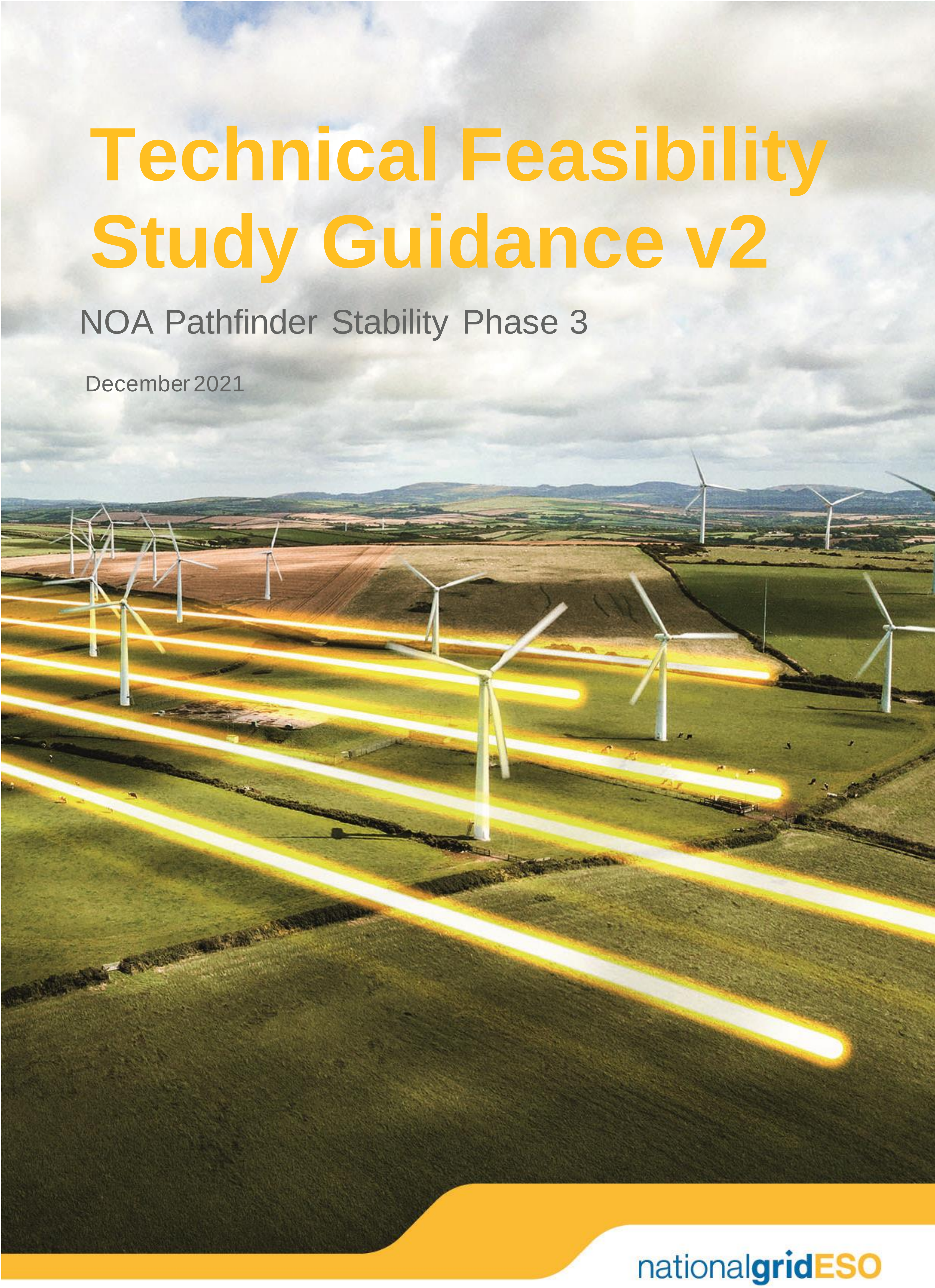
Technical Feasibility Study Guidance v2

NOA Pathfinder Stability Phase 3

December 2021



nationalgridESO

Information that is supplied to Tenderers as part of this ITT is supplied in good faith. The information contained in the ITT Tender Pack and in any related written or oral communication is believed to be correct at the time of issue but NGESO will not accept any liability for its accuracy, adequacy or completeness and no warranty is given as such. Any reliance by a Tenderer or any third party on the information provided by NGESO as part of this ITT is at the Tenderer's and/or third party's risk.

