

Use of High Voltage Direct Current (HVDC) and Series Compensation in the GB Transmission System

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Background

The EU Renewable Energy Directive 2009

The EU Renewable Energy Directive includes UK target of 15% of energy from renewable sources by 2020

- Seven fold increase from 2008 levels
- Includes electricity, heat and transport

The UK Renewable Energy Strategy 2009 envisaged

- More than 30% electricity from renewables (up from about 5.5%)
- Two thirds of renewable generation from on- and offshore wind

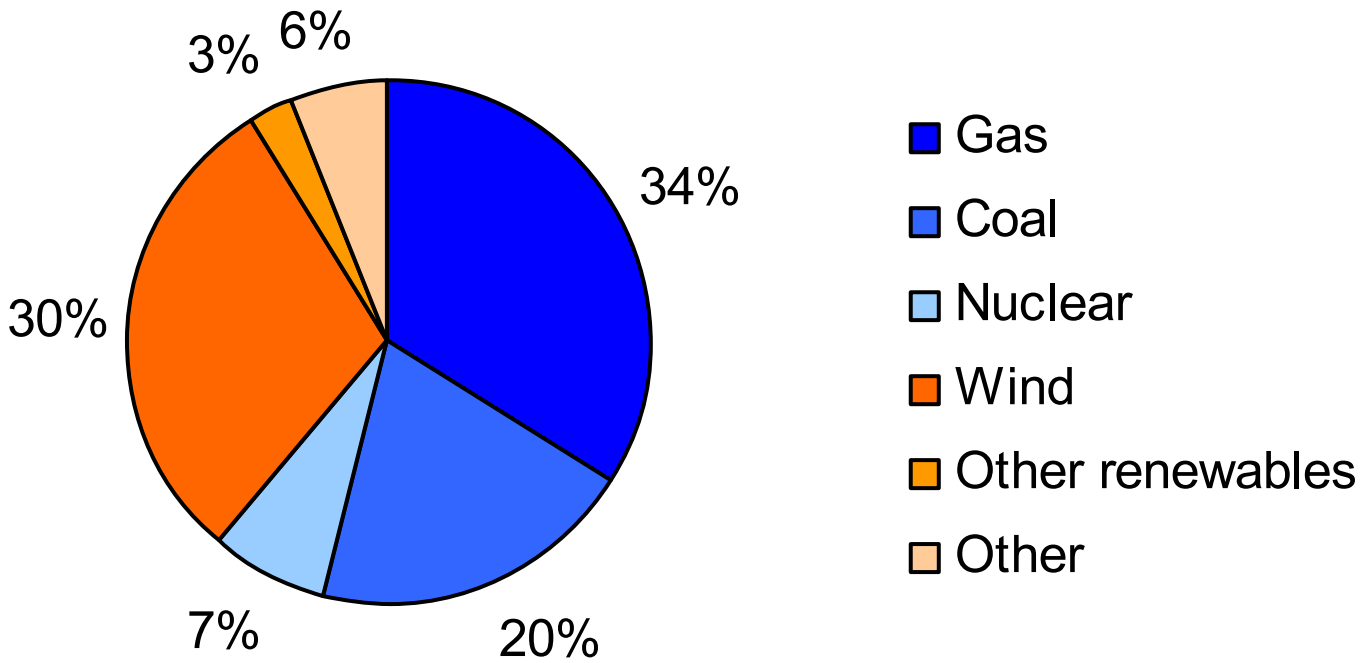
Report to the Electricity Networks Strategy Group

- Electricity Networks Strategy Group (ENSG)
 - Cross industry group jointly chaired by Department of Energy and Climate Change (DECC) and Office of the Gas and Electricity Markets (Ofgem)
- In July 2008 ENSG requested 3 GB Transmission Licence holders supported by Project Working Group to
 - Develop electricity generation and demand scenarios consistent with the EU 2020 target
 - Identify and evaluate a range of potential electricity network solutions to accommodate the scenarios

