

Phase Jump Incident reporting Sygensys input to GC0181

April 2026

Proposal

- NESO should publish incident reports that in phase data from PMUs that are being installed now.
- The data should include the GSP nearest the incident / where peak phase jumps would be expected and multiple places around the GB grid to the regional and national impact can be assessed.
- The data update rate should be that from the PMU, typically 10 or 20ms.
- It should cover before and after the event like frequency data.
- Phase jumps of >12 degrees at any GSP with a PMU should trigger a GC0181 incident report. Even if no generation tripped, so that we get a better idea of the size and regularity of large phase jumps.

Introduction: AC phase changing with time

- Given ABC phase voltages the phase angle can be determined instantly
- Frequency is rate of change of phase angle ($\Delta \text{phase} / \Delta \text{time}$)
- Frequency can be used to calculate RoCoF ($\Delta \text{frequency} / \Delta \text{time}$)
- **Frequency and RoCoF are measured over a period of time**
- In a dynamic system Frequency and RoCoF depend on
 - Low pass filtering
 - Measurement over a time window
- They only have a precise meaning if you have a defined algorithm
- A pure phase jump causes a spike in RoCoF
- **The peak amplitude, shape and duration of the RoCoF spike depends on the frequency and RoCoF algorithm.**

Phase jumps and ROCOF are interrelated

ENTSOE Inertia and RoCoF v17 clean

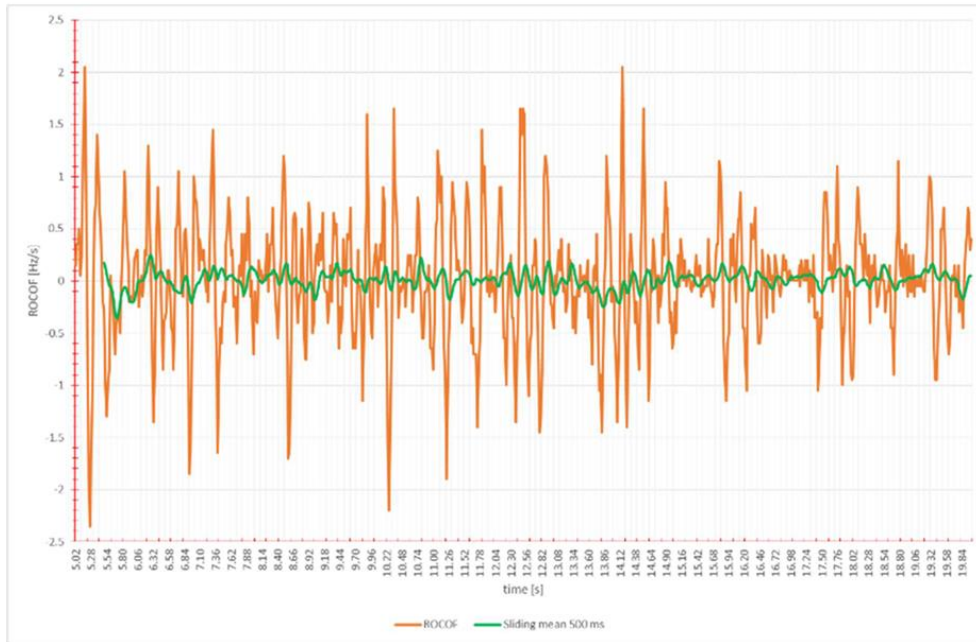
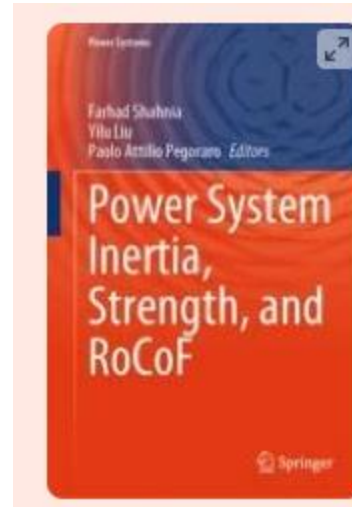


Figure 2 – RoCoF filtering (green colour) and un-filtered (brown colour) [11]



“The selection of appropriate RoCoF estimation methods is shown to be highly application-dependent, with no universal optimal approach existing across all use cases.”

