Developing the market for electricity system services… while avoiding paying too much

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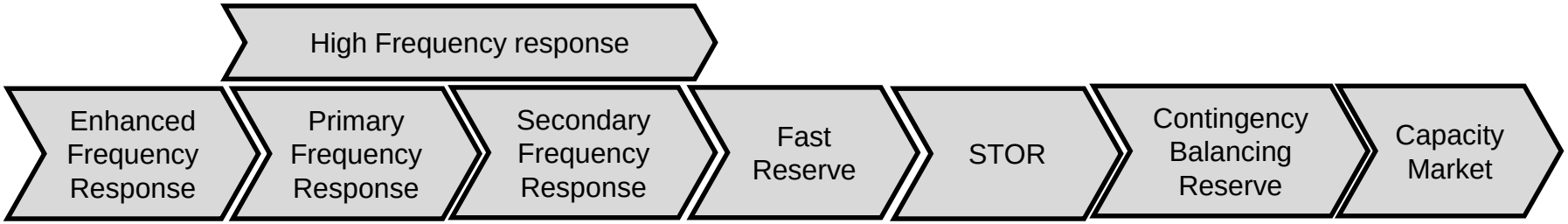
https://www.strath.ac.uk/staff/bellkeithprof/ http://www.ukerc.ac.uk/about-us/people/keith-bell.html

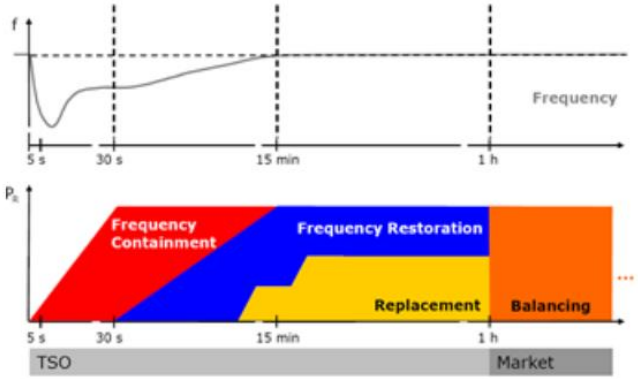
What are electricity system services and why do they matter?

- The electricity system is a single, complex, non-linear, dynamic system
  - When it goes wrong, it can go wrong very quickly and in a very big way
  - Much of the system is exposed and affected by the weather
  - Recovery from a major unreliability event is much harder than from regular events
- Energy balancing matters
- Energy markets not well suited to many technical ‘just in case’ requirements
  - Many ancillary services defined

North-East US blackout, August 2003
http://www.timesunion.com/news/slideshow/The-Northeast-Blackout-of-2003-47515/photo-3327282.php

Managing system frequency





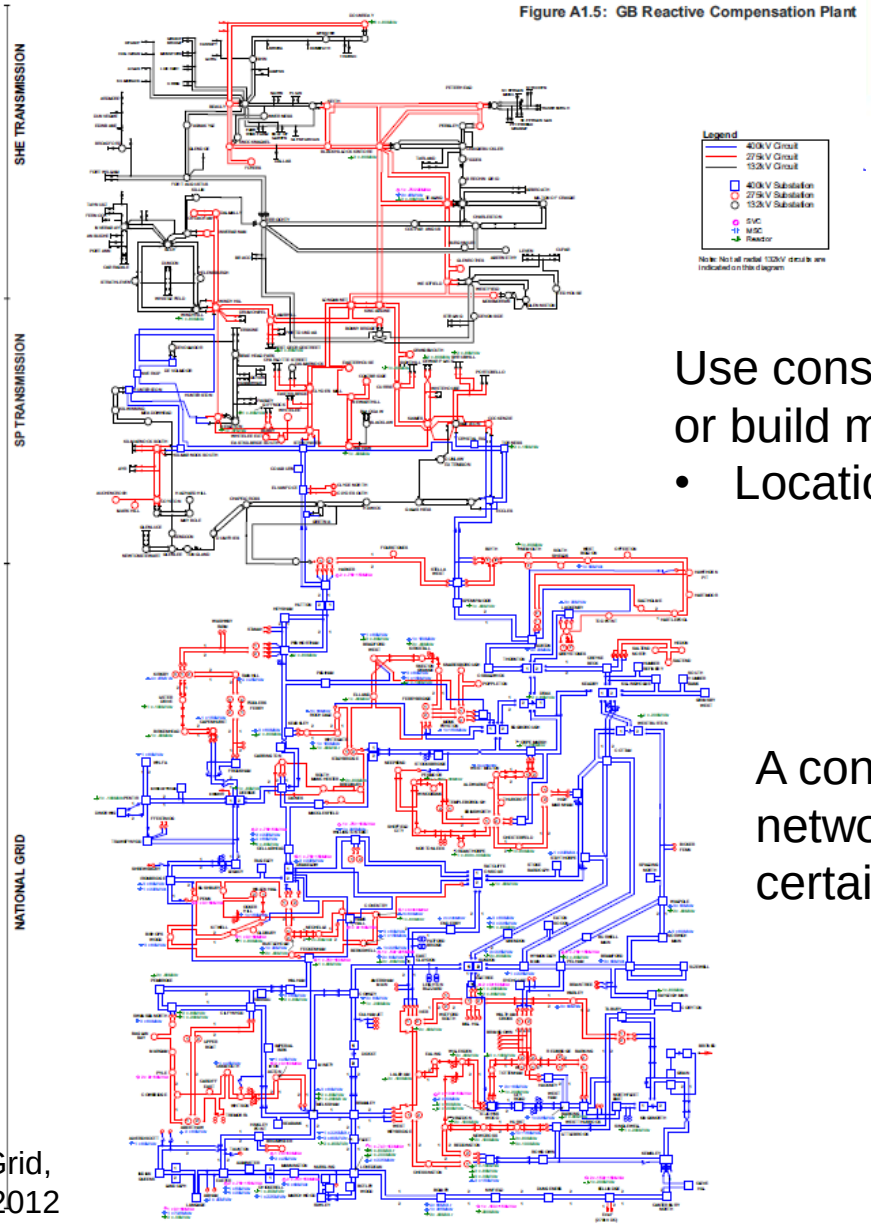
- Different providers have different capabilities and costs
  - One service buys time to access the next
- Almost all present day provision of response and reserve depends on stored energy
  - Kinetic energy (inertia)
  - Heat (high pressure steam)
  - Potential energy (hydraulic head)
  - Chemical energy
- Most currently depends on fossil fuels

