Managing Declining Inertia and Short Circuit Levels

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Agenda

- GB ESO Ambitions and Government targets
- System Trends across GB
- Scottish Oscillations August 2021
- Ongoing Initiatives

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:

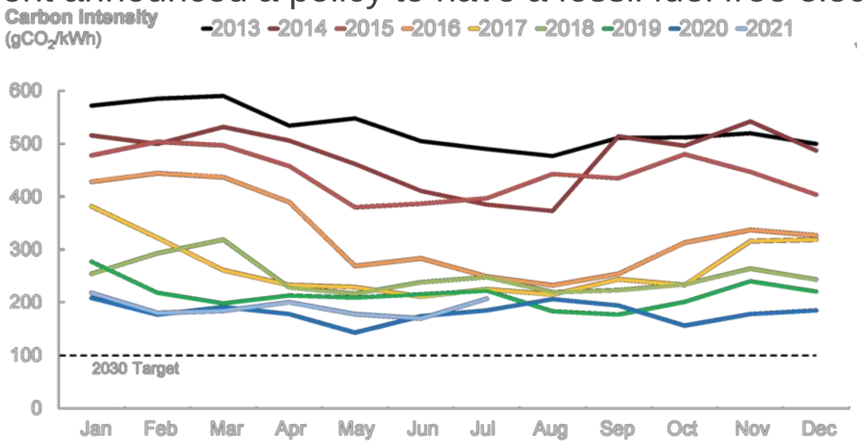
- When the GB market provides the GB Transmission System with only zero carbon generation the ESO will not take any system or balancing actions that result in carbon emissions

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

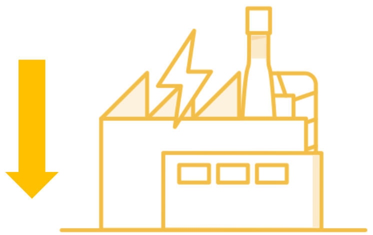
There has been massive GB decarbonisation progress over the past decade, with a 65% decrease in emissions from 2013 to 2020

- 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.
- In October 2021, the UK Government announced a policy to have a fossil fuel free electricity system by 2035



Engineering Challenges

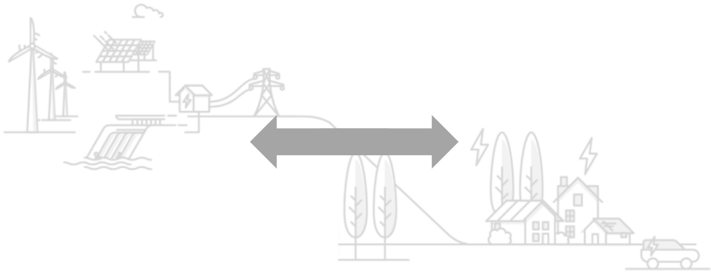
Decarbonisation of the GB power system has resulted in changes in four key areas:



Less dispatchable generation

More variable sources of generation

More asynchronous generation



Generation moving to different areas.