[Power System Inertia, Strength, and RoCoF | Springer Nature Link](#)

Standardised algorithms

- The Grid Code in one place sets out an algorithm:-

ECC.6.6.1.9 In order to accurately monitor the performance of a **Grid Forming Plant**, each **Grid Forming Plant** shall be equipped with a facility to accurately record the following parameters at a rate of 10ms : -

- **System Frequency** using a nominated algorithm as defined by **The Company**
- The **ROCOF** rate using a nominated algorithm as defined by **The Company** based on a 500ms rolling average
- A technique for recording the **Grid Phase Jump Angle** by using either a nominated algorithm as defined by **The Company** or an algorithm that records the time period of each half cycle with a time resolution of 10 microseconds. For a 50Hz **System**, a 1 degree phase jump is a time period change of 55.6 microseconds.

To the best of my knowledge NESO have not shared this algorithm? Request action on NESO

Ideally this would be similar/the same as used in PMUs type M or P?

[IEEE C37.118.1™-2011](#) and [IEEE C37.118.1a™-2014](#)

Impact of large phase jumps

- Undesired tripping due to Vector Shift loss of mains protection
 - Historically a well know issue in the GB grid, see later in this document
- Response from synchronous generators, in extreme cases with potential for out of step condition
- PLL unlock in grid following generators
- Stresses on synchronous motor loads
- Potential trigger for inter regional SSO
- Potential impact on protection system

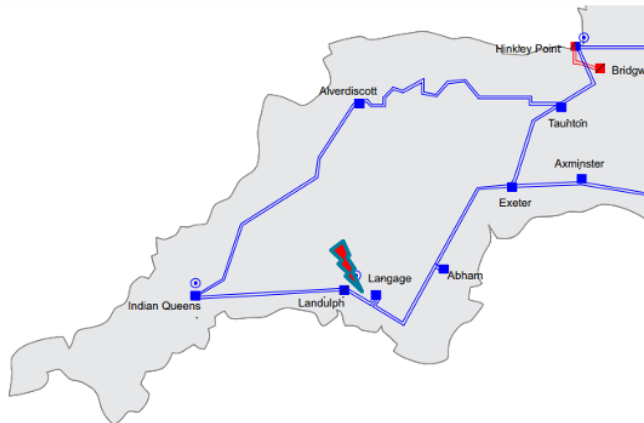
Phase jumps are a known issue

- There has been a long-term concern regarding the impact of phase jumps in GB system
- Initially this was related to Vector Shift loss of mains protection in distributed generation
 - This caused generators to trip for a vector shift of >6 degrees
 - Leading to coincident tripping of generation during system incidents

