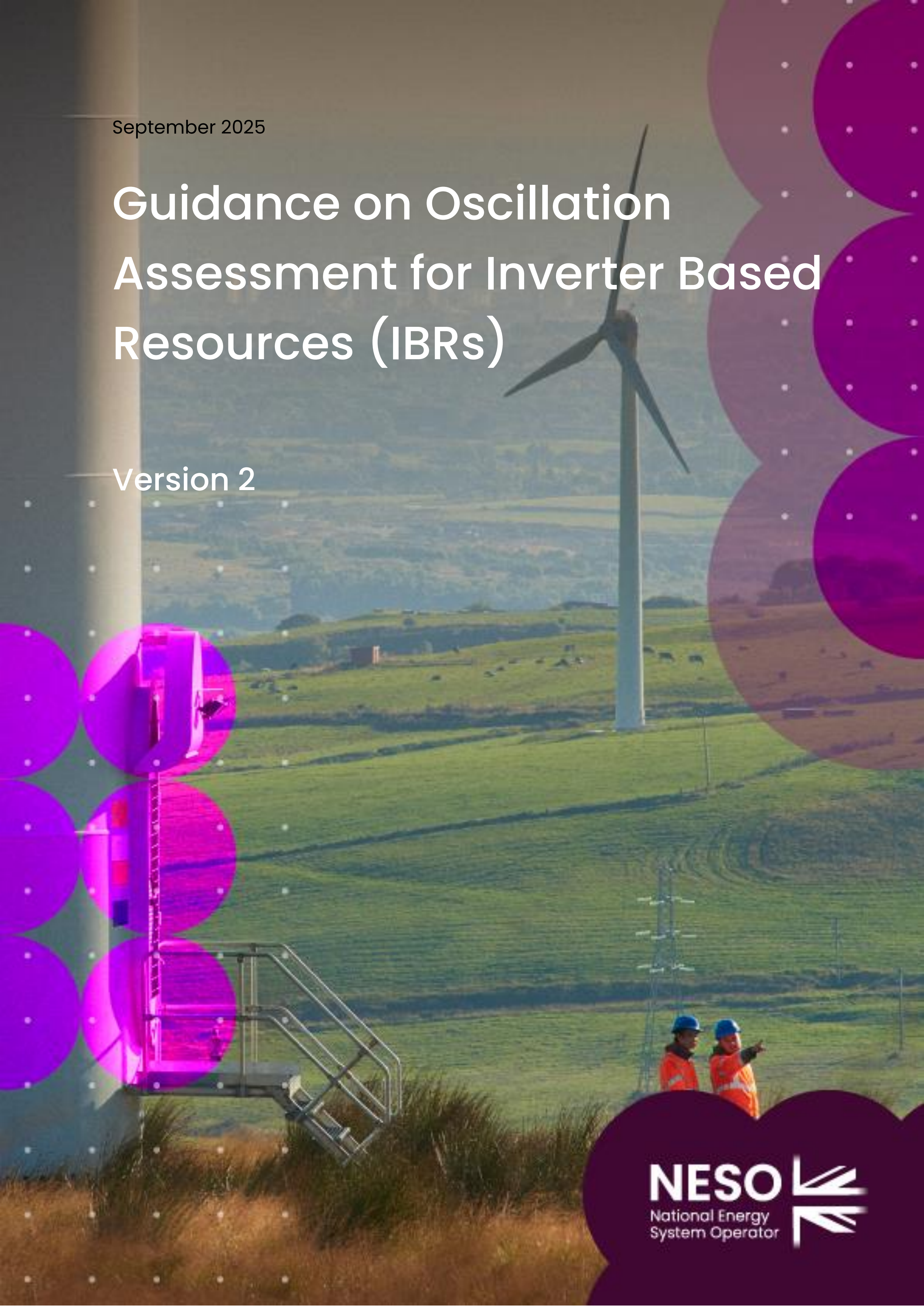
September 2025

Guidance on Oscillation Assessment for Inverter Based Resources (IBRs)

Version 2



NESO
National Energy System Operator

Contents

Forward 3
1 Introduction 4
2 Application of the Guidance Note 5
3 Simulation Tests 8
4 Reporting and Data Presentation 14

Forward

This Guidance Note has been prepared by the National Energy System Operator (NESO) to describe to Users how to demonstrate the appropriate damping performance of Inverter Based Resources (IBRs) against potential system oscillations. This Guidance Note specifies a set of studies which should be carried out by Users as part of the connection compliance process to ensure the safe operation and stability of the transmission system. This is the second version of the Guidance Note that incorporates feedback received from Users and the wider industry.

The prospective Users connecting directly or large Users embedded to the National Electricity Transmission System are required to be compliant with the Grid Code and requirements set out in Bilateral Agreement documents. This Guidance Note is prepared, solely, for the assistance of users to demonstrate the compliance.

The Operability Policy Manager (see contact details) will be happy to provide clarification and assistance required in relation to these notes. NESO welcomes comments including ideas to reduce the compliance effort while maintaining the level of confidence.

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1 Introduction

The fast pace of integrating IBRs into the transmission system is resulting in a significant change to the system dynamic and introducing new operational challenges. One of these challenges is system oscillations, especially sub-synchronous oscillations (SSO). While system oscillations are not a new phenomenon, the GB network has started to experience an increase in oscillation events. The recently observed oscillations were of higher magnitude and frequency compared to what was typically experienced in synchronous machine-based systems [1],[2].