Version Control

Date	Version number	Notes
	1.0	Initial version
	2.0	1. Tests steps are simplified irrespective of the technology. 2. Time constant for EMT to RMS conversion is specified. 3. Inertia availability requirement is updated. 4. Updated Inertia equations for Test 2. 5. Minor changes to align the Guidance Note with the Technical Specifications.

Contents

Overview

1. Aim

The aim of this document is to provide an overview of the desktop-based simulation studies that are required as part of the NOA Pathfinder Stability Phase 3 tender. Through the technical feasibility study, NGESO will:

- determine key technical capabilities of all proposed solutions
- decide if the proposed solutions meet the key technical specification

The information provided must be based on factual statements relevant to the Stability Phase 3 technical specification with relevant references and desktop-based simulation including:

- description of the proposed solution and its key technical considerations relevant to the technical specification
- any specific data needs that would be critical to the proposed solution
- feasibility demonstration for each proposed solution

2. Scope

Table 1 sets out the key performance criteria of the technical specification that will need to be demonstrated as part of this technical study. Simulation tests are set out in Appendix A to demonstrate key aspects of these clauses.

Please note that any simulation tests carried out and capabilities demonstrated during the Stability Phase 3 tender do not remove proving or compliance testing requirements before and after commissioning of the solutions.

Technical specification clause	Description	Feasibility Test (Appendix A references) and notes
2.1	Short circuit current value	Test 1 – value determined in the technical study will be used in the commercial assessment & contract
2.2	Inertia value	Test 2 – value determined in the technical study will be used in the commercial assessment & contract
1.5.3	Phase angle jump response	Test 3
1.9	Fast Fault current injection timing and magnitude	Test 1
Definitions section	Response within 5 ms	Tests 1, 2, 3
2.2	Inertia behaviour	Test 2
1.5.2	Voltage source behind a real physical reactance	Tests 1, 2, 3
2.6	Fault current nature (reactive current prioritisation)	Test 1

Table 1: List of tests with reference to the technical specification clauses

3. Outputs

The required output of the technical feasibility study is a technical report covering all solutions submitted by a Tenderer during the tender. A report template will be provided at the time of tender launch, which Tenderers would be requested to complete in conjunction with Section C of the Technical Submission Document.

- Each Tenderer must provide a complete technical study report. The technical study report (completed using the template provided) must include the simulation results of all the relevant tests in Appendix A for each solution that has been submitted.
- The report should demonstrate compliance with the technical specification as described in this document.
- The report must be in clear English. Where the report relies on data to demonstrate compliance, the data should be shown in the report in the form of a graph or figure that shall be clearly legible including any axes or legends.
- Where the report relies on equipment specification, copies of manufacturer documentation should be attached to the report as appendices.
- Where the demonstration of compliance is ambiguous in the report provided, NGESO may seek additional clarification and request additional information including but not limited to raw data, models, and additional study results. For avoidance of doubt this will not be an opportunity for a different or new submission but will purely be a clarification request for additional information.

4. Assessment criteria

Solutions must pass the technical feasibility simulation study part of the tender assessment. NGESO will consider a solution to pass the technical feasibility study if these key criteria are met:

- The Tenderer has completed all the relevant tests as described in Appendix A and followed the requirements set out in Section 3 of this report.

The Tenderer has completed Section C of the Technical Submission Document and meets all the pass/fail requirements in accordance with the Contract Award Criteria. Note:

- Test results should be presented to NGESO in a clear and concise report with clearly readable graphs and figures.
- The report must be submitted within the tender submission timescales.
- The report must be submitted using the template provided.
- The report must show performance that meets the relevant clauses of the specification stated in Table 1.

Technical queries

Any technical queries should be submitted to NGESO in accordance with the query process outlined in the Instructions to Tenderers document.

5. Confidentiality

All details of the ITT and associated documents must be treated as private and confidential and shall not be disclosed to any other party, except where this is necessary for Tenderers to prepare and submit a Tender. Tenderers must ensure that they have an adequate confidentiality agreement in place with any subcontractors, funders, consultants or agents before issuing them with any information concerning the requirements of this ITT. Tenderers must release only that part of the information concerning the requirements as is essential to obtain quotations from potential subcontractors, consultants or agents.

NGESO reserves the right to audit Tenderers to confirm if such confidentiality agreements are in place. If the Tenderer is not in compliance with these provisions, NGESO reserves the right to disqualify the Tenderer from further participation in the event.

By submitting a Tender, the Tenderer irrevocably consents to NGESO carrying out all necessary actions to verify the information that they have provided, including but not limited to third party verification.

