Contractibility and Finance-ability of New Services
SOF 2015 Development Process

Setting the Context (Historical Data + FES)
- Articulate the purpose for SOF, show historical trends, FES, and linkage with other publications such as ETYS, Winter/Summer Outlook, FES

Operability Assessment Methodology in SOF
- Explain the high level methodology of SOF, the dispatch model, key assumptions etc. and the process we go through

SOF 2015 Topics (how we have came up with them -> Stakeholder feedback)
- We justify the areas covered in 2015 based on the evidence of FES, stakeholder feedbacks, etc.

Assessments + Solutions (Individual Topics)
- Topic by topic assessment, showing the impact on operability and tipping points, and potential solutions

Future Operability Strategy
- 0-3 Years
- 3-5 Years
- 5-10 Years
- 10 Year +

Post assessment Webinars

Improvements to the Process

See next slide
Short Term (0-2 Years):

Need for capabilities which are already available both technically and commercially or immediate requirement for code changes.

Medium Term (2-5 years):

Need for services from new connections, use of existing investment processes, work on new code changes, highlight immediate innovation needs and influence future design.

Long Term (5+ Years):

Need to secure long term capability, influence new connections, ensure more innovative solutions are developed (e.g. NIA/NIC projects), carry out R&D, significant specification & capability requirements, strategy development.
### SOF 2015 Topics

#### Topic
- **System Inertia**
  - Whole System Minimum Inertia
  - RoCoF
  - Frequency Containment

- **System Strength and Resilience**
  - Protection
  - Voltage Dips
  - Voltage Management
  - Resonance and Harmonics
  - LCC HVDC Commutation Failure
  - Demand Reduction by Voltage Control
  - Black Start

- **Embedded Generation**
  - System Stability
  - Low Frequency Demand Disconnect
  - Active Network Management
  - Demand Forecasting

- **New Technology**
  - Interaction with Generator Shafts
  - Control Interaction
  - Compliance of New Nuclear Fleet
  - Electric Vehicles and Heat Pumps

#### Assessment

#### Impact
- Decreasing whole system minimum inertia in future years
- Trip of embedded generators protected by RoCoF relays
- Increase in volume of response
- Difficulty detecting and clearing faults on weaker networks
- Widespread voltage dips and disconnection of embedded generation
- Voltage containment and need for additional reactive compensation
- Power quality issues and need for additional filtering
- Inability to operate LCC HVDC links in weak network conditions
- Reduction in effectiveness of demand reduction by voltage control
- Reduction in black start plant and system restoration challenges
- Stability issues associated with increase in embedded generation
- Risk of cascade loss of generation should LFDD relays operate
- Uncoordinated TSO/DSO actions in constraint management
- Increased demand forecasting error and increase in balancing actions
- Shaft fatigue if not mitigated
- Potential oscillations and plant failure
- Increase in derogation cost
- New demand pick up times/volume
Need for new capabilities on the transmission system to manage system stability as a result of embedded generation connection.

Fault level decline is both more pronounced and more extensive than previously seen. Review of protection system is required.

Potential instability in load blocks used in system emergency restoration. Broader network restoration needs.

New nuclear generation fleet and other Synchronous technology capabilities.

Changes in Generation and Demand Side
Changes in Network and Technology

Electric Vehicles and Heat Pumps

Increased exposure to external grid disruption, increasing co-ordination
What does SOF Identify?

What matters most?

- **Now**
  - Energy
  - Capacity
  - System Services

- **2025**
  - Energy
  - Capacity
  - System Services

- **2035**
  - Energy
  - Capacity
  - System Services
Impact on System Services

Provision of Future System Services

Mandatory Requirements

Market Solutions

Contractibility

Finance-ability
<table>
<thead>
<tr>
<th>New Services and Potential Providers</th>
<th>Demand Side Services</th>
<th>Energy Storage</th>
<th>Flexible Synchronous Generation</th>
<th>Flexible non-Synchronous Generation</th>
<th>Interconnector Services</th>
<th>Synchronous Compensator</th>
<th>Support from Embedded Generation</th>
<th>DSO Services</th>
<th>New Services from Non-synchronous Generation</th>
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<tbody>
<tr>
<td>RoCoF Alternative</td>
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<td>Commutation of HVDC links</td>
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System inertia – a measure of how strong the system is in response to transient changes

System inertia has a direct effect on:

- Rate of Change of Frequency (RoCoF)
- Frequency containment and response requirement
- System stability

Synchronous Generators

Non-Synchronous Generators

Change in Generation Mix and Technologies

- Rotating Mass (inertia)
- Generator (Alternator Element)

Turbine Shaft
You lose half your audience every time you use an equation!
The lower the system inertia -> the higher of rate of change of frequency and vice versa

The higher the size of loss-> the higher the rate of change of frequency and vice versa

\[ H_{Total} = H_G + H_D + H_{EG} \]

\[ \text{RoCoF} = \frac{df}{dt} = \frac{1}{2} \times f_0 \times \frac{\Delta MW\text{loss}}{H_{Total}} \]

- \( H_{Total} \): Total System Inertia
- \( H_G \): Inertia from Transmission Generation
- \( H_D \): Inertia from Demand
- \( H_{EG} \): Inertia from Embedded Generation
- \( f_0 \): Nominal frequency (50Hz)
- \( \Delta MW\text{loss} \): Size of loss
• The reduction of system inertia increases the response requirement -> 30-40% extra by 2020

• Having sufficient volume of response from “conventional” sources will become challenging

• In some scenarios none of the system response requirement can be provided by synchronous plants
Background – System Inertia Variations in 2020

System Inertia (GVA.s)

Low demand period- Sunny Season

Windy Season

Low Inertia Periods
Background – A day in 2020

Summer Demand + Moderate Solar PV Output + Moderate Wind Output

Increase Volume of Response by 40% With Today’s Capability
Utilise New Services

System Inertia (GVA.s)

Time of the day

Summer Demand

Moderate Solar PV Output

Moderate Wind Output

Largest Loss Tolerance (MW)

Time

Moderate Demand

Solar PV Output

Wind Output

Increase Volume of Response by 40%

With Today’s Capability

Utilise New Services

Time
Background – A day in 2020

Do nothing!

