nationalgrid

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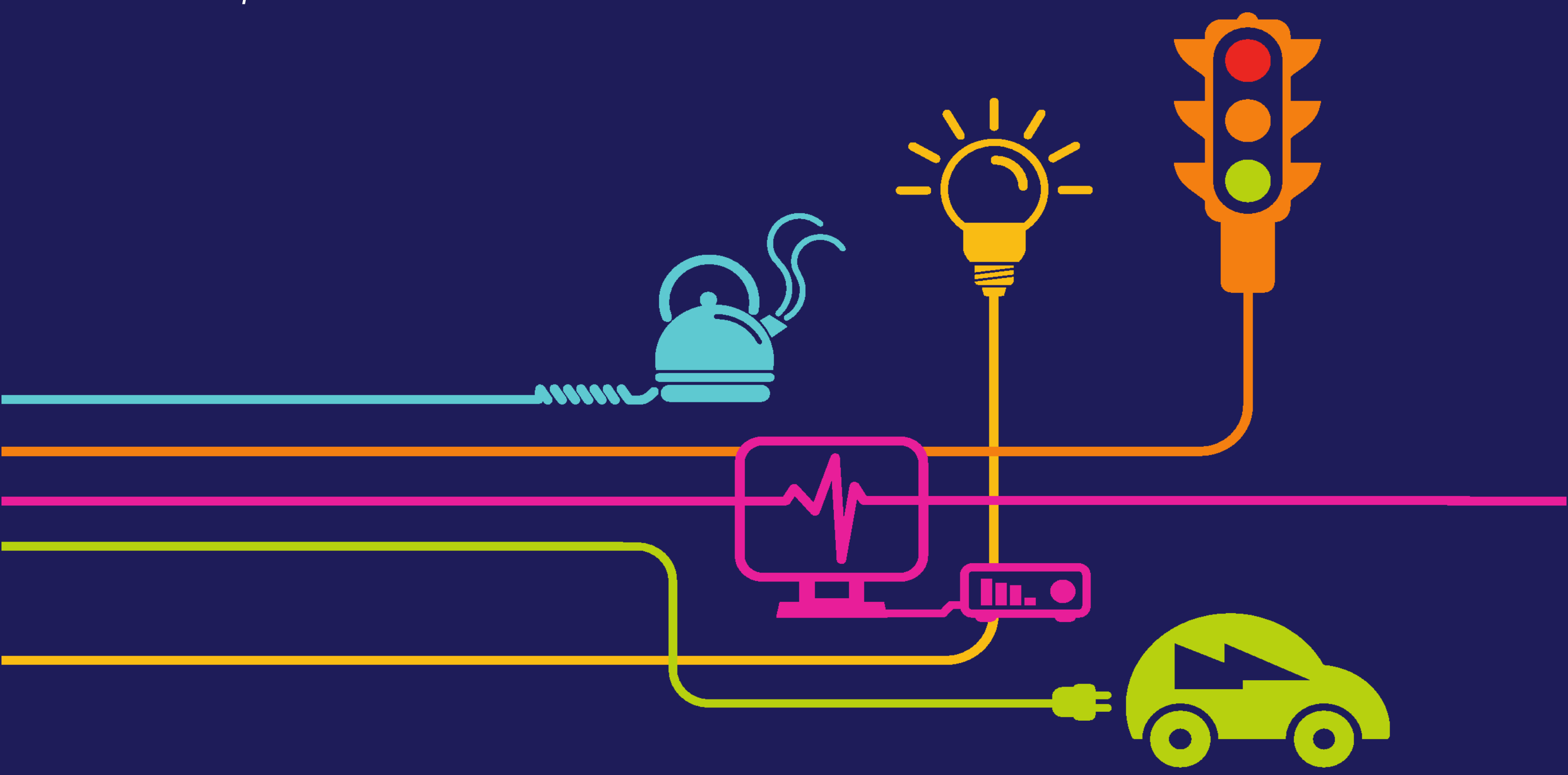
Historic Need Case (2012)

National Grid (North Wales Connection Project)

Regulation 5(2)(q) of the Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

First published October 2012



Application Reference EN020015

September 2018

North Wales Connections

Need Case

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North Wales Connections

Project Need Case

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1 Introduction

1.1 This Need Case has been prepared in accordance with the pre-application procedures adopted by National Grid Electricity Transmission plc ("National Grid") for those major infrastructure projects which may require a development consent order ("DCO") under the Planning Act 2008 (the "Planning Act").

1.2 Its purpose is to inform interested parties of the need to plan the extension of the National Electricity Transmission System (the "NETS") in North Wales in order to connect new generators to the transmission system and ensure that National Grid shall continue to comply with its licence standards.

1.3 This Need Case does not propose options for how the necessary electricity transmission system reinforcements could be achieved. An assessment of strategic options that could meet the requirement set out in this Need Case is presented in the North Wales Connections Strategic Options Report.

1.4 This document and other information regarding the North Wales Connections, can be found on the National Grid website at:

https://www.nationalgrid.com/uk/Electricity/MajorProjects/NorthWalesConnection/

1.5 This need case provides:

- an overview of the electricity industry (section 2)
- a description of the existing transmission system in North Wales (section 3)
- details of the levels of generation and demand in North Wales (section 4)
- details of the agreements to connect proposed generation in North Wales (section 5)
- results of the assessment of the impact of connecting the proposed generators (section 6), and
- key conclusions in section 7.

1.6 This Need Case document also includes appendices that contain more detailed information. The appendices provide:

- a summary of National Grid's legal obligations that are particularly relevant to this Need Case document (Appendix A).
- an overview of transmission system analysis principles including details of compliance requirements, key assessment criteria, factors that limit transmission system capability, possible consequences of exceeding capability limits and references to generic options for enhancing transmission system capability (Appendix B), and
- a glossary of terms and acronyms used in this Need Case document (Appendix C).

2 Background

2.1 A single electricity market serves the whole of Great Britain. In this competitive wholesale market, generators and suppliers trade electricity on a half hourly basis. Generators produce electricity from a variety of energy sources, including coal, gas, nuclear and wind, and sell the energy produced in the wholesale market. Suppliers purchase electricity in the wholesale market and supply to electricity consumers.

2.2 The peak electricity demand in Great Britain is over 60 GW and occurs during winter. The combined capacity of all generators and interconnectors connected to and/or using the electricity transmission system is greater than this peak demand; this excess is generally referred to as plant margin.

2.3 Network infrastructure is needed to ensure that electricity can be transported from where it is generated to where it is used. The transmission system operates at 400 kV and 275 kV and transports bulk supplies of electricity from generating stations to demand centres. Distribution systems operate at 132 kV and below in England and Wales, and are mainly used to transport electricity from bulk infeed points (interface points with the transmission system) to electricity consumers. See Figure 2.1.

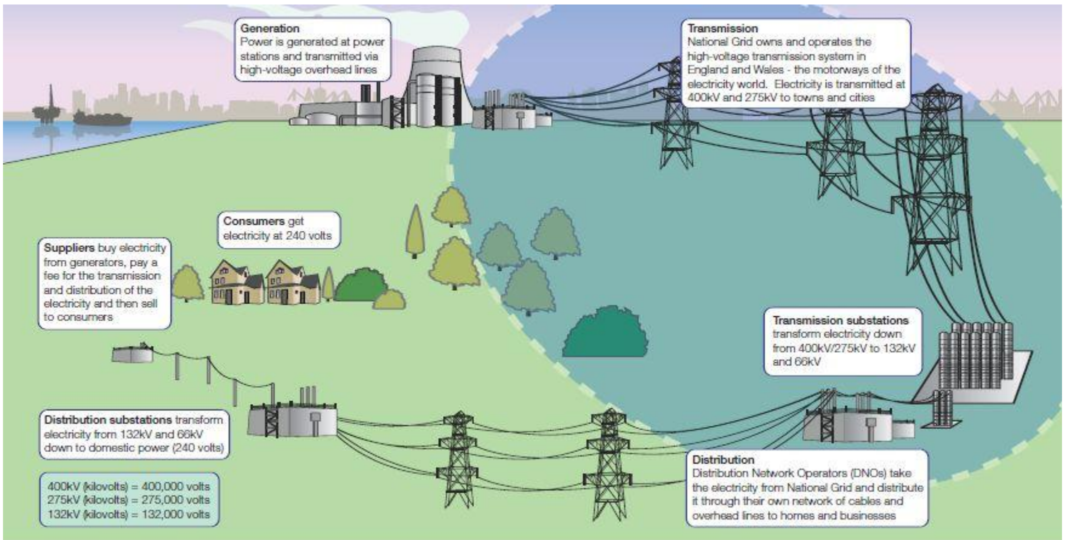

Figure 2.1: The electricity system from generator to consumer

2.4 Electricity generated and supplied in other European countries can also be traded in the GB electricity market. Interconnectors with transmission systems in

France, Northern Ireland and the Netherlands are used to both import and export electricity which can be bought and sold in the GB market.

