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Clean Power 2030: Power system stability Challenges

Dr Xiaoyao Zhou, NESO

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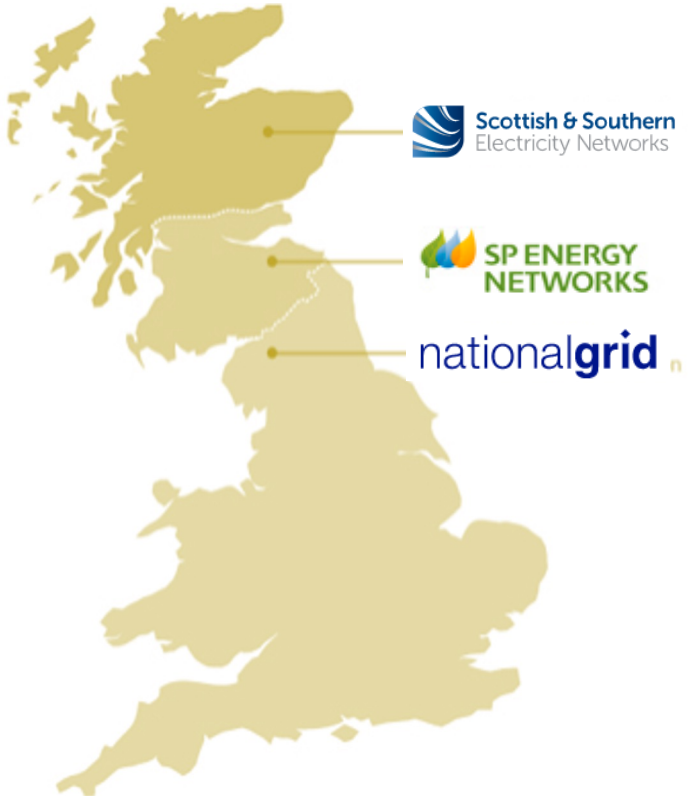
NESO's role

- 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

NESO (National Energy System Operator) from Oct 2024

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



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NESO's Zero-carbon operation ambition

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

Our plan for 2035:(Now 2030)

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

Notable records

- 92.2% zero carbon April 2024
- 19gCO2/kWh April 2024

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CP30 NESO advice

The Government has an ambition for Britain to be supplied with clean power by 2030. The Government has made Clean Power one of their five missions. Mission Control, led by Chris Stark, is overseeing the delivery of a clean power 2030 action plan, consistent with long-term net zero, security of supply and affordability objectives.

The National Energy System Operator was asked to provide independent advice on the pathway towards the 2030 ambition, with expert analysis of the location and type of new investment and infrastructure needed to deliver it. We submitted our advice to Government and published it in November 2024. Government will now consider the advice in developing its clean power action plan later this year.

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CP30 Headline Findings

- **Clean power by 2030 is achievable** - though outer edge of feasibility. It will be a herculean effort
  - .Required capacity less than that in current connections queue.
  - Network requirements broadly in line with 'Pathway to 2030' Holistic Network Design (2022) – need to deliver.
- **Clean power will require doing things differently,** establishing and maintaining momentum every year to 2030
  - Key elements for success: demand and supply flexibility, renewables acceleration, delivering FOAK technologies, timely network expansion, gas stays on but operates much less.
  - Key areas for action: planning reform; connection reform; market reforms; community engagement; supply chain; data/digital; and regulatory approvals.
- **Clean power can bring benefits for GB**
  - Help meet carbon targets and create local industrial and job opportunities
  - Cut the link with gas prices, without increasing costs to consumers
- **Broad stakeholder support for analysis**

CP30 NESO advice

Installed Capacities (GW)			
Technology	**2023**	**2030 Further Flex and Renewables**	**2030 New Dispatch**
Offshore wind	14.7	50.6	43.1
Onshore wind	13.7	27.3	27.3
Solar	15.1	47.4	47.4
Nuclear	6.1	3.5	4.1
Biomass/BECCS	4.3	4.0	3.8
Low carbon dispatchable power	0	0.3	2.7
Other renewables	4.7	5.7	5.7
Batteries	4.7	27.4	22.6
LDES	2.8	7.9	4.6
Interconnectors	8.4	12.5	12.5
Unabated gas	37.4	35.0	35.0