NESO have been working with academia, Transmission Owners, Users and other key industry stakeholders on the development of this guidance. The development has also taken into consideration lessons learned from recent oscillation investigations and other industry best practices including CIGRE[3] and ENTSO-e[4]. As a result, NESO proposes a set of small signal studies that should be carried out by all Users as part of the compliance process to identify and mitigate the risk of system oscillations.

This version of the Guidance Note prepared by the National Energy System Operator (NESO) describes to Users how to demonstrate the appropriate damping performance of Inverter Based Resources (IBRs) against potential system oscillations. The latest version of the Guidance Note incorporates the feedback NESO has received from industry on the previous version of this note.

The prospective Users are required to be compliant with the Grid Code and the requirements set out in Bilateral Agreement documents. This Guidance Note is prepared solely for the assistance of users to demonstrate compliance. Alternative methods and techniques can be adopted by the User after consultation with NESO.

The studies in this guidance shall be carried out with an AC grid represented either as a Thevenin source or by using an equivalent network model provided by NESO. It should be noted that whilst these SSO studies do not completely mitigate the risk of oscillations occurring, they have been seen to significantly reduce the risk. Further large-scale studies may still be required if necessary. The small signal tests proposed in this guidance document include both time domain and frequency domain techniques. It is suggested to compare both time domain and frequency domain methods to establish whether there are any issues. It is advised that these studies should be performed in the early phases of the project so that if any mitigation measures are required, they can be taken in a timely manner.

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[1] Real-World Subsynchronous Oscillation Events in Power Grids with High Penetrations of Inverter-Based Resources, IEEE Transactions on Power Systems, 2022.
[2] Sub-synchronous oscillations in GB Current state and plans for future management, NESO, 2024.
[3] Guidelines for Subsynchronous Oscillation Studies in Power Electronics Dominated Power Systems, CIGRE, 2023
[4] Interactions between HVDC systems and other connections, ENTSO-e, 2018.

2 Application of the Guidance Note

The tests presented in this document are applicable for all IBR technologies, including Battery Energy Storage System (BESS), Photovoltaic(PV), wind, co-located sites, etc. For HVDC systems and DC connected PPMs, the assessment should be covered by SSTI and SSCI studies instructed by NESO during the connection stage.
NESO may request further studies beyond or different to what is specified in this guidance if the results or field measurements reveal unexpected performance from the scheme under scrutiny.

Study Types

There are various simulation techniques that can be employed to investigate the behaviour of IBRs in a non-synchronous dominated network. The techniques proposed in this guidance are:

- Step change study
- Small signal injection study
- Active frequency scans
- Eigenvalue analysis

All simulations in this guidance should be performed in a detailed EMT environment using an EMT model of the scheme that is a true representation of the plant performance. The EMT model used should be the same one that is submitted to NESO as part of the Compliance Procedure. All controllers that influence the scheme's response to oscillations must be modelled accurately, including Power Park Controller (PPC) and any associated cycling time and communication delays.

Applicable Studies based on Connection Type

The studies that should be performed are based on the connection type. For each connection type there are suggested optional and required studies that should be performed. A matrix of the required studies for each connection type is displayed in Table 1.

Table 1 - Study Matrix

	SSO Test Methods				
Connection Type	Step change Section 3.1	Small signal injection Section 3.2.1	Small signal injection Section 3.2.2	Frequency scan Section 3.3	Eigenvalue analysis Section 3.4
Type A/B	Required	Not required	Not required	Not required	Not required
Directly Connected (Type C/D)	Not required	Required	Not required	Required	Not required
Large BEGA*	Not required	Required	Not required	Required	Not required
Medium BEGA*	Not required	Not required	Not required	Not required	Not required
Small BEGA*	Not required	Not required	Not required	Not required	Not required
BELLA**	Not required	Required	Not required	Required	Not required
LEEMPS***	Not required	Not required	Not required	Not required	Not required

* Bilateral Embedded Generator Agreement (BEGA)
** Bilateral Embedded Licence Exemptible Large Power Station Agreement (BELLA)
*** License Exemptible Embedded Medium Power Stations (LEEMPS)

Test Scenario Configurations

The studies should be performed under different operating conditions with the suggested configurations for all studies being:

- Control Mode**:** The studies should be performed with voltage control mode by default. If the plant is contracted for other control modes including reactive power control or power factor control, the tests should be performed in these modes as well.
- Short Circuit Level (SCL): All test cases should be done using minimum SCL unless otherwise suggested by NESO. For Grid Forming (GFM) technology, test cases should be performed with maximum and minimum SCL conditions.
- Active Power: Tests should be run at minimum and maximum active power levels with both import (where applicable) and export conditions.
- Reactive Power: If study is to be run in reactive power control mode, then the test should be performed at Min, Max and Zero reactive power level in combination with minimum and maximum active power dispatch.
- Frequency Response: Unless requested by NESO, Limited Frequency Sensitive Mode (LFSM) should be On and Frequency Sensitive Mode (FSM) should be Off.
- Operating Mode: The study should be conducted for both Grid Forming and Grid Following modes if the plant is intended to be operated in both modes.
- Dynamic Frequency Services: Operation while providing frequency services is not required as part of the Compliance process, however, they may be additional studies required as part of the balancing services process.