nationalgrid

EG tripping for transmission fault

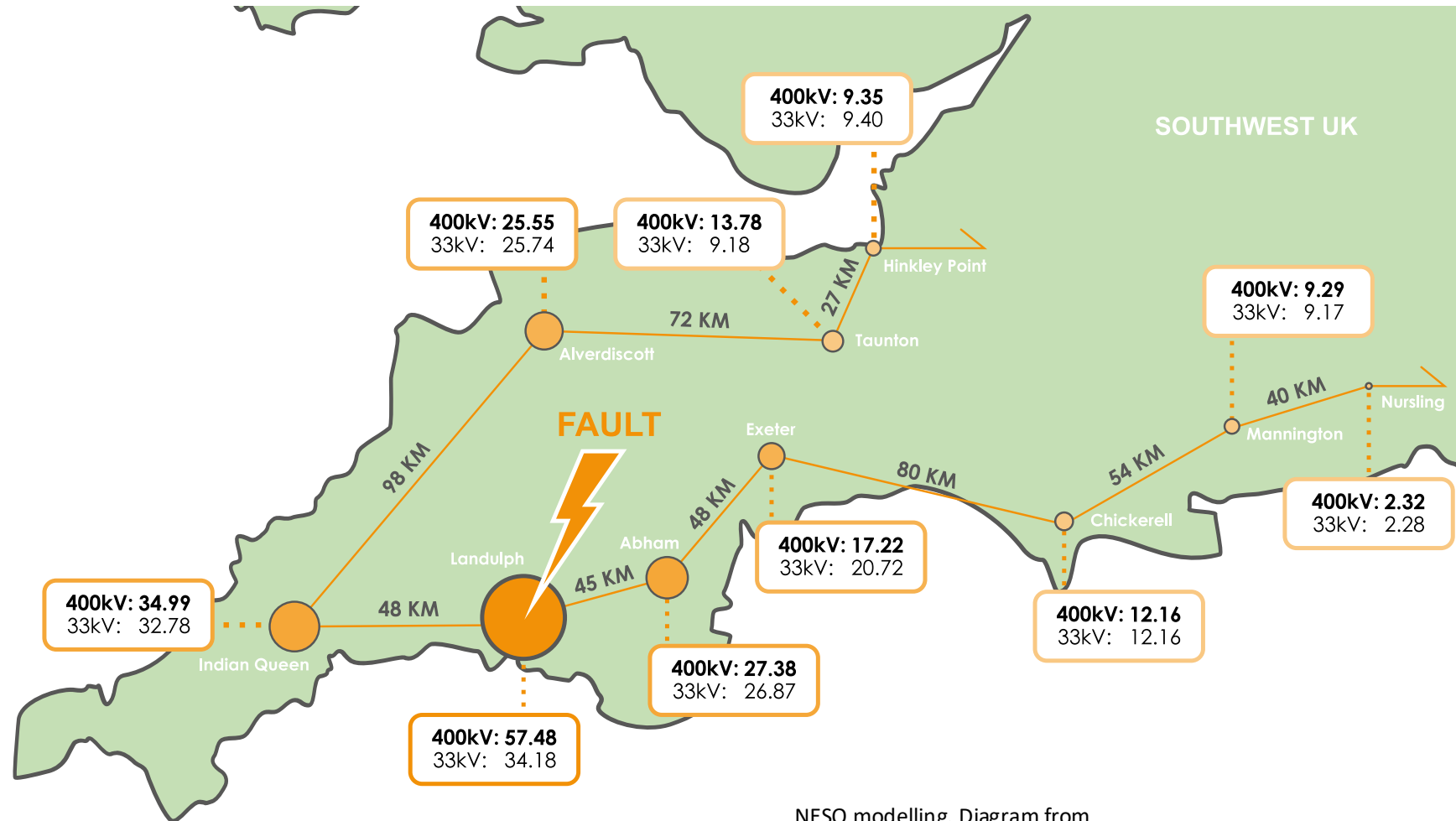
- VS protection could trip inappropriately over a wide area for transmission faults
- 22/5/2016 11:15; following the transmission fault at Langage – Landulph 400kV circuit, 380MW demand increase was observed



380MW “demand increase” from distribution network was due to coincident loss of distributed generation largely caused by phase jumps

[ENA LoM settings stakeholder workshop June 2018](#)

Example of vector shift >6 degrees across a large region around a fault



NESO modelling. Diagram from

<https://www.sygensys.com/wp-content/uploads/2022/09/Project-REV-WP2-Report.pdf>

Vector shift loss of mains protection has been therefore been prohibited

[GC0079 LoM decision letter](#) Dec 2017

[Vector Shift \(VS\) Based Loss of Mains Protection Settings: July 2017](#)

[Vector Shift Jul18 OpsForum.pptx](#)

Incomplete implementation of this change contributed to the scale of the 2019 outage

3.2. Summary of the Event

- At 16:52:33 on Friday 09 August 2019 there was a lightning strike on the Eaton Socon – Wymondley 400kV line. This was one of several lightning strikes that hit the transmission system on the day, but this was the only one to have a significant impact.
- The protection systems on the transmission system operated correctly to clear the lightning strike and the associated voltage disturbance was in line with what was expected.
- The lightning strike initiated the operation of Vector Shift protection resulting in the tripping of approximately 150MW of embedded generation.