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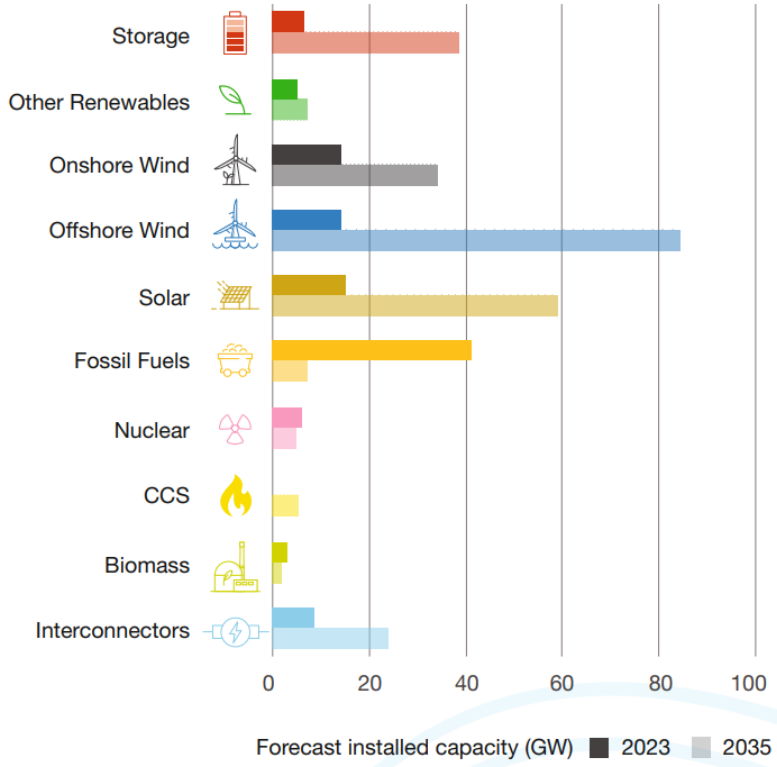
How GB system evolves



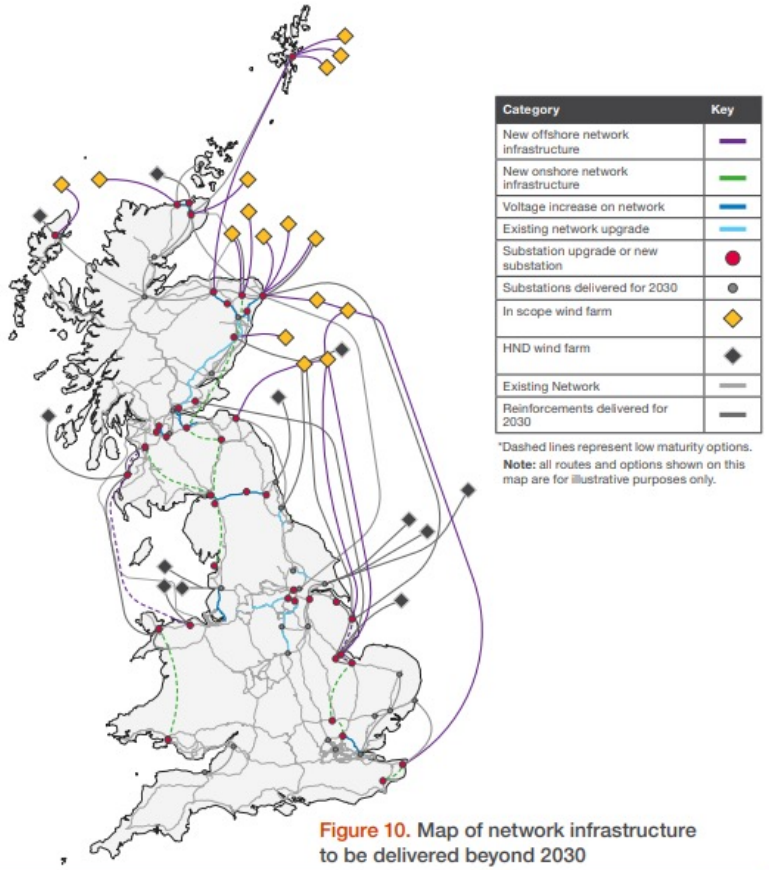


Figure 10. Map of network infrastructure to be delivered beyond 2030

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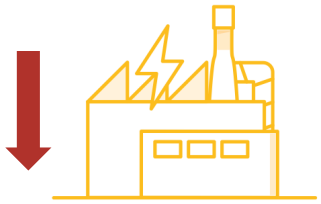
Operability Challenges

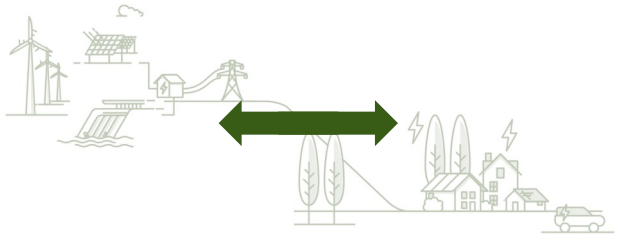
Decarbonisation of the GB power system has resulted in changes in four key areas:



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
- **Resource Adequacy –** the right generation mix, flexible demand and storage
- **Flexibility -** what, where and when can we leverage flexibility
- **System Restoration –** how do you restart a renewable dominated system