Technology Specific

- For co-located projects the studies should be conducted with all technologies that are part of the project in operation. As an example, for a co-located project involving a wind farm and a BESS, the complete study must be conducted for the wind farm and BESS both in operation.
- For extension projects, including capacity expansion, plant modification or control system update, the study should be conducted with both old and new equipment. The new control system that covers the overall site, including all changed parameters, if any, should be included in the model.
- For HVDC systems and DC-connected Power Park Modules (PPMs), the study is not needed if they have conducted detailed studies such as SSTI and SSCI. However, NESO may request the users to conduct a specific set of tests if the results or site performance reveal unexpected performance from the scheme under scrutiny.

3 Simulation Tests

This section describes the simulation tests and provides an overview of acceptable performance and expected reporting format. The test configurations are described in Section 2.

3.1 Step change study

In this study a series of small step changes are applied to the grid voltage and phase angle to demonstrate the behaviour of the scheme being studied. This study provides a good indication of scheme performance and hence it is advised to be performed as a first step.

Study Tests:

3.1.1 ±5% step change in AC grid voltage from nominal voltage.

3.1.2 ±30 degrees Phase Jump in AC grid voltage angle.

3.1.3 ±3% step change in AC grid Voltage combined with ±10-degree phase jump in AC grid voltage angle.

Report:

- Simulation study results should include Vac magnitude and phase, frequency, Qac, Pac, Iac magnitude and phase plots at the point of common coupling. Simulations should be run until steady state conditions are reached.
- A summary and observation of results should be to be provided.

Acceptable Response:

- Response time should be within the timings specified in the Grid code.
- Oscillation magnitude should not be more than 5% peak to peak and settling time should be less than 2s. In the case of wind farms, longer settling time may be acceptable.

3.2 Small signal injection study

Small signal EMT perturbation simulations have been widely recognised as one of the best ways to explore the behaviour of IBRs against small test signals.
For the purposes of these studies, the AC grid is represented as a Thevenin equivalent whilst the scheme under scrutiny should be represented using a detailed EMT model. The desired frequency of oscillation is injected into an AC grid voltage and angle to evaluate the behaviour of the scheme being studied.

3.2.1 Voltage magnitude oscillation injection

A PSCAD example of a voltage amplitude injection circuit is shown in the diagram below.

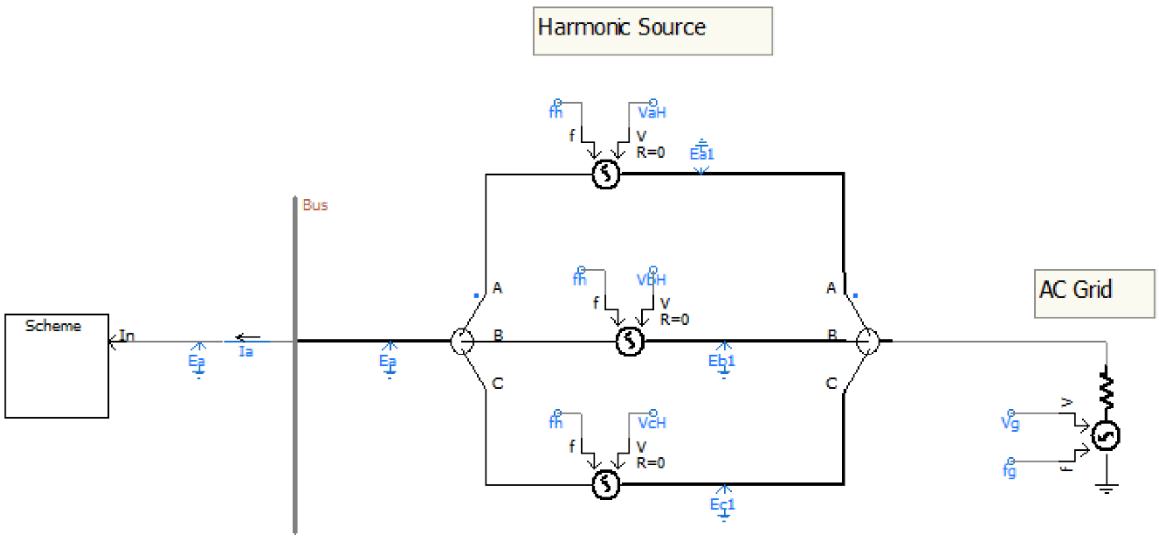

Figure 1 Example study setup for limited time domain study.

Recommended Test Parameters:

- Frequencies ranging from 1Hz to 100Hz (or a specific frequency range provided by NESO) to be injected in series with the grid with no more than 1Hz gap in each simulation.
- An injection signal magnitude of 1% of nominal voltage is recommended. The User is allowed to choose a different injection amplitude as long as the overall system remains in the linear region.
- Injection should remain until steady-state conditions have been reached or for 5 seconds, whichever is longer.