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

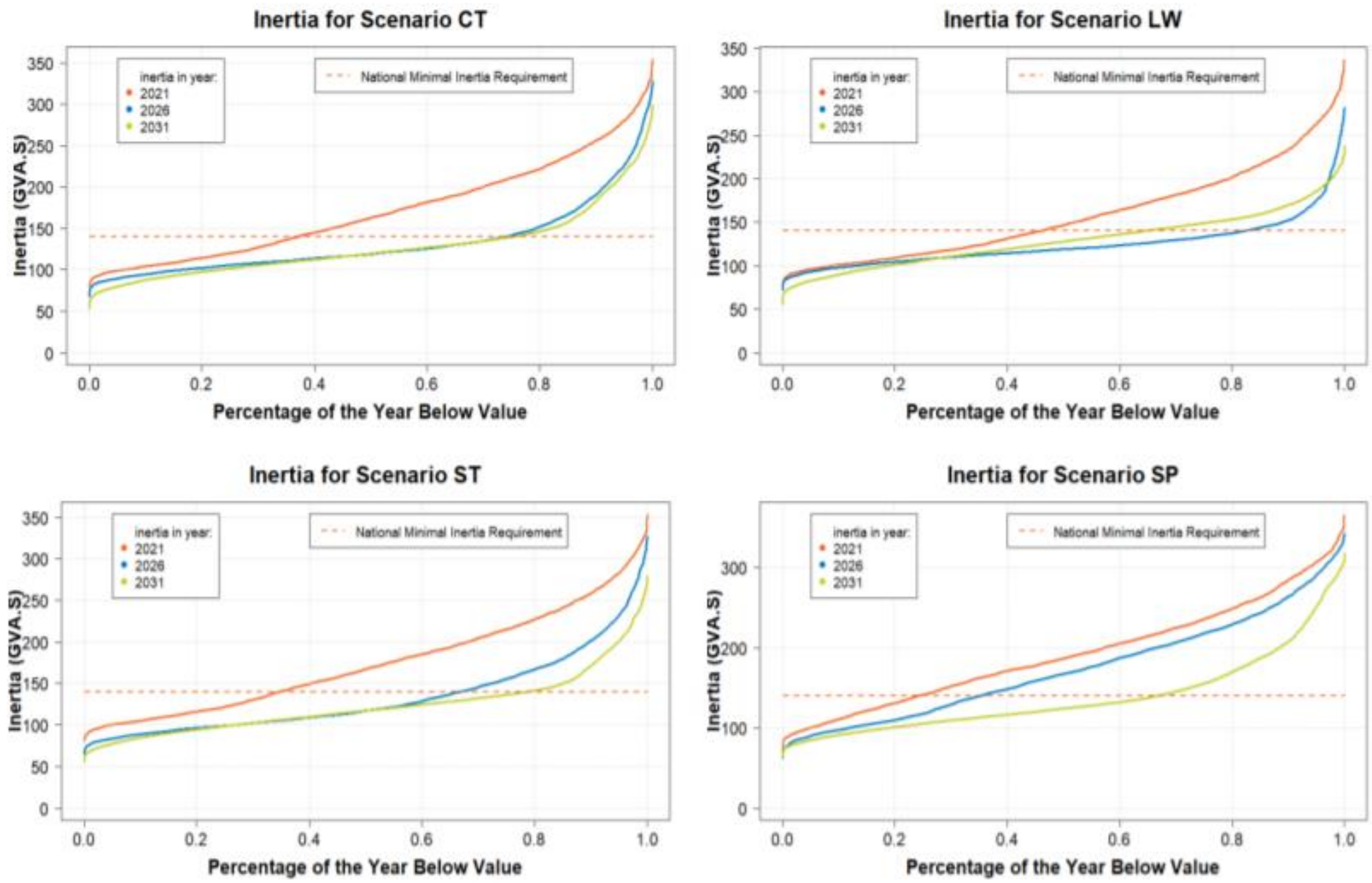
- **Frequency** - As more non-synchronous generation connects, system inertia lowers requiring faster acting response. More variability in the system requires fast acting reserves. Large and small loss sizes require services which respond dynamically to the frequency.
- **Stability** - More non-synchronous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

System Performance Trends across GB

Declining inertia

- The rate at which frequency changes following a loss of generation or demand depends on the total system inertia.
- The declining trend of the inertia is across all scenarios.