National Grid's Role

2.5 Transmission of electricity in Great Britain requires permission by a licence granted under Section 6(1)(b) of the Electricity Act 1989 (the "Electricity Act"). National Grid has been granted a transmission licence and is therefore bound by legal obligations, which are primarily set out in the Electricity Act and the transmission licence. A summary of relevant legal obligations is included in Appendix A.

2.6 National Grid is the operator of the high voltage transmission system in Great Britain and its offshore waters, the NETS, and is the owner of the high voltage transmission system in England and Wales.

2.7 Part of National Grid's role is to provide the contractual interface with those using the NETS (e.g. electricity supply companies) and those connected to, or seeking a connection to, the NETS. (e.g. generators, large factories and interconnectors to other countries)

National Grid's Transmission System

2.8 The transmission system was developed to transport electricity in bulk from power stations to demand centres. Much of National Grid's transmission system was originally constructed in the 1960s. Incremental changes to the transmission system have subsequently been made to meet increasing customer demand, to connect new power stations and to connect interconnectors with other transmission systems.

2.9 National Grid's transmission system consists of approximately 7,200 km of overhead lines and a further 700 km of underground cable, operating at 400 kV and 275 kV. In general, 400 kV circuits have a higher power carrying capability than 275 kV circuits. These overhead line and underground cable circuits connect over 300 substations, forming a highly interconnected transmission system. Further details of the transmission system including geographic and schematic representations are published by National Grid annually as part of its Seven Year Statement. [1]

2.10 Circuits are those parts of the system used to connect between substations on the transmission system. The system is composed of double-circuits (in the case of overhead lines carried on two sides of a single pylon) and single-circuits. Substations provide points of connection to the transmission system for power stations, distribution networks, transmission connected demand customers (e.g. large industrial customers) and interconnectors.

Requirement for Changes to the Transmission System

2.11 Under the terms of its licence and the Electricity Act, National Grid is required to provide an efficient, economic and co-ordinated transmission system in England and Wales. The transmission infrastructure needs to be capable of maintaining a minimum level of security of supply and of transporting electricity to and from customers. National Grid is required to ensure that its transmission system remains capable as customer requirements change.

2.12 The transmission system needs to cater for both demand and generation changes. Customers can apply to National Grid for new or modified demand or generation connections to the transmission system; National Grid is then required to respond to each customer application with an offer for a new or a modified connection, as appropriate.

2.13 Until recently, new power station connections have been requested and made at a steady rate that met increasing demand and replaced power stations that had reached the end of their operating lives. More recently, a large volume of applications have been made to National Grid for the connection of new generation at locations that are remote from the existing transmission system or which are in the vicinity of parts of the transmission system that does not have sufficient capacity available for the new connection. The majority of these applications have been for low-carbon generation projects.

2.14 Developing the transmission system in England and Wales may require one or more statutory consents, depending on the type and scale of the project. These

[1] The GB Seven Year Statement can be viewed at https://www.nationalgrid.com/uk/Electricity/SYS/current/

may include planning permission or use of permitted development rights under the Town and Country Planning Act 1990, a marine licence under the Marine and Coastal Access Act 2009 and a Development Consent Order (DCO) under the Planning Act 2008.

3 The Transmission System within North Wales

3.1 The transmission system within North Wales is illustrated in the map in Figure 3.1. It shows the transmission substations and the transmission routes joining them.

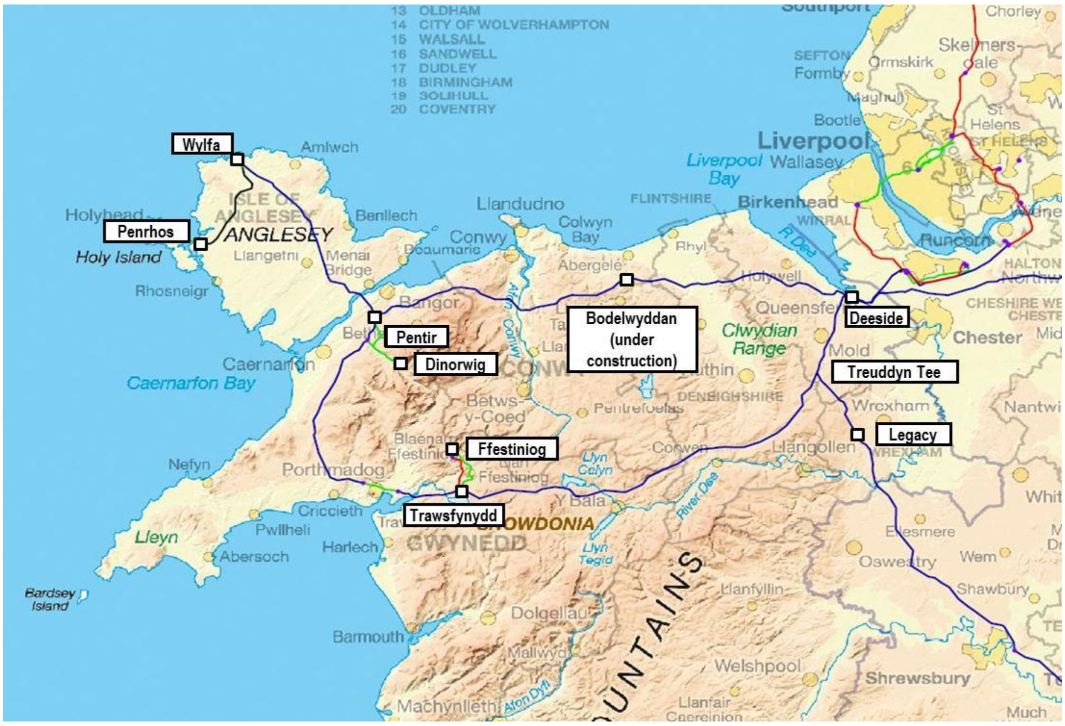

Figure 3.1 – Geographical Illustration of the transmission system within North Wales

3.2 Figure 3.2 illustrates the transmission system within North Wales in the form of a schematic diagram, again showing the transmission substations and circuits. The main generator power stations and their output capacities are also shown.

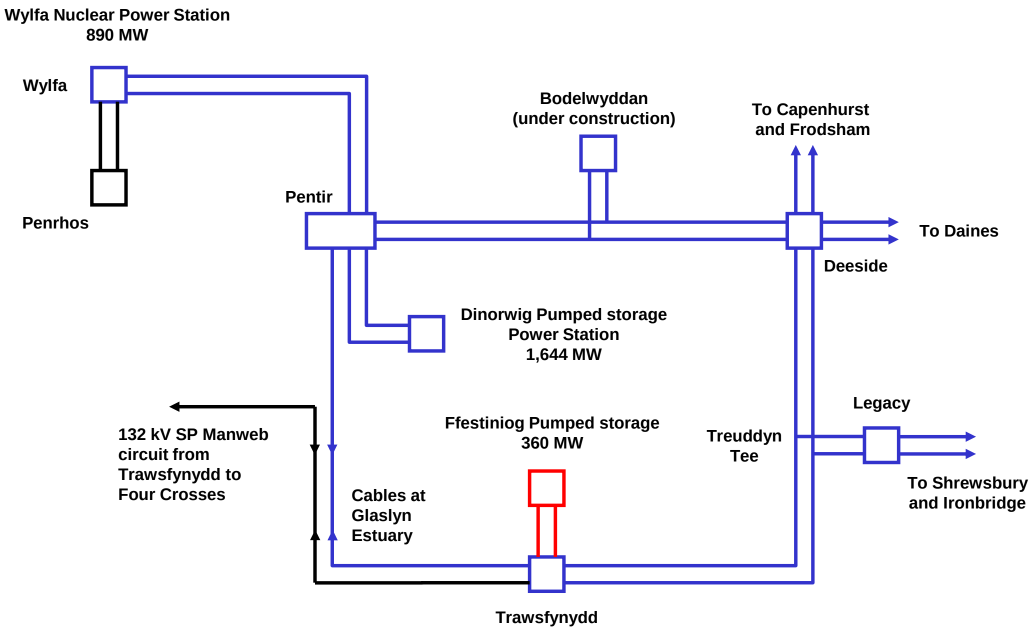

Figure 3.2 – Schematic Diagram of the Transmission System within North Wales

3.3 In summary, the transmission system within North Wales consists of:

- a 400 kV double circuit overhead line between Wylfa and Pentir
- a 400 kV double circuit overhead line between Pentir and Deeside
- two 400 kV circuits (partly cable, partly overhead line) between Pentir and Dinorwig
- a 400 kV single circuit between Pentir and Trawsfynydd, with an underground cable section between Wern and Y Garth (Glaslyn Estuary). This circuit occupies one side of a 400 kV tower route. Note that SP Manweb, the local electricity distribution company, has a 132 kV circuit on the other side of the 400 kV tower between Trawsfynydd and Bryncir, where is leaves the route and carries on to Four Crosses substation on wood pole structures, where it supplies electricity to the Llyn Peninsula.
- a 400 kV double circuit overhead line between Trawsfynydd, Legacy and Deeside
- a 275 kV double circuit overhead line between Trawsfynydd and Ffestiniog, and
- a 132 kV double circuit overhead line between Wylfa and Penrhos.

