Energy and climate modelling: the perspective of a power system researcher and former investment planner

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https://www.strath.ac.uk/staff/bellkeithprof/
Operating state

Weather, including
- Temperature
- Wind speeds
- PV generation
- Cloud cover

Temperature

Wind speeds

PV generation

Cloud cover

Starting and stopping of units

Available generation

Generation forced outages

Generation planned outages

Generation capacity

Fuel costs

Security criteria

Network planned outages

Other unplanned outages

Asset policy

Demand

Reserve policy

Electricity user behaviour

Weather, including
- Time
  - Season
  - Time of day
  - Day of the week

Network configuration and capacity

Fuel costs

Fine-tuning of system settings

Perspective of system operator
- Controllable
- Partially controllable
- Not controllable
- Not controllable but well or partially determined

Time

Security criteria

Dependences of system operating states
High wind speed shutdown

Unexpected hurricane
Denmark, January 8th 2005

- Will a high wind-speed shutdown happen?
- When will it happen?
- By how much will wind power drop?
- How quickly?

Source: Eltra
See http://www.eltra.dk/show.asp?id=15783
Weather-related transmission network faults in Southern Scotland

Analysis focussed on the Scottish Power Transmission area (Southern Scotland)

- Records of faults, 1984-2012 (28 years)
- Clusters of weather-related faulted identified

Year-round average: 0.006 faults/hour

<table>
<thead>
<tr>
<th>Weather type</th>
<th>Faults/hour</th>
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</thead>
<tbody>
<tr>
<td>“Ice, snow, sleet and blizzards”</td>
<td>11.4</td>
</tr>
<tr>
<td>Lightning</td>
<td>8.4</td>
</tr>
<tr>
<td>“Wind, gale, and windborne object”</td>
<td>18.6</td>
</tr>
<tr>
<td>“Corrosion, condensation and salt”</td>
<td>6</td>
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</tbody>
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Work by Euan Norris
Network development: assessing possible future system states

Some clustering methods better than others
None catch the HILP scenarios

Peak demand is not the worst condition

• How many of these cases will there be?
• How many should be satisfied?
Wind ‘drought’ for extended periods

Start Date: 23rd June 2018
Duration: 33 days
Peak gross demand: 38.0 GW
Average gross demand: 29.5 GW
Total gross demand: 23,445 GWh
Total wind output: 1,448 GWh

2018 Mean:
Average wind CF: 8.4% (28.1%)
Average wind output: 1.8 GW (6.0 GW)
Demand met by gas-powered generation: 46.1% (37.9%)

(wind index for 2018 = 99% of long term average)

Need not just MW capacity of schedulable, flexible generation, demand or storage but MWh capacity, i.e. persistence of output.
...but not just in summer

<table>
<thead>
<tr>
<th></th>
<th>2nd Jan 2019</th>
<th>21st Jan 2020</th>
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<tbody>
<tr>
<td>Start Date</td>
<td>2nd Jan 2019</td>
<td>21st Jan 2020</td>
</tr>
<tr>
<td>Duration</td>
<td>5 days</td>
<td>4 days</td>
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<tr>
<td>Peak gross demand</td>
<td>45.7 GW</td>
<td>45.2 GW</td>
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<tr>
<td>Average gross demand</td>
<td>36.2 GW</td>
<td>37.5 GW</td>
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<tr>
<td>Total gross demand</td>
<td>4,361 GWh</td>
<td>3,615 GWh</td>
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<tr>
<td>Total wind output</td>
<td>337 GWh</td>
<td>342 GWh</td>
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<tr>
<td>Average wind CF</td>
<td>12.8%</td>
<td>16.2%</td>
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<tr>
<td>Average wind output</td>
<td>2.8 GW</td>
<td>3.5 GW</td>
</tr>
<tr>
<td>Demand met by gas</td>
<td>56.4%</td>
<td>54.2%</td>
</tr>
</tbody>
</table>

Substantial volumes of energy that cannot be supplied by traditional peak-shifting or diurnal storage, and may occur at times when heat demand is at a peak and able to offer little flexibility.
System operation questions

• What will be the future correlation of demand with weather?
  • Increased cooling demand? More electrified heating?

• How to meet demand during long lulls in wind power?
  • How big would ‘essential’ demand be anyway?

• How to manage high wind speed shutdowns?
  • How deep would be the drop in wind output?
  • How fast might it happen?

• How many faults will there be during storms and how long will a storm last?
  • How many will involve equipment damage, e.g. due to high winds or flooding?
  • Will the system operator be able to operate defensively when a storm is coming?

• (The system operator depends on facilities made available by the investment planner)
Investment planning questions

- How often will ‘wind droughts’ occur?
  - What will the peak demand be for ‘essential’ services? (MW question)
  - How long will the drought last and how much energy will be demanded? (MWh question)
- What will the long-term average capacity factors of renewables be? (MWh question)
- What is the right mix of assets to meet demand for electricity?
  - Renewable generation capacity
  - Other low carbon generation capacity
  - Storage capacity (of different types)
  - Interconnector capacity
- How much network capacity will be needed to
  - accommodate the mix of generation, storage and interconnector capacity?
  - enable the system to survive faults and unavailability of generation?
- What equipment, personnel and communications facilities will be needed to recover from major disturbances?
- What can be assumed for the thermal ratings of equipment?