Slide by Simon Gill and Keith Bell

Managing power flows

Respect of network limits

- Constrain off generation in zones with excessive export (accept bid)
- Constrain on generation in zones with excessive import (accept offer)
- Balance the constraint action



National Grid,
Electricity Ten Year Statement 2012

Use constraint actions or build more network?

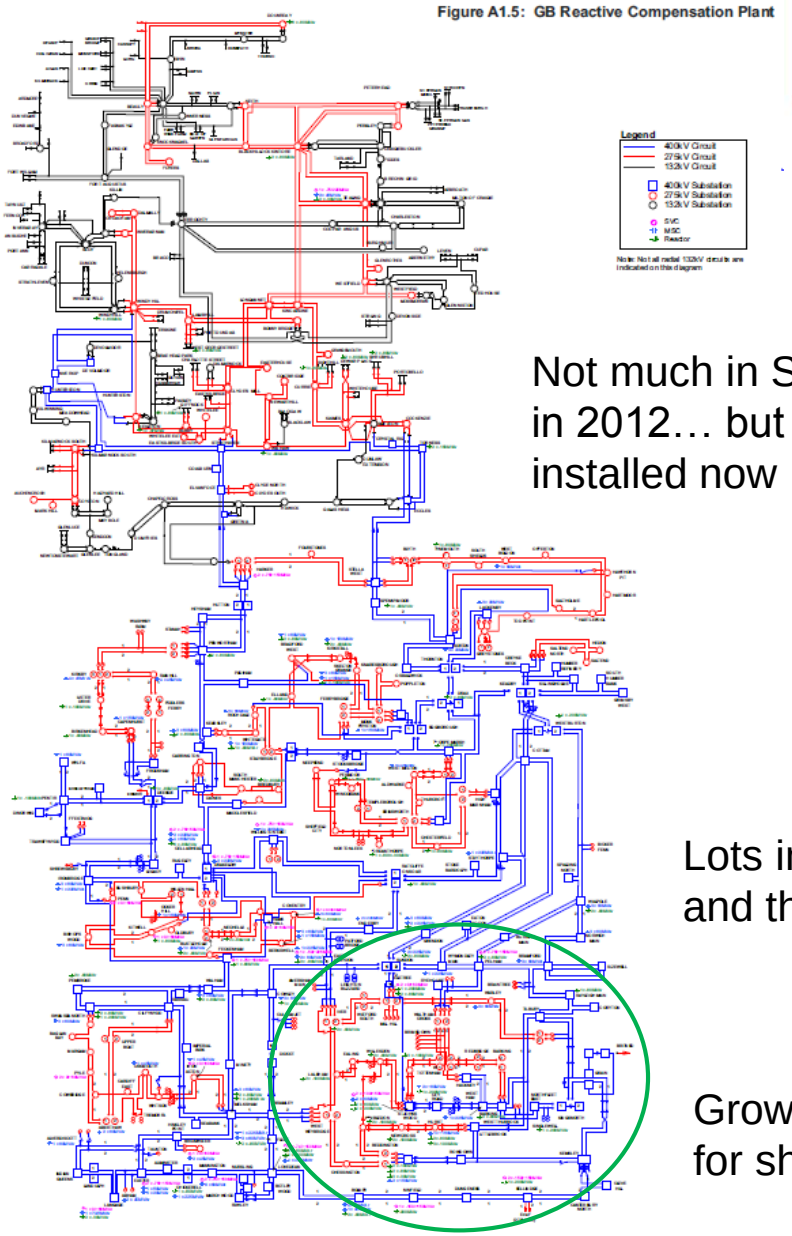
- Location matters

A constraint-free network is almost certainly over-sized

Voltage control and reactive compensation

Reactive compensation generally installed to regulate voltage in the absence or credible absence of generation