3.4 As shown in Figure 3.2, SP Manweb, the local Distribution Network Operator (DNO), has a single 132 kV circuit mounted on part of the Trawsfynydd to Pentir overhead line route which provides supplies to the Llyn Peninsula.

3.5 The double circuit from Pentir to Wylfa connects Wylfa Power Station, a Magnox nuclear station, to the transmission system. Wylfa was scheduled to close at the end of 2010 but it was recently announced by the owner, the Nuclear Decommissioning Authority, that the station is to continue generating electricity up to 2014.

3.6 The two circuits between Pentir and Dinorwig substations connect Dinorwig Power Station to the transmission system. Dinorwig Power Station is a pumped storage power station owned by First Hydro Company and is located at Llanberis, Gwynedd.

3.7 The two 275 kV circuits between Trawsfynydd and Ffestiniog substations connect Ffestiniog Power Station to the transmission system. Ffestiniog Power Station is also a pumped storage power station owned by First Hydro Company and is located at Ffestiniog, Gwynedd.

3.8 The transmission system within North Wales is connected to the rest of the transmission system via six 400 kV circuits:

- a 400 kV double circuit between Deeside and Daines
- a 400 kV double circuit between Deeside and the Mersey region, connecting into Capenhurst and Frodsham substations
- a 400 kV circuit between Legacy, Shrewsbury and Ironbridge substations, and
- a 400 kV circuit between Legacy and Ironbridge substations.

4 Generation and Demand in North Wales

4.1 Table 4.1 sets out details of the existing power stations connected within North Wales which have contractual rights to use the transmission system.

Power Station	Transmission Substation	Plant Type	Capacity (MW)
Dinorwig	Dinorwig	Pumped Storage	1,644
Wylfa	Wylfa	Nuclear	890
Ffestiniog	Ffestiniog	Pumped storage	360
Dolgarrog *	Pentir	Hydro	39
Maentwrog *	Trawsfynydd	Hydro	30
Cwm Dyli *	Trawsfynydd	Hydro	10
		Total	**2,973**

Table 4.1 – Power Stations connected within the North Wales area

* While these power stations are connected to the distribution system they have rights to make use of the transmission system.

4.2 The transmission system in North Wales also supplies electricity to the local distribution system, owned and operated by SP Manweb, and directly to Anglesey Aluminium Metal Ltd.

4.3 Peak electricity demand in North Wales is currently around 200 MW.

4.4 By comparing the generation and demand figures above it can be readily seen that North Wales generally exports power to the rest of the transmission system.

5 Connection Agreements

5.1 National Grid has received a number of applications for offers to connect generators to the transmission system within North Wales. Offers have now been made and accepted by the applicants. As such, National Grid has contractual and licence obligations to carry out the necessary transmission works to enable these generators to connect.

5.2 Table 5.1 sets out details of the connection contracts now in place.

Company	Generator Name	Substation	Completion Date	Plant Type	Capacity (MW)
Gwynt y Môr Offshore Wind farm Ltd	Gwynt y Môr	Bodelwyddan (Denbighshire)	2012 - 2014	Offshore wind	574
Dong Wind (UK) Ltd	Burbo Bank Extension	Bodelwyddan (Denbighshire)	2015	Offshore wind	234
Celtic Array Limited	Celtic Array Wind Farm	At or in the vicinity of Wylfa (Anglesey)	2017 - 2021	Offshore wind	2,000
Greenwire Limited	Greenwire Wind Farm - Pentir	Pentir	2018	Onshore Wind	1,000
Horizon Nuclear Power Wylfa Limited	Wylfa	Wylfa (Anglesey)	2020 - 2022	Nuclear	3,600
				Total	**7,408**

Table 5.1 – New connection contracts

5.3 Gwynt y Môr Offshore Wind farm Ltd is owned by RWE nPower Renewables and has a connection agreement for a wind farm to be located off the coast of North Wales with a generation capacity of 574 MW. It is in the process of being connected in stages over the period 2012 – 2014 to Bodelwyddan substation, which is currently under construction.

5.4 Dong Wind (UK) Ltd has a connection agreement for Burbo Bank Extension offshore wind farm which will be located to the west of the company’s existing operational Burbo Bank wind farm (located in Liverpool Bay off the North Wirral and Sefton coasts). It will have a generation capacity of 234 MW and it is planned to be connected in 2015 to Bodelwyddan substation which, as previously stated, is currently under construction.

5.5 Celtic Array Ltd, a joint venture between DONG Energy and Centrica Energy Renewable Investments Ltd, has connection agreements for offshore wind farms to be located in Zone 9 of the Irish Sea. They will have a total generation capacity of 2 GW and are planned to be connected over the period 2017 to 2021. The connection for these wind farms will be either to the existing Wylfa 400 kV substation or to a new substation located in the vicinity of Wylfa.

5.6 Horizon Nuclear Power is a UK energy company developing a new generation of nuclear power stations. It is a joint venture between E.ON UK and RWE Npower. It has a connection agreement for a new nuclear power station at Wylfa with a generation capacity of 3,600 MW and is planned to be connected over the period 2020 to 2022.

5.7 Greenwire Ltd signed a connection offer in July 2012 for 1,000 MW of generation capacity. The wind farm for this connection is located onshore in Ireland and Greenwire Ltd is responsible for the construction of the connection between the wind farm and Pentir. National Grid will, in commercial and technical terms, treat the wind farm as being onshore at Pentir. It is planned to be connected by the end of 2018.

