Economics of Wind

Wind Generation as a Commercial Entity

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EirGrid

Tuesday 30th January 2007
Overview of Presentation

• Overview of Irish System, including plant mix

• Wind & the Electricity Market

• Curtailment V Constraints

• 2020 Grid Study
Overview of the Irish Systems, including plant mix
## Description of Irish Systems (1)

### Ireland

- **Generation**
  - 5,788 MW installed excluding wind
  - 745 MW wind (increasing)
  - 642 MW max wind output
  - 6,533 MW total installed

- **Demand**
  - Peak 5,042 MW, and increasing

### Northern Ireland (UK)

- **Generation**
  - 1,807 MW installed excluding wind
  - 120 MW wind (approx)
  - 1,927 MW total installed

- **Demand**
  - Peak 1,719 MW, and increasing
Description of Irish Systems (2)

Interconnection

- Ireland – Northern Ireland
  - 2*600 MVA (275kV AC)
  - 2*120 MVA (110kV AC)
  - Further interconnection proposed

- Northern Ireland – Britain
  - 500MW HVDC undersea double pole cable

- Ireland – Britain
  - 500MW HVDC to be owned by EirGrid due 2012, following Government decision.
**Irish Transmission System**
- 439 km of 400kV
- 1,826 km of 220kV
- 4,447 km of 110kV
- 165 substations

**Northern Irish Transmission System**
- 400 km of 275kV
- 867 km of 110kV
- 38 substations
European Synchronous Power System
Total Generation Capacities

UCTE: 600,000MW
Nordel: 92,000MW
England Wales Scotland: 76,000MW
Ireland (incl NI): 8,500MW
## Special Characteristics of combined Irish Systems

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Large generating unit size</strong></td>
<td>420 MW with a peak of 6,761 MW and a minimum of 2,500 MW (single unit can be up to 15% of demand)</td>
</tr>
<tr>
<td><strong>Only HVDC interconnection to the island</strong></td>
<td>500 MW HVDC bipolar link from Northern Ireland to Scotland and thence to a single overhead 275 kV circuit to main UK grid</td>
</tr>
<tr>
<td><strong>System separation impact</strong></td>
<td>Must limit interconnector flows between two systems</td>
</tr>
<tr>
<td><strong>Frequency response</strong></td>
<td>&gt;0.5 Hz fall for loss of a large generator</td>
</tr>
<tr>
<td><strong>Operating reserve must be fast acting</strong></td>
<td>5 second response essential</td>
</tr>
<tr>
<td><strong>Dependence on imported gas</strong></td>
<td>Only 3 pipelines from same source</td>
</tr>
<tr>
<td><strong>Underfrequency can initiate defence measures</strong></td>
<td>Pumped storage response, gas-turbine peaking, contracted customer disconnection, load shedding</td>
</tr>
</tbody>
</table>
Fuel Mix 2005

- Coal 24%
- Gas 40%
- Oil 12%
- Peat 9%
- Wind/SSG 5%
- Interconnector 8%

2005 Peak = 4828 MW
Load rise is 1200 MW from 0600 to 0900

Difficulty in keeping necessary plant on load at night valley
Fuel Mix on Typical Winter Day
Fuel Mix on Typical Winter Day

Hydro

Peat
Fuel Mix on Typical Winter Day

- **Hydro**
- **Peat**
- **Wind**
Fuel Mix on Typical Winter Day

- Hydro
- Peat
- Wind
- Gas (CCGT)
- Coal
- Oil

Pumped Storage (Negative)
Fuel Mix on Typical Winter Day

- Hydro
- Peat
- Wind
- Coal
- Gas (CCGT)
- Gas (other)
- Pumped Storage (Positive)
- Pumped Storage (Negative)

00:00:00 to 23:00:00
Fuel Mix at Peak Demand Day

- **Gas**, 2,239 MW, 45%
- **Distillate Oil**, 183 MW, 4%
- **Coal**, 914 MW, 18%
- **Interconnector**, 238 MW, 5%
- **Wind**, 11 MW, 0%
- **Pumped Storage**, 164 MW, 3%
- **Peat**, 367 MW, 7%
- **Oil**, 723 MW, 14%
- **Hydro**, 204 MW, 4%

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Onshore and Offshore Wind Potential

Source: European Wind Atlas – RISØ National Laboratory
## Wind Generation on the Irish System

