System Oscillation Experience in the GB System

Dr Xiaoyao Zhou

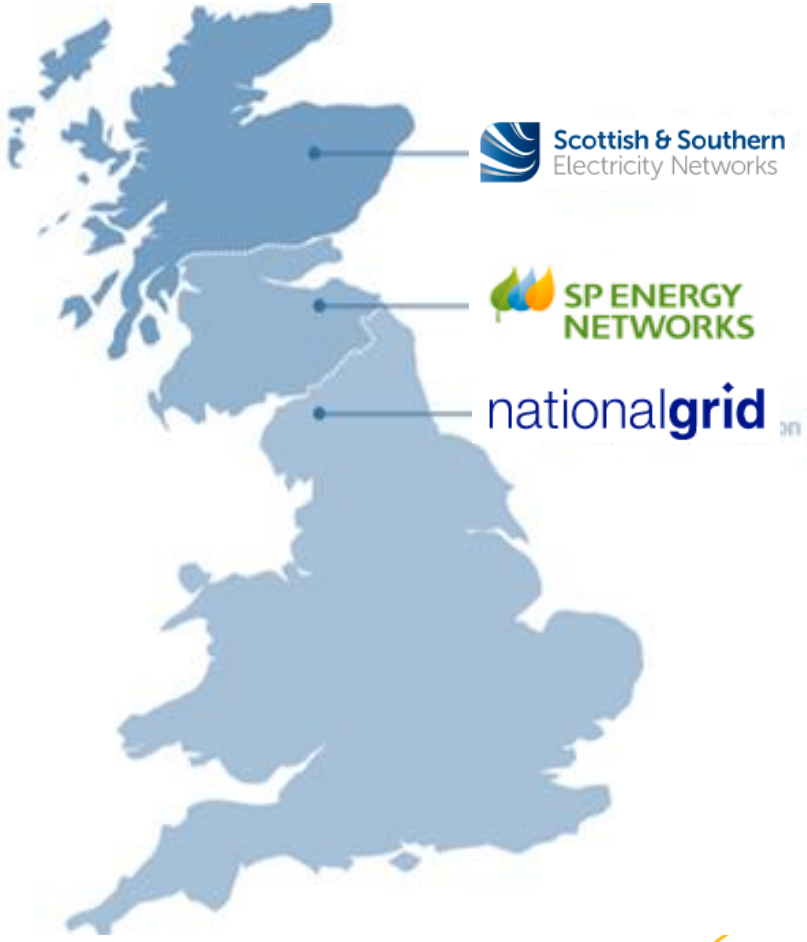
27/03/2004

ESO

National Grid ESO's role

- Operates and balances the system
- Provides electricity network recommendations
- Operational planning
- Connection agreements
- Widens access and promotes competition
- Responsible for GB transmission charging and billing

The **transmission operators** (TOs) own, build and maintain Britain's transmission infrastructure.



NESO (National Energy System Operator) from summer 2024

Zero-carbon operation

Fossil fuelled generation is reducing fast, causing operational challenges

- Frequency management
- Inertia and voltage control

Our plan for 2025:

- For short periods we can operate the transmission system carbon free and can accommodate all the zero carbon generation the market provides

