Integrating Gas and Electricity Systems

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Gas Impacts of Wind

- The University of Edinburgh has been conducting work on gas and electricity interaction since 2006
- The work presented here was undertaken in partnership with National Grid Gas and Advantica/GL
- Its aim was to examine the gas system consequences resulting from changes in the electricity system such as increasing penetrations of CCGT and wind generation
- It looked from the position of the system operator (SO) of the gas National Transmission System (NTS)
- It had a very deliberate ‘gas’ focus and employed tools available to the SO supplemented by other models
- Gained an understanding of how the SO could visualise if variation in wind generation within-the-day had negative impacts on gas system operation

Premise of Work

- The aim here was to represent the operation of the gas system in the way that SO views it
- The gas system is operated as a separate entity from the electricity system and is not co-operated or co-optimised
- The SO does not have detailed operational oversight of the electricity system and limited foresight of impending changes in gas generation
- Technical standards (e.g. GL/2) require models to be sufficiently accurate to capture real gas behaviour
- This requires that the system and its components are realistic, particularly with regard to compressors

Premise of Work

- A key requirement was to use *transient analysis* to solve the unsteady flow equations (mass, momentum and energy) and capture linepack as per the GL/2 standard
  - important given the potential impacts of CCGT ramping, startup and shutdown on gas pressures and flows
  - other analysis (e.g. Cardiff) employs a *quasi-transient* approach but unclear if this is adequate in networks of realistic complexity
- Also employed key SO contractual and operational assumptions including management of within-day swings
- Perform a *stress-test* for a 1-in-20 peak-day for a representative wind fleet and several gas supply scenarios

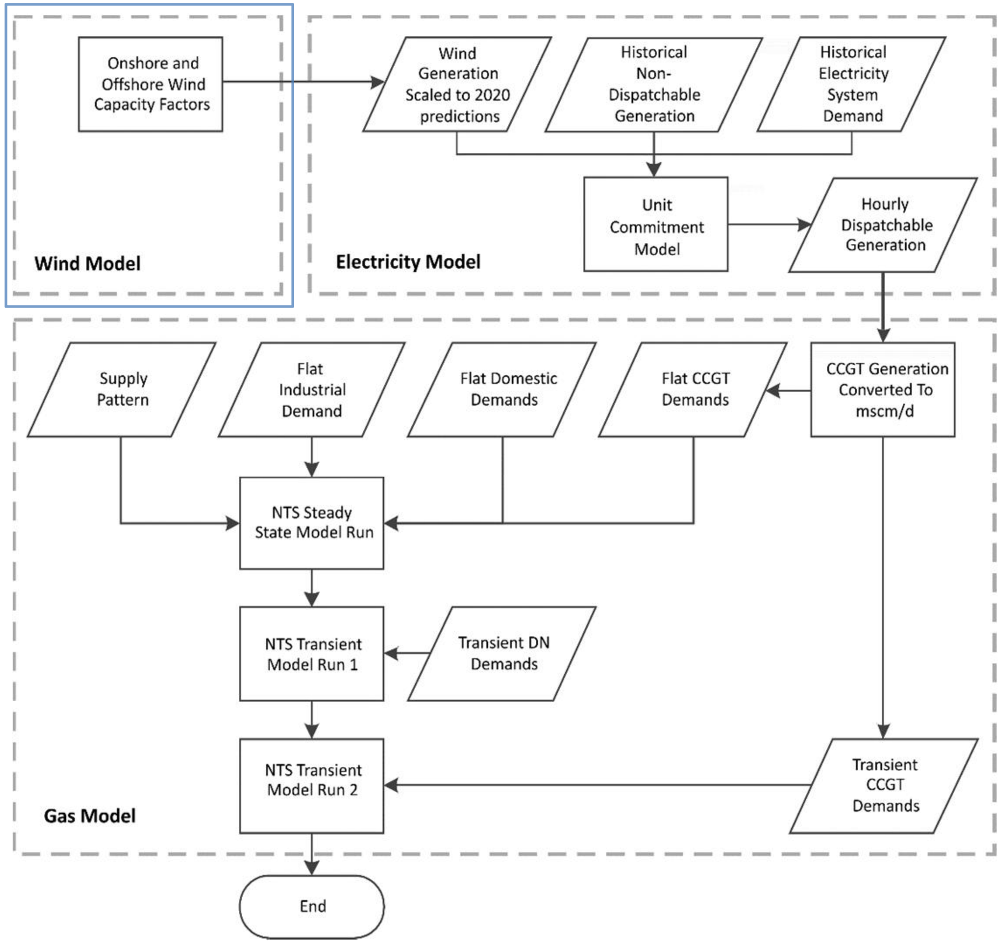
Methodology

- The working principle is that the gas SO does not anticipate changes in CCGT within-the-day and assumes operation has a flat profile
- The analysis tests ‘how wrong’ this assumption is when CCGT responds to wind variation and how higher or lower than expected gas offtake affects NTS operation
- There are 3 distinct models used:
  - Fully detailed transient model of the gas NTS
  - A detailed model of GB electricity system dispatch
  - Detailed wind hindcast