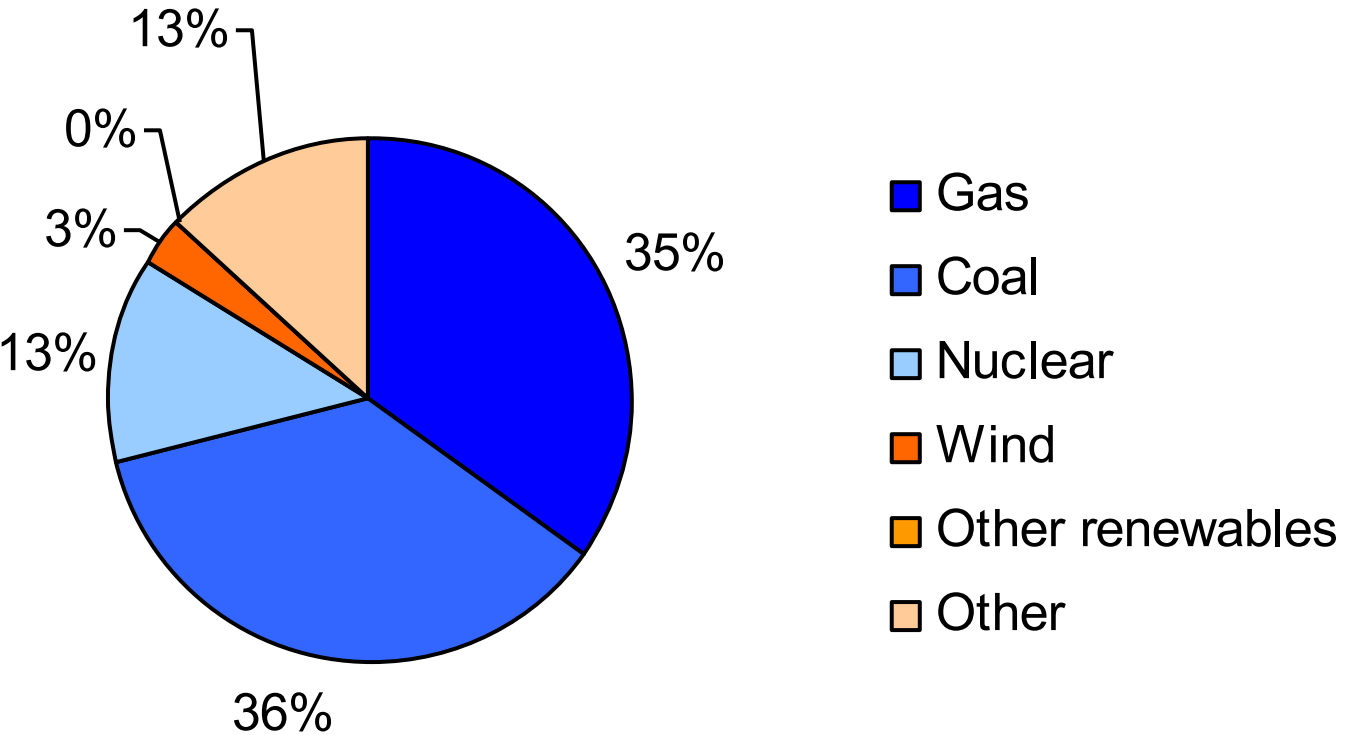
Report to the Electricity Networks Strategy Group

- 'Our electricity transmission network: A vision for 2020' full report published July 2009
- A report to the ENSG on the strategic reinforcements required to facilitate connection of the generation mix to the Great Britain transmission networks by 2020

2020 scenario – Gone Green



2010 generation mix



2020 scenario – Gone Green

- Generation closures
 - 12 GW coal and oil (Large Combustion Plant Directive)
 - 7.5 GW nuclear
 - Some gas and additional coal
- Significant new renewable generation
 - 32 GW wind (21 GW offshore, 11 GW onshore)
 - Some tidal, wave, biomass and solar photovoltaic
- Significant new non-renewable generation
 - 3 GW new nuclear
 - 3 GW new supercritical coal (some with carbon capture and storage)
 - 11 GW new gas

2020 scenario – Gone Green

- Renewable share of generation grows from 5% to 36%
 - Electricity demand remains flat
 - Reductions from energy efficiency measures
 - Modest increases from heat pumps and cars
- Contribution also required from heat and transport

Renewable generation capacities and locations

- Wind is the most mature renewable generation technology and most likely to be able to meet the EU target
- Onshore wind is more mature than offshore wind
- Up to 2015: Majority of new wind generation installed onshore in Scotland
- 2015 to 2020: Majority of new wind generation installed offshore in English and Welsh territorial waters
- Hydro, pumped storage, biomass, wave and tidal also contribute