5.8 The locations of the proposed new generation sites and connection points are indicated in Figure 5.1.

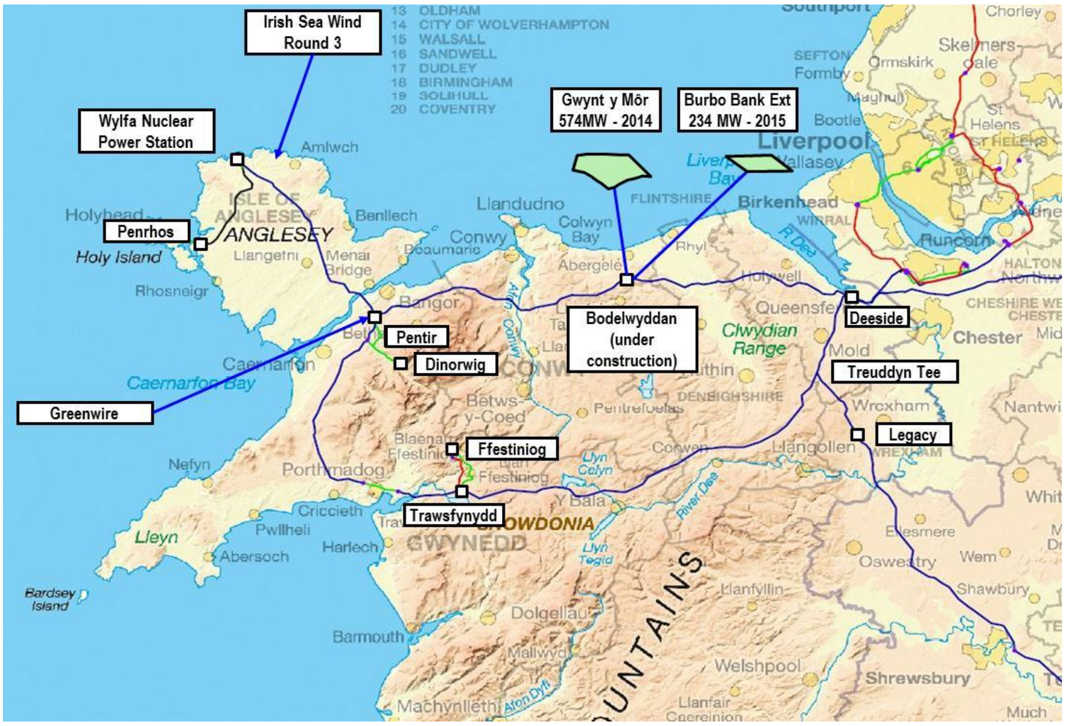

Figure 5.1 – Location of Proposed Generators

5.9 The additional generation capacity in North Wales is illustrated in Figure 5.2.

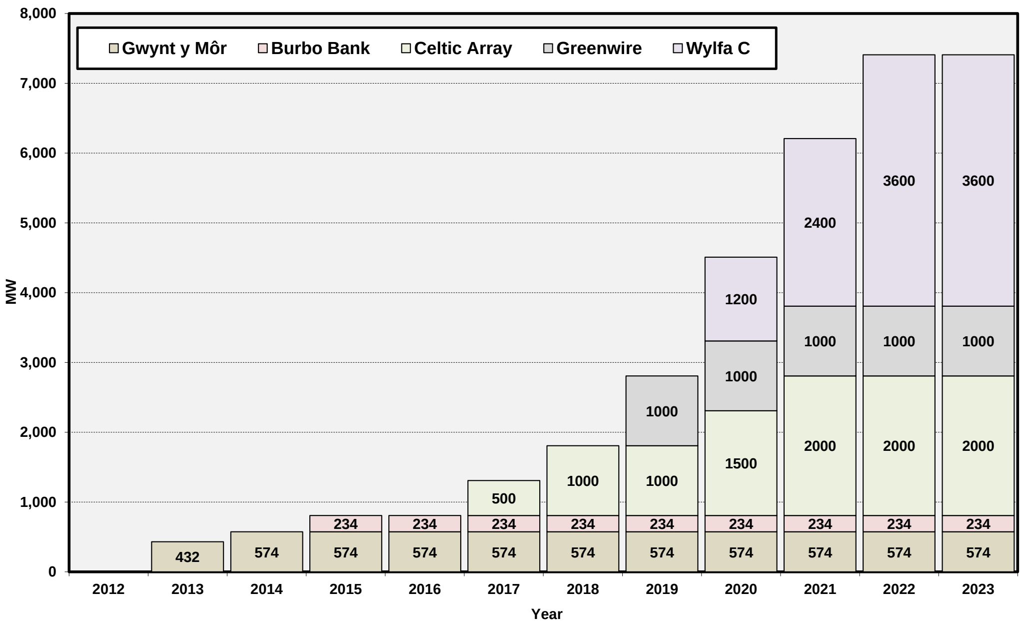

Figure 5.2 – Additional Contracted Generation in North Wales

6 Assessment of the Generator Connections

6.1 As described in sections 2 and 5, National Grid has obligations to plan the development of the transmission system in order to connect a number of generators in North Wales.

6.2 The design of new electrical connections between power stations and the transmission system, and any reinforcements or modifications to the existing transmission system, must comply with criteria set out in a number of documents particularly the National Electricity Transmission System Security and Quality of Supply Standard or "NETS SQSS". [2] This is a document which is required by Licence Condition C17 of the National Grid licence and sets out certain criteria which National Grid must comply with in planning, developing and operating the transmission system.

6.3 In accordance with the requirements of NETS SQSS, National Grid is required to continually assess the transmission system to ensure a number of electrical parameters stay within prescribed limits, for example, voltage, frequency, current carrying capacity, stability and fault current carrying capacity. There are two performance characteristics which are particularly relevant in the assessment of the transmission system in North Wales and these clearly demonstrate the need to upgrade the transmission system following the connection of new generation and their assessment is described in this section. They are:

(a) the potential for the disconnection of more than 1,800 MW of generation following two transmission faults ("loss of power infeed"), and

(b) the current carrying capacity of the circuits, or "circuit rating".

6.4 Other performance characteristics also demonstrate the need to upgrade the transmission system but failure against any of the criteria demonstrates the need and the two performance characteristics listed above are arguably the most conclusive.

<u>Loss of Power Infeed</u>

[2] NETS SQSS Version 2.1: http://www.nationalgrid.com/NR/rdonlyres/784F2DFC-133A-41CD-A624-952EF4CCD29B/45776/NETSSQSS_v21_March2011.pdf

6.5 Section 2 of the NETS SQSS contains the planning criteria applicable to the connection of power stations to the transmission system. Paragraph 2.6.4 of the NETS SQSS requires that following the concurrent fault outage of any two transmission circuits the loss of power infeed to the system shall not exceed a defined value. From 1 April 2014 that value will be set at 1,800 MW. It is set at a level which strikes an economic balance between the cost of connecting generation to the transmission system and the cost of having generators in a state of readiness to provide prompt support in the event of disconnecting fully operational generators.

Circuit ratings

6.6 Section 2.10 of the NETS SQSS requires that following certain defined events on the transmission system, whether planned, unplanned or a combination of both, in general terms, the ratings of circuits shall not be exceeded.

Transmission "Boundaries"

6.7 National Grid makes use of notional 'boundaries' on the transmission system when assessing the system against the various criteria contained in the NETS SQSS. In considering the North Wales area three boundaries have been developed and these are shown in Figure 6.1. Some tests can be more relevant to particular boundaries. For example, the loss of power infeed test is more relevant to boundary 1 than say, boundary 2, as only two circuits cross boundary 1.

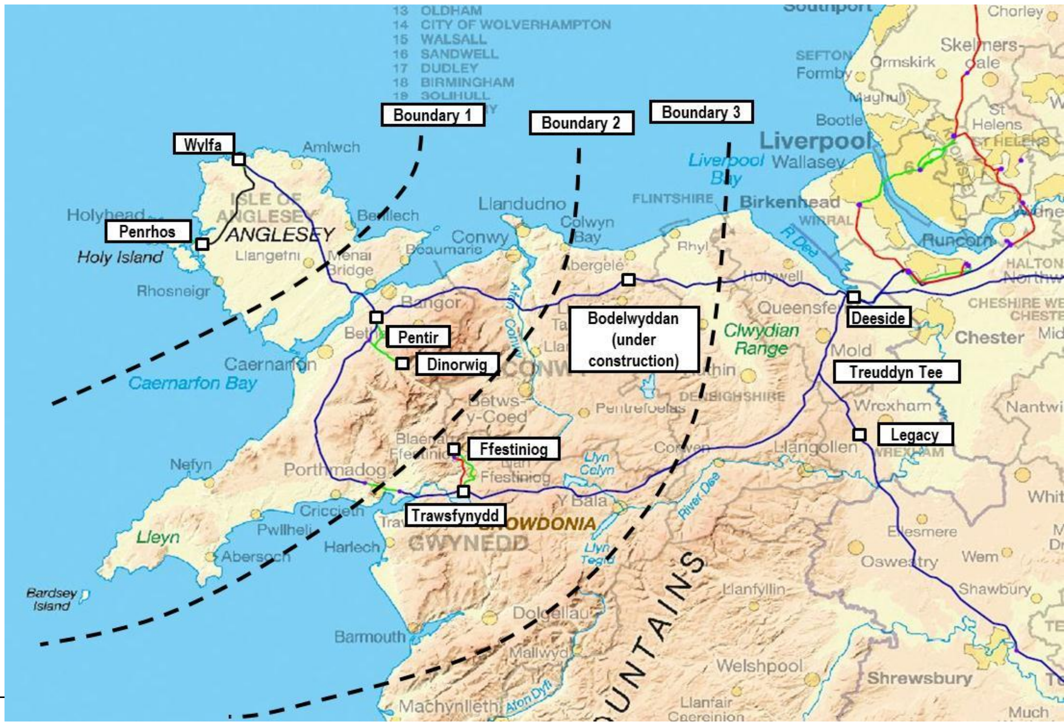

Figure 6.1 – System boundaries

Boundary Assessment

6.8 Consider boundary 1. As previously stated, paragraph 2.6.4 of the NETS SQSS requires that, after 1 April 2014, in the event of a fault de-energising the double circuit between Wylfa and Pentir no more than 1,800 MW of generation shall be disconnected from the transmission system. Figure 6.2 illustrates the total amount of generation connected 'behind' boundary 1.