Notable records

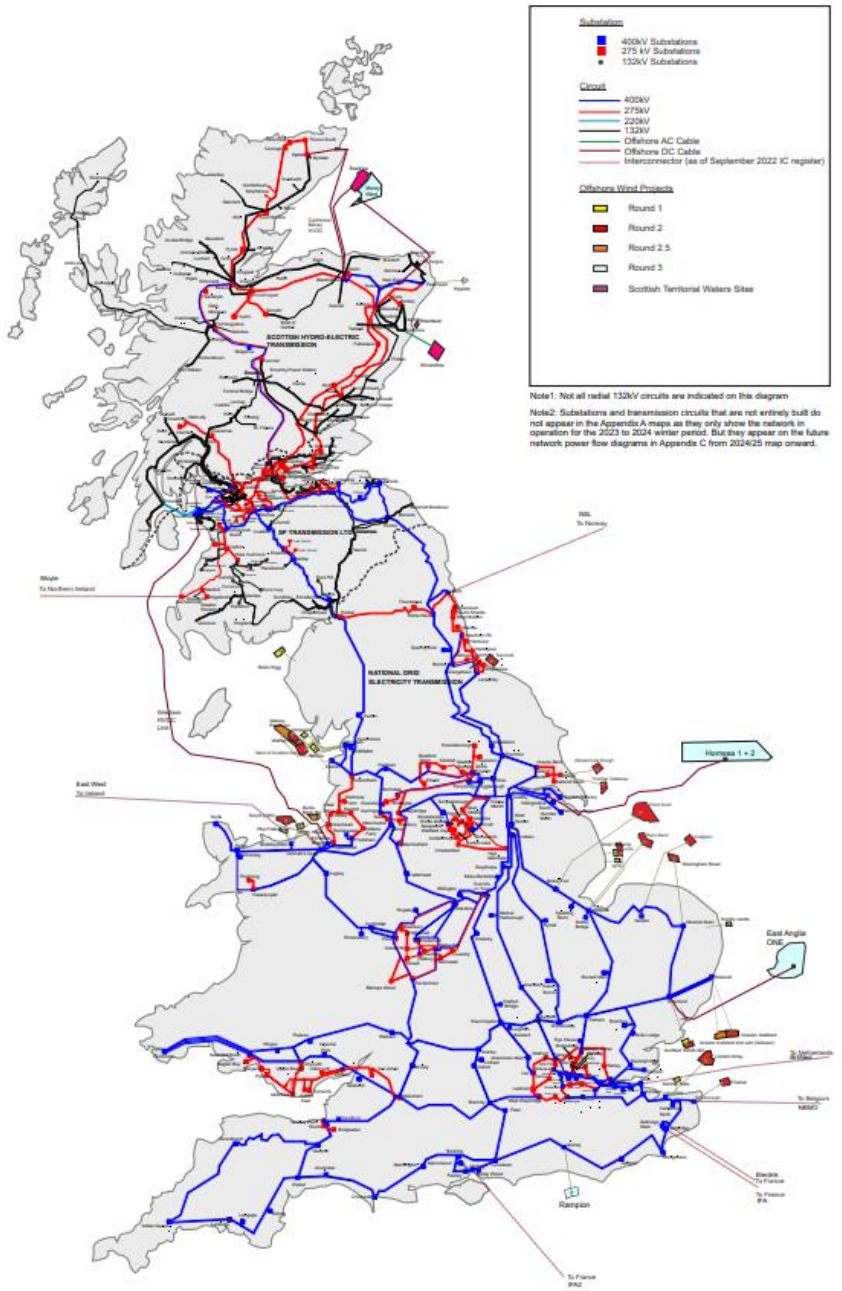
- **91% zero carbon** on Jan 7th 2023
- **21.8GW Max wind** on Dec 21st 2023

Our plan for 2035:

- Zero carbon operation all the time
- Manage new challenges of flexibility and adequacy

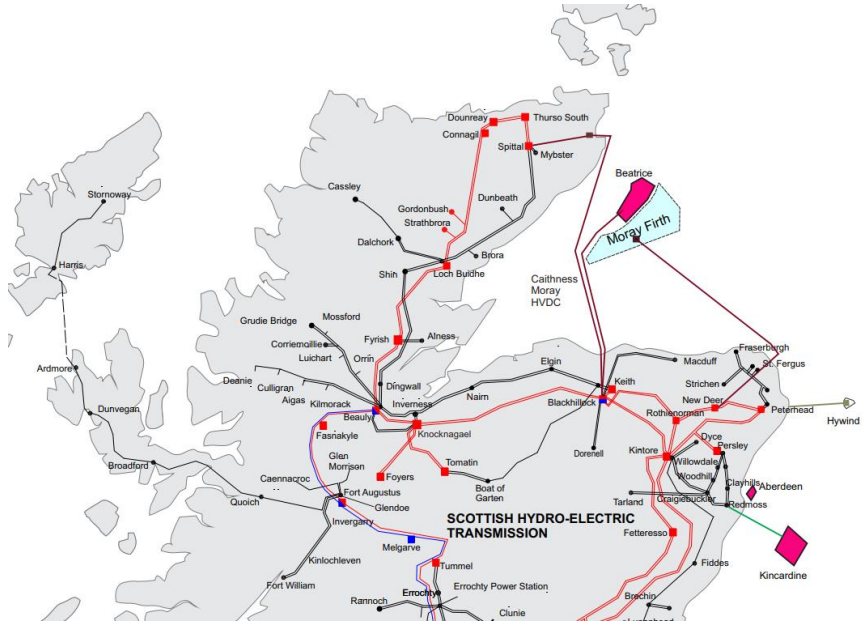
Past oscillations in synchronous machines dominated system