Scotland to England Boundary

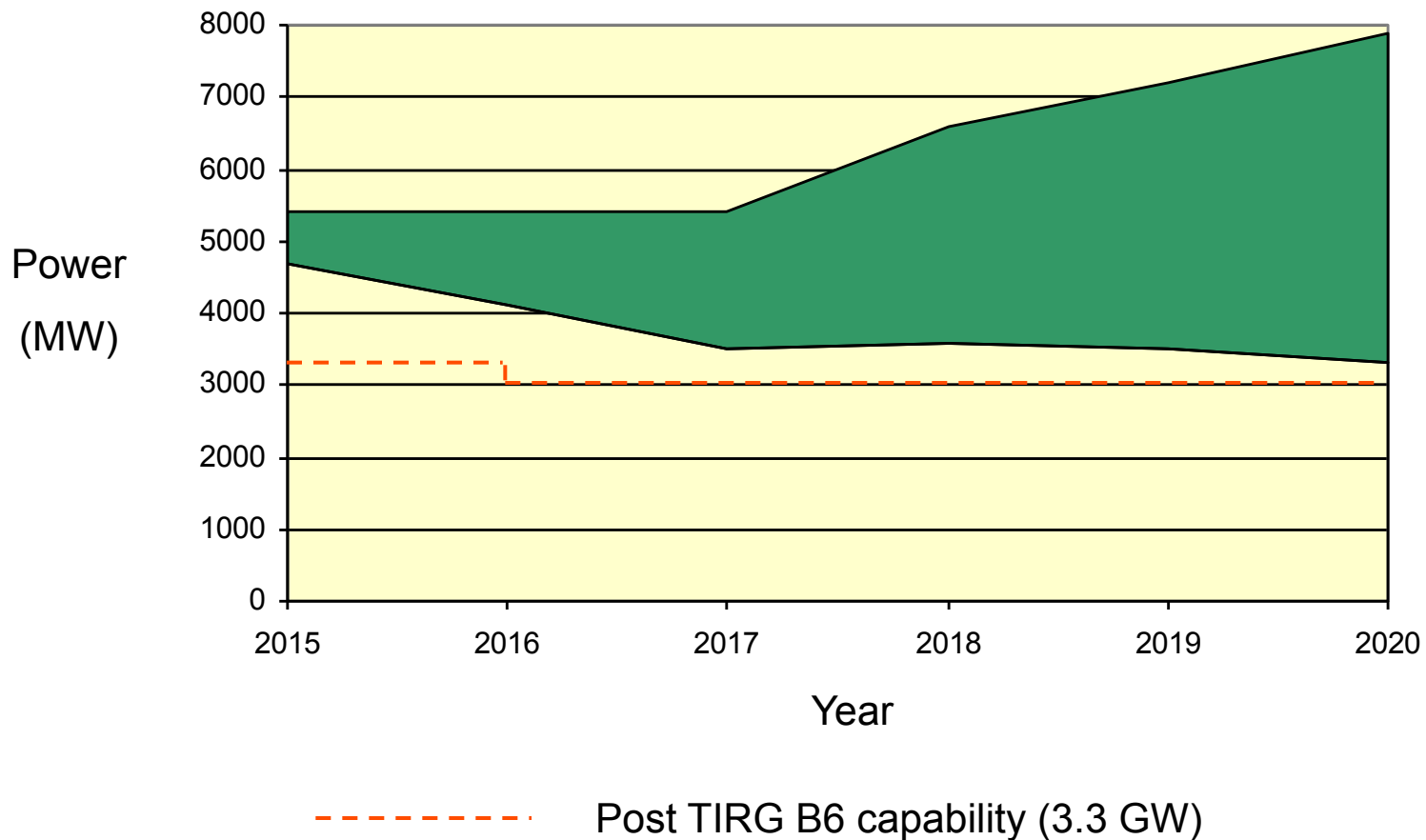
Scotland to England boundary

The generation scenarios envisage renewable generation in Scotland with a capacity between 6.6 GW and 11.4 GW

- The increase in generation leads to an increase in power transfer across the SPT – NGET boundary
- The two double-circuit 400 kV lines between Scotland and England currently have a capability of 2200 MW
- Reinforcements are in progress (Transmission Investment for Renewable Generation) that will increase the capability to 3300 MW in 2012/13
- The potential requirement for boundary capability varies from 5 to 8 GW at winter peak