Report:

- This test is expected to be run in an automated manner, with the main results captured in the body of the report and the detailed time-domain simulation studies provided in an appendix.
- The results in the body of the report can be summarised in a single graph that calculates the ratio of the voltage magnitude "with plant" to the voltage magnitude "without the plant" at a particular oscillation frequency. These magnitudes can be calculated using Fast-Fourier Transformation (FFT) and the instantaneous values of the voltages (see Section 4).
- Time series simulation results for the appendix should include Vac magnitude and phase, frequency, Qac, Pac, Iac magnitude and phase plots at the point of common coupling. Simulations should be run until steady state conditions are reached.
- A summary and observation of the results should be provided.

Acceptable Response:

- Ideally no increase in magnitude of injected oscillations with positive damping characteristics. The User is encouraged to provide mitigation measures for negatively damped frequency ranges. Response shall be demonstrated by plotting the PCC voltage with and without the scheme being studied connected. Refer to Section 4 for expected response from this study and suggestions for automating and presenting the results.
- No instability, under different mode of oscillation, or significant change in active or reactive power output should be observed during or after the injection.
- Once the injection is removed the system should recover to pre-disturbance conditions.

3.2.2 Voltage angle oscillation modulation

In this test, the Thevenin voltage source's angle is modulated to observe the behaviour of the scheme.

Recommended Test Parameters:

- Frequencies ranging from 1Hz to 49Hz (or a specific frequency range provided by NESO) to be modulated in voltage source of the Thévenin equivalent with no more than 1Hz gap in each simulation.
- Phase angle modulation of ±2 degrees should be applied.
- Injection should remain until steady-state conditions have been reached or for 5 seconds, whichever is longer.

Report:

- This test is expected to be run in an automated manner, with the main results captured in the body of the report and the detailed time-domain simulation studies provided in an appendix.
- Time series simulation results for the appendix should include Vac magnitude and phase, frequency, Qac, Pac, Iac magnitude and phase plots at the point of common coupling. Simulations should be run until steady state conditions are reached.
- A summary and observation of the results should be provided.

Acceptable Response:

- It is expected that grid following converters show very limited response for angle oscillations.
- Grid forming plant would have a P/f droop response below the 5Hz range. The inertia element of the grid forming plant is expected to be in phase with the modulated angle.
- Once the injection is removed the system should recover to pre-disturbance conditions.

3.3 Active frequency scans

A Dynamic Frequency Scan is a method to evaluate a scheme's impedance and phase angle, providing insight into scheme behaviour. Moreover, it is not practical to cover a large frequency range utilising a time domain study due to model complexity and computational time constraints. Therefore, to support the small signal time domain study, an active frequency scan is proposed.

To conduct this study, the scheme under scrutiny is represented by a detailed EMT model while the AC grid is represented as a Thevenin equivalent. A range of frequencies of interest are injected into the scheme being studied to obtain the characteristics.

In the previous guidance, a single-input single-output (SISO) approach was proposed. This approach simplifies the system to a single pathway from input to output which overlooks interactions and interdependencies present in real systems. To improve the frequency scan analysis this guidance proposes the use of a Multi Input Multi Output (MIMO) approach[5,6]. A MIMO approach provides more

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[5] MMC Impedance Modelling and Interaction of Converters in Close Proximity, IEEE Journal of Emerging and selected topics in Power Electronics, 2021

[6] Analysis of Multi-converter Network Impedance using MIMO stability Criterion for Multi-loop Systems, Electric Power Systems Research, 2022

accurate and reliable analysis by accommodating the complexity and multiple interactions present in real-world systems. However, the User is allowed to adopt either the SISO or MIMO method for the studies until six months following the publication of this guidance. Further updates and notices will be provided on NESO's website.

A MIMO approach requires positive and negative sequence injections to be applied with the results from both sets of injection used to determine the impedance characteristics. The small signal can be a voltage signal in series with a grid as shown in Figure 2(a) or a current injection in parallel with a grid as shown in Figure 2(b). The impedance characteristics of the scheme under scrutiny and the AC grid are measured by performing Fourier transformation on the Voltage (V) and current (I) signal.

There are several tools being developed that can perform the MIMO studies and analysis. For PSCAD users, it is recommended that they request a version of the MHI Full Impedance/Admittance Scanning (3 Phase) tool. The MHI tool generates all of the relevant information and plots for the report.

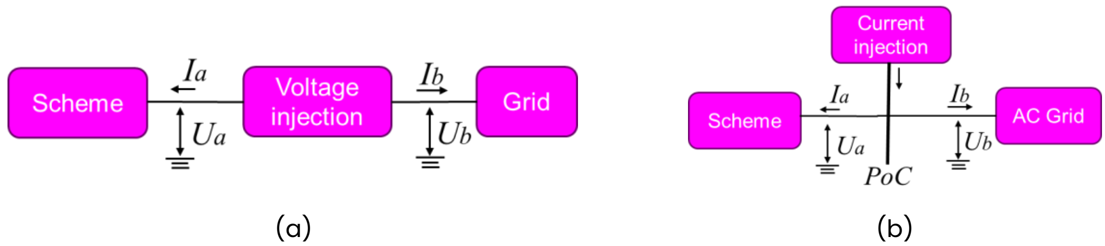

Figure 2 Example study setup for limited time domain study.

Recommended Test Parameters:

- The injected current or voltage amplitude should not be so small that it is lost in the noise and should not be too large to cause any non- linear effects. NESO normally starts the testing with a magnitude of 0.5%.
- The frequency increment should be 1Hz increment for 1-100 Hz, and 10 Hz increment for 100-500 Hz. If multiple injections at the same time is used then a maximum of five frequencies is allowed, but the User should ensure that the results are consistent with single harmonic injection.