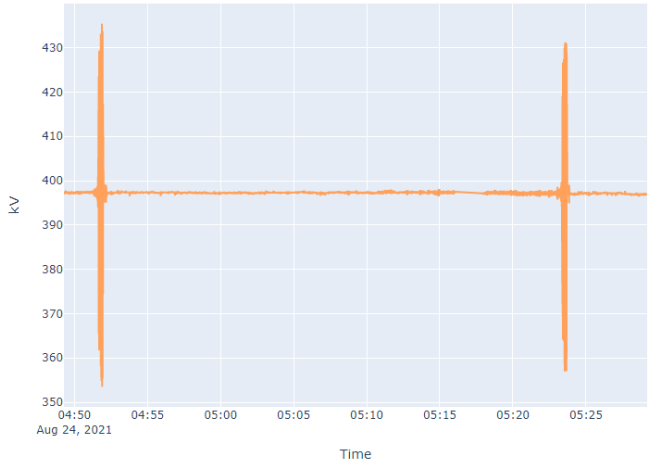
- Inter-area low frequency oscillations
- Low frequency oscillations due to not properly tuned AVR and PSS
- SSTI risk with series compensation

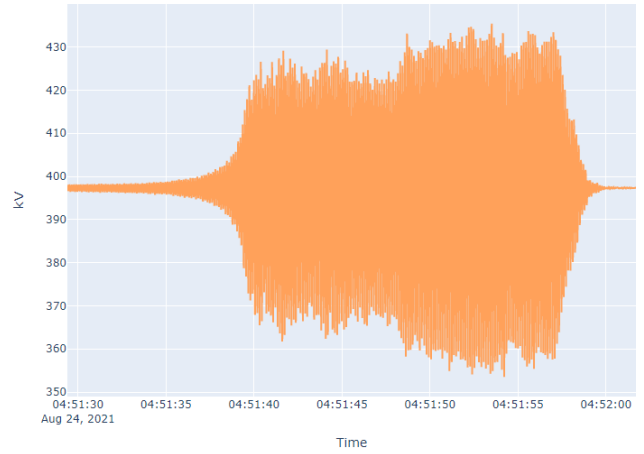


2021 8Hz Oscillations

- On 24th August, 2021, severe voltage disturbances were observed on the transmission system in Scotland
- The major disturbances lasted 20-25 seconds on two occasions, approx. 30 minutes apart
- Voltage oscillations of ≈8 Hz, up to ±35 kV at 400 kV
- Centred in north of Scotland, though impacted Central Belt







2023 SSOs Overview

- During June and July 2023, 8Hz Sub-synchronous Oscillation (SSO) occurred on five separate days, all centred in the Scottish network
- The SSO events caused disturbances on the power system which included the tripping of assets – no demand was lost at any time
- The ESO initiated defensive measures and set up an investigation team after the first event
- The ESO worked closely with relevant parties to gather and analyse data, and propose, implement and test changes
- There have been no further undamped SSO events
- The ESO has identified further work to reduce the likelihood of SSO
- No link to inertia, short-circuit levels, high wind levels, high transfers across the B6 boundary or decarbonisation in general

What happened

During June and July 2023, 8Hz Sub-synchronous Oscillation (SSO) occurred on five separate days, all centred in the Scottish network. The SSO was in the range 5 – 9Hz, mainly at about 8Hz (approximately 1/6th of 50Hz nominal frequency)

The SSO events caused disturbances on the power system which included the tripping of generation, tripping of an interconnector and HVDC link, and in one case a transmission circuit trip.

The ESO initiated defensive measures and started an investigation after the first event. A dedicated project team was established after the second event.

The project team led the investigation, co-ordinated the response across ESO and managed communication with relevant parties.

The most likely cause of the SSO was identified in mid-July.

The project team was stood down on 24th July 2023 and responsibility for concluding work transferred back to the relevant teams.

Changes have been made and there have been no further undamped SSO events.

Defensive measures

Immediately after the first event the Control Room initiated defensive measures

The defensive measures were refined and expanded during June and July before being withdrawn in mid-August

Reduce the likelihood of SSO occurring:

- Maximise the Short-Circuit Level (SCL) in Scotland
- Restrict planned switching in Scotland at times of low demand
- Increase the inertia in Scotland at times of low demand
- Manage the voltage to maximise stability of synchronous generators in Scotland at times of low demand

Manage the impact of SSO:

- To secure against the absolute worst-case loss of generation the ESO determined that it was necessary to increase the response and reserve holding
- Between 3rd July and 14th August, the ESO updated the response policy with increased DC-L requirement and procurement to cover a largest loss up to 1800MW. If the SSO loss risk was greater than 1800MW, actions could be taken in control timescales to procure additional Mandatory Frequency Response (MFR), curtail wind or reposition the Moyle interconnector.
- The ESO also reviewed reserve policy and agreed to hold additional reserve during SSO investigation. The increased reserve requirement would be covered by procuring additional short term operating reserve (STOR).