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System Performance Trends

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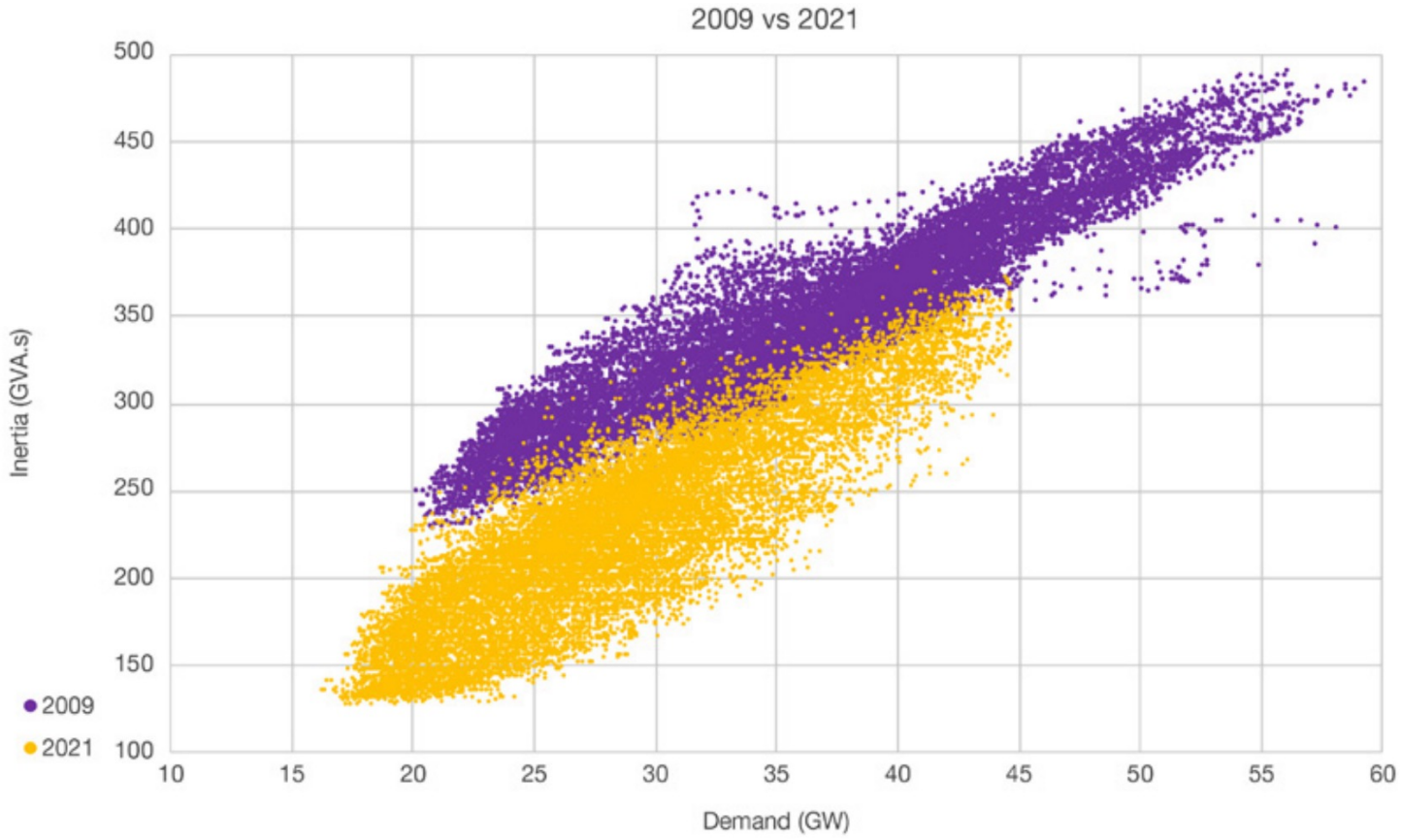
Decline of system inertia

Inertia vs Demand



- Generally the maximum inertia now is lower than the minimum inertia was in 2009
- Average inertia provided by the market (pre-NESO actions) in 2023 to date is 180GVA.s

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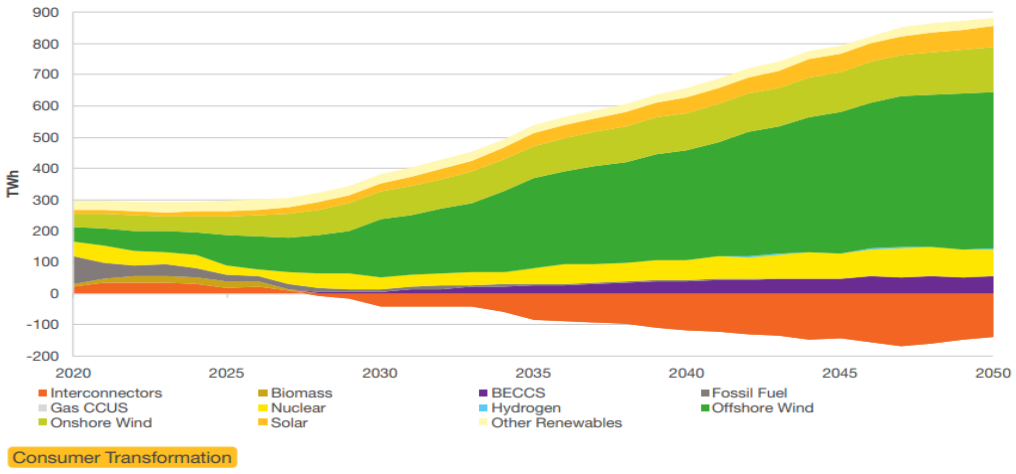
Decline of Short Circuit Level