In some instances, additional specific frequency ranges might be required and will be agreed with NESO.

Report:

- Scheme and AC grid impedance (3*3 matrix). Impedance magnitude (ohm) and angle (degree) vs Frequency (Hz) plots (editable version of the Scheme's impedance values should be included). Any reference frame is accepted, preferable Positive and Negative (PN). Zero sequence results may also be included if calculated.
- Small signal stability assessment: Include the Gain Margin for crossing points and their frequencies, with Nyquist plot in complex field and Bode plots showing the eigenlocus.
- A summary and observation of results.

Acceptable Response:

The assessment of small signal stability should demonstrate stable operation. The system is deemed to be stable if the eigenloci do not encircle the critical point of [-1, 0] when drawn in the complex Nyquist plot.

3.4 Eigenvalue analysis

The Eigenvalue analysis is another method of calculating the oscillatory modes, frequency of oscillation and damping co-efficient. It is becoming one of the main/preferred methods of investigating interaction phenomena and applying mitigation measures.

This is a frequency domain study, but detailed EMT model assumptions are required for the scheme under scrutiny. In this methodology the linear state space representation of the system and connected AC grid are represented as a Thevenin equivalent and are used to determine the Eigenvalues of the full system.

In the past it has been considered a complicated method to estimate the Eigenvalues but nowadays this functionality has been included in power system tools which solves the state space solution and provides oscillation modes, frequency of oscillation and damping co-efficient. In order to validate the study, it is recommended that results obtained from the Eigenvalue method should be consistent with the results obtained from studies of Section 3.1, 3.2 and 3.3.

Report:

- Oscillation frequencies of the scheme under scrutiny.
- Eigenvalue results comparison with frequency scan.

Acceptable Response:

- All closed-loop eigenvalues are expected to be in the left-hand plane of the Laplace plane.
- Minimum 10% damping ratio is expected for all oscillation modes.

4 Reporting and Data Presentation

The following summarises suggested and acceptable forms of data presentation in the report. The majority of the simulations proposed in this guidance are expected to be run using automation scripts. NESO would accept the detailed time domain results to be added in an automatically-produced appendix of the study while summary of the results and findings can be presented in the main report. The appendix must be well-labelled and captioned such that NESO is able to assess each case and trace it back to the main report. Users are expected to save any underlying data for the tests that is not part of the report and share it with NESO when requested.

<u>Step Change Studies</u>

While the detailed results of Section 3.1 can be provided in the study appendix, verbal summary of the results should be stated in the main report. Observations such as plant instability, unexpected oscillations, not meeting the requirement, etc. should be articulated clearly in the main report.

<u>Voltage Injection Studies</u>

For section 3.2.1, for each voltage oscillation injection a comparison of "with plant" and "without plant" would reveal whether the plant would damp or amplify the oscillation. Figure 3 shows an example of the voltage oscillations with a wind farm and without the wind farm. Note that in this example the introduction of the wind farm has resulted in damping the voltage oscillation at this particular frequency.

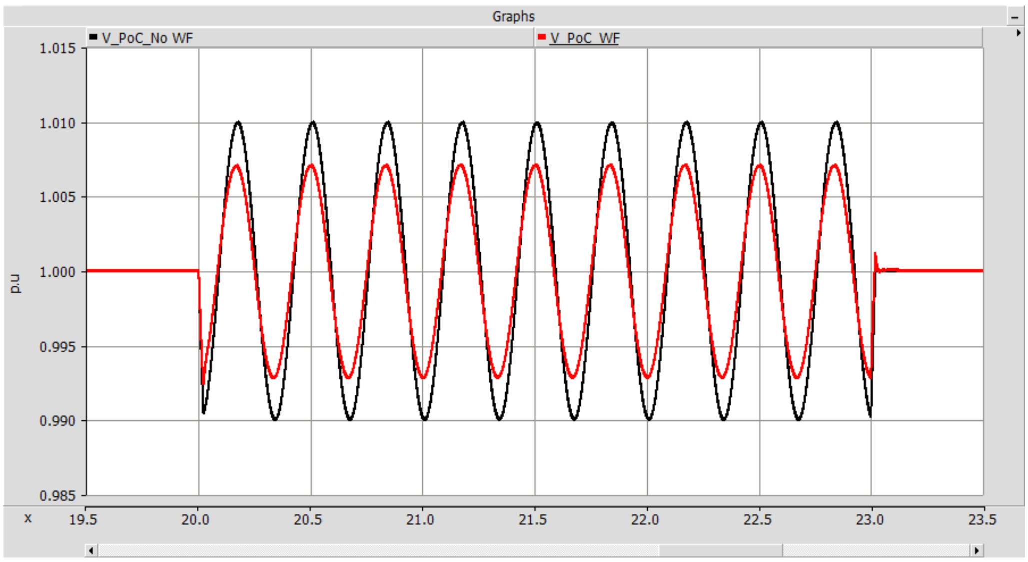

Figure 3 PoC voltage with and without the wind farm (WF)

The series of injections can be summarised into a single graph that calculates the ratio of the voltage magnitude "with plant" to the voltage magnitude "without the plant" at a particular oscillation frequency. These magnitudes can be calculated using Fast-Fourier Transformation (FFT) of the instantaneous values of the voltages. For example, Figure 4 shows an example of this ratio. When the ratio is below 1 this means that connecting the plant will result in improved system damping reducing the voltage oscillations magnitude.