Scotland to England boundary

Range of B6 boundary required transfers at peak demand



Scotland to England boundary

The SPT – NGET boundary capability is limited by stability considerations

- The limitation is dependent on circuit impedance rather than the thermal rating of the circuits
- Uprating of existing routes would do little to alleviate the stability limit
- One additional double-circuit OHL would provide less than 1 GW (east coast) or 1.5 GW (west coast) of additional capacity – still short of the potential requirement
- A solution is required that allows higher power transfers with no negative effect on system stability

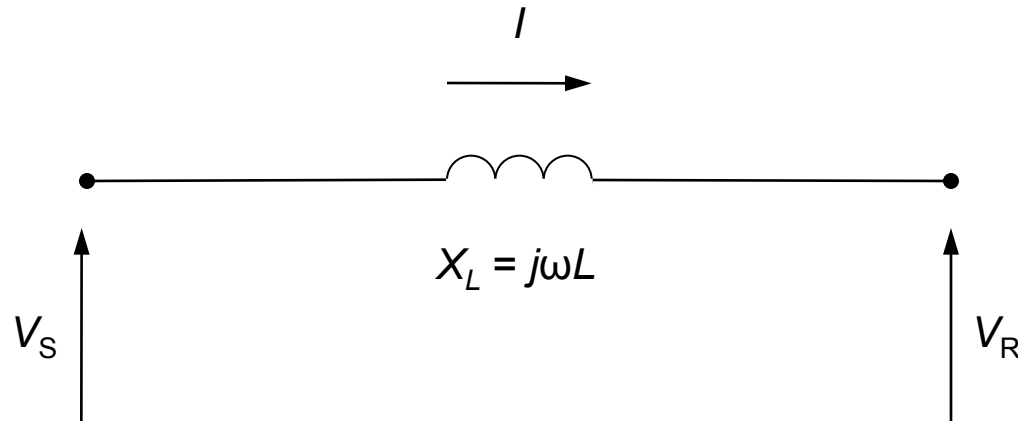
Scotland to England boundary

Potential solutions: Series compensation

- Series capacitors reduce the impedance of the transmission circuit in which they are connected
- Increases circuit capacity
- Improves stability of AC network

Series compensation

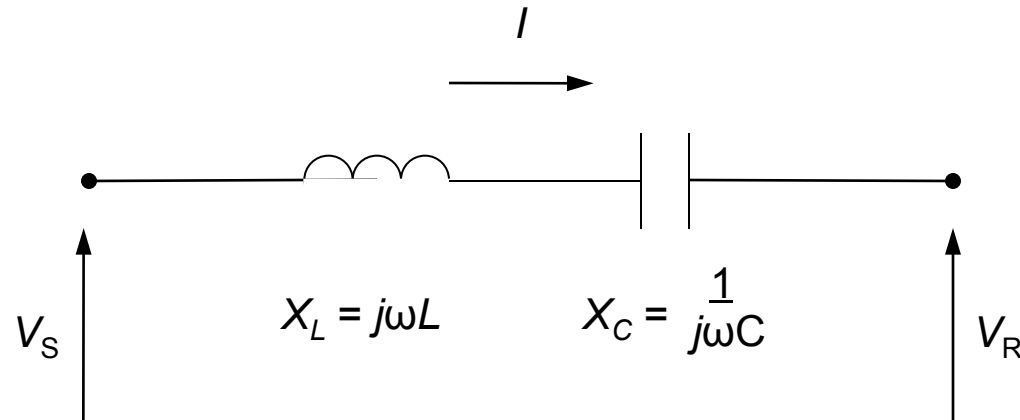
Uncompensated transmission line



$$P = \frac{V_S V_R \sin \delta}{X_L}$$

Series compensation

Transmission line with series capacitor



$$P = \frac{V_S V_R \sin \delta}{(X_L - X_C)}$$

Scotland to England boundary

Potential solutions: Series compensation

- Sub-synchronous resonance (SSR) may be an issue where fixed series capacitors used
 - Limit the level of compensation – but will limit circuit capacity, or
 - Use thyristor controlled series compensation (TCSC) - dynamically controllable, would rapidly respond to mitigate SSR
- Series compensation has not previously been used on the GB transmission system

Scotland to England boundary

Potential solutions: HVDC

- Lower losses when transmitting power over long distances
- No technical restriction on cable length
- Improves stability of AC network through controllable power flow, improved damping or AC voltage control
- Does not contribute to short-circuit levels on network

Proposed transmission reinforcements

The proposed upgrade comprises three main elements:

1. The ‘incremental’ upgrade

- Reconductoring and re-insulation of existing routes
- Development of new and existing substations
- Installation of series compensation in the 400 kV circuits crossing the SPT – NGET boundary
 - 35% maximum impedance correction
 - Stability limit raised towards thermal limit