- Location matters



Not much in Scotland in 2012… but some being installed now

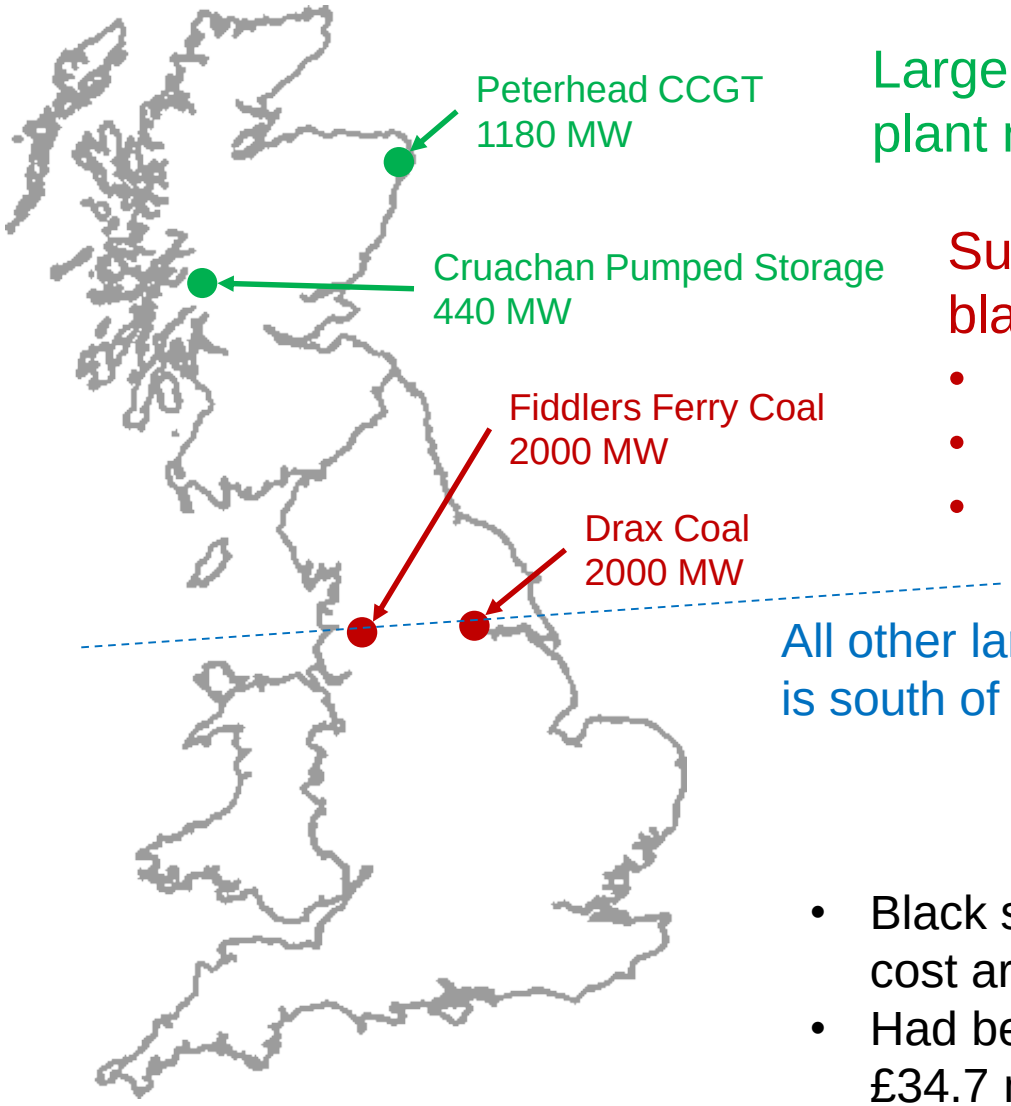
Lots in London and the South-East

Growing need for shunt reactors?

National Grid,
Electricity Ten Year Statement 2012

Black start

Location matters



Large, schedulable, non-nuclear plant north of York

Summer 2016: NGET awarded 1-year black start contracts at cost of **£113m**

- National Grid poor at forecasting?
- Poor at negotiating?
- Or had no choice?

All other large, schedulable plant is south of this line

- Black start capability in the past has often cost around £20 million per year
- Had been forecast by National Grid to cost £34.7 million in 2016/17

Overall balancing costs – 2016-17

http://www2.nationalgrid.com/UK/Industry-information/Electricity-transmission-operational-data/Report-explorer/Services-Reports/

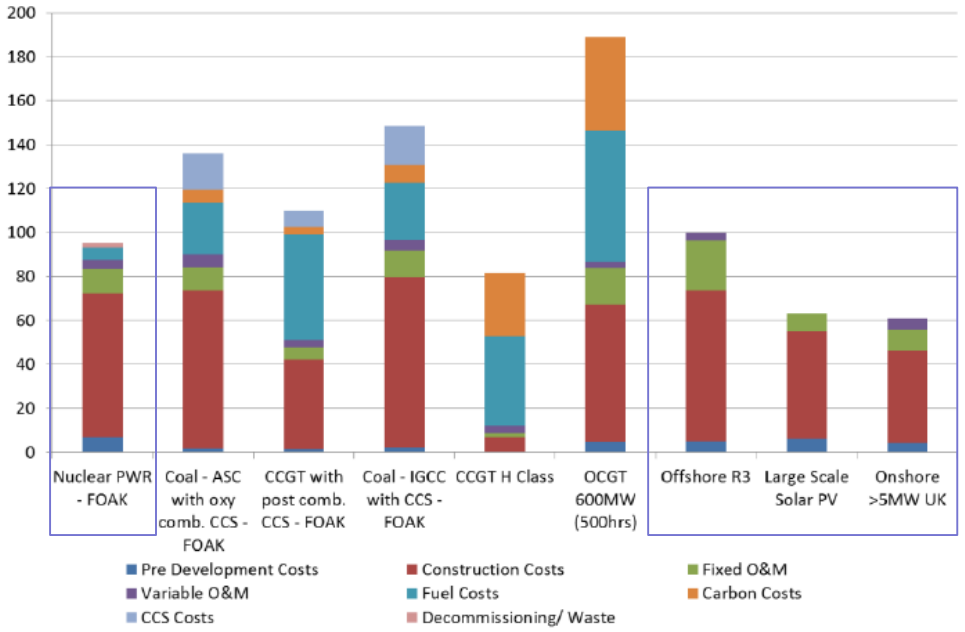
2016/17 £m	A. Year to Date Total Cost	B. Year To Date Target	C. Year to Date Latest Cost Forecast	D. Year to Date Initial Target Forecast	E. Projected Total Cost for Year (Cost Outturn + Latest Cost Forecast)	F. Projected Scheme Target Total (Year 1)	G. Initital Forecast for Year
Energy Imbalance	-£80.355	-£69.7	£1.4	-£13.6	-£80.4	-£69.7	-£13.6
Operating Reserve	£176.287	£97.0	£92.3	£79.2	£176.3	£97.0	£79.2
BM Startup	£6.470	£4.4	£2.2	£10.8	£6.5	£4.4	£10.8
STOR	£72.240	£69.3	£58.4	£65.5	£72.2	£69.3	£65.5
Constraints - E&W	£124.2	£350.0	£247.2	£748.8	£295.2	£350.0	£748.8
Constraints - Cheviot	£120.4						
Constraints - Scotland	£50.7						
Footroom	£24.257	£19.1	£9.1	£15.9	£24.3	£19.1	£15.9
Fast Reserve	£93.569	£152.9	£106.9	£137.4	£93.6	£152.9	£137.4
Response	£145.174	£183.0	£182.1	£173.3	£145.2	£183.0	£173.3
Reactive	£86.095	£88.8	£74.0	£85.3	£86.1	£88.8	£85.3
Black Start	£80.257	£31.8	£144.8	£31.8	£80.3	£31.8	£31.8
Minor Components	£19.398	£24.6	£16.0	£25.7	£19.4	£24.6	£25.7
ROCOF	£31.700	£12.3			£31.7	£12.3	
Black Start IAE Allowance	£54.088				£54.1		
Total SBR and DBSR	£117.834				£117.83		
TOTAL	######	£963.7	£934.3	£1,360.2	£1,122.2	£963.7	£1,360.2