Methodology

Wind model

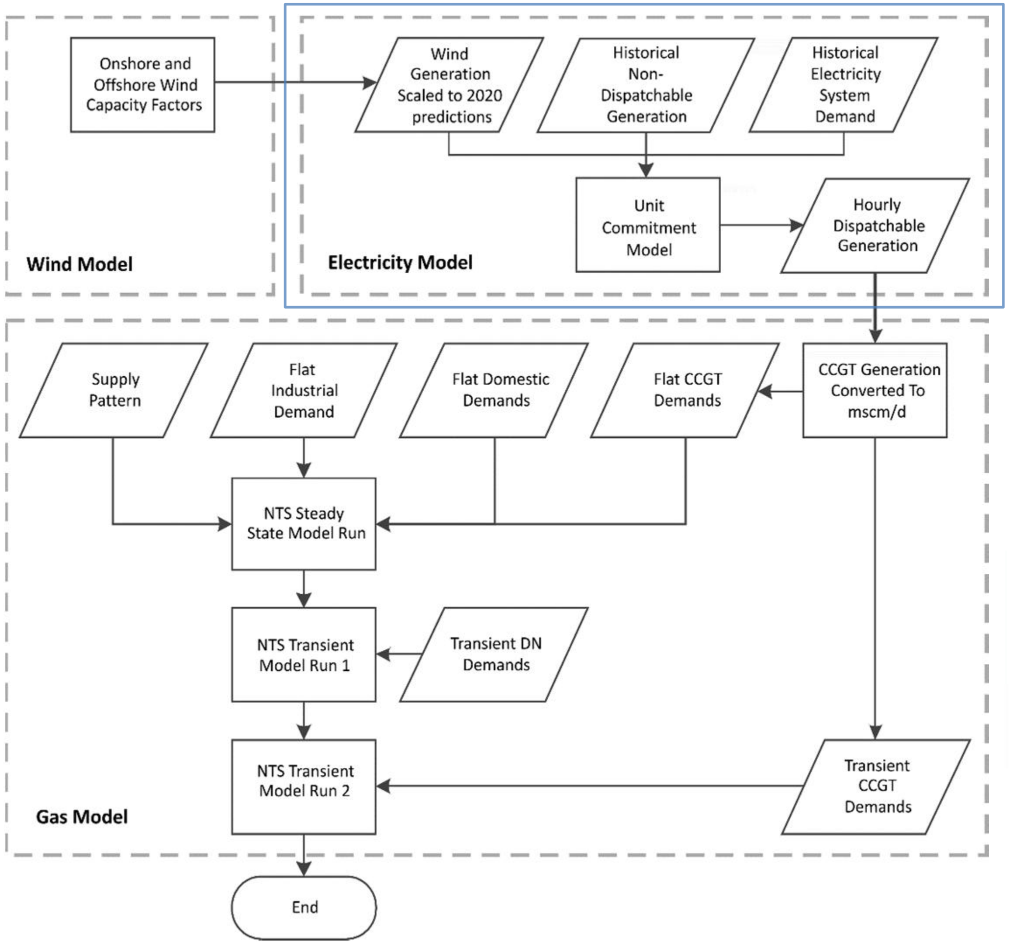
- On- and offshore wind production time series
- Uses an 11-year, 3 x 3 km WRF hindcast
    - 2005-2009 data used
- Wind speeds unbiased and aggregate output bias below 5%
- Modelled fleet: 13 GW onshore and 19.4 GW offshore



Methodology

Electricity Model

- Standard UC model
  - Costs include variable heat rate and O&M but not start-up or shutdown
  - 24 hour look-ahead
  - Perfect foresight
- CCGT time series feeds into gas demand
- Developed in AIMMS with CPLEX solver
- Modelled generation mix: 105 GW of nuclear, CCGT, coal, wind and other