Proposed transmission reinforcements

2. The Western HVDC link

- Subsea link between Hunterston in Scotland and Connahs Quay in Wales
- Around 2 GW HVDC
- Provides additional capacity across SPT – NGET boundary and Upper North of England
- Target completion date 2015

Proposed transmission reinforcements

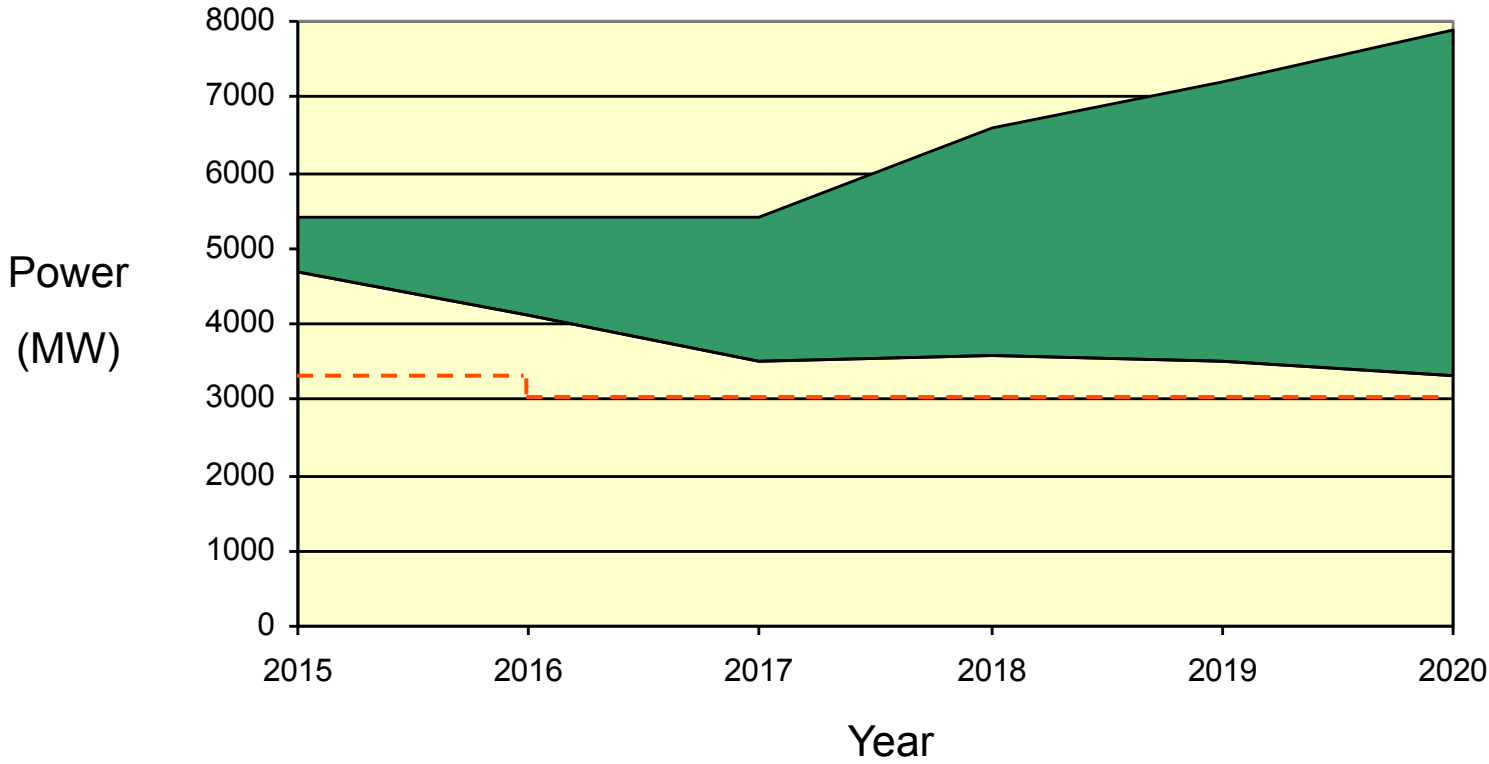
3. The Eastern HVDC link

- Subsea link between Peterhead in Scotland and Hawthorne Pit in England
- Around 2 GW HVDC
- Provides additional capacity between central Scotland and north of England, some additional capacity across north of England
- Target completion date 2018