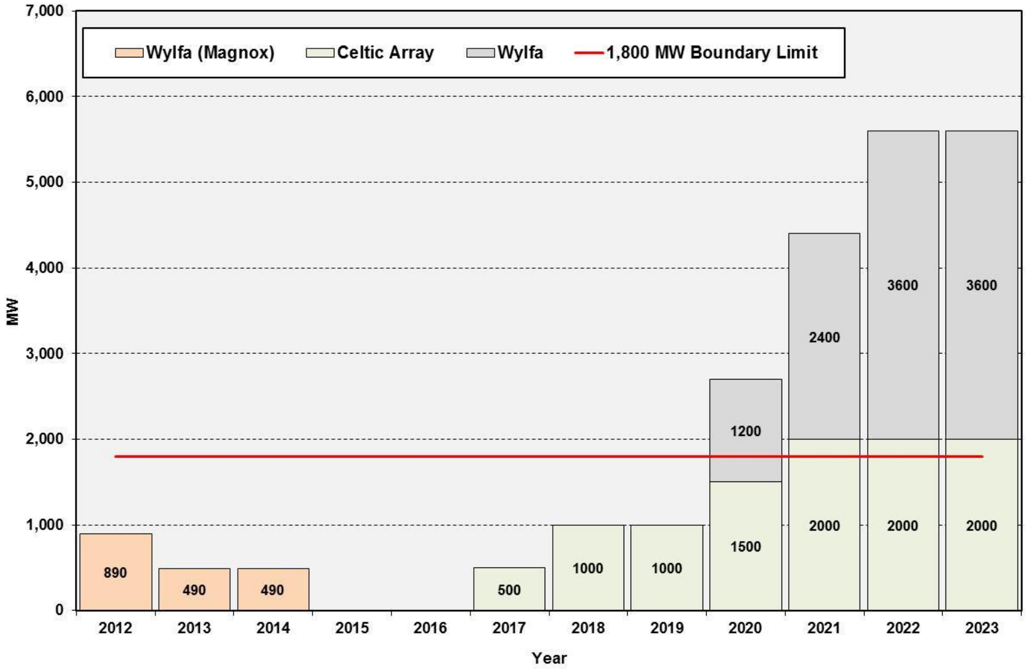

Figure 6.2 – Total contracted generation connected 'behind' boundary 1

6.9 It can be seen that when assessed against paragraph 2.6.4 of the NETS SQSS this area of the transmission system will not comply with the NETS SQSS by 2020.

Circuit Ratings

6.10 Consider boundary 2. There are three circuits crossing boundary 2, the two Pentir to Deeside circuits, each with a post-fault continuous summer rating of 2,220 MW, and the Pentir to Trawsfynydd single circuit, with a post-fault short-term summer rating of 2,480 MW. [3]

6.11 Paragraph 2.10 of the NETS SQSS requires that the transmission capacity for the connection of a power station shall be planned such that in the event of the de-energisation of two circuits there shall not be any unacceptable overloading of any transmission equipment.

6.12 The most onerous faults would be a fault on one Pentir to Deeside circuit and a fault on the Pentir to Trawsfynydd circuit occurring in summer. The maximum power that could then cross boundary 2, without any unacceptable overloading, would be 2,220 MW.

6.13 Paragraph 2.8.5 of the NETS SQSS requires that conditions on the NETS shall be set to those which ought reasonably to be expected to arise in the course of a year of operation. The generation and demand assumptions are as follows:

- Wylfa (Magnox) – 890 MW in 2011 and 2012 then 490 MW in 2013 and 2014, at which point it is expected to retire
- Dinorwig – 2 units running (548 MW)
- Gwynt y Môr – 432 MW in 2013 and 574 MW from 2014
- Burbo Bank Extension – 234 MW from 2015
- Celtic Array – 500 MW in 2017, 1,000 MW in 2018 and 2019, 1,500 MW in 2020 then 2,000 MW from 2021
- Greenwire – 1,000 MW from 2019
- Wylfa – 1,200 MW in 2020, 2,400 MW in 2021 and 3,600 MW from 2022, and
- 200 MW maximum demand and 20 MW minimum demand behind boundary 2.

6.14 Figure 6.3 illustrates the generation and demand normally expected behind boundary 2. It also shows the summer post-fault capacity across this boundary.

[3] These ratings assume unity power factor.

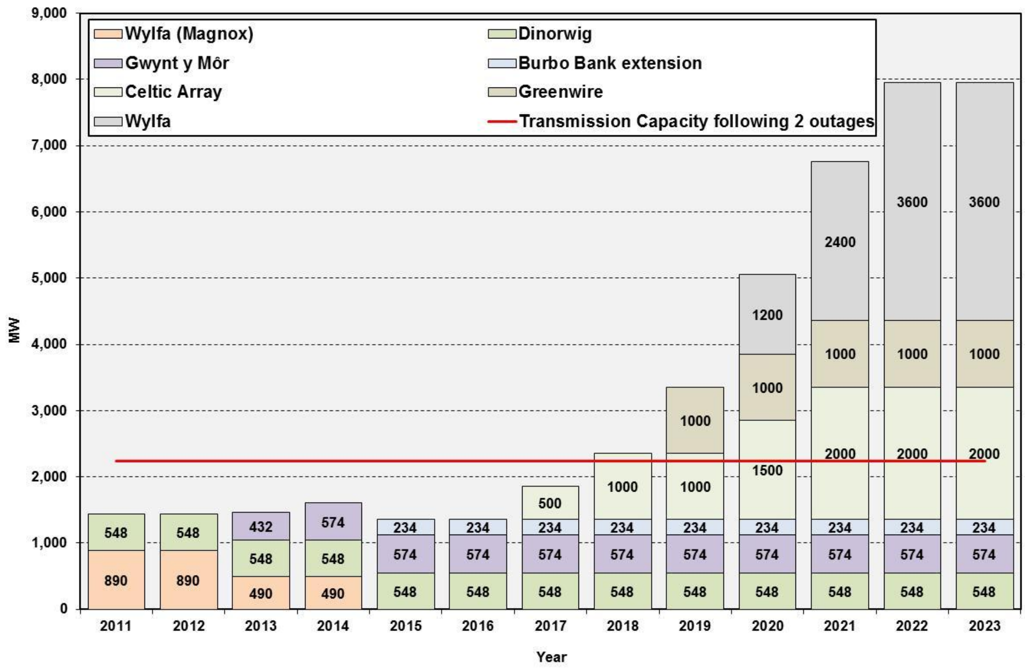

Figure 6.3 – Generation at boundary 2

6.15 It can be seen that when assessed against paragraphs 2.8.5 and 2.10 of the NETS SQSS this area of the transmission system would not comply with the NETS SQSS by 2018.

6.16 The assessment of boundary 3 is more involved than that of boundaries 1 and 2. This is introduced by the complexity of the three-ended circuits, Trawsfynydd – Legacy – Deeside and can only be studied using power flow computer models. These studies show that the transmission system capacity in this area needs to be enhanced in similar timescales to boundaries 1 and 2.

7 Conclusions

7.1 The key conclusions in this report are:

(a) National Grid has contractual obligations to connect 5.6 GW of new generation (3.6 GW of nuclear and 2 GW of Irish Sea wind) at or in the vicinity of Wylfa substation, i.e. behind boundary 1

(b) It also has contractual obligations to connect a further 808 MW of offshore wind located near the north coast of Wales and in the Liverpool Bay area and 1 GW of wind generation located onshore in Ireland at Pentir

(c) System analysis has demonstrated that there is insufficient transmission capacity to connect this level of generation and, at the same time, be compliant with the NETS SQSS, and

(d) Reinforcement of the transmission system in North Wales will be required by 2020 (boundary 1) and by 2018 (boundaries 2 & 3).

Appendix A – Summary of National Grid Legal Obligations [4]

A.1 Transmission of electricity in Great Britain requires permission by a licence granted under Section 6(1)(b) of the Electricity Act 1989 ("the Electricity Act").

A.2 National Grid has been granted a transmission licence and is therefore bound by the legal obligations primarily set out in the Electricity Act and transmission licence.

A.3 National Grid owns and operates the transmission system in England and Wales and is also responsible for operation of parts of the onshore transmission system that are owned by other transmission licensees (SP Transmission Limited and Scottish Hydro Electricity Transmission Limited).

A.4 National Grid has a statutory duty to develop and maintain an efficient, coordinated and economical system of electricity transmission under Section 9 of the Electricity Act.

A.5 Relevant Standard Licence Conditions [5] are summarised in the following paragraphs.

A.6 Standard Condition C8 [6] (Requirement to offer terms) of National Grid's transmission licence sets out obligations on National Grid regarding provision of offers to provide connections to and/or use of the transmission system. In summary, where a party applies for a connection National Grid shall offer to enter into an agreement(s) [7] to connect, or to modify an existing connection, to the transmission system and the offer shall make detailed provision regarding the:

- carrying out of works required to connect to the transmission system
- carrying out of works (if any) in connection with the extension or reinforcement of the transmission system, and

[4] Summary is not intended as an exhaustive list of National Grid's legal obligations but provides information about the obligations that are particularly relevant to this report.

[5] Standard conditions of the electricity transmission licence: http://epr.ofgem.gov.uk/document_fetch.php?documentid=15184

[6] The condition also relates to the use of system and some embedded generating plant.

[7] Paragraph 6 of Licence Condition C8 sets out exceptions where National Grid is not obliged to make an offer e.g. where to do so would put it in breach of certain other contracts or regulations.

