Leading the Way Towards All-Renewable Synchronous Systems

Ivan Dudurych

PSCC 2018 Keynote, Dublin 12 June 2018
Power Systems of Ireland and Northern Ireland

- 9500 MW of conventional plant
- 4500 MW of windfarms
- Peak Demand of 6500 MW
- Valley Demand 2500 MW
- Northern Ireland – Scotland
  - 500 MW HVDC (LCC)
- Ireland – Wales
  - 500 MW HVDC (VSC)
- In consideration:
  - 700 MW HVDC Ireland-France: “Celtic Interconnector”
  - 500 MW HVDC Ireland-Wales: “Greenlink Interconnector”
Installed Wind

- 2% in 2003

Wind, MW

- 1999: 0
- 2000: 0
- 2001: 0
- 2002: 0
- 2003: 2%
- 2004: 0
- 2005: 0
- 2006: 0
- 2007: 0
- 2008: 0
- 2009: 0
- 2010: 0
- 2011: 0
- 2012: 0
- 2013: 0
- 2014: 0
- 2015: 0
- 2016: 0
- 2017: 0
- 2018: 0
Installed Wind

Wind, MW

Year


65%
2020 Wind Targets

* Based on analysis of National Renewable Action Plans (NREAPs) as submitted by Member States
Operational Security

Steady-state
- Short-circuit current level
- Thermal
- Voltage
- Frequency
- Reserves
- Ramping

Static limits

Dynamic
- Synchronous (Rotor angle stability)
- Non-synchronous (Fault-ride-through)
- Voltage stability
- Frequency stability
- Oscillatory stability

Stability limits

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Transient and Voltage Stability

% CCTs below 200ms

Wind / (Load + Exports)

Voltage, pu

Wind, MW

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Inertia and Frequency Stability

![Inertia vs Wind Percentage Graph](image1)

- **Wind, %**
- **Inertia, Thousands MWs**

![Frequency vs Time Graph](image2)

- **Frequency, Hz**
- **Time, s**

Graphs showing the relationship between inertia and wind percentage, as well as frequency stability over time.
Studies and Assessments

Technical Analysis

All Island TSO Facilitation of Renewables Studies

Ensuring a Secure, Reliable and Efficient Power System in a Changing Environment

June 2011
To ensure system security

DS3 System Services

To manage forecast uncertainty

Inertial Response

Reserve

Ramping

POR

SOR

TOR1

TOR2

RR

Ramping

Transient Voltage Response

Voltage Regulation

Network

Dynamic Reactive Power

Steady-state Reactive Power

Network Adequacy

Grid 25

0 – 5s

5 – 90s

90s – 20min

20min – 12hr

ms – s

s – min

min – hr

0 – 5s 5 – 90s 90s – 20min 20min – 12hr

Inertial Response

Reserve

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Ramping

Transient Voltage Response

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Network

Dynamic Reactive Power

Steady-state Reactive Power

Network Adequacy

Grid 25

To ensure system security

To manage forecast uncertainty
Investment Decision

- 60-73 €m
- 7-11 Services
- 235 €m cap in 2020/21
- 14 Services
- More Zero/Low Marginal Cost energy
Dynamic Models of Power System

- Excitation system equations
- Prime mover / governor equations
- Generator rotor circuit equations
- Generator swing equation

Differential equations

Algebraic equations

- Generator stator equations
- Transmission network equations

(V, I) (V, I) (V, I) (V, I)

Nonlinear loads Other static models

Other generators Induction motors Other dynamic models
WSAT Secure Wind
Other Control Centre Tools

Monitoring the New Operational Metrics

<table>
<thead>
<tr>
<th></th>
<th>SONI</th>
<th>EGRD</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inertia</td>
<td>10251</td>
<td>20898</td>
<td>31149</td>
</tr>
<tr>
<td>SYS INERTIA</td>
<td>31149</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Largest In-feed Calculator

Based on initial RoCoF calculation formula:

\[ RoCoF = \frac{f \times \Delta P}{2(K_{sys} - K_{lost})} \]

where:
- \( f \) is the system frequency
- \( K_{sys} \) is system inertia in MWs
- \( K_{lost} \) is the inertia lost in MWs
- \( K = H \times MVA \) in MWs
- \( H \) is the inertia constant

Frequency (Hz): 50

Wind Dispatch Tool

Wind Dispatch Tool - Main Page

<table>
<thead>
<tr>
<th>System Status: Curtailment Remove</th>
<th>Active List Status:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cat1: OFF</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operating Area: ESB</th>
<th>Constraint State: OFF</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Curtailment State: OFF</th>
<th>Constraint State: OFF</th>
</tr>
</thead>
</table>

DISPATCH FUNCTIONS

- Category 1 Wind Farm
- Curtailment Apply
- Curtailment Relax
- Curtailment Removal
- Constraint Apply
- Constraint Relax
- Constraint Removal
- Generator Testing

OTHER FUNCTIONS

- Frequency Control Settings
- FAILED: Removed From Dispatch
- SUSPECT: Removed From Dispatch
- Ineligible for Dispatch
- General Info
- Wind Message Log
- Select OPA
- Dispatch Limit
Coping with Extreme Weather Events

Storm “Darwin” 12 Feb 2014

Hurricane “Ophelia” 16 October 2017
Coping with Extreme Weather Events

Storm “Darwin” 12 Feb 2014

Hurricane “Ophelia” 16 October 2017
## Key Operational Milestones

<table>
<thead>
<tr>
<th>SNSP</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>60% -&gt; 65%</td>
<td>65% -&gt; 70%</td>
<td>70% -&gt; 75%</td>
<td>75%</td>
</tr>
<tr>
<td>RoCoF</td>
<td>0.5 Hz/s</td>
<td>0.5 -&gt; 1 Hz/s</td>
<td>1 Hz/s</td>
<td>1 Hz/s</td>
</tr>
<tr>
<td>Inertia</td>
<td>23,000 MW.s</td>
<td>20,000 MW.s</td>
<td>17,500 MW.s</td>
<td>17,500 MW.s</td>
</tr>
<tr>
<td>Min Sets</td>
<td>8</td>
<td>8</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Exports</td>
<td>300 -&gt; 500 MW (interim)</td>
<td>500 MW (interim)</td>
<td>500 MW (interim -&gt; enduring)</td>
<td>500 MW (enduring)</td>
</tr>
<tr>
<td>System Services</td>
<td>Current providers, 11 Services</td>
<td></td>
<td></td>
<td>New providers, 14 Services, increased volumes to operate at high RES</td>
</tr>
</tbody>
</table>
Beyond 2020

- More Real Time Operation Security
- Scenario Planning
- Control Room Evolution
- Horizon 2020 projects
- Innovation and Technology Strategy
- Business Policies Evolution

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