<table>
<thead>
<tr>
<th>Status</th>
<th>TSO / DSO</th>
<th>Total MEC (MW)</th>
<th># Wind Farms</th>
<th>Cumulative Total</th>
<th>Wind as % of Installed Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connected</td>
<td>TSO</td>
<td>332.66</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Connected</td>
<td>DSO</td>
<td>411.83</td>
<td>61</td>
<td></td>
<td></td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>744.48</strong></td>
<td><strong>69</strong></td>
<td><strong>744.48MW</strong></td>
<td><strong>11%</strong></td>
</tr>
<tr>
<td>Contracted</td>
<td>TSO</td>
<td>280.53</td>
<td>8</td>
<td></td>
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<tr>
<td>Contracted</td>
<td>DSO</td>
<td>265.9</td>
<td>29</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>546.43</strong></td>
<td><strong>37</strong></td>
<td><strong>1,260.91MW</strong></td>
<td><strong>17%</strong></td>
</tr>
<tr>
<td>Gate 2</td>
<td>TSO</td>
<td>467.20</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gate 2</td>
<td>DSO</td>
<td>832.84</td>
<td>101</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>1,300.03</strong></td>
<td><strong>117</strong></td>
<td><strong>2,590.91MW</strong></td>
<td><strong>~25%</strong></td>
</tr>
<tr>
<td>Unsigned Applicant</td>
<td>TSO</td>
<td>891.88</td>
<td>19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unsigned Applicant</td>
<td>DSO</td>
<td>1,041.55</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>1,933.43</strong></td>
<td><strong>99</strong></td>
<td><strong>4,524.37MW!</strong></td>
<td><strong>??</strong></td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td><strong>322</strong></td>
<td></td>
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</tbody>
</table>
Wind & the Single Electricity Market
Single Electricity Market (SEM) Structure

• New All-island Wholesale Electricity Market

• Mandatory pool with single clearing price (SMP)
  – All energy must be sold directly into and bought from the pool
  – Separate physical energy trades are not permitted

• Capacity payments, Uplift Payments, Constraint Payments

• Locational Tariffs and Loss factors

• Specific rules for “special” participants
Mandatory Pool

- Generators bid in energy
- Suppliers buy @ SMP
- Physical Contract

Wholesale Market

TSO

- Supplier Unit
- Generator Unit
- Customer

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How Generators Get Paid for Energy

- Energy Payments to all Generator Units based on:
  - Market Schedule Quantity (MSQ)
  - System Marginal Price (SMP)

- Energy Payment = MSQ x SMP

- SMP is normally understood to equal the incremental cost of supplying next MWh of energy demand

- MSQ is the quantity of generation as determined by the Ex-Post Unconstrained Schedule (EPUS)
Generator Classifications in the SEM

Predictable Generators
- Dispatchable or Controllable
  - Price Maker

Variable Generators
- Dispatchable or Controllable
  - Price Maker
  - Price Taker

Autonomous Generators
- Not Dispatchable or Controllable
  - Price Taker

Large Oil/ Gas/ Coal/ Peat Generators

Renewables:
- Wind Farms & Run-of-River Hydro
- Small Wind Farms/ CHP/ Bio Mass/ SS Hydro
Constraints V Curtailment
Definitions

• Constraints :
  – Applicable to all generators
  – Due to transmission network limitations – typically local or regional
  – Other reasons such as provision of operating reserve

• Curtailment :
  – Requirement to limit total wind output at a point in time
  – A “system-wide” issue
What are Constraints

Generation & Demand

Line 1

Line 2

Line 3

Each line has a normal continuous rating of 100MVA
Generation exceeds Demand

Line 1: 110MVA

Line 2: 90MVA

Line 3: 80MVA

Normal continuous rating for Line 1 is exceeded
→ Generation must be constrained

All lines are back within their normal continuous line ratings

Generation constrained

Line 1 100MVA
Line 2 85MVA
Line 3 75MVA
Constraints

Generation

>>

Demand

Line 1

Line 2

Consider loss of Line 2

Line 3
Constraints

Generation >> Demand

Line 1
130MVA

Line 2

Line 3
110MVA

Emergency Ratings of lines is 120MVA
→ Generation must be constrained

Generation constrained further

Line 1
120MVA

Line 2

Line 3
120MVA

All lines are back below their emergency ratings
Application of firm/non-firm direction

- Introduced for Gate 1 offers

- Wind Generators may connect before deep reinforcements are complete

- Applies to generators with the ability/systems for constraint

- Generators not financially compensated for constraints associated with non-firm access