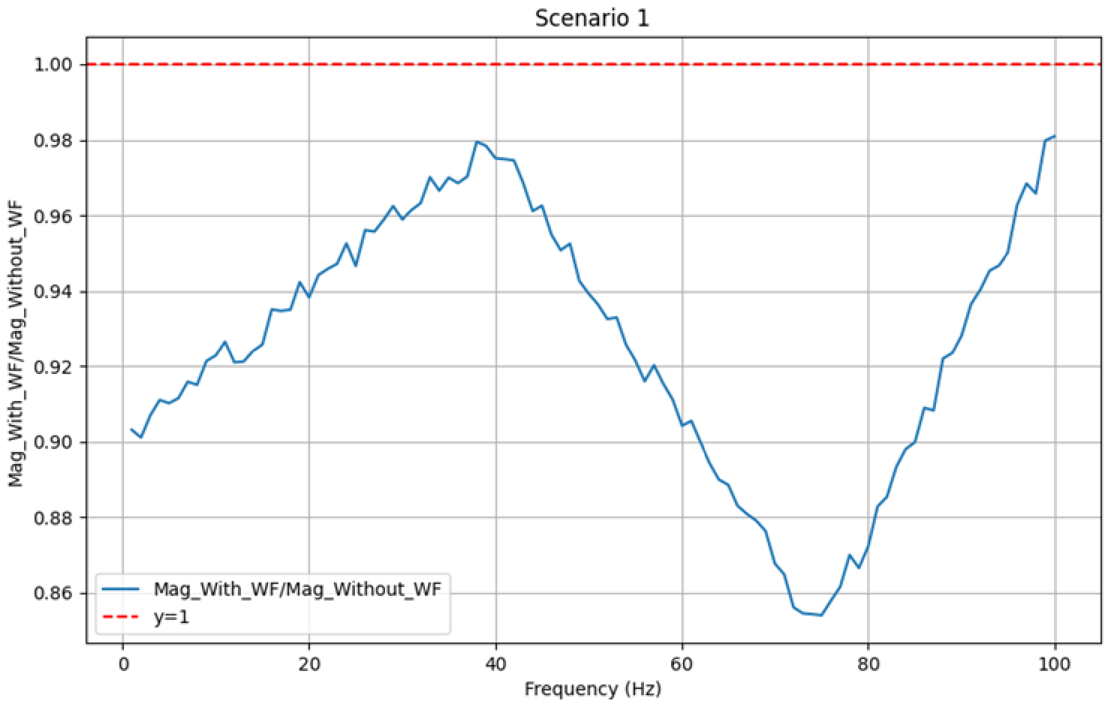

Figure 4 Ratio of the voltage oscillation magnitude with the plant to without the plant. Data is provided as an example; actual plant performance may be different.

The above presentation of the results allows for the result to be automated and reviewed in straightforward manner. It is expected that figures similar to Figure 4 to be presented in the main report while the detailed time domain results of every injection presented in the appendix.

<u>Active Frequency Scans</u>

For the active frequency scans in section 3.3, it is expected that the MIMO tool being used produces the required information and plots.

An example is provided here to illustrate the impedance plots and graphics for a specific operating point using a preliminary version of the MHI MIMO tool (Full Impedance/Admittance Scanning (3 Phase) tool). The PSCAD model example "statcom_6pls_pwm" is used in this example. Impedance scanning is performed from 1 Hz to 500 Hz, one frequency at a time.

The parameters used in PSCAD for performing the scan in this example are:

Parameter	Value
System Frequency (Hz)	60
Base Voltage (L-L, RMS) (kV)	115
Disturbance Magnitude (% of Base Voltage)	0.5%
Minimum Frequency (Hz)	1
Maximum Frequency (Hz)	500
Number of Frequency for Each Injection Set (Hz)	1
Time to Start Scanning (s)	3
Time to Sample Impedance Calculation (s)	2
Duration of Run (s)	3003
Solution Time Step (us)	20

The scheme and source impedance data produced by the MIMO tool are shown below.