National Grid Monthly Balancing Services report, March 2017

Under which heading does the cost of constraining on a synchronous unit to operate in the lead appear?

The changing nature of generation

- Fossil fuelled plant
  - Fuel a significant cost
- Low carbon generation
  - Limited choice of location
  - Limited ‘schedulability’
  - More variability
  - Higher capex, lower opex
  - Competitive wholesale markets hinge on short-run marginal costs (SRMC)
    - How to recover the long-run costs if income based on SRMC is small? → the ‘missing money problem’
- Less money based on energy, more on ‘services’



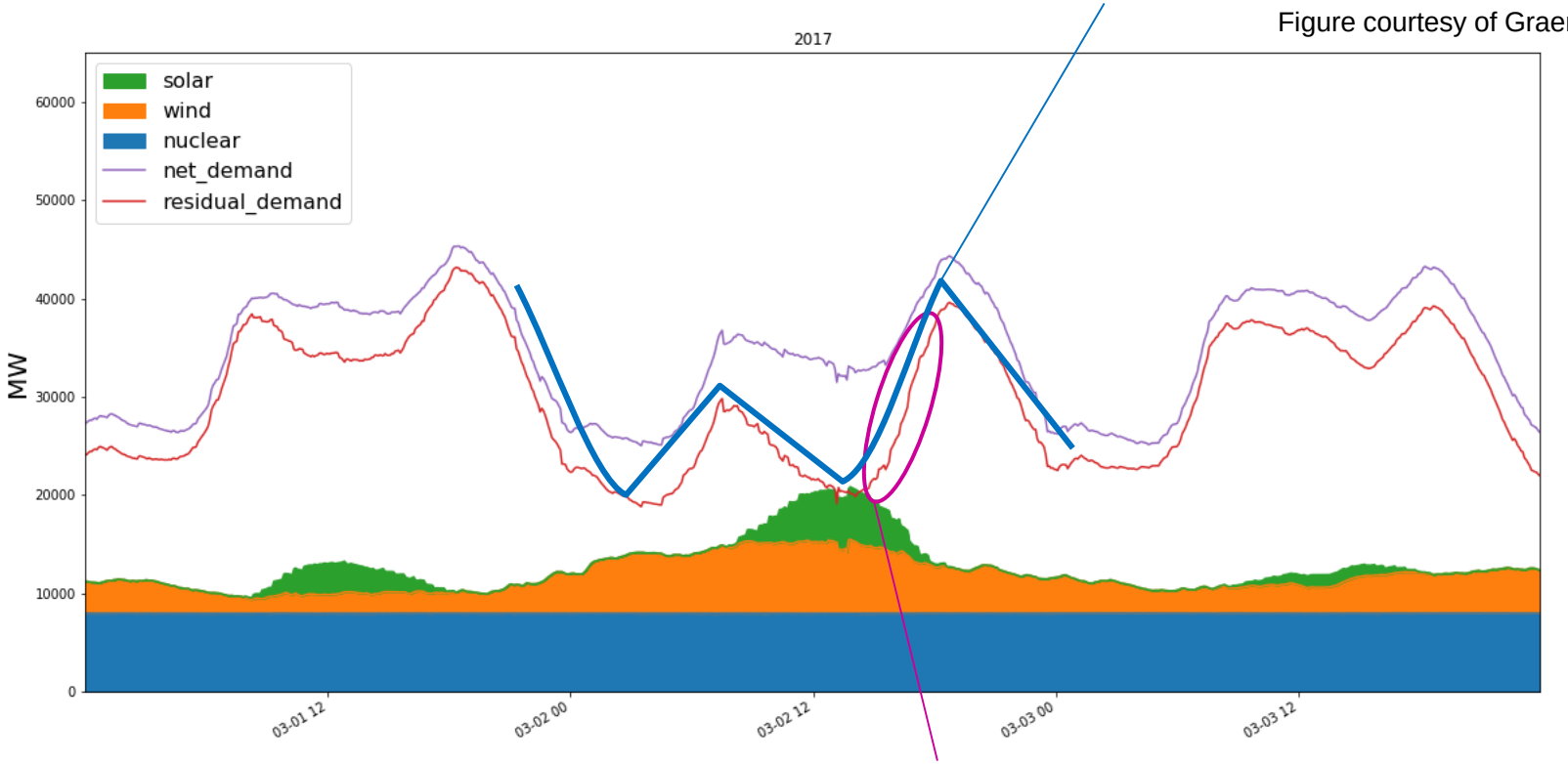
Levelised cost of energy, £/MWh
Department for Business, Energy & Industrial Strategy, Electricity Generation Costs, November 2016

The need for flexibility

"Residual demand": that to be met after using available low carbon power

More starting and stopping of schedulable plant?