Methodology

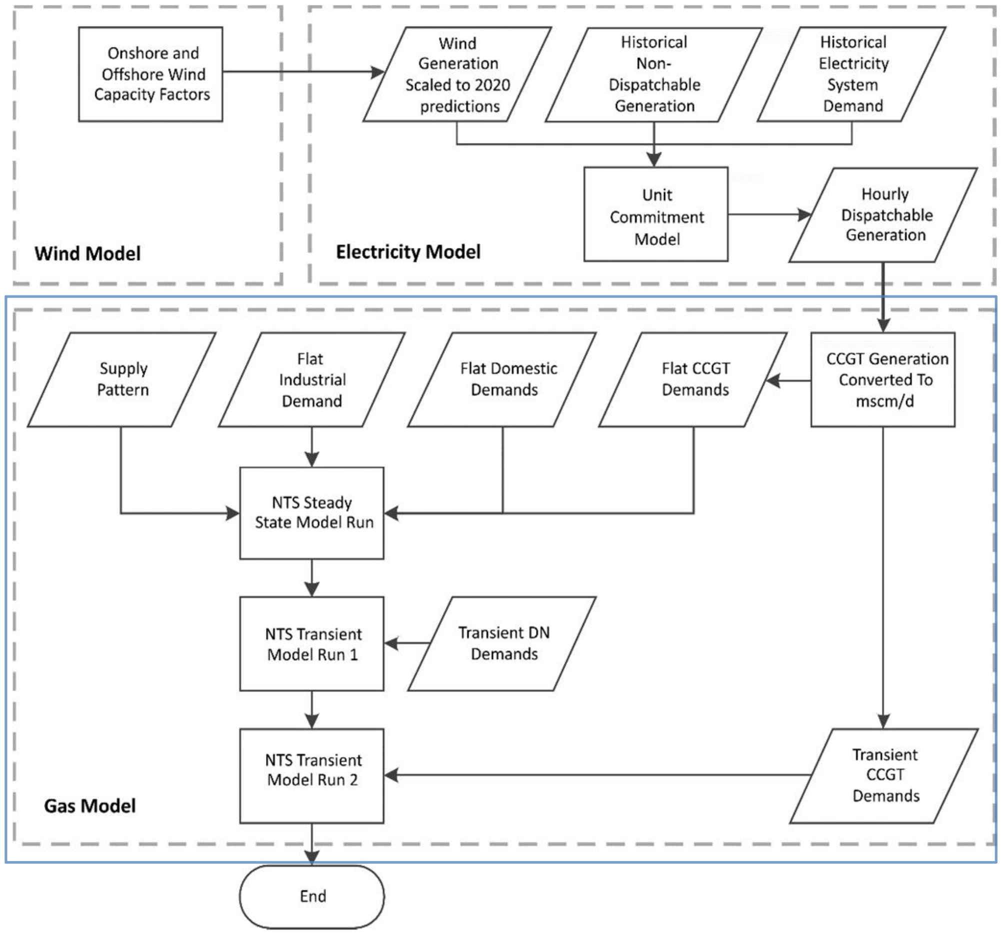
Gas Model

- Full model of NTS
  - 855 nodes, 803 pipes, 32 regulators, 98 valves, 48 compressors
- Graphical Falcon software
  - Manual operation necessary
  - Iterative and skilled exercise that approximates SO action
- Constraints
  - Entry and exit pressures
  - Differential pressure across valves and regulators
  - Full compressor envelopes
  - Soft limits: linepack and reserve (‘operating margins’)

Simplified schematic

Methodology

- 3 gas model runs used
- Steady-state:
  - fixed supply/demand
- Transient run 1:
  - ‘settling day’ with transient demand & flat CCGT profiles
  - allows ‘adequate’ linepack
  - represents CCGT contractual position and SO expectations
- Transient run 2:
  - with transient CCGT
- Difference is a measure of operational uncertainty and indicates changes needed to accommodate wind