The information submitted as part of this technical study will also be treated as confidential. The NGESO will only share relevant information where required, for example with relevant TOs in relation to the Stability Phase 3 connections approach, or with all participants in an anonymised and generalised way.

6. Changes later in process

Information provided in the technical feasibility study that will be used in the tender assessment cannot be changed. This includes value of short circuit current contribution at the Grid Entry Point and inertia. Any changes post contract award will be subject to the contract terms.

Appendix A: List of desktop simulations

This appendix provides a list of desktop simulations that are required as part of the technical study. For each test category, the Tenderer must give an overview of the test method and provide output results, observations, limitations in clear English and in a legible format.

All tests are required for each solution submitted, for each technology type, rating and substation location within the solutions.

Grid Entry Point (GEP)

Unless otherwise stated in individual tests, all feasibility test results should be shown at the Grid Entry Point. The Grid Entry Point is defined as the point where the solution will directly or radially connect to the transmission system (this shall be at 275kV or 400kV in England & Wales network). Any equipment between the solution and the Grid Entry Point that impact the solution's performance (e.g. connection transformers/cables/circuits etc.) must be explicitly modelled.

The test simulation must be run for long enough to allow the system to settle to a steady state before any event is applied and long enough after the test to allow the system to return to steady state.

For every test, the following must be recorded:

- voltage magnitude and phase angle at the Grid Entry Point and solution terminal.
- active power and reactive power at the Grid Entry Point and solution terminal.
- active, reactive and total current at the Grid Entry Point and solution terminal.
- frequency and RoCoF at the Grid Entry Point.

An Excel workbook or a csv file for **every test**, containing the above recorded measurements, must be submitted as a supplementary dataset along the feasibility study report. For Hybrid solutions, datasets of the measurements at the GBGF-I terminals must be provided in addition to the datasets of the measurements at the GEP for the overall hybrid solution.

Unless otherwise stated:

- all positive sequence RMS results should be recorded.
- for EMT simulation, EMT and RMS quantities must be provided. The method adopted to compute RMS values must be clearly stated and explained.
- The time constant for EMT to RMS conversion (for GBGF-I and Hybrid solutions), must be 20ms.
- all results must be recorded with step sizes not higher than 1ms.
- Both AC and DC components must be included for EMT measured current.

The test model must be set up as follows:

a. The solution must be modelled in EMT for GBGF-I and Hybrid solutions. For GBGF-S solutions RMS models are required. The model in all cases must accurately reflect actual solution's performance and limitations.

b. Any equipment that impacts the performance at the Grid Entry Point must be modelled.

c. The transmission network should be modelled as an ideal voltage source behind an impedance, for which network short circuit level and X/R ratio values has been provided by NGESO.

d. Nominal settings and ratings of assets should be used in the model and simulations. When a range of parameters is indicated in the manufacturer datasheet, the simulations can be performed considering the nominal values.

e. All simulation settings, model parameters, transformer tap changer position, model settings and controllers' parameters must remain unchanged for all tests. Any change in these settings and parameters, other than those requested by NGESO (e.g. reactive power set point, frequency of the system, etc.) must be declared, justified and approved by NGESO.

Test 1. Short-circuit events

The purpose of this test is to understand:

- the fault current injection at the Grid Entry Point during a fault at the Grid Entry Point.
- the fault current injection at the Grid Entry Point in response to a retained voltage experienced at the Grid Entry Point as a result of a remote fault at a specified Reference point.
- for GBGF-I, that the fault current injection at the Grid Entry Point starts within 5ms and reaches the Peak Current Rating no later than 30ms of fault occurrence for zero retained voltage at Grid Entry Point.

For all solutions, please refer to Table 2 for a description of the tests required. Please note that Steps 1-6 can be omitted for solutions that do not have the capability to export or import MW. However, for numbering consistency, please keep numbering the steps as Steps 7-10 even if Steps 1-6 are not performed.

Steps 1-9 are required to establish the lowest fault current for a range of credible operating conditions. Step 10 is required to understand the fault current contribution of the solutions with respect to specific Reference point(s), which are equivalent to the points on the network where the stability services are required. As the fault current contribution to the Reference points will depend on the impedance between the Grid Entry Point and the Reference point, Step 10 will need to be repeated for each reference point within the region being targeted.