Annual distribution of inertia for four future energy scenarios



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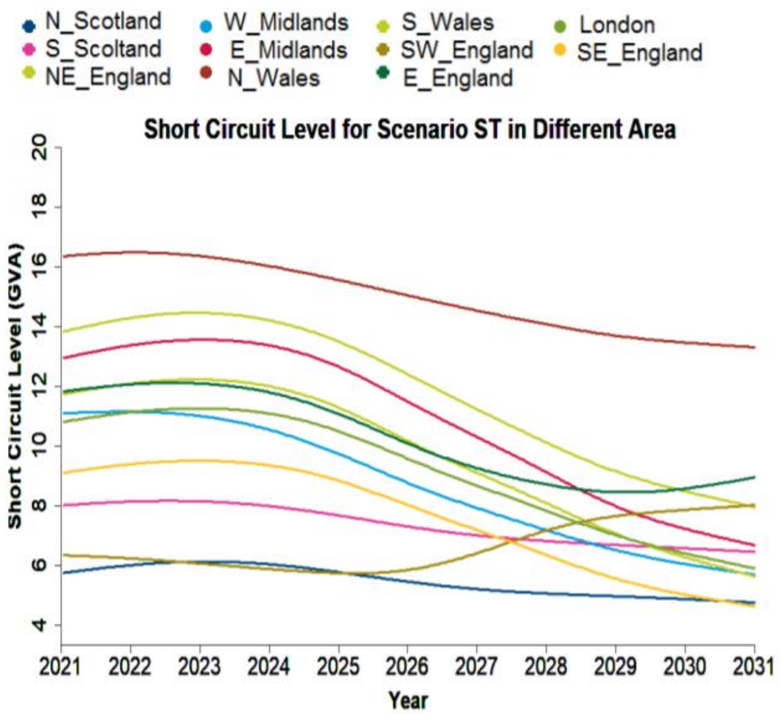
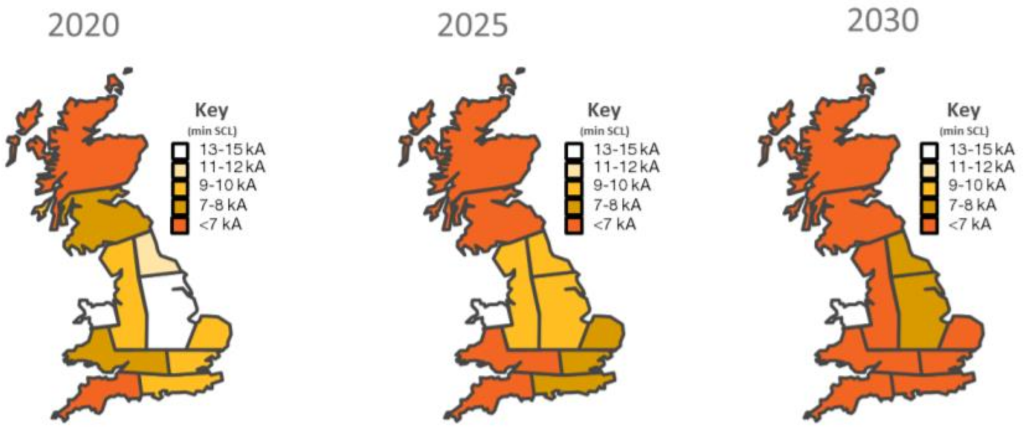
Declining Short Circuit Level (SCL)

- Protection on the transmission network relies on the large current flowing in the system during a system fault.
- During a fault, a lower SCL results in lower retained voltage levels across the network which can compromise a generator’s ability to ride through the fault conditions.
- Lowering fault levels means that the voltage magnitude and angle will respond to a disturbance to a greater extent, there will be less dynamic damping available and voltage recovery will be slower.
- We see low SCL trend continuing in Scotland