Grid and Distribution Code modification history

GC0035, GC0079, DC0079, GC0137, GC0155

"That vector shift protection technique should not be used as Loss of Mains protection for type tested generators and that **the generation must not trip for vector shifts of up to 50°.**"

http://www.dcode.org.uk/assets/uploads/DC0079_Report_To_The_Authority_Type_Testing_Plant_Phase_2_Final_version_280318v1.pdf

"On further discussion with these manufacturers, it became clear that the need to undertake repeat type testing, particularly the proposed level of vector shift immunity of 50°, may require further investigation and specification before it is prescribed as a requirement."

http://www.dcode.org.uk/assets/uploads/Report_To_the_Authorityv3_1.pdf

Phase jump ride through is and Internationally recognized issue

IEEE P1547 requires that multi-phase DER ride through the following in the sub-cycle-to-cycle time frame: (1) positive-sequence phase angle changes of less than or equal to 20 degrees, and (2) individual phase angle changes less than 60 degrees.

<https://www.nrel.gov/grid/ieee-standard-1547/assets/pdfs/smart-inverters-applications-in-power-systems.pdf>

AS/NZS 4777.2:2020 states that “the inverter shall remain in continuous operation for a single phase voltage angle shift within a voltage cycle of at least 60 electrical degrees”.

<https://arena.gov.au/assets/2022/05/realising-electric-vehicle-to-grid-services-lessons-learnt-2.pdf>

[EN 50549-1:2019/A1:2023](#) type A and B generators

Introduced new phase jump immunity requirements
Minimum immunity for symmetrical **phase jumps $\geq 20^\circ$** .

Odessa Disturbance Texas 2021

Table 1.1: Causes of Reduction	
Cause of Reduction	Reduction [MW]
PLL Loss of Synchronism	389
Inverter AC Overvoltage	269
Momentary Cessation	153
Feeder AC Overvoltage	147
Unknown	51
Inverter Underfrequency	48
Not Analyzed	34
Feeder Underfrequency	21

* See explanation below.

https://www.nerc.com/pa/rrm/ea/Documents/Odessa_Disturbance_Report.pdf

IEEE 2800 - 7.3.2.4 Voltage phase angle changes ride-through

- The IBR plant shall ride through positive-sequence phase angle changes within a sub-cycle-to-cycle time frame of the applicable voltage of less than or equal to 25 electrical degrees.
- In addition, the IBR plant shall remain in operation for any change in the phase angle of individual phases caused by occurrence and clearance of unbalanced faults, provided that the positive-sequence angle change does not exceed the forestated criterion.
- Active and reactive current oscillations in the post-disturbance period that are positively damped shall be acceptable in response to phase angle changes.
- **Current blocking** in the post-disturbance period shall not be permitted.

https://www.ercot.com/files/docs/2022/05/24/EPRI_ERCOT_IBRTF_Meeting_Apr_8-2022.pdf

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Grid forming

New technology to help control maximum RoCoF

- Requirement for response from grid forming resources (phase jump active power)

“ENTSO-E sees the introduction of grid forming capabilities as a key element in the energy transition.”

[ENTSO-E views on RoCoF and Grid Forming capabilities related amendments of the Connection Network Codes](#)

- NESOs proposed new grid forming GC modification
 - What is the required response?
 - What size phase jump is a generator expected to ride through?
 - This should be for all IBR, not just grid forming
 - It should also set out requirements that could be applied to DERs

NESO expects all IBR plans to ride through phase jumps of 30 to 60 degrees.