Frequency	Zdd (ohm)	Zdd (degree)	Zqd (ohm)	Zqd (degree)	Z0d (ohm)	Z0d (degree)	Zdq (ohm)	Zdq (degree)	Zqq (ohm)	Zqq (degree)	Z0q (ohm)	Z0q (degree)	Zd0 (ohm)	Zd0 (degree)	Zq0 (ohm)	Zq0 (degree)	Z00 (ohm)	Z00 (degree)
1.00E+00	3.31E+01	-4.87E-02	5.49E+00	1.73E+02	4.33E-04	-1.79E+02	1.46E+02	-1.27E+00	3.00E+01	1.74E+02	1.39E-03	1.79E+02	4.65E-07	9.51E+01	9.04E-08	-1.00E+02	2.47E-01	6.58E+01
2.00E+00	3.08E+01	2.66E+00	1.97E+00	-1.34E+02	6.11E-05	-1.75E+02	1.35E+02	2.33E-01	1.37E+01	-1.48E+02	1.89E-04	-1.78E+02	6.06E-07	1.29E+02	7.62E-08	2.67E+01	4.55E-01	7.71E+01
3.00E+00	2.92E+01	7.65E+00	5.78E+00	-7.81E+01	8.97E-06	-1.69E+02	1.28E+02	4.39E+00	2.73E+01	-9.23E+01	2.70E-05	-1.72E+02	9.99E-07	1.12E+02	1.79E-07	2.14E+01	6.75E-01	8.12E+01
4.00E+00	2.87E+01	1.30E+01	9.99E+00	-7.66E+01	1.35E-06	-1.63E+02	1.24E+02	8.66E+00	4.62E+01	-8.65E+01	4.01E-06	-1.66E+02	1.51E-06	1.22E+02	5.35E-07	2.82E+01	8.97E-01	8.32E+01
5.00E+00	2.84E+01	1.80E+01	1.39E+01	-7.56E+01	2.06E-07	-1.58E+02	1.22E+02	1.25E+01	6.35E+01	-8.51E+01	6.02E-07	-1.60E+02	1.75E-06	1.29E+02	9.53E-07	3.46E+01	1.12E+00	8.44E+01
6.00E+00	2.80E+01	2.15E+01	1.62E+01	-7.68E+01	3.11E-08	-1.53E+02	1.20E+02	1.51E+01	7.50E+01	-8.61E+01	8.97E-08	-1.56E+02	1.91E-06	1.44E+02	1.28E-06	4.33E+01	1.34E+00	8.52E+01
...																		
4.99E+02	2.46E+02	7.86E+01	9.04E+01	-1.97E+01	9.31E-11	-1.24E+01	9.65E+01	1.64E+02	2.13E+02	8.12E+01	1.84E-10	1.26E+01	4.78E-05	1.20E+02	6.36E-05	1.42E+02	2.16E+02	8.33E+01
5.00E+02	2.42E+02	7.81E+01	7.37E+01	-2.99E+01	1.09E-10	1.45E+02	9.72E+01	1.62E+02	2.13E+02	7.97E+01	4.69E-11	-1.37E+02	2.51E-04	-1.50E+02	5.37E-04	1.40E+02	2.18E+02	8.33E+01

Figure 5: Scheme impedance from MHI tool, dq0 frame, 3*3 matrix

Frequency	Zdd (ohm)	Zdd (degree)	Zqd (ohm)	Zqd (degree)	Z0d (ohm)	Z0d (degree)	Zdq (ohm)	Zdq (degree)	Zqq (ohm)	Zqq (degree)	Z0q (ohm)	Z0q (degree)	Zd0 (ohm)	Zd0 (degree)	Zq0 (ohm)	Zq0 (degree)	Z00 (ohm)	Z00 (degree)
1.00E+00	4.61E+00	5.07E+00	2.60E+01	-3.26E-01	8.82E-04	-1.79E+02	2.60E+01	1.80E+02	4.61E+00	5.05E+00	2.82E-03	1.79E+02	7.14E-09	8.55E+01	1.87E-07	8.21E+01	4.58E-01	8.96E+01
2.00E+00	4.67E+00	9.97E+00	2.60E+01	-6.87E-01	1.24E-04	-1.75E+02	2.60E+01	1.79E+02	4.67E+00	9.46E+00	3.85E-04	-1.78E+02	1.28E-08	8.42E+01	3.59E-07	8.65E+01	9.02E-01	8.96E+01
3.00E+00	4.76E+00	1.49E+01	2.60E+01	-9.66E-01	1.82E-05	-1.70E+02	2.61E+01	1.79E+02	4.73E+00	1.52E+01	5.50E-05	-1.73E+02	1.91E-08	8.61E+01	5.31E-07	8.83E+01	1.36E+00	8.95E+01
4.00E+00	4.89E+00	1.96E+01	2.60E+01	-1.29E+00	2.75E-06	-1.64E+02	2.61E+01	1.79E+02	4.89E+00	1.97E+01	8.15E-06	-1.66E+02	5.09E-08	9.04E+01	7.45E-07	8.68E+01	1.81E+00	8.93E+01
5.00E+00	5.05E+00	2.38E+01	2.60E+01	-1.63E+00	4.18E-07	-1.58E+02	2.60E+01	1.78E+02	5.05E+00	2.38E+01	1.23E-06	-1.61E+02	3.45E-08	8.75E+01	8.86E-07	9.01E+01	2.26E+00	8.92E+01
6.00E+00	5.24E+00	2.79E+01	2.61E+01	-1.94E+00	6.33E-08	-1.54E+02	2.60E+01	1.78E+02	5.27E+00	2.75E+01	1.83E-07	-1.57E+02	6.27E-08	9.01E+01	1.07E-06	9.11E+01	2.71E+00	8.90E+01
...																		
4.99E+02	1.25E+02	3.44E+01	8.56E+00	-1.11E+02	1.16E-12	-1.07E+02	8.54E+00	6.89E+01	1.25E+02	3.44E+01	2.27E-12	-7.75E+01	2.26E-05	-1.30E+02	5.10E-05	-9.46E+01	1.26E+02	3.43E+01
5.00E+02	1.25E+02	3.44E+01	8.54E+00	-1.11E+02	1.52E-12	3.17E+01	8.54E+00	6.90E+01	1.25E+02	3.44E+01	6.10E-13	-5.92E+01	4.29E-05	-1.49E+02	6.59E-05	-1.26E+02	1.26E+02	3.42E+01

Figure 6: Source impedance from MHI tool, dq0 frame, 3*3 matrix

The scheme and source impedance plots are shown below.