- date by when any works required permitting access to the transmission system (including any works to reinforce or extend the transmission system) shall be completed.

A.7 Standard Condition C10 (Connection and Use of System Code) requires National Grid to prepare a connection and use of system code ("CUSC") which sets out, among other things, the terms of the arrangements for connection to and use of the transmission system.

A.8 Standard Condition C14 (Grid Code) requires National Grid to "prepare and at all times have in force and shall implement and comply with the Grid Code". This document (among other things), sets out the technical performance and data provision requirements that need to be met by users connected to or seeking to connect to the transmission system. The document also sets out the process by which demand data from Network Operators and other users of the transmission system should be presented on an annual basis to allow National Grid to plan and operate the transmission system.

A.9 Standard Condition C17 (Transmission system security standard and quality of service) requires National Grid to at all times plan, develop and operate the transmission system in accordance with the National Electricity transmission system Security and Quality of Supply Standard (NETS SQSS). This condition includes specific arrangements (Connect and Manage Derogation) that permit National Grid to offer to connect a customer to the transmission system before all reinforcement works to achieve compliance with the NETS SQSS are complete. Such permissions are subject to National Grid publishing Connect and Manage Derogations and reporting to Ofgem.

A.10 Standard Condition C26 (Requirements of a connect and manage connection) supplements the obligations [8] applicable to National Grid when making an offer of connection to the transmission system. The connect and mange connection regime was introduced in August 2010. One intention of this regime is to facilitate the timely connection of new generation projects.

[8] Standard condition C8 of the electricity transmission licence.

A.11 As well as the technical standards described above, Schedule 9[9] of the Electricity Act 1989 require National Grid, when formulating proposals for new lines and other works, to:

"*…have regard to the desirability of preserving natural beauty, of conserving flora, fauna, and geological or physiographical features of special interest and of protecting sites, buildings and objects of architectural, historic or archaeological interest; and shall do what [it] reasonably can to mitigate any effect which the proposals would have on the natural beauty of the countryside or on any such flora, fauna, features, sites, buildings or objects*" .[10]

A.12 National Grid's Stakeholder, Community and Amenity Policy [11] ("the Policy") sets out how the company will meet the duty to the environment placed upon it. These commitments include:

- only seeking to build new lines and substations where the existing transmission infrastructure cannot be upgraded technically or economically to meet transmission security standards
- where new infrastructure is required seek to avoid areas nationally or internationally designated for their landscape, wildlife or cultural significance; and
- minimising the effects of new infrastructure on other sites valued for their amenity.

A.13 The Policy also refers to the application of best practice methods to assess the environmental impacts of proposals and identify appropriate mitigation and/or offsetting measures. Effective consultation with stakeholders and the public is also promoted by the Policy.

[9] Section 38 of the Electricity Act states that Schedule 9 shall have effect.

[10] Schedule 9 of the Electricity Act (http://www.legislation.gov.uk/ukpga/1989/29/contents)

[11] National Grid's Stakeholder, Community and Amenity Policy : http://www.nationalgrid.com/uk/LandandDevelopment/SC/Responsibilities/sched9/schedule+9.htm

Appendix B – Transmission System Analysis Principles

B.1 This appendix provides a more detailed overview of:

- Transmission system performance requirements (defined in the NETS SQSS)
- Transmission system capability assessment methods, and
- Factors that limit transmission system capability.

NETS SQSS Requirements

B.2 The NETS SQSS is a document that defines the minimum standards that National Grid must apply when planning and operating the transmission system. These criteria include the type of faults (or breakdowns) and combinations of faults that the transmission system must be able to withstand, the impact on customers in terms of maximum level of supply interruptions, and impacts on supply quality that are permissible.

B.3 The NETS SQSS is open to industry and public scrutiny, is subject to periodic review and consultation and any changes are implemented by a change to the licence Standard Conditions and approved by the industry regulator, Ofgem. [12]

B.4 The NETS SQSS requires that National Grid must plan for all demand and generation conditions (or "backgrounds") "which ought reasonably to be foreseen to arise in the course of a year of operation … [and] shall include forecast demand cycles, typical power station operating regimes and typical planned outage patterns."

B.5 Application of the NETS SQSS achieves minimum performance requirements for the transmission system. These minimum performance requirements underpin the performance of the transmission system in terms of reliability of service delivered and availability of the system for use by generators, demand customers and other users of the transmission system.

[12] http://www.ofgem.gov.uk/Pages/OfgemHome.aspx

B.6 The NETS SQSS defines the performance required of the transmission system in terms of maximum levels of supply interruptions and also in terms of technical limits including that at all times:

- electricity system frequency should be maintained within statutory limits
- no part of the transmission system should be overloaded beyond its capability
- voltage performance should be within acceptable statutory limits, and
- the system should remain electrically stable.

B.7 Any transmission system is susceptible to faults that affect the ability of that transmission system to transfer power. Most faults are temporary and many are related to weather conditions such as lightning or severe wind. Many transmission system circuits can be automatically restored to operation within minutes of a transient fault (e.g. a lightning strike). Other faults may be of longer duration and would require repair or replacement of failed electrical equipment.

B.8 While some of these faults may be more likely than others, faults may occur at any time and it would not be acceptable to have a significant interruption to electricity supply as a result of credible fault conditions, including certain concurrent combinations of faults. The principle underlying the NETS SQSS is that the transmission system should have sufficient resilience that credible fault conditions do not result in widespread electricity supply interruptions. The level of security of supply that has been determined ensures that the risk of supply interruptions as a consequence of faults on the transmission system is managed.

B.9 The total generation capacity connected to the transmission system exceeds maximum demand. National Grid is not required to provide transmission system infrastructure that is capable of accommodating the total output from all connected generators as with current market arrangements, this would not be a credible operating scenario. Appendix C of the NETS SQSS [13] defines the technique that should be used to scale generation outputs.

[13] NETS SQSS Version 2.1: http://www.nationalgrid.com/NR/rdonlyres/784F2DFC-133A-41CD-A624-952EF4CCD29B/45776/NETSSQSS_v21_March2011.pdf

B.10 A comprehensive review of the NETS SQSS has now been completed by the SQSS Review Group[14] in conjunction with industry [15]. A report from this review proposing changes to introduce technology specific Availability Scaling Factors, has been submitted to Ofgem for decision. If implemented the changes would define in the NETS SQSS, Availability Scaling Factors of 85% for nuclear power stations, 70% for wind farms (reflecting the intermittency of wind power) and 83% for other generators,. The proposed changes to the NETS SQSS are consistent with the current requirements of Appendix C of the NETS SQSS.

B.11 National Grid has applied the Availability Scaling Factors identified in the recent NETS SQSS review to individual generator outputs when analysing the transmission system and assessing transmission system reinforcement requirements to ensure that sufficient infrastructure is installed to meet demand requirements for most scenarios. This scaling of generation output is a method by which National Grid ensures that infrastructure design appropriately reflects the operating arrangements of generation across the whole system (e.g. generators running at a reduced output so as to respond to generator breakdowns; variability in renewable outputs; expensive generators [16] running only periodically).

B.12 Based on normal operation of the electricity market and the fact that generators need to secure customers for electricity produced, National Grid considers that it is reasonable to expect generators to reduce their output or turn off as demand levels decrease. Daily peak demands vary across the year between 100-70% of their peak winter value.

Transmission System Capability Assessment

B.13 Transmission system capability is determined by the rating of plant and equipment, how individual items are connected to form parts of the transmission system and the technical characteristics of customer equipment connected to that part of the transmission system. Capability can be further limited by the need to meet the minimum requirements set out in the NETS SQSS.

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14 http://www.nationalgrid.com/uk/Electricity/Codes/gbsqsscode/Review+Group/index.htm

15 See "Review of Required Boundary Transfer Capability with Significant Volumes of Intermittent Generation", GSR009, SP Transmission, Scottish and Southern Energy and National Grid, 11 June 2010 and "Review of Required Boundary Transfer Capability with Significant Volumes of Intermittent Generation – NETS SQSS text", GSR009-01, SP Transmission, Scottish and Southern Energy and National Grid, 4 October 2010. (Available at http://www.national grid.com/uk/Electricity/Codes/gbsqsscode/fundamental/Wind+Integration).

16 "Expensive Generation", can be considered as generators which require a high energy price to make it economic to produce electricity. Such examples could be combined cycle gas turbines (CCGT) generation which has to burn fuel (gas) which has a cost. The highest electricity prices are generally seen at times of high electricity demand.

B.14 The NETS SQSS defines the performance required of the transmission system in terms of maximum levels of supply interruptions and also in terms of technical limits including that at all times:

- electricity system frequency should be maintained within statutory limits
- no part of the transmission system should be overloaded beyond its capability
- voltage performance should be within acceptable statutory limits, and
- the system should remain electrically stable.