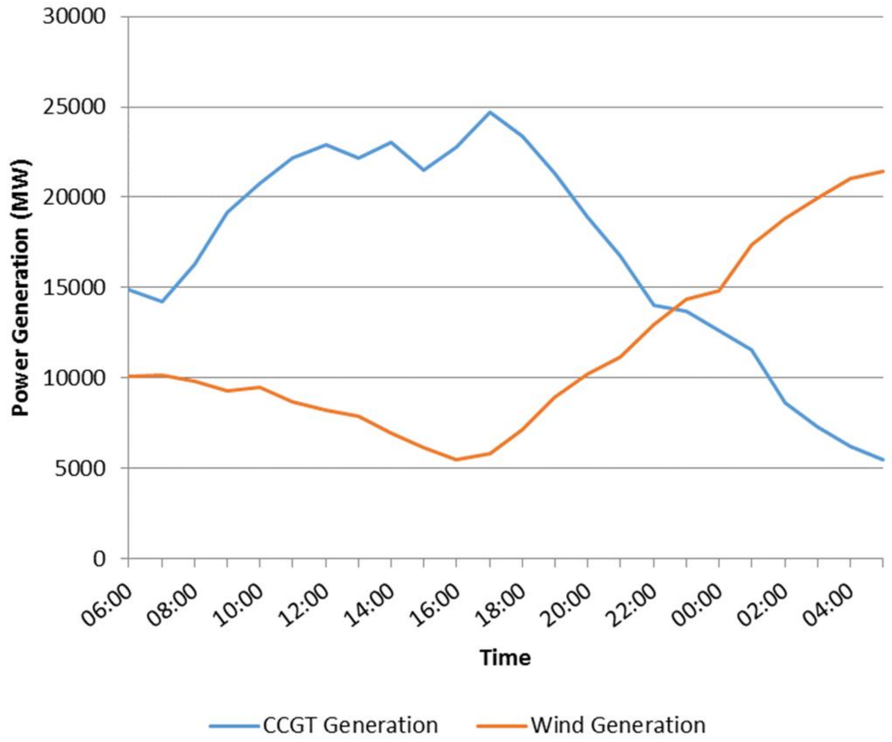
Methodology

- Gas modelling carried out interactively to develop a ‘strategy’ to convey gas from supply terminals to offtakes by setting compressors, valves and regulators
- Alarms alert analyst to change operation
- Finally minimise compressor use to maximise efficiency
- Process not truly ‘optimal’ in a mathematical sense
- If all credible strategies have been investigated and constraints cannot be satisfied then the particular conditions represent a ‘network failure’ which forces use of reserve ‘operating margins’ gas to adjust pressures
- Ultimately beyond that requires recourse to on-the-day market and finally load shedding (not examined)

Stress Test

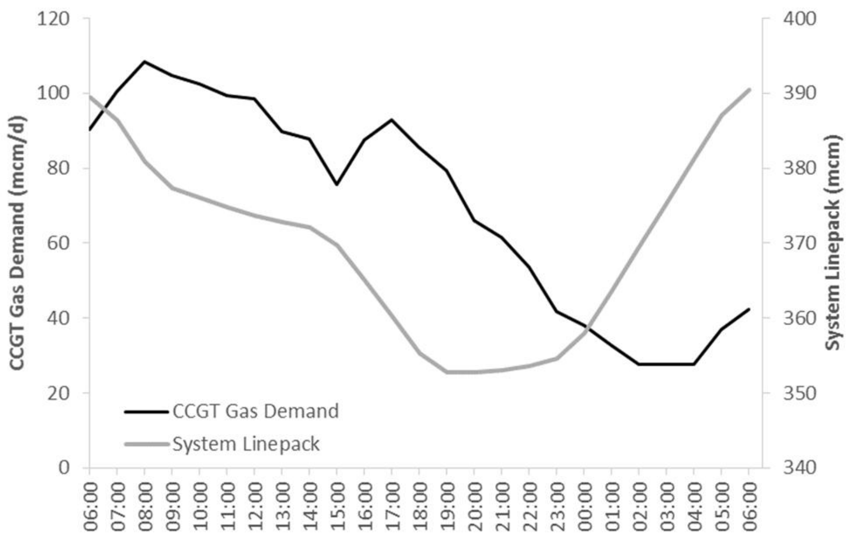
- Six supply scenarios varied where and how much gas was entering system and from storage
- The 5 year wind series used to dispatch CCGT
- The ten 'worst case' days for gas system were extracted based on the size of the within-day swing in CCGT gas demand
- Brief 'walk through' of one

