G-PST Session on System Services

Nicholas Harvey, ESO
G-PST Research Workshop
London, UK 10/11/2022
ESO Ambition

The ESO has an ambition to be able to operate the Transmission Network of Great Britain Carbon Free by 2025.

For the ESO this means:

- When the GB market provides the GB Transmission System with only zero carbon generation the ESO will not take any system or balancing actions that result in carbon emissions

To achieve this we must:

- Open up all our system and balancing services to zero carbon technologies
- Ensure that the consumer does not lose out when zero carbon options are chosen in place of carbon emitting options

There has been massive GB decarbonisation progress over the past decade, with a 65% decrease in emissions from 2013 to 2020

- By 2025 we are targeting a system with 0gCO2/kWh for some periods
- The next challenge will be to increase the number and duration of periods where 0gCO2/kWh is possible as we transition to net zero.
Engineering Challenges

Decarbonisation of the GB power system has resulted in changes in four key areas:

- **Frequency** - As more non-synchronous generation connects, system inertia lowers requiring faster acting response. More variability in the system requires fast acting reserves. Large and small loss sizes require services which respond dynamically to the frequency.

- **Stability** - More non-synchronous generation is reducing the levels of stability capability provided to the network. To ensure the system is stable for faults on the network services to provide inertia and short circuit levels need to be procured.

- **Voltage** - Less dispatchable generation and changes to network flows brought about by generation moving away from demand is increasing the requirements to absorb reactive power on the GB network.

- **Thermal** – More variable sources of generation combined with generation moving to different areas are creating more thermal constraints on the network requiring more innovative solutions to manage congestion prior to network build.

Each of these changes brings about new engineering challenges which have to be resolved to operate a zero carbon network.

- **Frequency** - As more non-synchronous generation connects, system inertia lowers requiring faster acting response. More variability in the system requires fast acting reserves. Large and small loss sizes require services which respond dynamically to the frequency.

- **Stability** - More non-synchronous generation is reducing the levels of stability capability provided to the network. To ensure the system is stable for faults on the network services to provide inertia and short circuit levels need to be procured.

- **Voltage** - Less dispatchable generation and changes to network flows brought about by generation moving away from demand is increasing the requirements to absorb reactive power on the GB network.

- **Thermal** – More variable sources of generation combined with generation moving to different areas are creating more thermal constraints on the network requiring more innovative solutions to manage congestion prior to network build.
### Key grid services

<table>
<thead>
<tr>
<th>Existing approaches</th>
<th>New approaches</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thermal</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Voltage</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Frequency</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Stability management (inertia, short circuit level)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Black start</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Existing approaches**
- Constraint managements services
- Bids/offers in real time
- Intertrip arrangements
- Demand side response

**New approaches**
- Expanding our constraints pathfinder for long term contracts for intertrips
- Reactive market development – exploring T-4, T-1, D-1 markets
- Dynamic containment, Dynamic regulation, Dynamic moderation
- Stability market development – exploring T-4, T-1, D-1 markets

---

- Reactive power services provided by connected generation – minimum specification in the GB grid code
- Long term contracts for new reactive power capability – voltage pathfinders
- Frequency response services provided by connected generation – minimum specification in the GB grid code
- Synchronisation of plant in real time for inertia
- Long term contracts for inertia and SCL for new capability – stability pathfinders
- Regional black start tenders
- Opening tenders to distribution connected assets
Challenge for Future Inverter-based Resources (IBR) Dominated GB Electricity System

SOF Document “Impact of Declining Short Circuit Levels”
Status-Quo of Short-Circuit Level

- Short Circuit Level (SCL) is a standard measure of Grid Strength to indicate how stable is the electricity system.
- Various interests in Grid Strength from key players across GB Electricity Market but all have different perspective and different requirements.