B.15 National Grid assesses the adequacy of its transmission system on a regular basis to ensure its continued compliance with the minimum standards of security and quality of supply defined in the NETS SQSS. Assessments are also made by National Grid when there are changes to customer requirements (e.g. a request for a new connection) or when existing transmission system equipment approaches the end of it design life.

B.16 When assessing the capability of the transmission system, National Grid needs to ensure that the minimum standards of the NETS SQSS can be met. The NETS SQSS defines criteria that must be applied when designing or operating the transmission system.

B.17 National Grid carries out detailed transmission system analysis work using a computer model ("power system analysis"). The computer model replicates the electrical characteristics of the transmission system and relevant sections of all customer connections to the transmission system. Using this computer based tool, National Grid is able to carry out a range of analysis including:

- load flow (assess level of power flows in each part of the transmission system)
- fault level (assess level of short duration power flows when there is a fault)
- transient stability (assess dynamic performance of the transmission system), and
- power quality (ensure that limits in the Grid Code are not exceeded).

B.18 National Grid's assessment of transmission system capability, capacity, NETS SQSS compliance and any transmission system reinforcement requirements is informed by results from power system analysis. National Grid assesses the adequacy of its transmission system in accordance with the principles detailed in the NETS SQSS.

B.19 NETS SQSS compliance is always assessed at maximum demand conditions. It is often the case that if the capability of the transmission system is sufficient to meet maximum demand it will be sufficient to meet lower levels of demand. However, National Grid is required to ensure that its transmission system complies with the NETS SQSS requirements at all times of the year for conditions that can be reasonably foreseen. It is possible for the most onerous transmission system operating conditions to occur other than at times of maximum demand. Therefore National Grid also considers lower demand conditions (in particular for parts of the electricity transmission system where there is much more generation than demand).

B.20 National Grid is required to design new generator connections to the transmission system to ensure that the maximum export from the new generator connection can be accommodated. The design criteria that National Grid applies when designing generator connections are defined in Section 2 of the NETS SQSS.

B.21 Section 4 of the NETS SQSS sets out the design criteria for the main interconnected transmission system. When assessing compliance of the system and planned developments of the system, National Grid is obliged to consider all operating conditions that can be reasonably foreseen. Any assessment of compliance with the design criteria in Section 4 of the NETS SQSS will take account of diversity between the expected operation of different connected plant.

B.22 National Grid is required to assess power flows between regions of the transmission system ("Planned Transfers"). The Planned Transfer from the region is calculated by taking the Maximum Peak Demand in the region from the Total Scaled Generation. The Planned Transfer is therefore the amount of power which will flow between regions at peak. The Boundary Capability is the maximum permissible Planned Transfer from one part of the transmission system to the neighbouring part of the transmission system.

B.23 Planned Transfer calculations will always consider the power flows for the maximum demand conditions. From a security of supply perspective, National Grid will seek to ensure that transmission system infrastructure is adequate to meet national, demand customer requirements during operating conditions that could reasonably occur.

B.24 Power flows from source (e.g. power station) to demand and will always tend to flow on the shortest routes that provide the least resistance. On the transmission system, this will be along the higher voltage routes e.g. 400 kV and 275 kV. Assessments of power flows on the transmission system are made by National Grid using a computer model of the transmission system ("power system studies"). The power system studies take account of characteristics that influence power flows (e.g. route length, conductor size and type, number of circuits between substations) as well as customer requirements (including demand, generation, interconnector users).

Factors that Limit Transmission System Capability

B.25 The transmission system must be capable of being operated in a safe and secure manner within thermal, voltage, fault level, stability and phase (voltage) unbalance capability limits and minimum transmission system performance standards.

B.26 The following sections discuss each of these limiting factors, the possible consequences of exceeding capability limits, and generic options that can be used to enhance capability.

Thermal Capability

B.27 All metallic electrical conductors expand with increasing temperature and have electrical resistance which causes heat to be generated when electrical current flows through the conductor. Overhead and underground conductors are designed to operate up to a certain temperature. For each conductor type, there will be a maximum current which can flow without exceeding the upper operating temperature. This maximum rating will depend on the ambient air or ground temperature, wind speed and any special cooling equipment utilised or specialist materials used to bury conductors.

B.28 Exceeding the upper operating temperature in overhead lines will cause conductors to sag and safe clearances between the conductors and the ground will no longer be maintained. Also operation above the upper operating temperature of overhead lines may cause lasting damage to the conductor system. Exceeding the upper operating temperature of underground cables and Gas Insulated Lines (GIL) causes damage to the conductor system and risks ultimate failure.

B.29 The maximum power that can be carried by any electrical circuit is directly proportional to the maximum current and is referred to as the "thermal limit" or "rating". Transmission circuit ratings are dependent on ambient air (overhead lines) or ground (underground cables) temperatures. The maximum rating of a transmission circuit is achieved when ambient temperatures are low and is often referred to as the "winter rating". A transmission circuit achieves a lower rating when ambient temperatures are higher and the minimum rating is often referred to as the "summer rating".

B.30 A transmission circuit may contain a number of different component parts (e.g. overhead lines, underground cables, transformers, other electrical plant such as busbars). Whilst it is usual practice for National Grid to seek to match ratings of components within a transmission circuit, it is not always possible. Where component ratings do not fully align, National Grid produces a composite rating for the transmission circuit which reflects the rating of the limiting component (i.e. aligns with the lowest rating within the transmission circuit).

B.31 As use of the transmission system changes (e.g. changes in use by existing and new customers), the power flows on the transmission system also change. As power flows increase, transmission system infrastructure becomes more heavily utilised and the thermal capacity margin (difference between utilisation and thermal limit) reduces. If utilisation of a transmission circuit is greater than its thermal limit, then that circuit is "overloaded". One of the key criteria in the NETS SQSS is that transmission circuits should not be overloaded for operating conditions (including fault conditions) that are reasonably foreseen.

B.32 Transmission circuit thermal capacity can be enhanced by:

- operating existing transmission circuits at higher temperatures (only where such operation can be achieved safely).

- uprating existing transmission circuits (e.g. by installing larger conductors).
- operating existing transmission circuits at a higher voltage (where existing pylons can be modified to support higher voltage circuits).
- increasing the number of transmission circuits (e.g. by constructing a new transmission circuit).

B.33 Transmission circuit upgrade options can be identified for overhead line and underground cable transmission circuits. Transmission system reinforcement options have varying levels of efficiency and complexity depending on the thermal compliance issue identified and therefore potential solution options are identified on a project specific basis.

Voltage Capability

B.34 Generally transmission circuits on National Grid's transmission system are operated at either 400 kV or 275 kV. Transmission circuits have to be designed and constructed so that they can operate safely at the specified, operating voltage.

B.35 The voltage on the transmission system is directly proportional to power and as power flows, there is a difference in voltage at the sending end (e.g. a power station) and the receiving end (e.g. demand). This difference is often referred to as a "voltage drop".

B.36 National Grid is legally required [17] to maintain voltage levels on the transmission system within a defined bandwidth of ±10% of the declared operating voltage (for circuits of 132 kV and above).

B.37 As use of the transmission system changes (e.g. changes in use by existing and new customers), the power flows on the transmission system also change. As power flows increase, the voltage drops on the transmission system also increase. If voltage on any point of the transmission system is outside of either of these legal thresholds, then there is a voltage compliance issue. One of the key criteria

[17] Electricity Safety, Quality and Continuity Regulations: http://www.legislation.gov.uk/uksi/2002/2665/contents/made

in the NETS SQSS is that there should not be unacceptable voltage conditions on the transmission system.

B.38 Transmission circuits generate reactive power. This characteristic can be useful at times of high demand by supporting voltage on the transmission system so that it remains above the required minimum levels. However, at times of low demand this characteristic can be problematic and cause voltage levels to rise beyond the permitted maximum.

B.39 Transmission circuit voltage capability can be enhanced by:

- making adjustments to output voltage from transmission system transformers by tap change operations.
- temporary changes to existing transmission system configuration by National Grid carrying out other switching actions.
- requiring generators to provide reactive power support from power stations that are operating to also export active power onto the transmission system.
- entering into commercial contracts with generators for additional reactive support from power stations.
- installing fixed devices (e.g. manually switched capacitors, shunt reactors) on the transmission system that can produce or absorb reactive power.
- installing dynamic devices (e.g. static voltage compensators) on the transmission system that can produce or absorb reactive power.
- uprating existing transmission circuits (e.g. by installing larger conductors).

B.40 Transmission circuit upgrade options can be identified for overhead line and underground cable transmission circuits. Transmission system reinforcement options have varying levels of efficiency and complexity depending on the unacceptable voltage condition identified and therefore potential solution options are identified on a project specific basis.