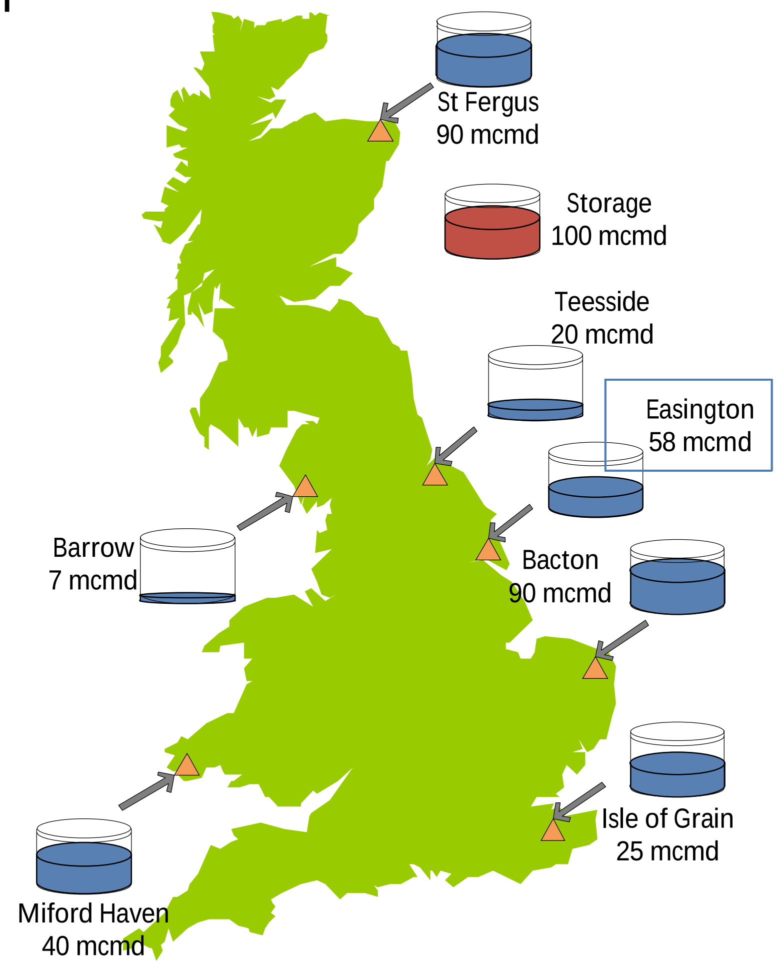
Example 'worst case' day



Stress Test

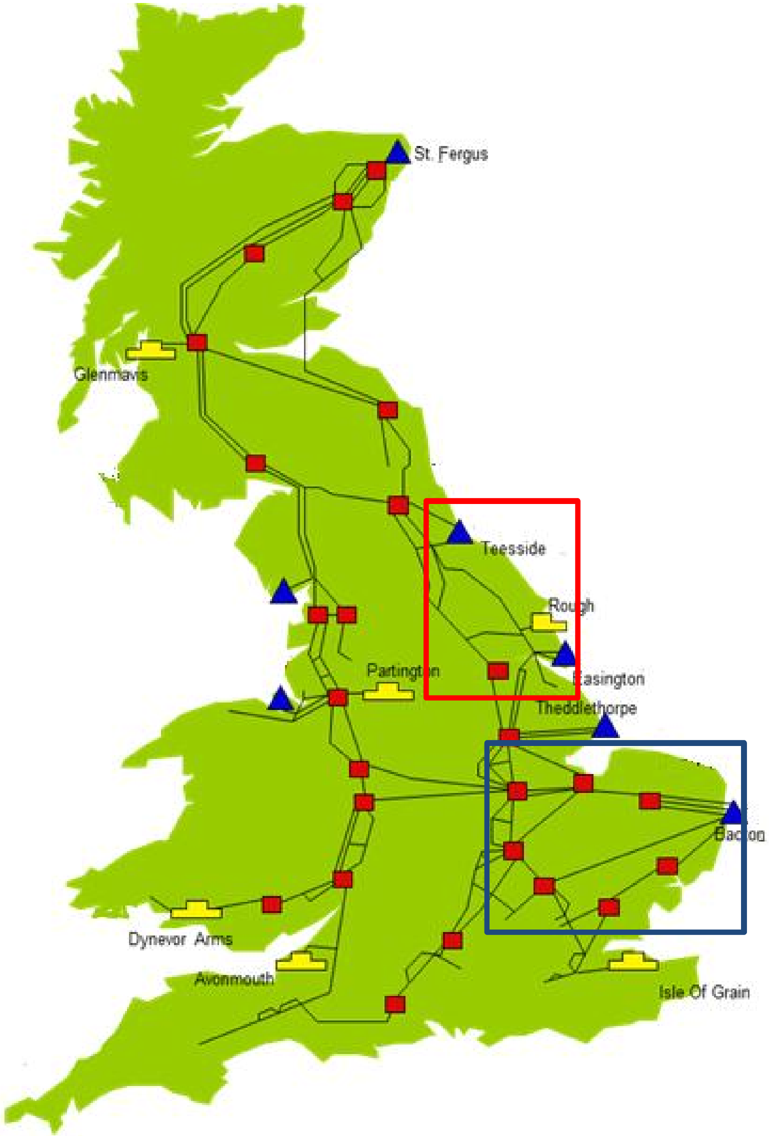
- This case sees unusually low supply from Norway into Easington terminal
- Wind high initially but falls through the day then picks up overnight
- CCGT response: ramps up, then down
- Large swing linepack (below)