Throughout these steps, the short circuit current contribution from the solution should be recorded as the positive sequence RMS fault current at 100ms after the fault initiation, measured in kA at the Grid Entry Point, following a three phase to earth fault at the stated location. It is the lowest short circuit current value from Steps 1-9 which will be entered in the service contract against which contract payments will be considered. Effectiveness factors, which have been provided by NGESO at the time of tender launch, will be considered to evaluate the fault current contribution from the Grid Entry Point (derived from Step 10) to the relevant Reference points. The results from Step 10 will be considered in the commercial assessment.

All solutions must demonstrate all short circuit values from Test 1 Steps 1-9 in the compliance stage and proving tests along with requested aspects of the technical specification. Service commencement will be dependent on this demonstration.

Table 2 below are for all solutions and present the different steps for the short circuit test along with the network configuration, initial conditions and fault event applicable for each step.

Step	Network Configuration	Initial Conditions	Simulated Event
1	Figure 1	Pre-event voltage at the Grid Entry Point equal to 1p.u. If applicable, solution operating at **maximum active power export** (generation). Solution operating at **maximum reactive power export** (i.e. lagging mode or reactive power injection).	Simulate a 3 phase to earth fault at the Grid Entry Point that is cleared after 140ms.
2	Figure 1	Pre-event voltage at the Grid Entry Point equal to 1p.u. If applicable, solution operating at **maximum active power export** (generation). Solution operating at **maximum reactive power import** (i.e. leading mode or reactive power absorption).	Simulate a 3 phase to earth fault at the Grid Entry Point that is cleared after 140ms.

3	Figure 1	Pre-event voltage at the Grid Entry Point equal to 1p.u. If applicable, solution operating at **maximum active power export** (generation). Solution operating at **zero** reactive power output	Simulate a 3 phase to earth fault at the Grid Entry Point that is cleared after 140ms.
4	Figure 1	Pre-event voltage at the Grid Entry Point equal to 1p.u. If applicable, solution operating at **maximum active power import** (demand). Solution operating at **maximum reactive power export** (i.e. lagging mode or reactive power injection).	Simulate a 3 phase to earth fault at the Grid Entry Point that is cleared after 140ms.
5	Figure 1	Pre-event voltage at the Grid Entry Point equal to 1p.u. If applicable, solution operating at **maximum active power import** (demand). Solution operating at **maximum reactive power import** (i.e. leading mode or reactive power absorption).	Simulate a 3 phase to earth fault at the Grid Entry Point that is cleared after 140ms.
6	Figure 1	Pre-event voltage at the Grid Entry Point equal to 1p.u. If applicable, solution operating at **maximum active power import** (demand) Solution operating at **zero** reactive power output	Simulate a 3 phase to earth fault at the Grid Entry Point that is cleared after 140ms.
7	Figure 1	Pre-event voltage at the Grid Entry Point equal to 1p.u. Solution operating at **zero** active power output. Solution operating at **maximum reactive power export** (i.e. lagging mode or reactive power injection).	Simulate a 3 phase to earth fault at the Grid Entry Point that is cleared after 140ms.
8	Figure 1	Pre-event voltage at the Grid Entry Point equal to 1p.u. Solution operating at **zero** active power output Solution operating at **maximum reactive power import** (i.e. leading mode or reactive power absorption).	Simulate a 3 phase to earth fault at the Grid Entry Point that is cleared after 140ms.
9	Figure 1	Pre-event voltage at the Grid Entry Point equal to 1p.u. Solution operating at **zero** active power output Solution operating at **zero** reactive power output.	Simulate a 3 phase to earth fault at the Grid Entry Point that is cleared after 140ms.

10	Figure 2	From steps 1 to 9, the combined reactive power and active power outputs resulting in the **lowest** short circuit current injected at the GEP should be used as the active and reactive power setpoints for Step 10. Repeat Step 10 for all specified Reference point(s) for the targeted locations.	Simulate a 3 phase to earth fault **at a Reference point** on the network, where the fault impedance between the Reference point and the GEP is Z_f. The fault should be cleared after 140ms.

Table 2: Test 1: Simulations required for all solutions

Number of simulations for each solution: minimum of 10 per locations targeted for solutions with non-zero MW capability and minimum of 4 (Steps 7-10) for zero MW solutions, assuming that the Grid Entry Point is not the same as the Reference point(s). Please note that some locations may have to simulate faults with respect to multiple Reference points within a region (e.g. for substations in the East of England and South Wales regions).

If the solution is planned to connect to a substation where a bay has been reserved for the Stability Pathfinder Phase 3, the maximum current from Steps 1-9 must not exceed the reserved short circuit capacity of the bay.