Fault Level Capability

B.41 Strengthening the transmission system to increase thermal and/or voltage capability can also increase the fault levels across the transmission system. "Fault level" is a measure of power that would be expected to flow if there was a fault on the transmission system.

B.42 Items of electrical plant have a fault rating which defines the maximum power flow that the plant item can withstand for the short duration until the fault is disconnected from the transmission system. For safe operation of the transmission system, the fault level at any particular point on that system must be within the rating of relevant electrical plant items.

B.43 Fault level capability issues can be managed by National Grid:

- revising the substation running arrangements where possible,
- uprating/reinforcing any affected infrastructure,
- incorporating new devices to limit the fault levels
- replacing the affected infrastructure with modern equivalent assets which have higher ratings

B.44 Works to manage fault level issues will tend to be confined to within the substation boundary and are therefore not discussed further in this report.

Transient stability

B.45 While transmission system stability is recognised as a specialist area, the following paragraphs provide an overview of this complex topic.

B.46 The alternating voltage at every point on the transmission system is designed to be in synchronism (or "synchronised") with the alternating voltage at every other point on that system. In effect, during normal operation the entire transmission system, together with all the connected local distribution systems, generators and synchronous motors are "on the same electrical cycle". The majority of generation, connected to the transmission system is made up of large "synchronous machines". These machines maintain a speed which outputs electrical power at the mains frequency of 50 hertz (50 positive and negative cycles per second) and remain in synchronism with this frequency.

B.47 The NETS SQSS requires that at all times the system remains "electrically stable". There are many types of electrical stability issues that could arise, but of particular importance when designing the transmission system for the connection of new generation is "generator transient stability", which is about maintaining the synchronism of generation following a large disturbance to the power system (e.g. the fault of a transmission circuit).

B.48 Generator transient stability issues can occur when a fault disrupts the electrical power flows on the transmission system in the vicinity of any generator. The power flow disruption causes the generator to accelerate. The generator accelerates because during the fault, the electrical power output from the generator reduces to a level that is effectively very small, whilst the mechanical power being put into the generator by the fuel source (steam, wind etc.) remains the same. The greater a generator's power output at the time of the fault the more it will accelerate during the fault. Generators close to the fault on the transmission system will be affected more than generators that are further away.

B.49 If a generator accelerates to such an extent that its inertia becomes too strong (i.e. its mass is moving too fast), a situation called "pole slipping" can arise. A consequence of pole slipping is that the generator loses synchronism with the transmission system and the forces involved can cause both electrical damage and mechanical damage to that generator.

B.50 The transmission system is designed so that the faulty sections are automatically disconnected. This type of automatic action is referred to as the electrical fault being cleared. In order to minimise the risk of damage to the transmission system and its connected customers, electrical faults would normally be cleared within tenths of a second.

B.51 During the time needed to clear the transmission system fault, the generator may have accelerated to such an extent that pole slipping occurs and the generator is no longer synchronised with the rest of the transmission system. Such a loss of synchronism can result in damage to the generators as well as potential interruptions to power supplies. Protection equipment that would disconnect the generator if pole slipping occurs, in accordance with the Grid Code, may also be required by National Grid.

B.52 Once the electrical fault on the transmission system is cleared, the number and electrical characteristics of the remaining circuits on the transmission system will determine how quickly the extra energy from accelerated generators that remain connected to the transmission system, can be absorbed by that transmission system. In general, the stronger the transmission system capacity, the quicker the extra energy can be absorbed.

B.53 Generator transient stability issues can be resolved by increasing the capacity of circuits on the transmission system. However, repeatedly increasing the capacity of transmission circuits is not generally an appropriate solution option as it may not provide an efficient nor economic solution. Also, the physical load carrying capability of existing infrastructure would not be sufficient for very large conductors and would require major rebuilding of the entire system in an area to manage the increased capacity with larger, heavier pylons.

B.54 The capacity of the transmission system can be increased by providing additional circuit(s). This can be an efficient solution option in areas where thermal capacity issues have also been identified. Additional transmission circuit(s) can resolve generator transient stability issues as well as other thermal capacity issues.

B.55 The precise behaviour of generators prior to, during and following a fault is unique to their individual locations on the transmission system, the control systems used to manage each generator and its physical design. Generator specific parameters therefore need to be considered in particular detail when planning any new connection to the transmission system.

Phase (voltage) unbalance

B.56 Unbalance of both currents and voltages on the transmission system can be caused by loads that are not equally balanced across the three phase supply and also by impedance unbalance within the transmission system. Overhead lines can be a major source of transmission system unbalance.

B.57 Alternating current in a conductor will induce alternating currents in another conductor in close proximity. This phenomenon underpins the operation of generators, electric motors and transformers.

B.58 Pylons have a circuit on each side (as described in section 4) and power of significant magnitude can flow in opposite directions on these circuits. The current in one conductor of a transmission line will induce currents in the other conductors. This effect occurs between transmission line conductors that make up:

- a different phase on the same transmission circuit (e.g. on the same side of a pylon), and
- two different transmission circuits on either side of a pylon.

B.59 The strength of this induced current effect is dependent on the physical position of the conductor and the magnitude of power flow in each conductor. Each conductor (pylon positions of top, middle and low) induces different currents in each of the other conductors. If uncorrected these different induction effects can lead to imbalances between the currents in the different phases of each circuit.

B.60 Negative phase sequence currents flow as a consequence of unbalance between phases and these can, in turn, give rise to imbalanced stresses in generators and industrial motors with excessive heat being generated within them. An assessment of phase (voltage) unbalance can be made from the negative phase sequence currents, which can be measured on the transmission system using specialist recording equipment.

B.61 National Grid is required as a condition of its licence to have in force the Grid Code, which, amongst many other technical requirements, stipulates maximum limits for phase (voltage) unbalance on the transmission system. Unbalance between phases in an electricity system if not adequately limited, can adversely impact on power quality and lead to system disturbance and/or damage to electrical plant and equipment. The Grid Code defines a limit of 1% for phase (voltage) unbalance for normal operating conditions and 2% for abnormal operating conditions (e.g. during fault conditions). Parties connected to the transmission system are required to ensure that their equipment is capable of withstanding phase (voltage) unbalance conditions up to the maximum limits defined by the Grid Code.

B.62 National Grid seeks to keep phase (voltage) unbalance at all connection points on the transmission system within the specified limits by switching the position (or "transposing") the phases of transmission lines where possible. Typically overhead lines are arranged such that the overall effect is mitigated across the network. However, this arrangement which works effectively when the currents in both circuits is flowing in the same direction will not be effective when the currents in the two circuits are flowing in opposite directions, and especially when the magnitudes of these opposing currents are large. Moreover, the compensation will be less effective when there is current flowing in one circuit but not in the other due, say, to the second circuit being on outage.

B.63 Negative phase sequence currents can be limited by ensuring situations which cause power to flow in opposing directions on the transmission system are reduced and where possible removed. This can be done by removing complex system configurations such as teed circuits, or circuits on the same pylon connecting to different locations. Removing complex configurations is normally achieved by construction of new substations, new transmission circuits or reconfiguration of existing transmission system circuits.

Appendix C - Glossary of Terms and Acronyms

Alternating Current (AC)	A continually oscillating electrical current which reverses many times in a second. The standard frequency is 50 cycles per second (50 Hertz)
Development Consent Order	An order granting development consent pursuant to the Planning Act 2008.
Direct Current (DC)	An electrical current which always flows in one direction.
Double Circuit	A overhead line design where two circuits are mounted on a single set of towers.
km	Kilometre
National Electricity Transmission System "Transmission System"	The GB electricity transmission system, both onshore and offshore, operated by National Grid.
National Electricity Transmission System Security and Quality of Supply Standard or "NETS SQSS"	The document of that name referred to in Licence Condition C17 of the National Grid licence. It sets out certain criteria which National Grid must comply with in planning and developing its transmission network and in operating the transmission system.
Ofgem	Office of Gas and Electricity Markets The regulatory body that is responsible for electricity and gas supply markets and networks.
Plant Margin	The excess of generation capacity over maximum demand.
Volt (V)	The electrical unit of potential difference. 1 kilovolt (kV) = 1,000 volts

Watt (W)	The SI unit of power 1 kilowatt (kW) = 1,000 watts 1 megawatt (MW) = 1,000 kW 1 gigawatt (GW) – 1,000 MW
Watt hour (Wh)	A unit of energy. 1 kilowatt hour (kWh) = 1,000 watt hours 1 megawatt hour (MWh) = 1,000 kWh 1 gigawatt hour (GWh) = 1,000 MWh 1 terrawatt hour (TWh) = 1,000 GWh