- Non-firm physical access to apply for Gate 2
Constraints – case 3

Add New Generation

Generation & Demand

Line 1

Line 2

Line 3

Each line has a normal continuous rating of 100MVA
Constraints – case 3

Add New Generation

Generation & Demand

Line 1

Line 2

Line 3

Line 4

Must build a new line to be able to export generation from the area
Generation *may* be constrained

Add New Generation

Line 1
100MVA

Line 2
85MVA

Line 3
75MVA

Before new line is built generation may be constrained

& not compensated
Definitions

• Constraints:
  – Applicable to all generators
  – Due to transmission network limitations – typically local or regional
  – Other reasons such as provision of operating reserve

• Curtailment:
  – Requirement to limit total wind output at a point in time
  – A “system-wide” issue
Problematic Wind Profiles

• From analysis of a typical yearly Wind Power Series, a number of problematic profiles emerged

• These wind profiles are problematic because of
  – Timing of the occurrence
  – Reduction in energy over a short period of time

• The ability to forecast these types of profiles is crucial to the safe, secure operation of the system
Large Increase: 89% increase over ~9 hours. Max 2-hour increase is 44%. Note the lag of ~2 hours between load rise and wind rise.
49% reduction in 2.5 hours coinciding with the morning rise. Between 10.00 and 11.00 there is a reduction of 27%.
Large Decrease:
4hr decrease = 54%
2hr decrease = 39%
Curtailment management

• Wind Management Techniques
  – EirGrid is developing techniques to minimise curtailment
    – This will be a progressive task
    – Maximise wind to run as high as is feasible while maintaining system security and standards
    – ‘Active’ real-time monitoring and analysis of system conditions is necessary to ensure that curtailment is no greater than required
Analysis of Future Levels of Curtailment

• Analysed 1,100MW of wind generation (installed capacity) in 2010

• Case A - Accurate Wind Forecasting
• Case B – Existing rate of Forecasting Errors

<table>
<thead>
<tr>
<th></th>
<th>Case A</th>
<th>Case B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined Total Curtailment</td>
<td>1.3%</td>
<td>4.2%</td>
</tr>
<tr>
<td>Combined Total Curtailed GWh</td>
<td>45</td>
<td>140</td>
</tr>
</tbody>
</table>
All Island Grid Studies for Renewables
Workstreams

1. Resource Identification
2. Variability
   - Impact on system operation, fuel costs etc.
   - Management
3. Network Issues
4. Economic and Stakeholder assessment
Workstream 1

- Estimate amount and location of each renewable technology
  - Probably two scenarios – with and without offshore wind
- Estimate cost of deployment
- Workstream 1 is being carried out by ESBI
- Inputs required for later workstreams are virtually complete
Screening Study – Workstream 2A

- After Workstream 1 consultation, it was decided to carry out a screening study of scenarios
- Considered a wide range of input parameters (gas price, carbon price, financing costs etc.,)
- Identified a range of generation portfolios to be considered in the more detailed studies
Screening Study
Recommended Portfolios

• The portfolios recommended for further study include:
  – Renewable penetration ranging from 16% to 54%
  – Installed wind ranging from 2,000 MW to 8,000 MW
  – Wind energy ranging from 11% to 36%

• The more detailed phases of the study will assess the feasibility and impacts of these portfolios from a system perspective

• The portfolios have been revised to account for the additional combined cycles that have been or are likely to be approved.
Workstream 2B

• Assess how much variable and unpredictable generation can be accommodated

• Impact on total system costs and emissions

• Will consider impact of
  – Different plant mix
  – Improved forecasting
  – Storage
Workstream 3

• Investigate extent of network development required for renewables
  – Amount of transmission reinforcement that might be required for various scenarios
  – The regional spread of the reinforcements
  – Associated capital costs
Workstream 4

• Based on outputs from workstreams 1, 2 and 3, assess overall economic, stakeholder, market impacts etc.

• Draw the overall results of the study together

• Scope being developed at present

• Consultation meeting probably in early 2007
Present Position

- WS 1 (resources) in progress
- WS 2A (screening study) completed
- WS 2B (variability) under way
- WS 3 (network) commencing
- WS 4 (economic and stakeholder impact) scope being developed
- There are no results yet! - mid-2007
Summary

• EirGrid recognizes the many benefits that wind generation has for the system as a whole and is working to facilitate the integration of wind onto the system

• There are a number of factors that will influence the economics of wind generation on the system in the future

• EirGrid is actively involved in various research projects examining this issue in collaboration with the industry, policy makers and the regulators.
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