Scotland to England boundary

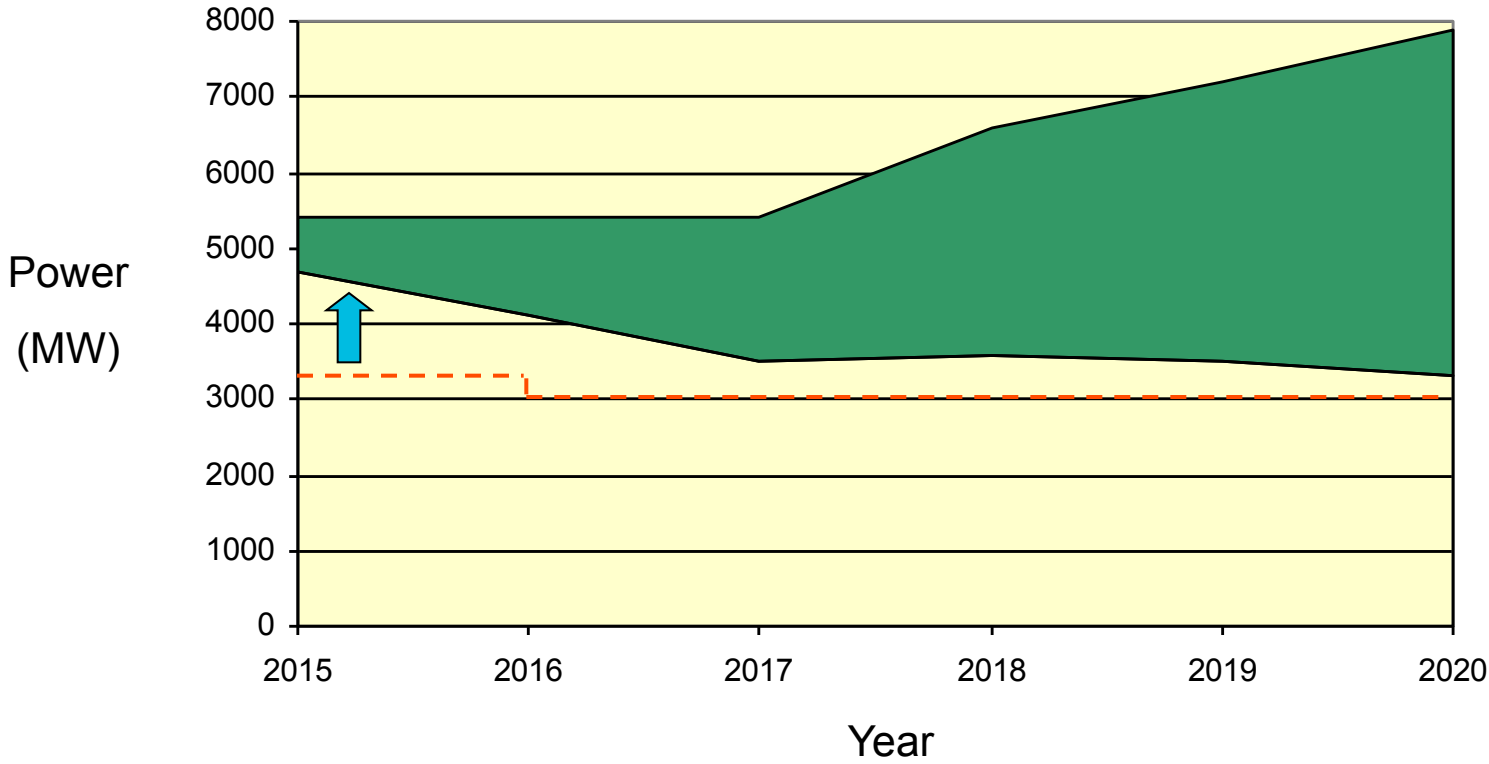
Range of B6 boundary required transfers at peak demand



----- Post TIRG B6 capability (3.3 GW)