Customer Transformation (CT)

System Transformation (ST)

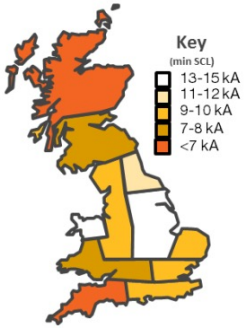
Leading the Way (LW)

Steady Progression (SP)

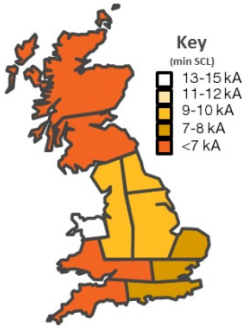


Consumer Transformation

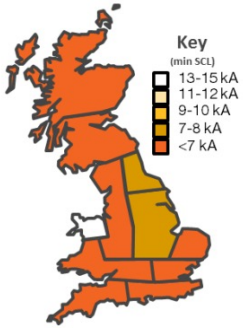
2020



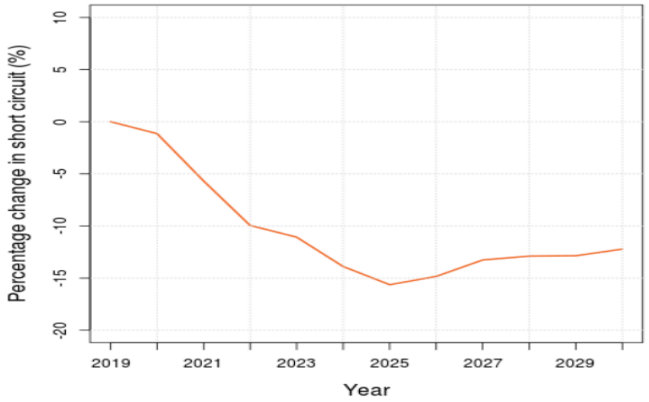
2025



2030



National change in short circuit level from 2019 value



SOF Document "Impact of Declining Short Circuit Levels"

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GB Grid Forming Grid Code Development

GB Grid Forming Development

nationalgridESO

Workgroup Consultation GC0137
Published on 31 March 2021

Workgroup Consultation

GC0137:

Minimum Specification Required for Provision of GB Grid Forming (GBGF) Capability (formerly Virtual Synchronous Machine/VSM Capability)

Overview: This modification proposes to add a non-mandatory technical specification to the Grid Code, relating to GB Grid Forming Capability (which was formerly referred to as a Virtual Synchronous Machine ("VSM") capability. The detail pertaining to its creation may be found in Section 3 "Why Change?" but the high-level overview is that the specification will enable parties to offer an additional grid stability service. This will be fundamental to ensuring future Grid Stability, faciliatating the target of zero carbon System operation by 2025 and providing the opportunity to take part in a commercial market which would sit alongside other market arrangements such as the stability pathfinder work and dynamic containment.

Modification process & timetable

1. Proposal Form — 12 December 2019
2. Workgroup Consultation — 31 March 2021 – 30 April 2021
3. Workgroup Report — 27 May 2021
4. Code Administrator Consultation — 01 June 2021 - 22 June 2021
5. Draft Modification Report — 21 July 2021
6. Final Modification Report — 29 July 2021
7. Implementation — 01 October 2021

Have 5 minutes? Read our Executive summary

Have 20 minutes? Read the full Workgroup Consultation

Have 60 minutes? Read the full Workgroup Consultation and Annexes.

Status summary: The Workgroup are seeking your views on the work completed to date to form the final solution(s) to the issue raised.

This modification is expected to have a: High impact - National Grid ESO – successful implementation of this specification and the subsequent launch of a commercial market would result in the provision of additional stability services. The primary aim being the ability to run the entire electricity transmission system on low carbon generation sources ,that include nuclear power, whilst at the same time ensuring a safe, secure and economic system. Consequently, the likelihood would be a net-positive in terms of the ESO's ability to balance the GB electrical grid and respond to unplanned interruptions to electricity supply. **Medium impact** - Generators and Interconnectors – successful implementation of this specification and the subsequent launch of a commercial market would provide generators and Interconnectors with a potential new revenue stream. In order to take part in such a market, Generators and Interconnectors may wish to amend/modify their plant,