[Guidance on Oscillation assessment for IBR](#)

Study Tests:

±30 degrees Phase Jump in AC grid voltage angle.

±3% step change in AC grid Voltage combined with ±10-degree phase jump in AC grid voltage angle.

This is a de facto requirement for IBRs, introduced by guidance not the grid code. There was no formal industry consultation.

GB Grid forming grid code limits are

Phase Jump Angle Withstand	degrees		60 degrees specified
Phase Jump Angle limit	degrees		5 degrees recommended

[Microsoft Word - Phase Angle Jump Performance Supplementary Guidance - Issue 1.docx](#)

NESO plan to use grid forming to help control phase jumps

THE GRID CODE

ISSUE 6

REVISION 36

12 December 2025

Phase Jump Angle	The difference in the measured phase angle of the voltage at the Grid Entry Point or User System Entry Point in a given mains half cycle compared with the measured phase angle of the voltage at the Grid Entry Point or User System Entry Point in the previous mains half cycle.
Phase Jump Angle Limit	The maximum Phase Jump Angle when applied to a GBGF-I which will result in a linear controlled response without activating current limiting functions. This is specified for a System angle near to zero which will be considered to be the normal operating angle under steady state conditions.
Phase Jump Angle Withstand	The maximum Phase Jump Angle change when applied to a GBGF-I which will result in the GBGF-I remaining in stable operation with current limiting functions activated. This is specified for a System angle near to zero which will be considered to be the normal operating angle under steady state conditions.

[Grid Forming Guidance Note – Issue 3.](#)

[Phase Angle Jump Performance Supplementary Guidance](#) Feb 2026

[Guidance on Oscillation assessment for IBR Version 2](#) Sept 2025

[Stability Pathfinder Phase 2 Compliance Note NESO](#) Version 2 June 2025

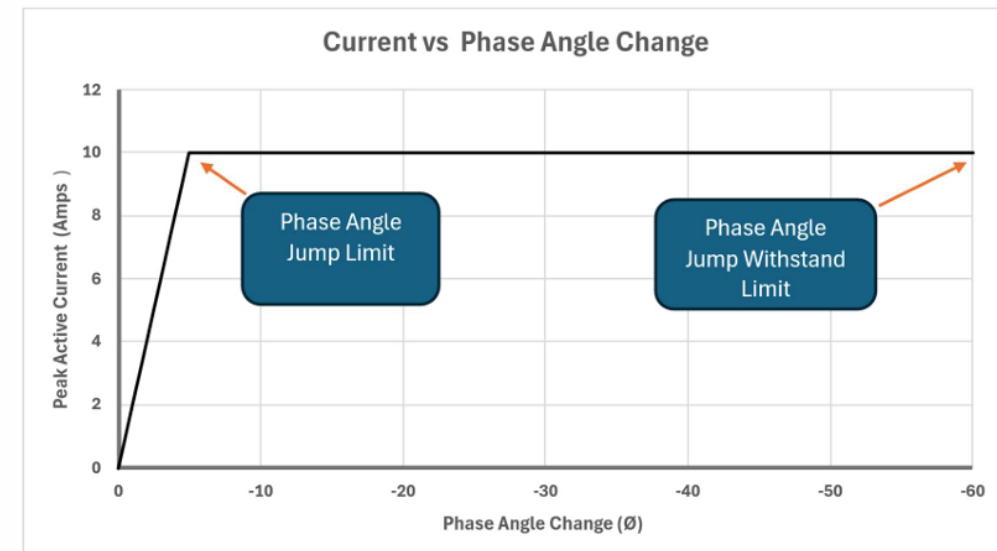


Figure 2: Phase Angle Jump Withstand Mode

NESO have provided related no data of real grid events

System security relies on phase jump, Frequency and RoCoF event ride through and control