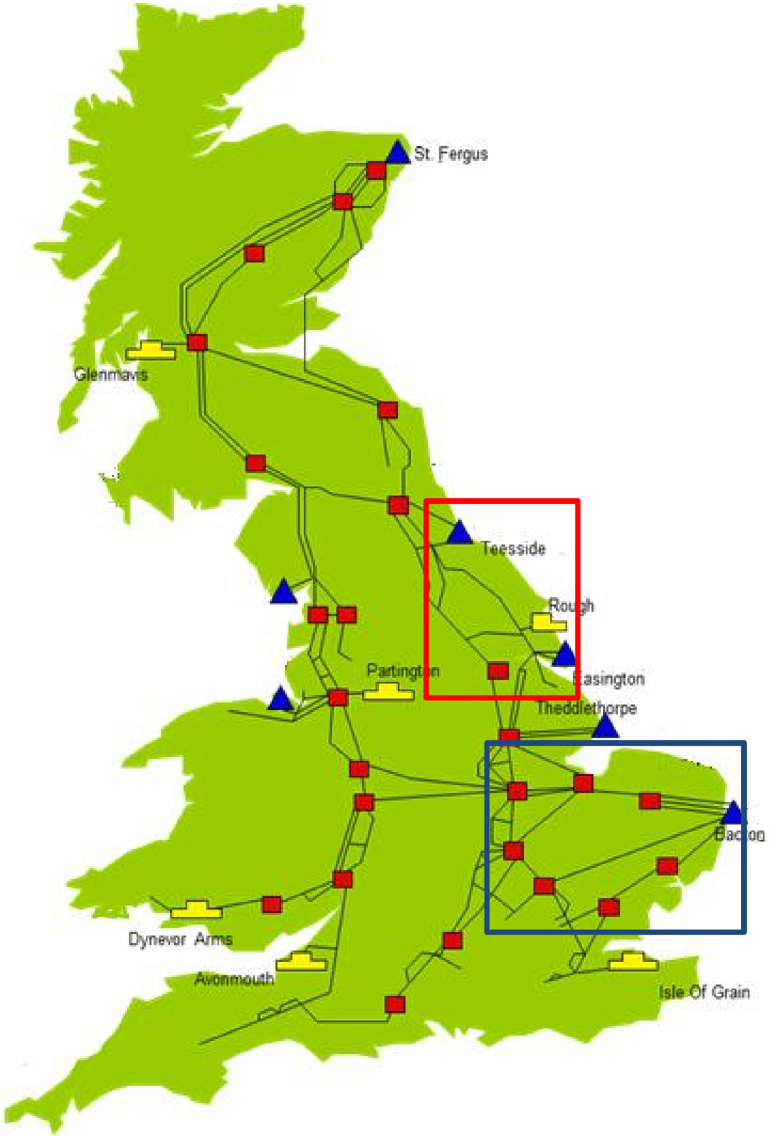
Stress Test

- Much CCGT is concentrated around Easington (red box)
- The CCGT gas demand pattern creates low pressures in this region in the morning and high terminal pressures overnight
- Important ‘knock-on’ localised breaches in southeast (blue box)
- Could not alleviate by systematic compression to push gas from the north and Scotland
- Ultimately required gas held in reserve (as LNG) to be released to remove constraint



Stress Test

- Wider scenarios and 'worst case' profiles show great variation
- Regional variations in type and timing of problems
- Scenarios involving north-south flows less stressful (cf. east-west)
- Linepack requirements go up
- Constraint management services required in all cases and use reflects severity
- Choices over reinforcement difficult but selective investment in flexibility appealing



Summary

- Industrially credible analysis may require use of highly detailed models
- These are challenging to apply efficiently
- They do highlight issues that do not tend to be visible in heavily simplified modelling
- Uncertainty over gas supply appears to be a major operational challenge
- Operational oversight of electricity system will tend to assist in managing effects of wind
- Raises as many questions as it answers!