Scotland to England boundary

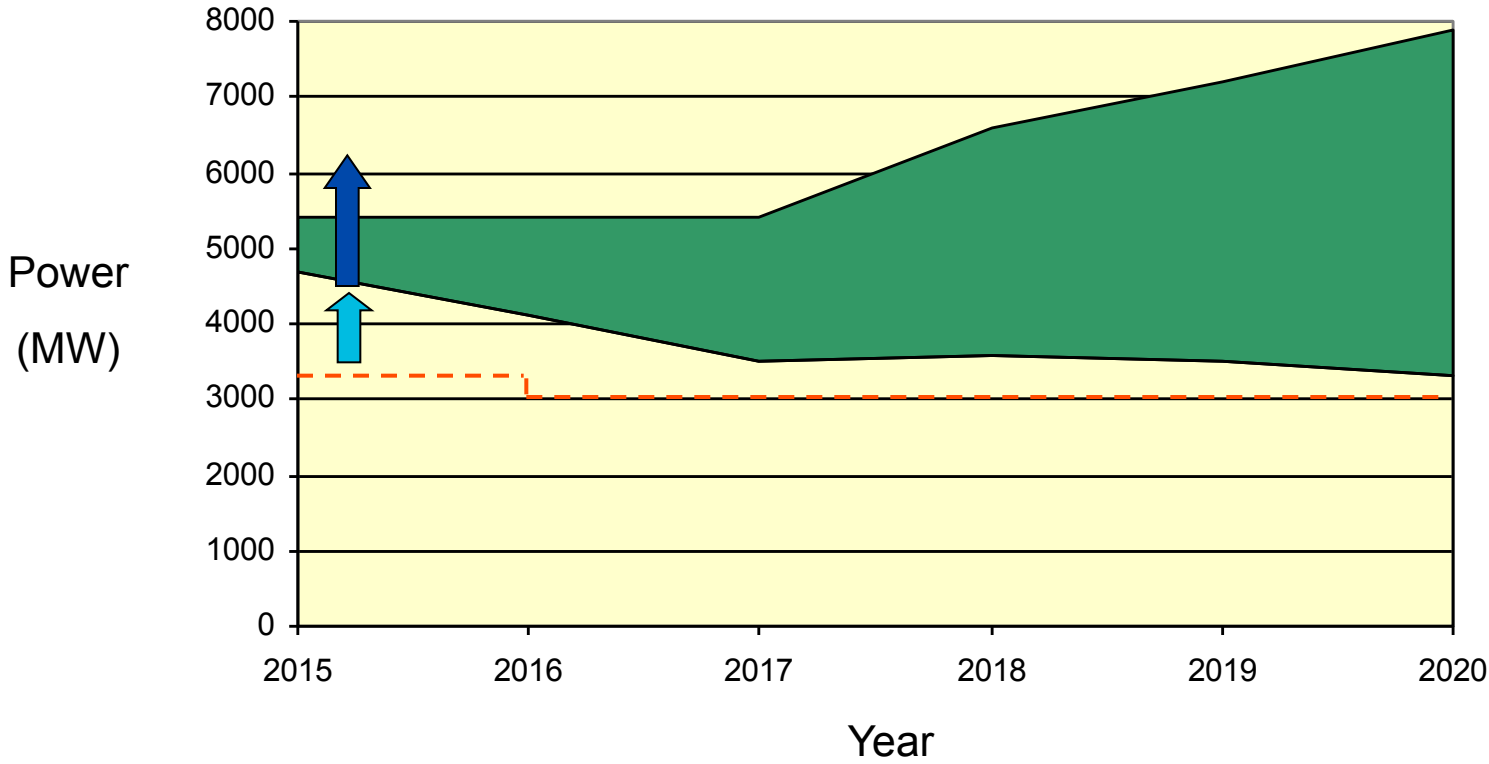
Range of B6 boundary required transfers at peak demand



Incremental reinforcements to B6 (4.4 GW)