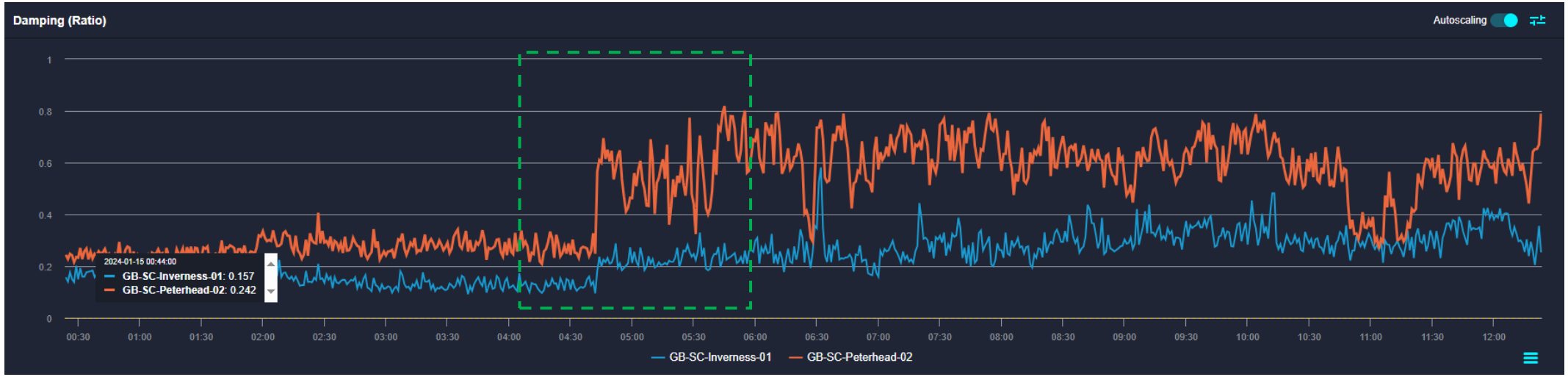
How it was resolved

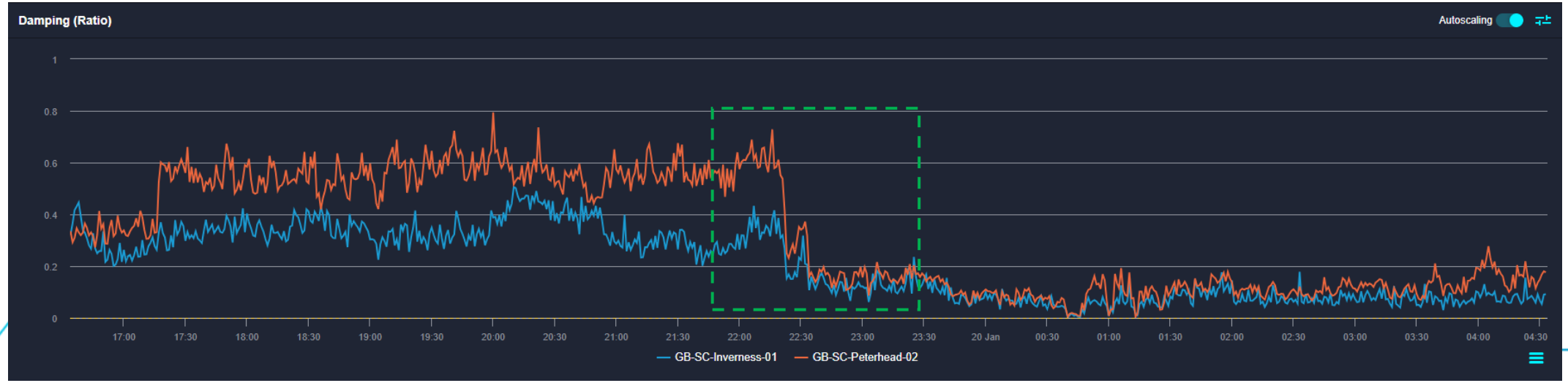
- The ESO worked closely with relevant parties to gather data, particularly from Phasor Measurement Units (PMUs)
- The ESO worked closely with asset owners to help model and analyse the behaviour of the power system during SSO
- This analysis and other investigations identified the asset that contributed most to the SSO and helped to rule out causal behaviour of others
- Further modelling and analysis of some equipment was undertaken by asset owners which identified control system changes which would significantly reduce the likelihood of SSO
- The relevant equipment owner made changes to controller settings and the assets were brought back into service in a controlled process
- Close monitoring of the power system has shown that the changes had the intended effect and no further SSO events have been observed.

