THE IMPORTANCE OF FORECASTING REGIONAL WIND POWER RAMPING: A CASE STUDY FOR THE UK

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INTRODUCTION

• In 2016, 12% of UK electricity was produced by wind power. This proportion is expected to increase to approximately 20% by 2020.

• Emphasis on large offshore wind farms.

<table>
<thead>
<tr>
<th>Zone</th>
<th>GW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moray Firth</td>
<td>1.5</td>
</tr>
<tr>
<td>Firth of Forth</td>
<td>3.5</td>
</tr>
<tr>
<td>Dogger Bank</td>
<td>9</td>
</tr>
<tr>
<td>Hornsea</td>
<td>4</td>
</tr>
<tr>
<td>East Anglia</td>
<td>7.2</td>
</tr>
<tr>
<td>Southern Array</td>
<td>0.6</td>
</tr>
<tr>
<td>West Isle of Wight</td>
<td>1.2</td>
</tr>
<tr>
<td>Atlantic Array</td>
<td>1.5</td>
</tr>
<tr>
<td>Irish Sea</td>
<td>4.2</td>
</tr>
</tbody>
</table>

5 GW under construction
THAMES ESTUARY CLUSTER

• Clustering capacity - Thames estuary region: 1.7 GW within approximately 3000 km$^2$.

• Concerns of large local high frequency power fluctuations

<table>
<thead>
<tr>
<th>Farm</th>
<th>Size (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Kentish Flats</td>
<td>90</td>
</tr>
<tr>
<td>2 Gunfleet Sands</td>
<td>172</td>
</tr>
<tr>
<td>3 London Array</td>
<td>630</td>
</tr>
<tr>
<td>4 Thanet</td>
<td>300</td>
</tr>
<tr>
<td>5 Greater Gabbard</td>
<td>504</td>
</tr>
</tbody>
</table>
LOCAL POWER RAMPS

• Obtained generation data from the cluster at 5 min resolution for 2014.
• Determined the ramps in power on time scales of less than 6 hours.

\[
\text{Ramp (t)} = \text{Power (t+\Delta t)} - \text{Power(t)}
\]

5 min ramps:
Max: 26.5% (450 MW)
Min: -21.6% (370 MW)

30 min ramps:
Max: 56.5% (960 MW)
Min: -59.5% (1012 MW)

6 hour ramps:
Max: 86.6% (1.5 GW)
Min: -90.8% (1.54 GW)

Ramping of generation in Thames Estuary 2014
RAMPING ANALYSIS

1. Identify all ramping events for all time scales
   - 4 hours: $\Delta CF > 40\%$
   - 60 mins: $\Delta CF > 25\%

*Only considered independent ramping events.*

2. Determine mechanism
   - Reanalysis
   - Surface station data
   - Rainfall radar

3. Early warning indicator
   - Large scale meteorological conditions
   - Rainfall radar (*e.g. Trombe et al., (2013)*)
RAMPING CLASSIFICATION

• 4 hour ramping events:
  • 74 ramp-up events and 69 ramp-down events.
  • DJF (39%), MAM (22%), JJA (24%) and SON (15%).
  • All ramps linked to passage of a low pressure system
RAMPING CLASSIFICATION

• 60 min (14 events)
  • Winter ramps: High wind speed cut-out or post frontal
  • Summer ramps: Thunderstorms
THUNDERSTORM

(a) Capacity factor

(b) Maximum rainfall rate

(c) Potential Gradient

(d) Manston Surface Pressure
CASE STUDY: 3RD NOVEMBER 2014

- Post frontal ramp
- Thames Estuary Generation

18:00
SYSTEM IMPACT

Unpredicted ramp leads to electricity price spike.

Not enough generation

Too much generation

Electricity price
 (£ per MWh)

Balance of electricity
 (MWh)
HIGH RESOLUTION FORECASTS

- Did the UK Met Office high resolution models capture the feature?
  - MOGREPS UK:
    - Regional high-resolution ensemble
    - 2.2 km resolution
    - Analysis + 11 members
    - 54 hour forecast
  - UKV
    - High resolution deterministic
    - 1.5 km resolution
    - 54 hour forecast
UKV RESULTS

- Model captures the feature.
- Wind power ramp not captured clearly if precise turbine locations used.
- Improved by considering maximum wind speed within 10 km area around each turbine.
- Lead time: Feature present 24 hours ahead.
MOGREPS RESULTS

- Feature not captured when forecast uses ensemble mean wind speed.
- Need the information of the ensemble members.
- When does model capture it?

<table>
<thead>
<tr>
<th>Forecast</th>
<th>P(R&gt;20%, t±3)</th>
<th>P(R&gt;20%, t±1)</th>
<th>P(R&gt;40%, t±3)</th>
<th>P(R&gt;40%, t±1)</th>
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</thead>
<tbody>
<tr>
<td>02/11/2014 12:00</td>
<td>20.8</td>
<td>20.8</td>
<td>4.2</td>
<td>4.2</td>
</tr>
<tr>
<td>02/11/2014 18:00</td>
<td>25.0</td>
<td>16.7</td>
<td>12.5</td>
<td>4.2</td>
</tr>
<tr>
<td>03/11/2014 00:00</td>
<td>45.8</td>
<td>20.8</td>
<td>20.8</td>
<td>4.2</td>
</tr>
<tr>
<td>03/11/2014 06:00</td>
<td>62.5</td>
<td>29.2</td>
<td>33.3</td>
<td>12.5</td>
</tr>
</tbody>
</table>
CURRENT WORK

• Skill in high resolution UK Met Office models at capturing extreme local ramping events.

  • UKV – 1.5 km resolution

  • MOGREPS- 2.2 km resolution, 12 members

CONCLUSIONS

Investigating the impact of clustering wind capacity in large offshore wind farms on wind power ramping

- **Individual clusters (Thames Estuary):**
  - 4 hr ramping – caused by frontal features associated with low pressure systems.
  - Higher frequency ramps (60 min): cut-out, post-frontal, thunderstorms.
  - Extreme events can have big impact on the power system (in terms of balancing and costs). There is a need to forecast these events.
  - Small scale meteorological phenomena need to be captured by forecast models – assessing skill of UK Met Office high resolution model.
EXTRAS
RAMPING CLASSIFICATION

- Determined 60 min and 30 min ramps for whole dataset. Repeated with periods with frontal ramps removed.
- Extreme 30 min and 60 min ramps not result of frontal features.