Mean Short Circuit Level for System Transformation scenario in different area





Regional minimum short circuit level

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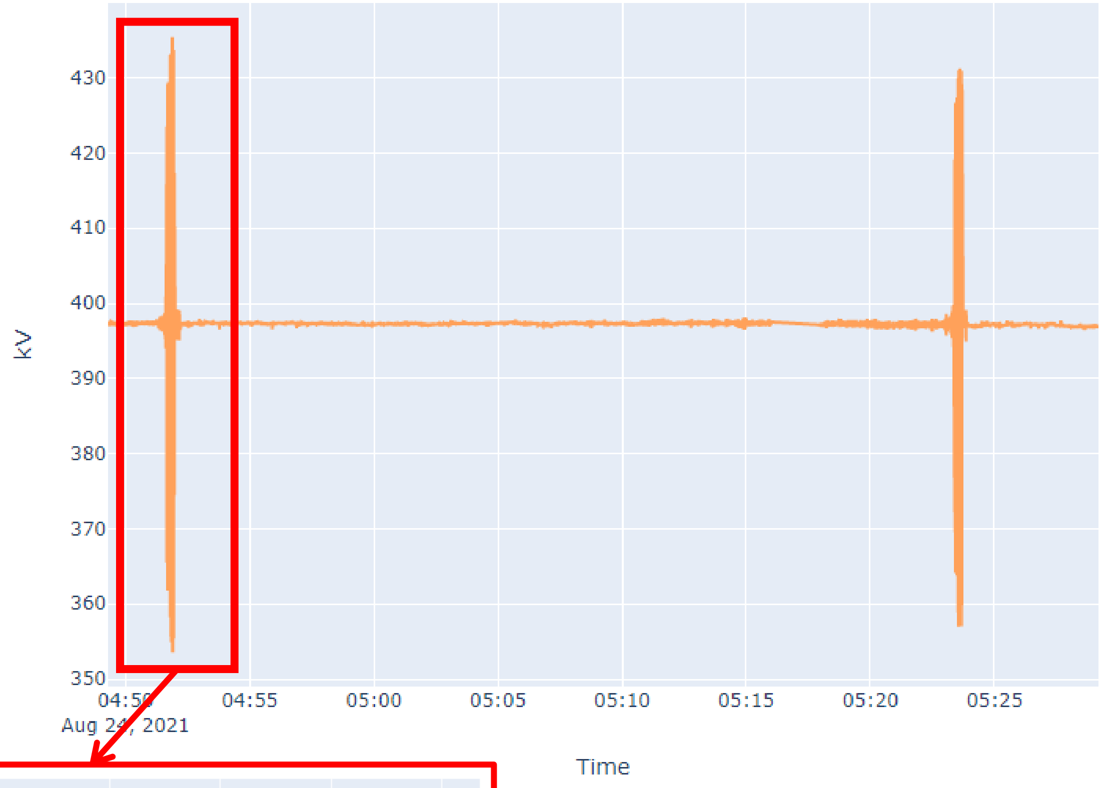
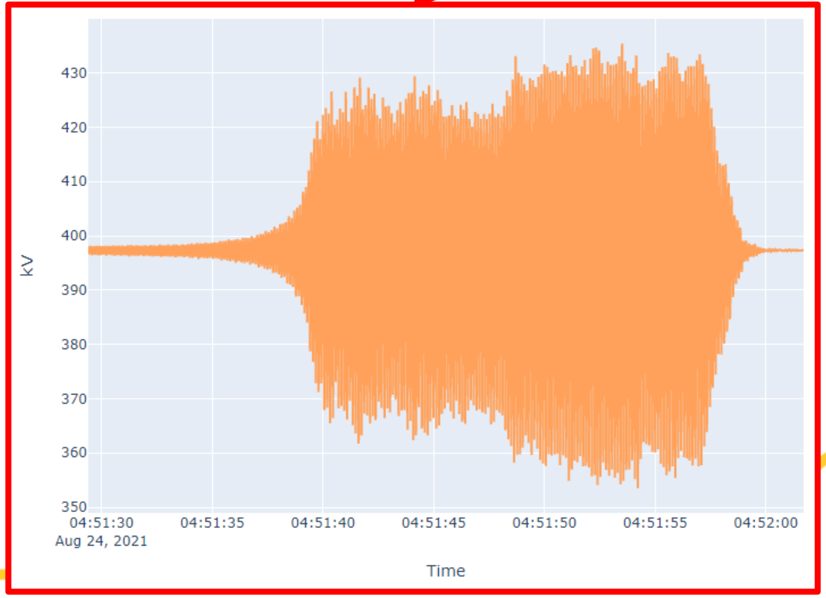
Voltage Oscillations in Scotland in 2021

Voltage Oscillation in Scotland in 2021

- On 24/08/2021 severe voltage disturbances were observed on the SSEN-T and SPEN transmission systems.
- Major disturbance lasted 20-25 seconds on two occasions, approx. 30 minutes apart
- Investigation of available data suggests:
    - The oscillations with the largest magnitude were in the north of Scotland
    - The oscillations had a frequency of ≈8 Hz
- Some Users tripped off during the disturbances