Figure courtesy of Graeme Hawker



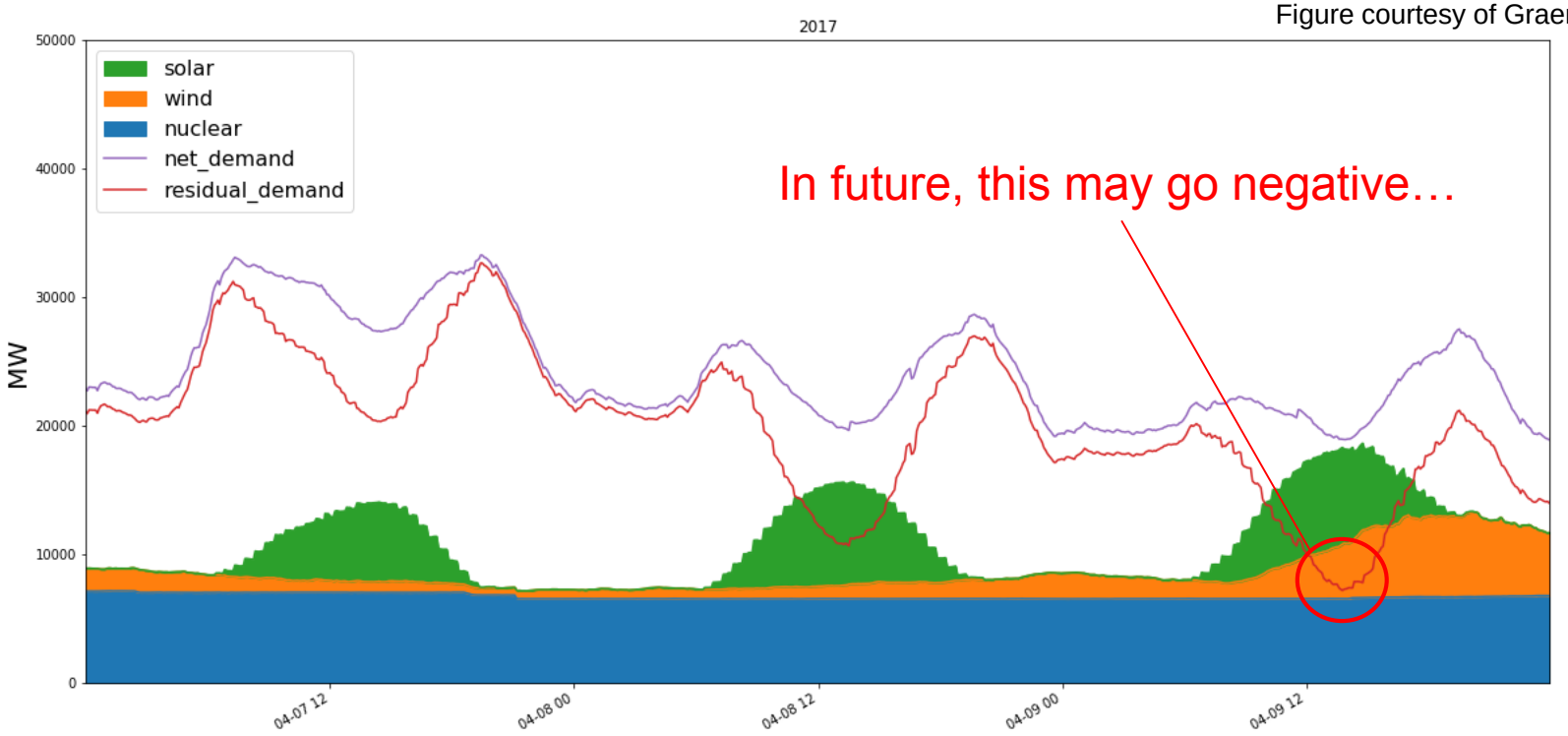
Enough schedulable plant will be needed that can ramp quickly enough

How to ensure that new schedulable plant has the requisite dynamic capability?

Too much low carbon electricity?

"Residual demand": that to be met after using available low carbon power

Figure courtesy of Graeme Hawker



Too much low carbon electricity?

University of Strathclyde Engineering

National Grid warns of action to cut big UK power plants' output

Gas and nuclear stations may have to make way for renewables as summer demand falls