Investigation conclusion

- The ESO analysed a large data set including plant status and system conditions across all the events:
  - This data showed no link between the oscillations and system conditions (system inertia, short circuit levels or any specific type of generation) and therefore no specific link to decarbonisation
  - No SSO has been observed since the relevant assets returned to service after making changes to their configuration
  - Based on all of the analysis and actions taken, the ESO is confident that the main contributory factor has been removed.
- Post-event, multiple lessons learnt and recommendations have been identified which can be broken into the below categories:
  - Real time monitoring and alarms in the frequency domain
  - Review of the compliance processes
  - Improvements to electromagnetic transient (EMT) modelling

Real time monitoring and alarms in frequency domain



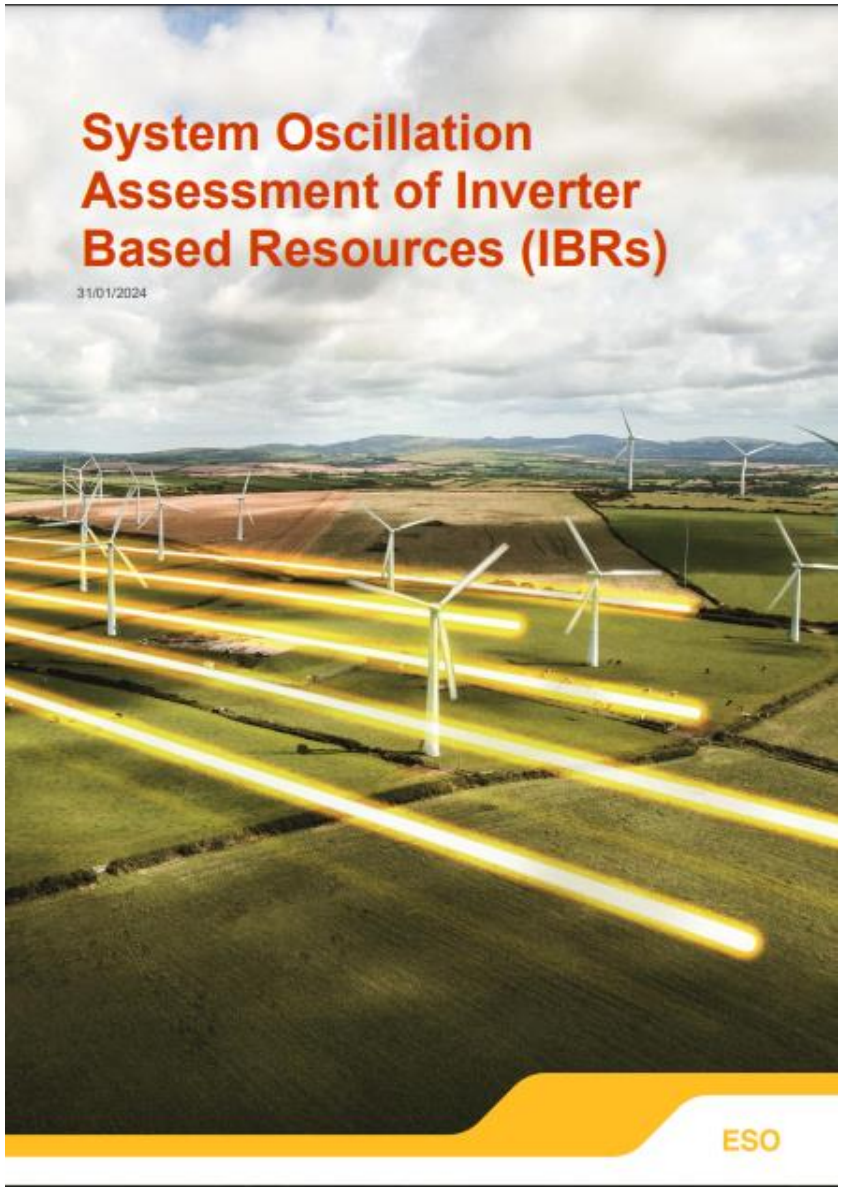


Compliance process review

- The oscillation assessment guidance was published recently as the result of SSO investigation.