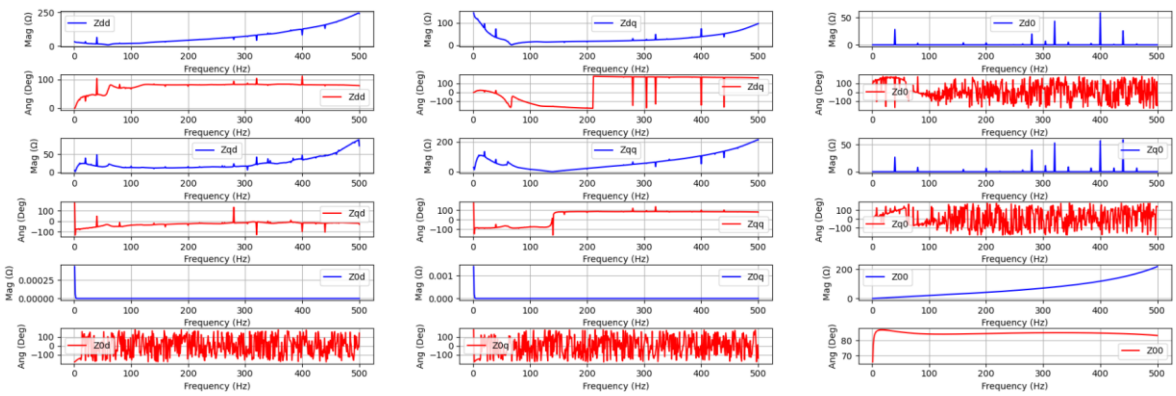

Figure 7: Scheme impedance from MHI tool, dq0 frame, zero sequence included

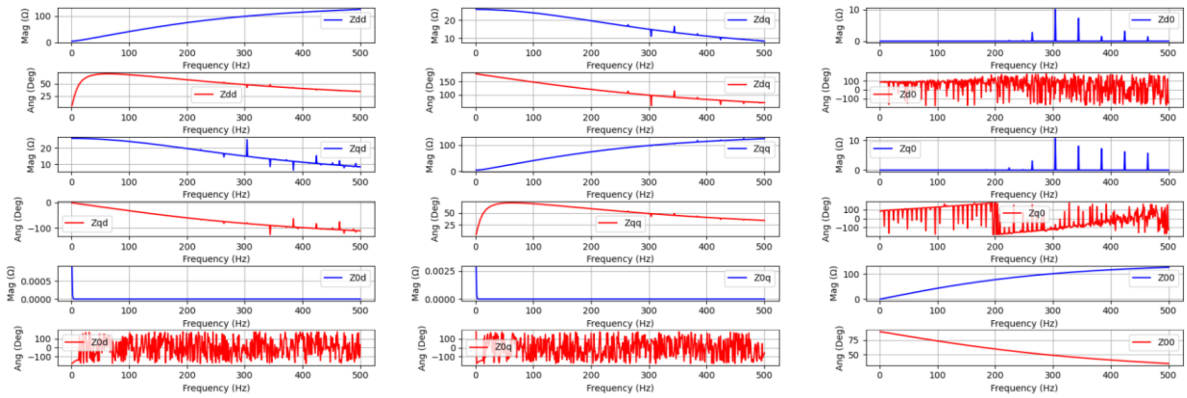

Figure 8: Source impedance from MHI tool, dq0 frame, zero sequence included

An example of the Nyquist plot that gets generated is shown below. From the plot, the scheme is deemed stable if the eigenloci do not encircle the critical point [-1, 0].

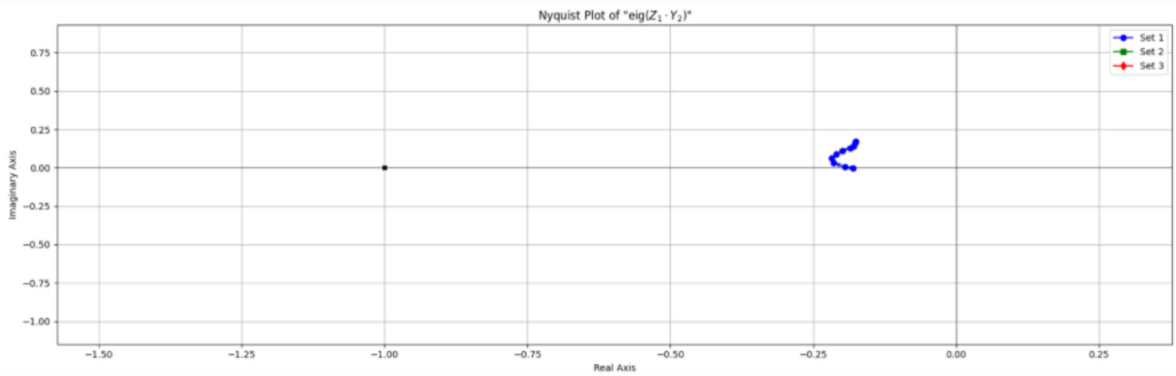

Figure 9: Nyquist plot

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