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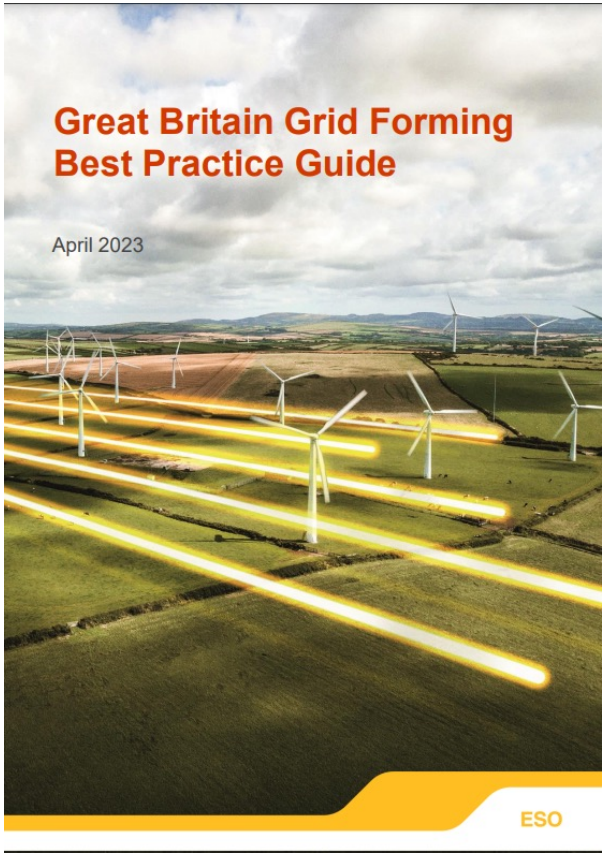

GC0XXX
Submitted: DD MONTH YEAR

ESO

Grid Code Modification Proposal Form

GC0XXX:

GB Grid Forming (GBGF) - capability mandate, clarity on definitions, changes to performance requirements and changes to compliance tests and simulations.

Overview: This modification aims to mandate Grid Forming Capability on certain types and sizes of plants. This modification also aims to update the Grid Code in respect of the Grid Forming requirements arising from i) the Great Britain Grid Forming Best Practice Guide, ii) Stakeholder comments, iii) the industrial experience gained from the Stability Pathfinder work / Compliance Process, iv) developments in Europe.

Modification process & timetable

TBD

Status summary: The Proposer will be setting up an Expert Group which aims to develop recommendations ahead of a formal Grid Code Modification.

This modification is expected to have a: High impact

Manufacturers, Generators, the ESO, Transmission Owners, Offshore Transmission Owners.

Modification drivers: Harmonisation, New Technologies, System Operability, System Planning, System Security, Net Zero

Proposer's recommendation of governance route	Standard Governance modification with assessment by a Workgroup

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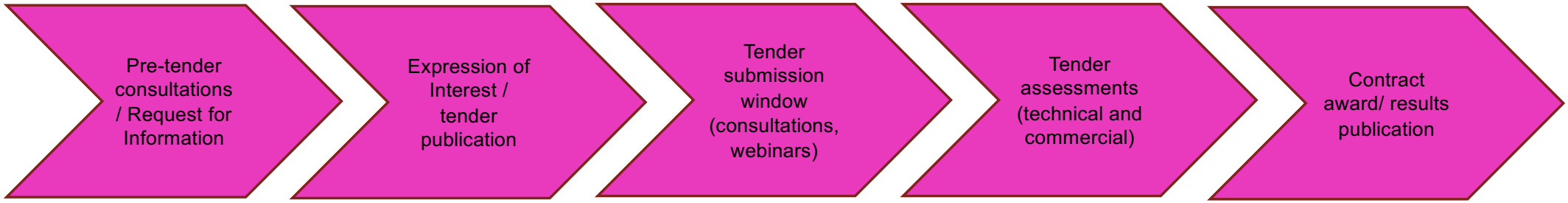
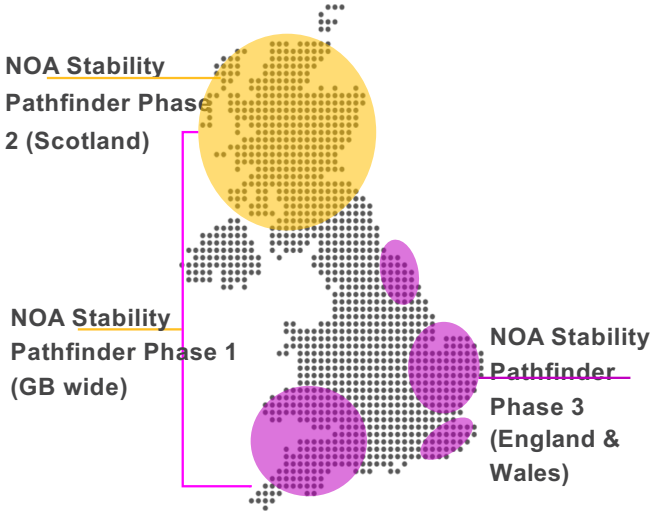
Stability Pathfinder

Stability Pathfinder



Stability Pathfinder

	Stability Pathfinder Phase 1	Stability Pathfinder Phase 2	Stability Pathfinder Phase 3
Requirement	Inertia and dynamic voltage GB wide	Inertia, SCL and dynamic voltage	Inertia, SCL and dynamic voltage
Status	All Synchronous compensators most units now live	5 GFM BESS 5 SynComp Go-live from Apr 24	29 Synchronous compensators Go-live expected from 2025
Participating technology	0MW Synchronous Compensators only	Synchronous and Grid Forming Converter based	Synchronous and Grid Forming Converter based
Procurement regions	GB wide	Scotland	England and Wales
Procurement volume	12.5 GW.s of inertia	8.4 GVA of SCL 6 GW.s of inertia	7.5 GVA of SCL 15 GW.s of inertia
Contract Detail	Up to 6 years	End of Mar 2034	End of Mar 2035 £1.35b
Contract payments	Availability payments for SCL& Inertia Utilisation payments for reactive power		



https://www.neso.energy/industry-information/balancing-services/network-services-procurement/stability-network-services-procurement