For Generation-side e.g. Wind Farm
Recovery after Low-Voltage Ride-Through Event

For TOs/DNOs
Appropriate Protection Configuration based on Fault Current

For GBESO
System Stability
Traditionally synchronous generation has provided stability characteristics
  - Inertia
  - Short Circuit Level (SCL)
  - Dynamic reactive power

As more non-synchronous generation enters the system, we need to find alternative sources of stability.

Stability Pathfinders
  - Finding the most cost-effective way to address stability issues
  - Comparing commercial market-based solutions as well as transmission owner-based solutions
  - Providing long term commercial contracts
  - 'Learning by doing' approach
## Stability Pathfinder

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Stability Pathfinder Phase 1</th>
<th>Stability Pathfinder Phase 2</th>
<th>Stability Pathfinder Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inertia and dynamic voltage GB wide</td>
<td>Inertia, SCL and dynamic voltage</td>
<td>Inertia, SCL and dynamic voltage</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Status</th>
<th>Stability Pathfinder Phase 1</th>
<th>Stability Pathfinder Phase 2</th>
<th>Stability Pathfinder Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tender concluded in Jan 20 with most units now live</td>
<td>Tender concluded in Apr 22. Go-live from Apr 24</td>
<td>Tender period - Commercial window now closed. Go-live expected from 2025</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Participating technology</th>
<th>Stability Pathfinder Phase 1</th>
<th>Stability Pathfinder Phase 2</th>
<th>Stability Pathfinder Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0MW Synchronous Compensators only</td>
<td>Synchronous and Grid Forming Converter based</td>
<td>Synchronous and Grid Forming Converter based</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Procurement regions</th>
<th>Stability Pathfinder Phase 1</th>
<th>Stability Pathfinder Phase 2</th>
<th>Stability Pathfinder Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>GB wide</td>
<td>Scotland</td>
<td>England and Wales</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Procurement volume</th>
<th>Stability Pathfinder Phase 1</th>
<th>Stability Pathfinder Phase 2</th>
<th>Stability Pathfinder Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.5 GW.s of inertia</td>
<td>8.4 GVA of SCL</td>
<td>7.5 GVA of SCL</td>
<td></td>
</tr>
<tr>
<td>6 GW.s of inertia</td>
<td>15 GW.s of inertia</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contract duration</th>
<th>Stability Pathfinder Phase 1</th>
<th>Stability Pathfinder Phase 2</th>
<th>Stability Pathfinder Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 6 years</td>
<td>End of Mar 2034</td>
<td>End of Mar 2035</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contract payments</th>
<th>Stability Pathfinder Phase 1</th>
<th>Stability Pathfinder Phase 2</th>
<th>Stability Pathfinder Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability payments for SCL &amp; Inertia</td>
<td>Utilisation payments for reactive power</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ongoing Strength to Connect Innovation Project with Imperial College

- **Issues**
  - Short Circuit Level (SCL) is a Standard Measure of Grid Strength to indicate the electricity system’s stability.
  - Grid "strength" is decreasing
  - IBR have different disturbance behaviours

- **Four emergent areas need separate Grid Strength measure**
  - Substandard voltage regulation
  - Increased recovery times from voltage dips
  - Potential instability of grid-following inverters
  - Mal-operation of protection

- **Scope for each area**
  - Properly defined grid strength metric
  - Properly defined and declared compatibility levels for grid strength
  - Tool creation for locational compatibility levels metric, and heat maps to visually describe compatibility of the whole system
  - Assessment guidance of IBR capability to add strength and evaluation on their ability to work in low grid strength

SCL is still a good all-purpose indicator?
Focusing on system strength

Our current procurement is for SCL and inertia,

• Is that still the right approach?
• Are better measures available?
• Can new measures be adopted?
• How would we procure these services?
• How do we ensure all technologies can compete equally for these services?
Other system needs

- The need for synchronization
  - Very few large synchronise machine
  - IBRs
- The need for damping
  - Sub-Synchronous Modes
  - Super-Synchronous Modes
- The need for interoperability
  - Synchronise machines, Grid Forming IBR, Grid Following IBRs work in harmony