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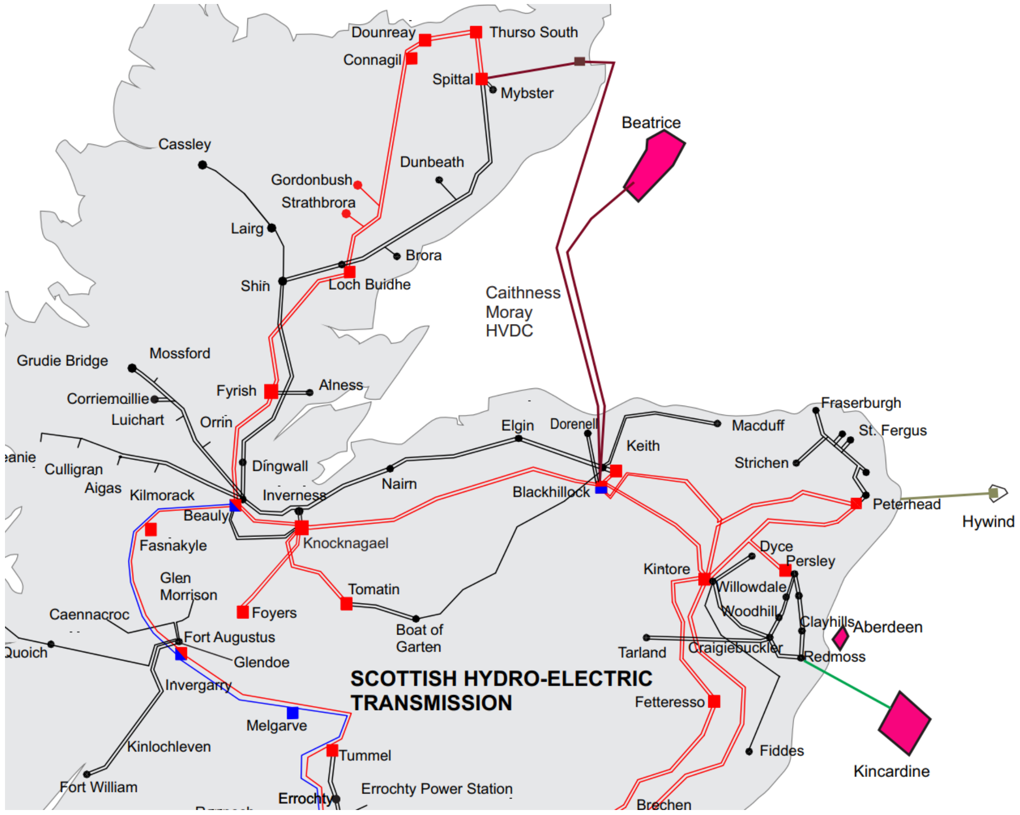
What is being done?

- We provided short term operational advice to our control room, focussing on system strength
- We need to understand nature of these oscillations and their source:
    - Data requested from Users (see next slide)
    - Working group convened with ESO and TO representatives to investigate events in more detail, aiming to:
        - Investigate the underlying drivers for the oscillations
            - EMT modelling of the supergrid network in the north of Scotland
            - Analyse events to explore underlying system behaviours
        - Investigate and recommend remedial actions that can be explored further with Licensees and/or Users as appropriate
        - Assess suitability of alternative screening techniques for use in operational timescales



Event Data requested

- To assist with the investigations, and to help identify potential triggering events or conditions, Users in Scotland were asked to provide:
    - Metering data at the times of the oscillations
    - Any alarms or actions from protection systems that may have taken place during the events
    - Other SCADA alarms or events that indicate abnormal or unusual operating conditions during the events
    - Their network configuration including number of turbines in service
    - Any change in state of plant, such as turbines being taken in or out of service
    - Any available fault recorder traces
    - Any controller tuning or framework updates carried out in the preceding months
- These can help in the modelling and analysis work to identify and assess potential triggers

EMT modelling development

- Having accurate/representative of models of the network and the users is very important
- Understanding the risk of control system interactions as converter based generation increases will requires detailed electro-magnetic transient (EMT) studies to be carried out which in turn requires more detailed modelling of the network as well as the converters
- Ongoing Grid Code modification for user to provide detailed EMT model as part of connection process
- Innovation Project **Transmission Owner Tools for EMT Modelling (**TOTEM)
  - TOTEM which is developing a full GB network model in the EMT environment
  - https://smarter.energynetworks.org/projects/nia_shet_0032/
- Innovation Project **Developing Enhanced Techniques to Evaluate Converter-dominated Transmission System Operability (**DETECTS)
  - DETECTs is exploring the best practices for conducting such EMT studies using a specific study case in an area where converter-based generation is already prominent
  - https://smarter.energynetworks.org/projects/nia_ngso0031/
- Innovation Project **Probabilistic planning for stability constraints**
  - This is exploring, developing and testing cutting-edge automated and probabilistic approaches for modelling of angular stability. This will enable year-round boundary capability calculation for stability accounting for a number of sources of variability and uncertainty and enabling ESO to consider the possible issues across the system.
  - https://smarter.energynetworks.org/projects/nia_ngso0036/