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Stability Market Design Overview

- To maintain compliance and reduce costs associated with managing stability, we are conducting an innovation project with AFRY to explore designing new markets to procure stability services. More details can be found here.
- Phase 1 concluded in 2022 and recommended that a blend of long and short-term competitive procurement is the optimal approach.
- Phase 2 concluded in 2023 built on Phase 1 and provided more detailed evaluation of eligibility rules, contract structure and procurement strategy.

		Long Term (Y-4)	Mid Term (Y-1)	Short Term (D-1)
Purpose		– Procure capacity in advance (LT), to signal the need for new assets – Allow financing of new build capacity (and enhanced capability, TBD) through LT contracts	– Procure capacity in advance (MT), to adjust LT procurement in case necessary – Allow MT financing of new, incremental and existing capability able to provide stability	– Procure capacity to fulfil residual of total requirements for Stability closer to real time (ST) – Allow remuneration of marginal costs for providing Stability.
Timeline	*Procurement lead time*	– Y-4	– Y-1	– D-1
	Contract duration	– 10+ y	– 1 y	– Service windows
Product	*Contract type*	– Baseload availability	– Baseload availability	– 4 h (EFA blocks)
	Contract obligations	– e.g. 90% availability	– e.g. 90% availability	– 100% availability

Sub-synchronous Oscillations in GB System

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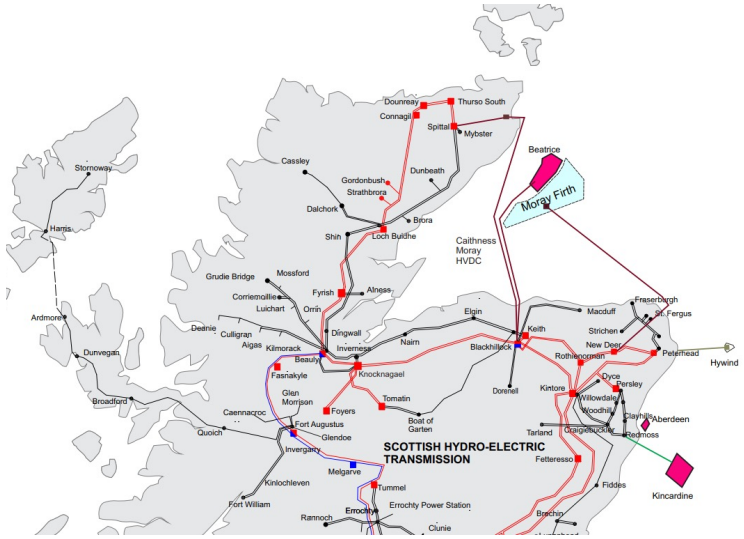
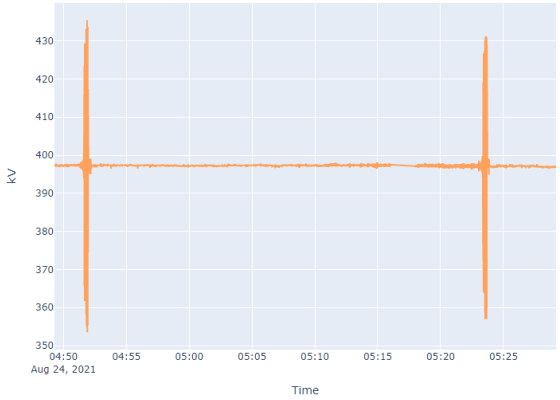
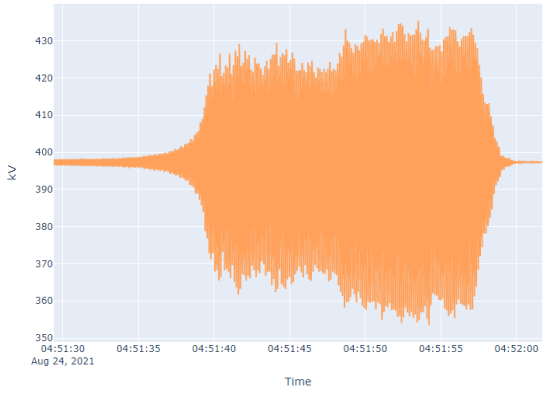
Emerging Sub-synchronous Oscillations

- 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







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2023 SSOs: 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 NESO 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 NESO 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 in 2023.