- The impact of vector shift events on system security is still a concern
- [FRCR 2025](#), [Frequency Risk and Control Report 2025 Authority Decision](#)
- There is no explicit vector shift ride through requirement in the GB grid code
- Regional RoCoF is increasingly raised as a concern

concerns about the lack of explicit requirements for vector shift fault ride-through capability.	Whilst acknowledged the concern, we clarified the risks should be managed via Grid Code modification and compliance route. The discussion on fault ride-through requirements is included in industry engagement sessions when addressing Grid Forming Technology (GFM).
Regional RoCoF assessment, Regional inertia and system operability	We will be running an industry workshop to collate wider views and opinions about regional inertia and regional RoCoF. In the meantime, we are following system events to understand better the impact from regional inertia and regional RoCoF. Additionally, we are engaging with industry to develop GFM compliance requirement and market development.

[Frequency Risk and Control Report \(FRCR\) 2025 Update to SQSS Panel](#)

Current status

- Increase in proportion of grid following renewable generation
 - GFL generators provide no inertia
 - Rapid change of phase more likely
 - Phase jumps impact a wider area
 - Leading to higher RoCoF, over wider areas
- GB Mitigating actions
 - Vector shift protection prohibited
 - Limit for DER RoCoF anti islanding protection increased to 1Hz/sec for 500 ms
 - Procurement of Stability Services (inertia) – GFM and synchronous condensers
 - Introduction of grid forming
 - Roll out plan for PMUs to monitor grid phase angle changes
 - Limited reporting of RoCoF (GC0105 GC0151 reports) but
 - Only for major events
 - Limited to a national figure, with no regional information
 - Underlying phase data not provided
- **No phase jump data is published in NESO incident reports**
- **No phase jump ride through requirements specified**

Phase jump data

- NESO provide no regular reporting on phase jumps
- It would be useful to the industry
 - What size phase jumps are seen in the GB grid?
 - How frequently do they occur?
 - How would generators (and loads) respond to these events?
- It would be helpful in IBR control algorithm and protection relay development and validation
 - High sample rate (10 or 20 ms) phase data
 - In the region close to the fault for FRT and phase jump active power
 - Over a wide area for SSO prevention and PSS validation

Why 12 degree threshold proposed?

- Ideally SQSS would state maximum phase jump limit that is used by NESO and the TOs in system design, and operation and the grid code would clearly specify related ride through requirements.
- VS protection was at 6 degree
 - Setting threshold at this level would probably lead to too many reports
- EN standard for Type A and B generators is set for 20-degree ride through
- As does IEEE P1547
 - As there is no explicit GB requirement it is likely some GB plant will designed to comply with these international specifications
- 12 degree is proposed to high enough to avoid over reporting, yet low enough to give early warning of potential DER tripping.
 - Ideally data would also be available for GBGF developers on frequency of phase jumps of ~5 degrees, to support their analysis of NESOs recommended Phase Jump Angle Limit.

Housekeeping: Obsolete reference in grid code

ECC.A.5.4.1

Low Frequency Relays installed and commissioned after 1st January 2007 shall be type tested in accordance with and comply with the functional test requirements for **Frequency Protection** contained in Energy Networks Association **Technical Specification 48-6-5** Issue 1 dated 2005 “ENA **Protection Assessment Functional Test Requirements – Voltage and Frequency Protection**”.

This has been superseded by issue 3, search 48-6-5 on [ENA Document Catalogue \(ena-eng.org\)](http://ena-eng.org)

this is related to changes outlined in [IEC 60255 1xx: Protection relay functional standards for all | Megger](#)

[Frequency Risk and Control Report \(FRCR\) 2025 Update to SQSS Panel](#)

LFDD relay effectiveness – Some LFDD relays are very old from a higher inertia and lower RoCoF.

This is out of FRCR scope and is included in ENA Technical Specification 48-6-5 Issue 1 dated 2005 “ENA Protection Assessment Functional Test Requirements – Voltage and Frequency Protection” requirement on LFDD testing to be carried out every 3 years. This is referred by GC/ECC CC.A 5.4.1. This information is also included in the main report.