Ongoing Initiatives to Enable a Stable GB Network

World’s First Inertia Measurement System

reactive technologies

New Services and Products

Need to manage the trade off and balance between frequency response and inertia

Faster acting frequency response products

- increasing over time FFR, EFR and now Dynamic Containment
- Dynamic Containment (DC) is a fast-acting post-fault service to contain frequency within the statutory range of +/-0.5Hz in the event of a sudden demand or generation loss. The service delivers very quickly and proportionally to frequency but is only active when frequency moves outside of operational limits (+/- 0.2Hz). With full delivery in 1second.

Stability Pathfinders

- Trail by doing – define the need, let the market innovate
- Phase 1 contracted January 2020 – 12GVAs equivalent to 5 to 8 machines £320M for 6 years
- Phase 2 – Scotland focus for Short Cct infeed and inertia – contracted summer 2021
- Phase 3 Nationwide inertia requirements – process to be launched later in 2021

Grid Code Modification GC0137

Minimum non-mandatory specification within the Grid Code for parties wishing to offer a Grid Forming capability –

Such plant would support the Grid during unplanned events/faults particularly in respect of:

i) limiting the rate of change of system frequency following the loss of a generating unit or load;

ii) injecting instantaneous active power into the system at the time of a fault as a result of the corresponding phase change;

iii) injecting instantaneous Fast Fault Current into the system at the time of a fault as a result of the corresponding voltage change;

iv) Contributing to damping power;

v) Limiting vector shift;

vi) Contributing to synchronising torque;

vii) Contributing to the maintenance of an improved voltage profile during a fault – a fundamental pre-requisite for fault ride through.

This is a key step in opening up the stability/ short circuit infeed market to procuring ‘traditional services’ from renewables

Short Circuit Level (SCL) Management

- Grid “strength”, often measured as the short-circuit level is decreasing and we need to find the right strategy to manage the issue:
  - Developing right measure for system strength /SCL
  - Developing a suitable method to estimate the minimum SCL to maintain resilient system operation: ensure protection works, maintain system voltage etc
  - Understanding the IBR’s capability to remain stable in low SCL system
  - Determining the right balance on how much SCL provided by system / IBR SCL needs
  - Developing a process on how SCL requirements could be implemented in design and operation timescale

Ongoing initiatives to meet stability challenges

- NOA Stability Pathfinder Projects
    - Phase 1 – awarded contracts in Jan 2020 for 12.5 GW.s of inertia https://www.nationalgrideso.com/future-energy/projects/pathfinders/stability/Phase-1
    - Phase 2 – will buy inertia of 6 GW.s and SCL of 8.4 GVA in Scotland https://www.nationalgrideso.com/future-energy/projects/pathfinders/stability/Phase-2
    - Phase 3 – will buy inertia of 15 GW.s and SCL of 7.5 GVA in areas of England & Wale https://www.nationalgrideso.com/future-energy/projects/pathfinders/stability/Phase-3
- Introducing GB Grid Code change for Grid Forming Technologies
    - Grid Code Working Group GC0137 https://www.nationalgrideso.com/industry-information/codes/grid-code-old/modifications/gc0137-minimum-specification-required
- Stability Market development Innovation project
    - Aims is to understand if there is a need for a stability market https://www.nationalgrideso.com/future-energy/projects/stability-market-design
- Accelerated Loss of Mains Change Program (ALoMCP)
    - Under which initiative the electricity distribution companies are updating settings for the RoCoF loss of mains protection relays from 0.125 to 1Hz/s, with a definite time delay of 500ms
    - This will allow us to reduce spend on RoCoF related system constraints.

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