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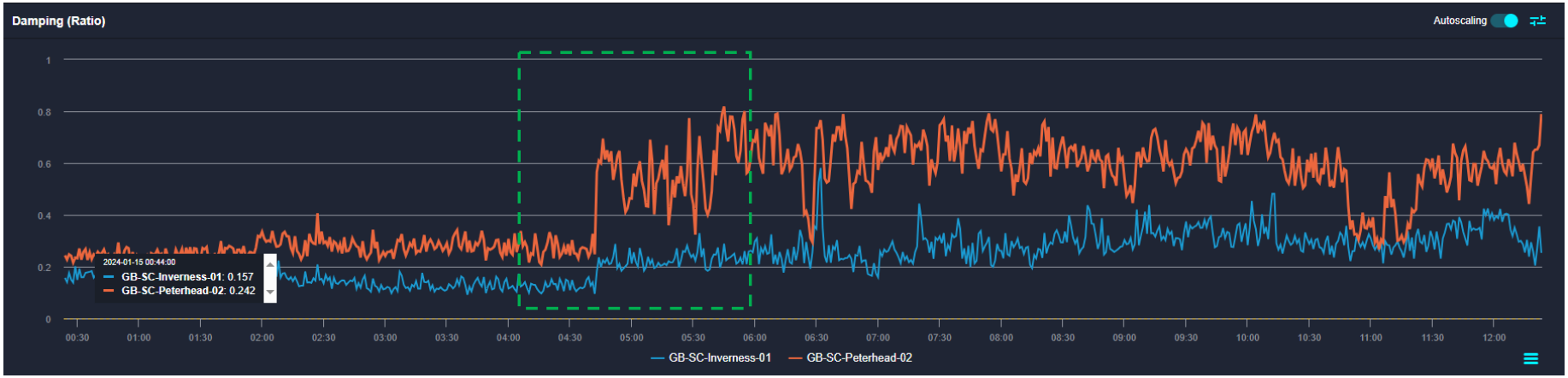
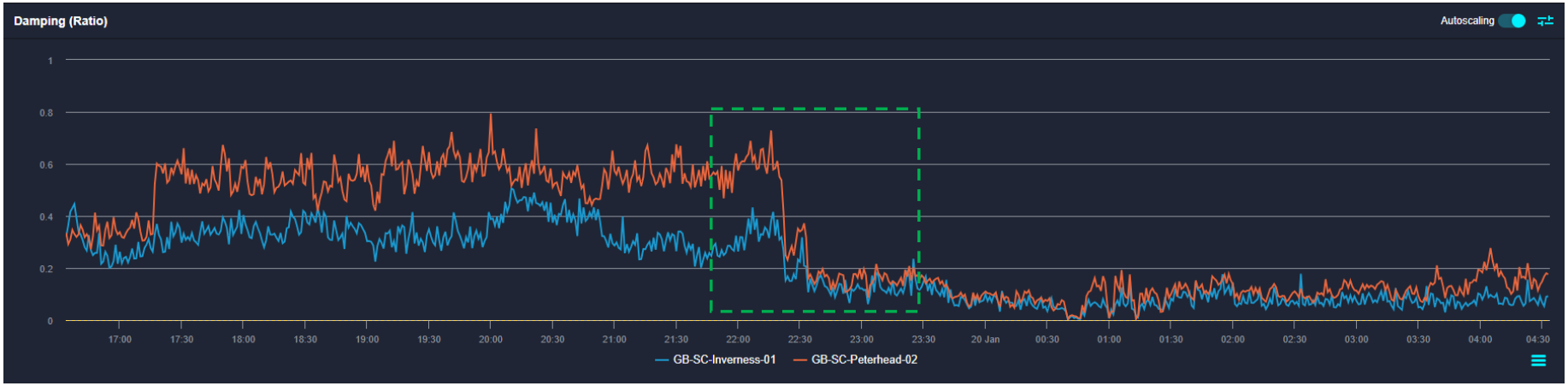
Real time monitoring and alarms in frequency domain