Scotland to England boundary

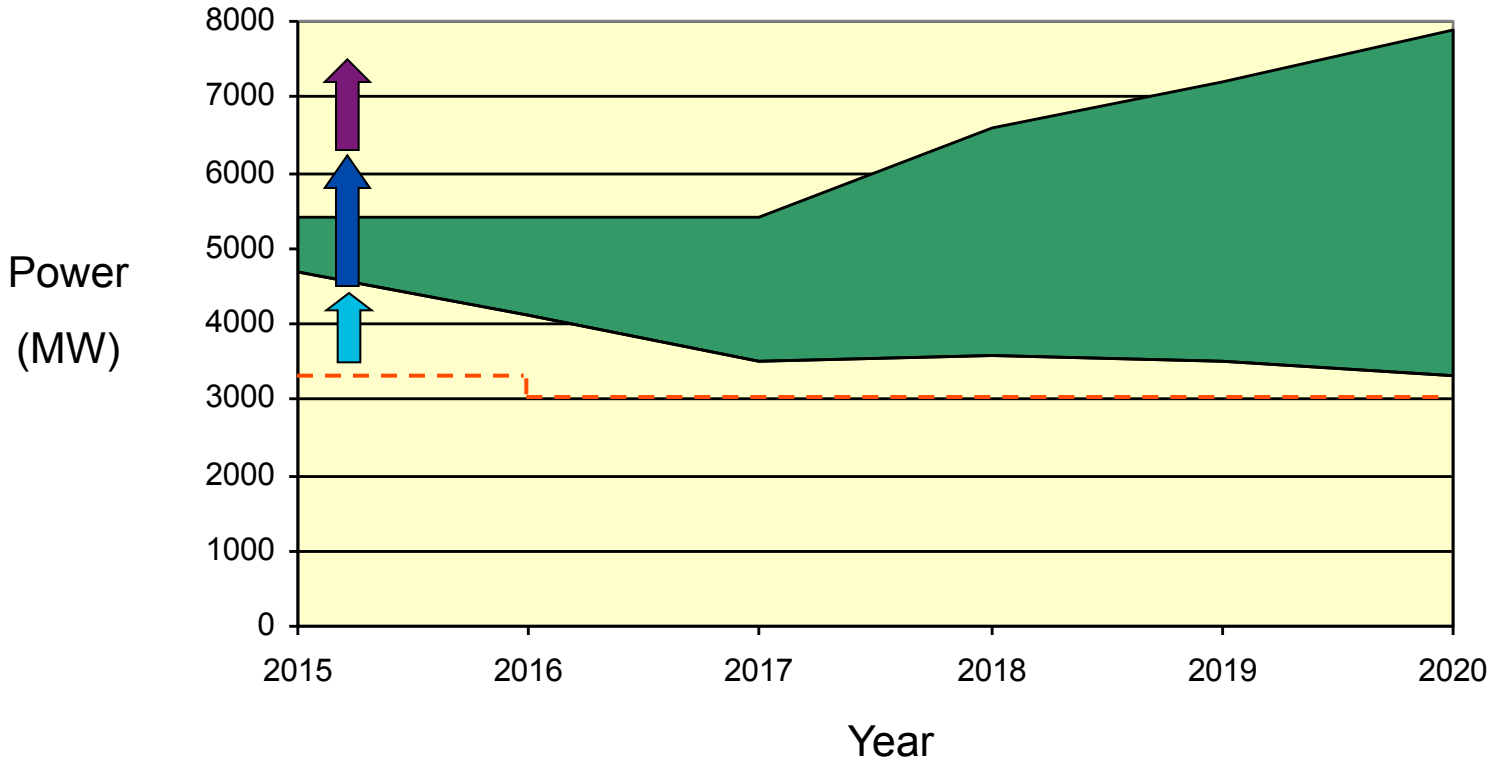
Range of B6 boundary required transfers at peak demand



Single HVDC link to support B6 (6.2 GW)

Scotland to England boundary

Range of B6 boundary required transfers at peak demand



Two HVDC links to support B6 (7.4 GW)

The Western HVDC Link

The Western HVDC link

The Western HVDC link is being jointly developed by National Grid and SP Transmission

- First application of HVDC technology embedded within the GB Transmission System
- Over 400 km HVDC cables

The Western HVDC link

The proposed works comprise

- Converter station at Hunterston
- Underground cable between Hunterston and Ardneil Bay
- Subsea cable between Ardneil Bay and the Wirral
- Underground cable from Wirral foreshore to Connahs Quay
- Converter station at Connahs Quay



The Western HVDC link

Project programme



STAGE 1	STAGE 2	STAGE 3	STAGE 4	STAGE 5	STAGE 6
<ul style="list-style-type: none"> •Project development & option appraisal •Identify preferred option 	<ul style="list-style-type: none"> •Consultation with statutory & non statutory groups •Consultation with local communities, landowners & other stakeholders 	<ul style="list-style-type: none"> •Environmental appraisal including specialist land and seabed surveys •Technical studies to develop project design 	<ul style="list-style-type: none"> •Pre-application consultation with interested parties including public •Submission of planning & marine licence applications 	<ul style="list-style-type: none"> •Appointment of specialist companies to manufacture cable and develop converter stations •Pre-construction planning 	<ul style="list-style-type: none"> •Construction of converter stations and installation of underground and subsea cables •Western HVDC link operational end of 2015