The Economics of Flexibility

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This is the web version of my talk, with notes added in bubbles that should be visible if you run the mouse over them.

14 February 2020
• Flexibility is the ability to respond to the changing needs of the power system
  – Generators
  – Demand response
  – Storage
  – Transmission
£6bn per year cost saving for a 50g/kWh power system
£4.5bn per year for a 100g/kWh system
Will we deliver it?

- Flexibility involves a range of services from a range of providers, some currently unpriced
- How do we coordinate everything?
- What are the right incentives?
- How large are the transactions costs?
Why is flexibility needed?
Constrained Optimisation

(making the power system work)

- Generation = Demand + Losses + net Storage + net Exports
- Line Flows ≤ Limits
- Voltages within acceptable ranges (reactive power)
- Generators meeting their own constraints
  - Minimum on/off times
  - Maximum ramp rates
  - Minimum stable generation
- Reserves sufficient, given risks and response times
Variable Generators

Coal, Gas and Oil, versus Wind and Solar

Source: Electric Insights (data are for GB)
Variable Generators (x2)

Wind and Solar versus Coal, Gas and Oil

GW

Availability-led

GW

Demand-led

Source: Electric Insights (data are for GB)
Renewable Generators… (wind and solar)

- may be more likely to...
  - be in the wrong place relative to load
  - be at the wrong time relative to load
  - have too little inertia
The price of flexibility
Day-ahead and Real-time Prices

GB data, quarterly averages

£/MWh

2009Q1  2011Q1  2013Q1  2015Q1  2017Q1  2019Q1

Price: Day Ahead
Price: Real-time
St. dev: Day Ahead
St. Dev: Real-time

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When does “free” electricity mean higher prices?

When the system’s not flexible…
Load, PV Output and Prices

California, 2012 and 2016

GW 35

$/MWh 70

Load
2012
2016

Solar Output
2012
2016

Real-Time Price
2012
2016

Source: Adapted from Bushnell and Novan, 2018

See also Hirth (2015) http://dx.doi.org/10.1049/iet-rpg.2014.0101
Could free power be too expensive to use?
The importance of inertia

Post-fault system frequency

Acceptable wind output

System may not be able to absorb it

Output Shed

Output Usable

Flexible System

Inflexible System

GW wind capacity

Strbac et al., 2016
National Grid awards £328m contracts to manage stability of electricity grid

This new approach is expected to save consumers up to £128m over the six-year period

Contracts with 5 providers at 7 sites, giving 12.5 GVA.s of inertia
The value of flexibility will rise over time
Marginal Value of Storage

(Strbac et al., 2012)

\[ \text{£/kW-year} \]

\[ \text{GW} \]

Capex Savings

Opex Savings

Generation

Transmission

Distribution

Interconnectors

£/kW-year

0 5 10 15

GW
The value of storage over time

$\text{£/kW}$

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The value of flexibility sources depends on what else is available
Any substitutes for storage?

Increasing asset utilisation and efficiency of operation

Increasing asset utilisation and efficiency of operation

Interconnection increases

NPV of storage, £/kW

GW of storage

Flexible Demand

Flexible Generation

Demand Response

Interconnection

Storage

Flexible Generation

Increasing asset utilisation and efficiency of operation

Interconnection increases
The need to multi-task
System Value of Energy Storage

- **Arbitrage**
  - Participate in day-ahead energy market

- **Balancing services**
  - Participate in real-time balancing market

- **Network Support**
  - Reducing need for T & D network reinforcements

- **Frequency regulation services**
  - Providing primary/secondary / tertiary frequency regulation services

- **Capacity market**
  - Contributing to meeting peak demand, reducing need for peaking plant
System Value of Energy Storage

(1) = Arbitrage only
(2) = (1) + Balancing
(3) = (2) + PV support
(4) = (3) + Network support
(5) = (4) + FR provision
(6) = (5) + Capacity market

Strbac et al. (2017), http://dx.doi.org/10.1109/MPE.2017.2708858
Balancing Great Britain

National Grid Costs, financial years

Source: National Grid ESO
Getting the right incentives
What’s the right mix of fast and slow response to buy?
  − How valuable is each type?
  − What is on offer?

Greve and Pollitt suggest a Vickrey-Clark-Groves auction
  − System operator calculates the value of each combination
  − Chooses combination that maximises value minus bid
  − Pays selected providers their contribution towards maximised social value
    • Value with that provider, minus value without
  − Incentive compatible – best to bid your true cost!
Do we pay enough for flexibility?
Interconnectors with Reserve

- Social Value
- Commercial Value
- MC in exporting region
- MC of energy and reserve
- MC of energy avoided in importing region

Unit Cost of I/C

Commercial I/C Capacity

Optimal I/C Capacity

Price Equalisation

GW
Thank you