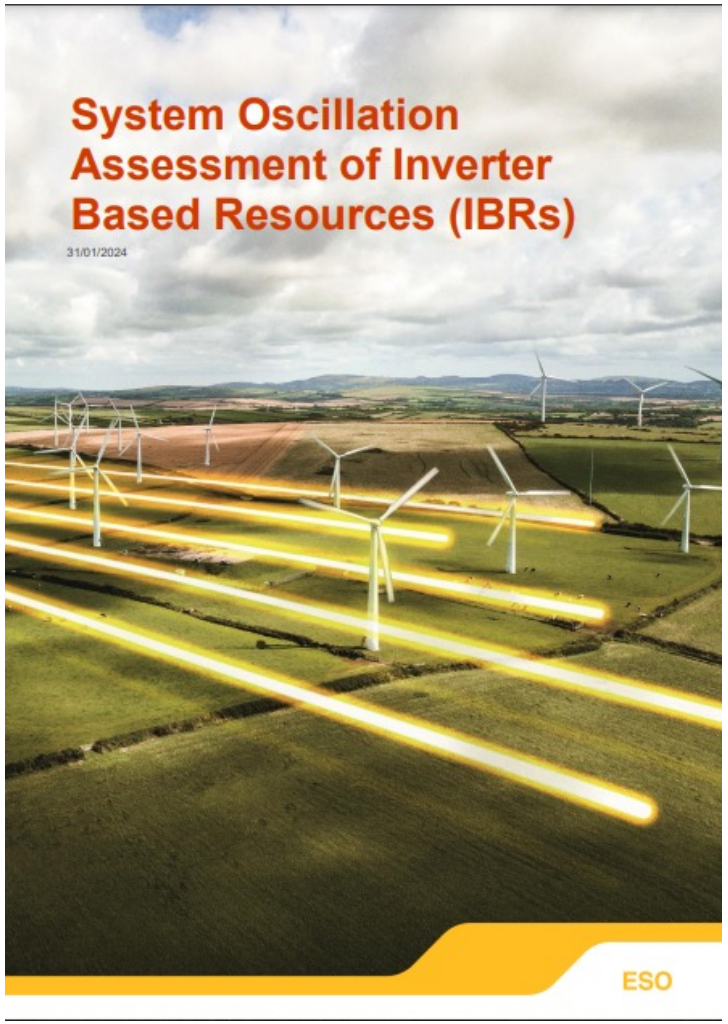


Compliance process review

- 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 (neso.energy)

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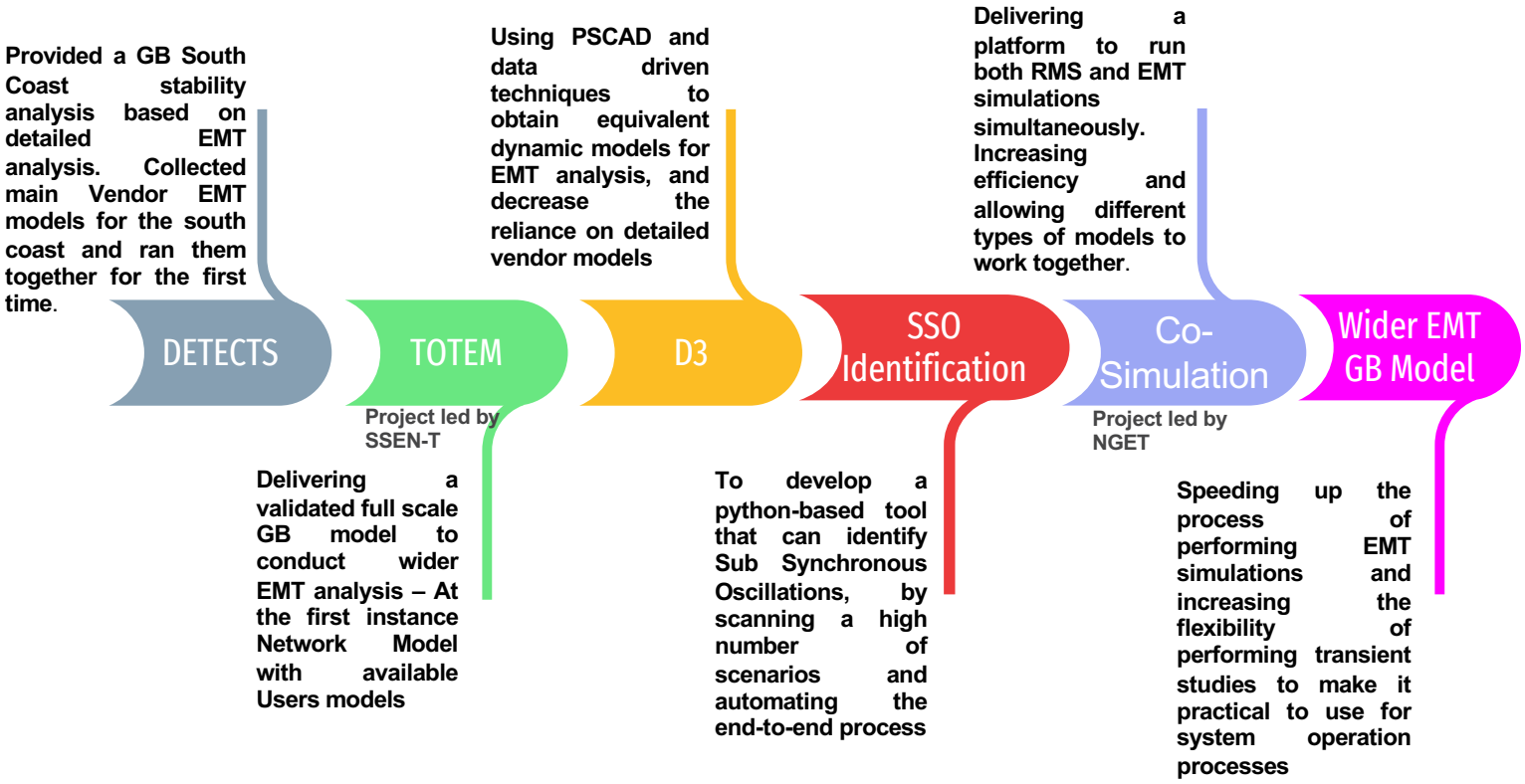
EMT modelling improvement



- **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

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Thank You!

Questions?

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