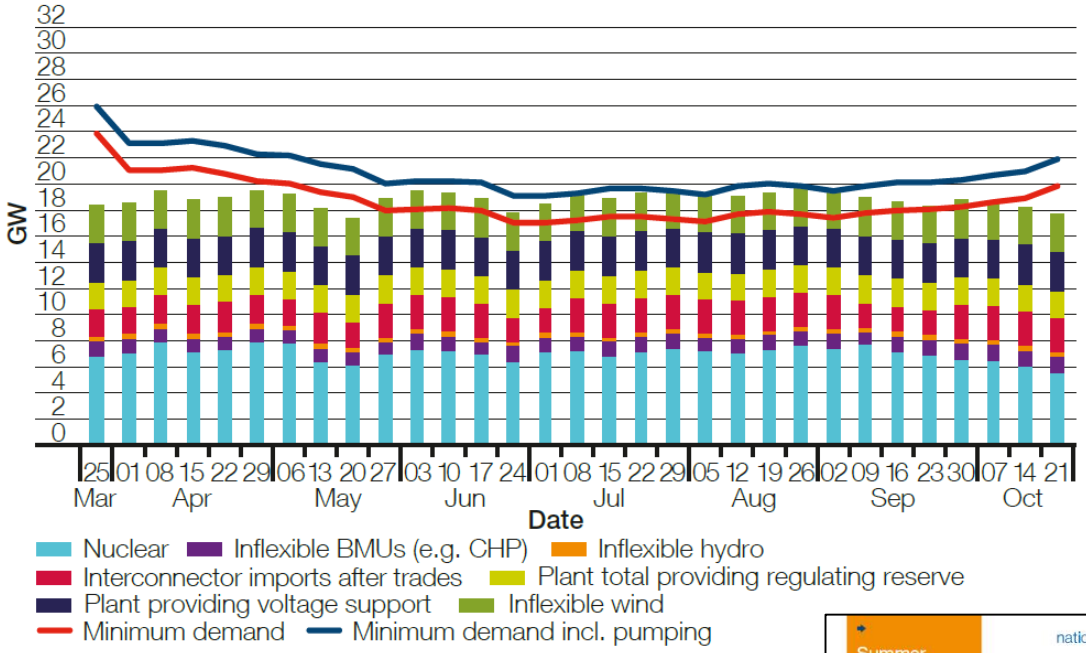
Almost 13gW of solar generating capacity is connected directly to local distribution networks © Getty

Andrew Ward, Energy Editor YESTERDAY 33

National Grid has warned operators of large gas and nuclear power stations that they may be instructed to curtail output this summer to accommodate rising amounts of wind and solar generation.

FT, April 10, 2018

Generation and weekly minimum demand



- System Operator can't see or control what's going on in the distribution network
- Nuclear units lack flexibility
- 2.5GW constrained on for "voltage support"?

What reactive capability does plant have?

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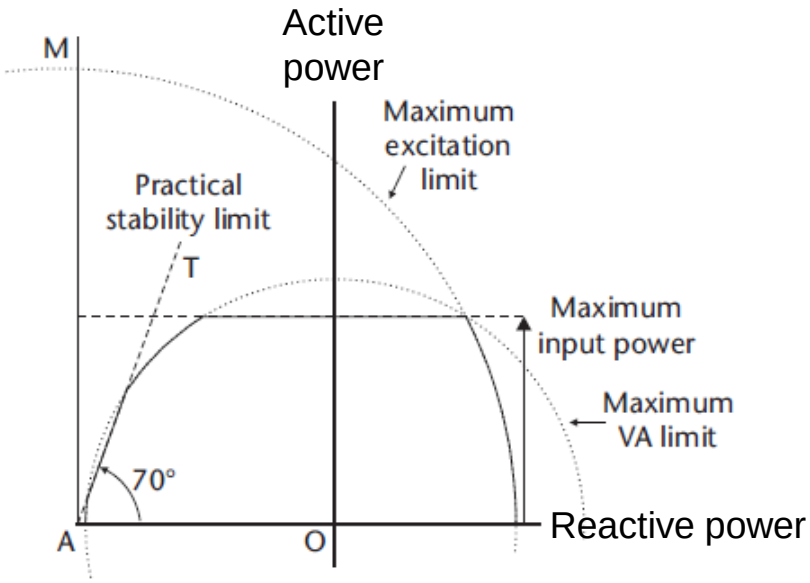
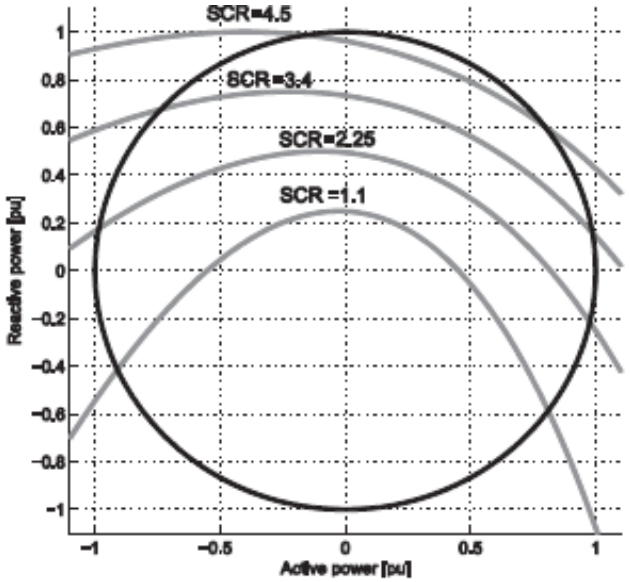
Synchronous generator



Voltage source converter



Egea et al, “Capability curves of a VSC-HVDC connected to a weak AC grid considering stability and power limits”, 2015

There is inherent reactive power capability

- You only need to limit active power if you need the extremes of reactive capability

Effective utilisation of reactive power capability depends on coordination of voltage targets