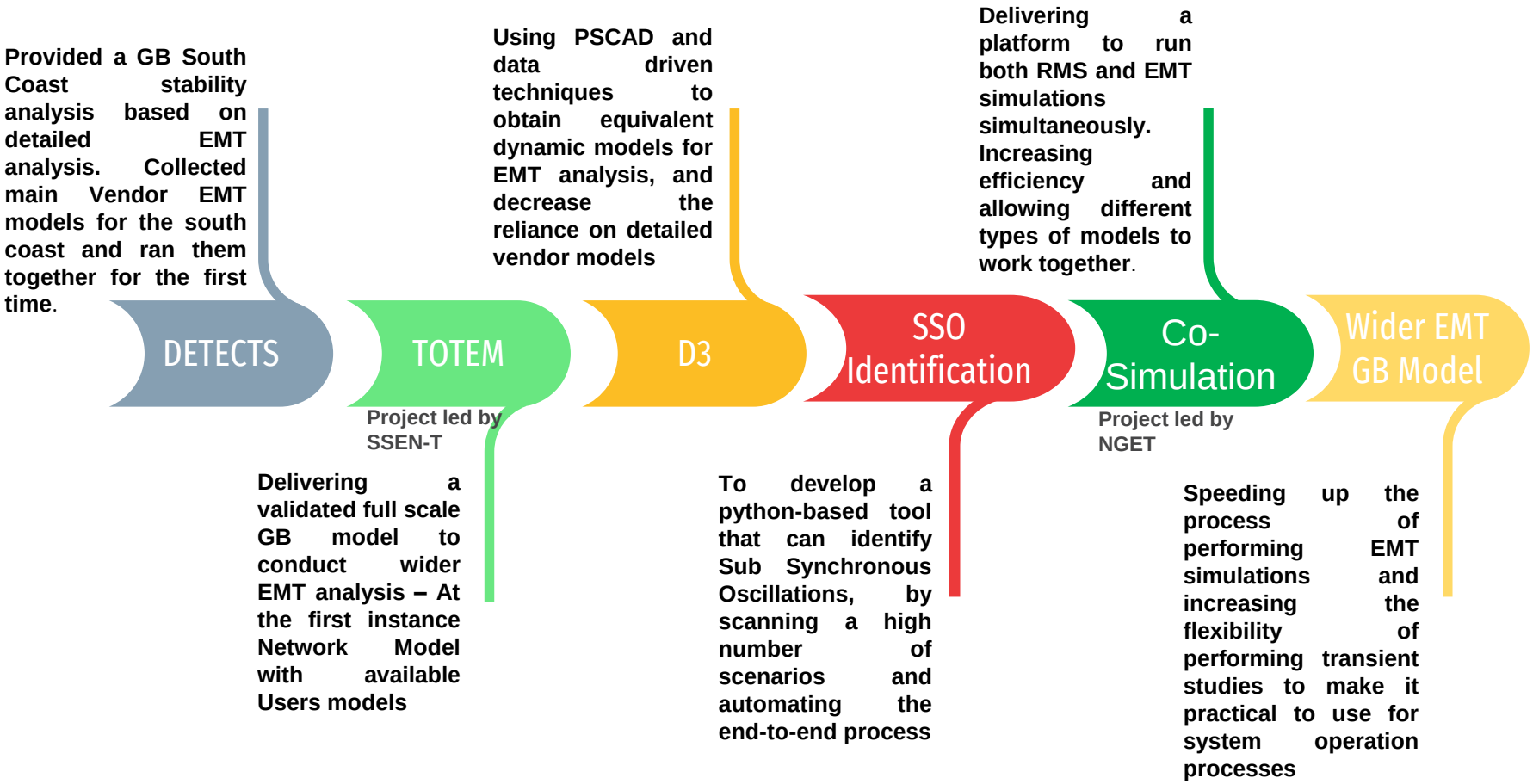
- The guidance describes a set of small signal studies which should be carried out by Users as part of the connection compliance process to demonstrate good damping performance.

    - Step change
    - Small signal injection study
    - Frequency scan
    - Eigenvalue analysis



Document is available at: download (nationalgrideso.com)

EMT modelling improvement



- **Grid Code modification:** to obligate the existing Users to submit EMT models
- **Development of EMT simulation portal :** to allow users to connect to portal and carry out studies without access to sensitive IP data