind farm 3
wind farm 4
Development Zone
Total XMW


Onshore
Offshore
>100km
>1500MW
wind farm 1
wind farm 2
wind farm 3
wind farm 4
Development Zone
Total XMW
GSP1
Interconnector to EU
Operated under an electricity interconnector licence


Onshore
Offshore
>100km
>1500MW
GSP1
wind farm 1
wind farm 2
wind farm 3
wind farm 4
Development Zone
Total XMW
Interconnector to EU
Operated under an electricity interconnector licence

4.3 CBA Methodology Development

In order to actually perform a CBA, a methodology and supporting tools must be developed to use the various inputs to assess the cost-effectiveness of different design options. The goal of the CBA methodology is to identify the design options that will minimise the combined cost of:

- cost of offshore and onshore transmission capital investment, including:
    - undersea cable network
    - offshore platforms with associated equipment (transformers, reactive compensation and switchgear etc)
    - onshore circuits and substations
    - onshore reactive compensation
- capitalised operational costs:
    - corrective maintenance
    - additional system operational costs (reserve and response)
- capitalised cost of expected constrained energy due to preventive and corrective maintenance, as well as losses over the period of the asset life.

Invariably, minimising the overall cost necessitates a balance between the capital cost of infrastructure and the lifetime operating costs.

While the CBA methodology and tools to be utilised are broadly consistent with those used to develop the existing offshore criteria, some changes have been necessary due to the higher capacity equipment and interconnected-network designs likely to be cost-effective for Round 3 network designs. Implementing these changes has been a significant area of work for WG5. Additionally, improved loss models for long distance cables and for HVDC converter stations have been implemented, and the calculation of AC cable capabilities and reactive requirements have been updated to include voltage step-change effects. Initial case studies for various wind farm ratings has been conducted and the findings discussed at working group meetings.

Once the CBA input parameters have been finalised, the tools will need to be some additional update to include the costs, capabilities and requirements of any additional equipment items.

5 Further Work

Once all of the input data has been identified and agreed, a large number of analyses will need to be performed to assess the merits of different design options in a range of circumstances.

Given the fast rate of change within the offshore transmission industry (particularly with innovations in technologies such as VSC HVDC) and the sensitivity of equipment costs to commodity prices, a basic CBA could rapidly become out of date. Therefore a number of sensitivities will also need to be carried out to confirm the robustness of the results to parameter changes.

The network designs (e.g. the arrangement and capabilities of equipment) identified as being optimal in different circumstances will then need to be analysed, with a view to identifying any common attributes. For example, whether there is a cost-effective level of redundancy for different capacity wind farms. The final step will then be to develop deterministic criteria that will define networks that contain these cost-effective attributes.

Once this is completed, the proposed criteria will be subject to industry consultation before being recommended for incorporation into the NETS SQSS.

Annex A Working Group 5 Terms of Reference

The Offshore Transmission Systems Working Group will build upon National Grid's earlier change proposals (dated 29 April 2008) and:

- Analyse and define the basis for an offshore security standard that can cater for generation projects of the size (i.e. larger than 1500MW) and location (i.e. more than 100km from the shore) of R3 projects and the connection of External Interconnections (from External Systems) to offshore transmission systems.

- The work will include:
    - Establish an agreed Data Set/s for use in cost benefit analyses on Round 3 projects and in respect of the connection of External Interconnections to offshore transmission systems;
    - Conduct further cost benefit analyses, as appropriate, to support any new and/or modified recommendations relative to those underlying the NGET change proposals dated 29 April 2008;
    - Develop new recommendations and / or modifications to the existing recommendations underlying the offshore generation connection criteria contained in the NGET change proposals dated 29 April 2008;
    - Translate the new or modified recommendations into appropriate criteria and/or methodologies; and
    - Assist the GB SQSS Drafting Working Group, as necessary, in developing change proposals to the GB SQSS in the form of additional or modified change proposals to the current NGET change proposals dated 29 April 2008.

- In addition, the Working Group shall take due account of:
    - Interactions with the work of other Fundamental Review Working Groups; and
    - In the context of any change proposals to the GB SQSS arising, compatibility with other industry Codes (e.g. GB Grid Code).

Annex B Working Group 5 Membership

Ivo Spreeuwenberg (NG), part-time chairperson
Jo Habberley (NG), part-time chairperson
Mark Perry (NG), part-time chairperson
Goran Strbac (SEDG)
Noel McGoldrick (NG), part-time
Paul Neilson (SHETL)
Peter Roper (SP)
Predrag Djapic (SEDG)