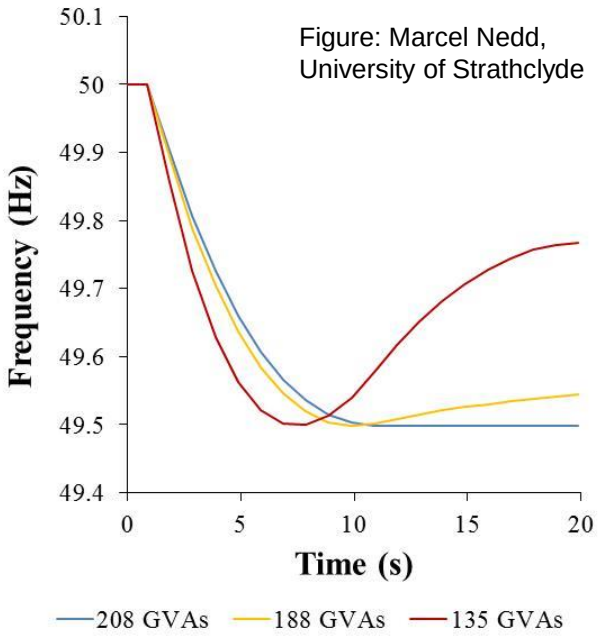
- Leave a margin to respond to faults

Services to manage system frequency

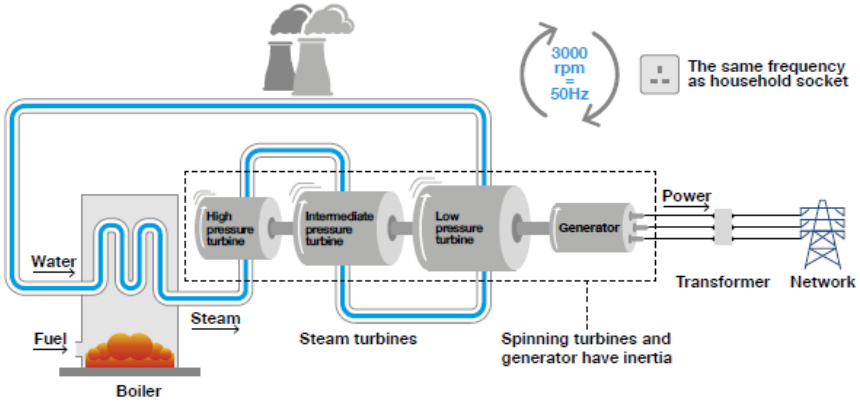
- Schedule more frequency containment reserve (response and reserve)
- Constrain on plant to increase system inertia
- Reduce the size of critical largest infeed

Pay for MWh to get access to stored MWh

Reduce the need for stored MWh



What kind of response? (How fast?)



$$dP = \left(\frac{2 \times H_{sys}}{f_0}\right) \times \left(\frac{df}{dt}\right)$$

Figure: National Grid, System Operability Framework, 2016

Industry developments

Future of balancing services

As the UK moves to a low-carbon economy, the way we operate the electricity system is evolving. A smart, flexible system that makes the best use of all the energy resources available will enable us to meet our customers' needs in a balanced, efficient and economical way.

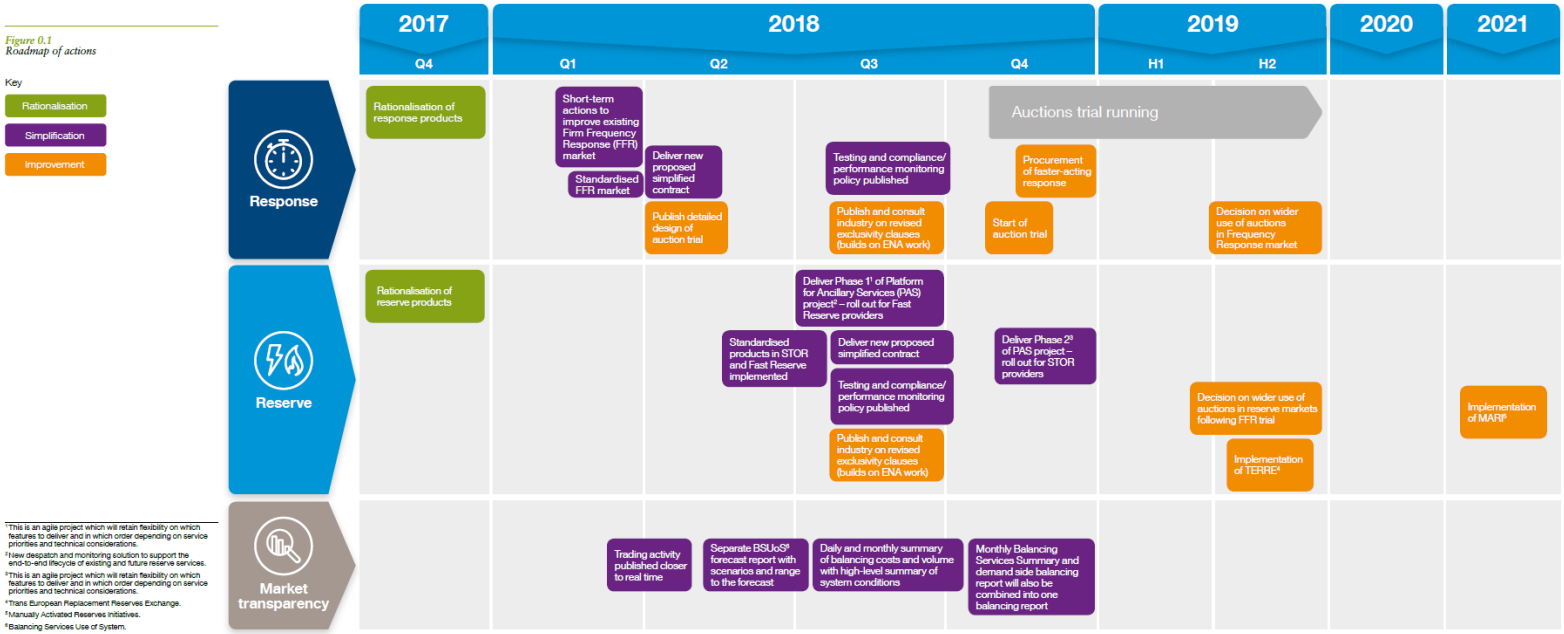
Our aim is to create balancing services markets that meet our changing system needs, and in which all technology types can compete on a level playing field. To achieve this, we will:

- provide market information that plainly sets out our needs;
- simplify our products to create transparency; and
- ensure routes to market for all participants.