Curtailment volume just on one I/C pole

French I/C: 14269MWh
Britned: 1x: 6549MWh
New I/C:?

Total: 20.8 GWh +
Background – A day in 2020

Headroom Created at cost of carrying 40% more response

Still not sufficient to accommodate larger Units & not a long term solution
Better Response Services

Natural Inertia

Operability Strategy – Frequency Response

System Needs

New Services

Potential extra cost for managing low inertia system if no new solution is developed

£300m
£100m

2015
2020

For illustration purpose only
Background – A day in 2020

- Much greater headroom by utilising enhanced services
- Potential for reducing the cost of services by diversifying the market
Operability Strategy – Frequency Response

System Needs

Better Response Services

Natural Inertia

New Services

New Services on Solar PV and Wind
Energy Storage
Interconnector Services
Demand Side Services

Flexible Synchronous Generation
Flexible non-Synchronous Generation
Synchronous Compensator
Voltage Management
• High volts has evolved from a regional challenge to a national issue.
• Large volume of embedded solar generation offsets transmission MW and substantially increases transmission Mvar requirements.

Reactive Requirements
• 2.86Gvar of new reactors installed between now and 2017.
• Across all scenarios additional 4.8Gvar by 2025, 14Gvar by 2035.

Whole System Solutions
• Transmission options alone are not sustainable, efficient or effective against these projections.
Changing Daily Demand Profile

Consumer Power 2035

Transmission Demand (GW)

Year

- 2015
- 2035 – sunny day
- 2035 – cloudy day
- Inflexible generation
Minimum Demand by Scenario

- Consumer Power (AM)
- Consumer Power (PM)
- Gone Green (AM)
- Gone Green (PM)
- Slow Progression (AM)
- Slow Progression (PM)
- No Progression (AM)
- No Progression (PM)
Increase in Embedded Generation

Installed Capacity of Embedded Generation

Installed Capacity (MW)  2015/16

1,000+ 950-1,000 900-950 850-900 800-850 750-800 700-750 650-700 600-650 550-600 500-550 450-500 400-450 350-400 300-350 250-300 200-250 150-200 100-150 50-100 0-50

2035/36

Consumer Power  Gone Green

No Progression  Slow Progression

national grid
Cost to Constrain MW for Mvar Provision

![Graph showing the cost to constrain MW for Mvar Provision from 2011/12 to 2015/16 by month.]
Operability Strategy

System Needs
- Enhanced Voltage Control from Generation
- Additional Reactive Compensation in Networks

New Services
- Support from Embedded Generation
- Energy Storage
- Flexible Synchronous Generation
- DSO Services
- Synchronous Compensators
- New Services from Solar PV and Wind
- Interconnector Services
- Whole System Approach to Reactive Compensation

System Needs
- Additional Reactive Compensation in Networks
Black Start Strategy and Providers
- Reduction in thermal plant driving review of future strategy
- Potential role for interconnectors and aggregated distributed generation

Changing System Requirements
- Greater electrical distances between generation and load
- Increasing network energisation challenge

Increased Demand Side Significance
- Certainty of load blocks
- Protection of distributed generation
Decline in flexible thermal plant in merit at minimum demand periods will restrict black start plant availability in future years.
## Operability Strategy

### System Needs
- **Active Power Delivery**
- **Flexible Compensation**
- **Certainty of Block Loads**

### New Services
- Services from Aggregated Distributed Generation
- Aggregated Embedded Generation with Mvar Capability
- Revised Protection and Control Methods
- Energy Storage for Network Energisation
- Pre-emptive Islanding Approach
- Coordinate DSR and Embedded Generation with Approach
- Options for New Synchronous Plant Black Start
- Compensation from Non-synchronous Sources
Next Steps

• Continue to develop commercial appraisal methodology:
  – Multiple-service approach
  – Dependencies
  – Consultation with the industry (early 2016)

• Extend technical assessments to economic assessment

• Workshop on New System Services Contracting (30th November)
<table>
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<tr>
<th>Time</th>
<th>Session Title</th>
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<tr>
<td>9:30 - 10:00</td>
<td>Arrival, Registration and Coffee</td>
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<tr>
<td>10:00 - 10:10</td>
<td>Welcome and Brief Overview of the Day</td>
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<tr>
<td>10:10 - 10:25</td>
<td>SOF in the Context of Electricity Network Capability</td>
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<td>10:25 - 10:35</td>
<td>Future Energy Scenarios (FES) 2015 Updates</td>
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<td>10:35 - 11:30</td>
<td>System Operability Framework 2015</td>
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<td>11:30 - 12:30</td>
<td>Industry Perspectives on Key Themes of SOF 2015</td>
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<td>12:30 - 13:15</td>
<td>Break (Business Lunch) and General Q&amp;A</td>
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<td>13:15 - 15:15</td>
<td>Contracting for New Services Workshop</td>
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<tr>
<td>15:15 - 15:30</td>
<td>Next Steps and Future Engagement</td>
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</tbody>
</table>

30th November at National Grid HQ in Warwick
Thank you for your attention!

To provide further views on the themes discussed, please email:

box.transmission.sof@nationalgrid.com