We'll publish updates on services and system needs via this page as we progress. If you would like to be kept informed, please sign up by filling in our 'future of balancing services updates' form.

https://www.nationalgrid.com/uk/electricity/balancing-services/future-balancing-services

Figure 0.1
Roadmap of actions



[1] This is an agile project which will retain flexibility on which features to deliver and in which order depending on service priorities and technical considerations.
[2] New despatch and monitoring solution to support the end-to-end lifecycle of existing and future reserve services.
[3] This is an agile project which will retain flexibility on which features to deliver and in which order depending on service priorities and technical considerations.
[4] Trans European Replacement Reserves Exchange.
[5] Manually Activated Reserves initiatives.
[6] Balancing Services Use of System.

Avoiding rent and encouraging investment

- Economic rent (according to Henry George, 1879, as reported by wikipedia):
  - "the part of the produce that accrues to the owners of land (or other natural capabilities) by virtue of ownership"
  - "the share of wealth given to landowners because they have an exclusive right to the use of those natural capabilities."
- Why pay generators or owners of VSC for what is inherent?
  - Synchronous machines can't sell energy *without* providing inertia
- Can you have a market in MVArh? The need for MVAr:
  - varies by location and by time from generation to absorption
  - depends heavily on the demand for MW
- There is value in enhanced *capability*, e.g. in inertia, reactive power, ramping or short circuit power
  - It can save on the need for network assets or balancing actions
  - It is reasonable for any investment in enhanced capability to be remunerated: institute a competitive process?

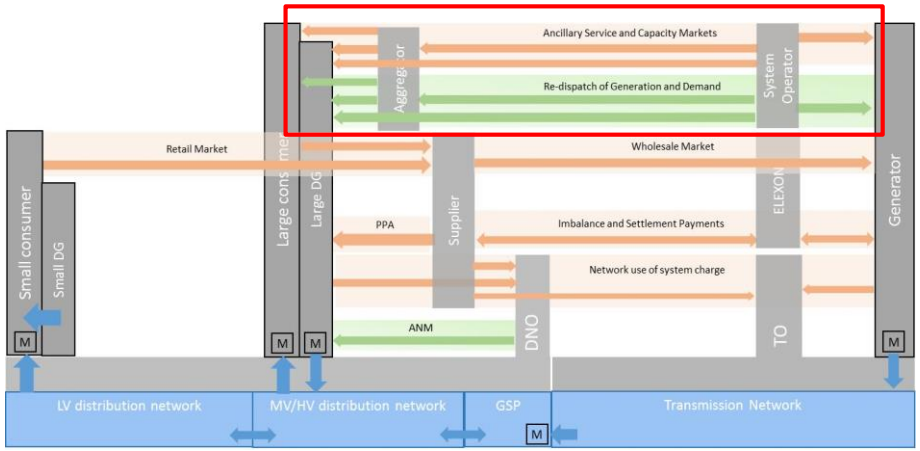
Procuring services

- Different ancillary services currently procured separately
  - Value of each revealed
- Only capacity and cost currently valued in the capacity market
  - No consideration for location or dynamic capability
- What if a certain non-network service provider loses individual service contracts but is cost-effective as a *package*?
  - Align tender rounds for different services and decisions on contracts?
  - Should help generators, flexible demand and storage gain confidence in accessing multiple income streams
    - Take care that providers (a) are actually available when required and (b) do not get paid twice for the same action
  - Difficult to evaluate many possible combinations?

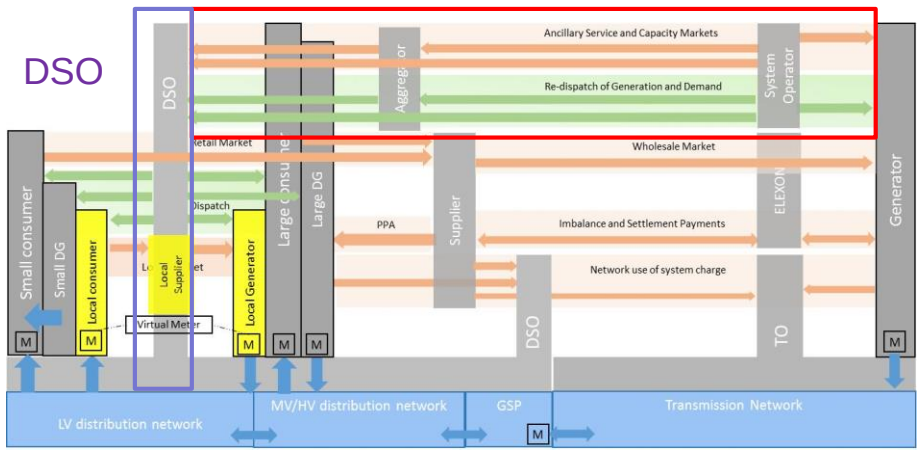
Who pays? Who gets paid?

- Services from distributed resources increasingly important
  - Who buys and invokes the services?
  - Potential for conflict between transmission and distribution needs

Actuation of and payment for balancing services



Present day



Future ‘maximal DSO’ model?

- Investment in new generation capacity
  - How is investment in enhanced dynamic capability justified now if the capability isn’t needed for some years?
    - Set statutory capability requirements?
    - Leave it to a market that doesn’t exist yet?