Network Configurations for Short Circuit Test

Figure 1 illustrates the single-line diagram of the system to be simulated in Test 1, Steps 1-9. The equivalent system impedance (Z_{sys}) for each location has been provided by the NGESO at the time of tender launch.

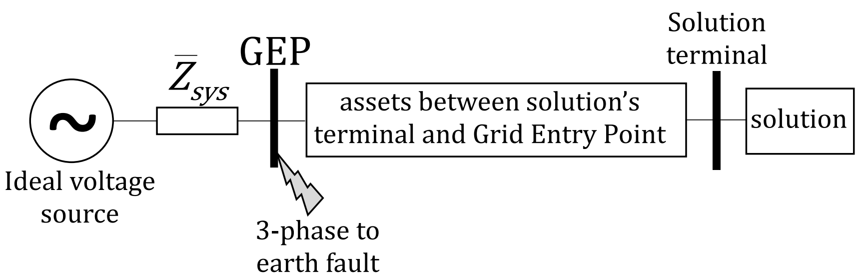


Figure 1. Network configuration for Test 1, Steps 1-9

Figure 2 illustrates the single-line diagram of the system to be simulated in Test 1, Step 10. The equivalent system impedance (Z_{sys}) and the fault impedance (Z_f) for each location has been provided by the NGESO at the time of tender launch. Please note that for the fault at the Reference point, only **positive (injection) reactive fault** current is considered in the assessment. Any negative reactive fault current (absorption) will be considered as null contribution.

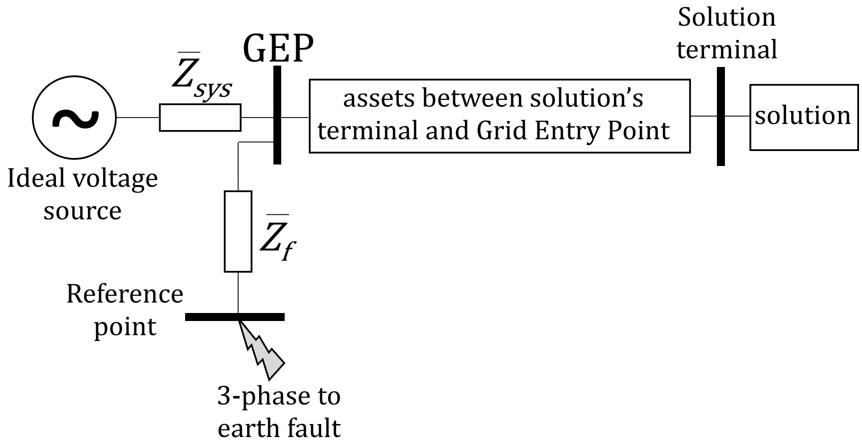


Figure 2. Network configuration for Test 1, Step 10

Test 2. Frequency events

The purpose of this test is to understand inertial response of the solution.

The Tenderer must demonstrate that their solution can:

- respond to a change in frequency with a change in active power output within 5ms.
- provide an inertial response equal to the amount to be declared in the tender.
- provide an inertial response which is adequately damped.

The frequency events must be modelled as a change in the grid source frequency. Using other methods such as sudden decrease/increase of demand or generation will not be accepted.

2.1 Test conditions

In the following frequency events the calculation should show how the performance in the tests relates to the declared values for inertia (MW.s).

For all solutions, please refer to Table 3 for a description of the tests required. Please note that Steps 1-4 can be omitted for solutions that do not have the capability to export or import MW. However, for numbering consistency, please keep numbering the steps as Steps 5-9 even if Steps 1-4 are not performed.

For each **solution**, the tests described in Table 3 are required:

Step	Network Configuration	Initial Conditions	Simulated Event
1	Figure 3	Pre-event voltage at the Grid Entry Point equal to 1p.u. If applicable, solution operating at **maximum active power export** (generation). Solution operating at **maximum reactive power export** (i.e. lagging mode or reactive power injection).	Simulate frequency event to drop from 50Hz to 49Hz with RoCoF of 1Hz/s.
2	Figure 3	Pre-event voltage at the Grid Entry Point equal to 1p.u. If applicable, solution operating at **maximum active power export** (generation). Solution operating at **maximum reactive power import** (i.e. leading mode or reactive power absorption).	Simulate frequency event to drop from 50Hz to 49Hz with RoCoF of 1Hz/s.
3	Figure 3	Pre-event voltage at the Grid Entry Point equal to 1p.u. If applicable, solution operating at **maximum active power import** (demand). Solution operating at **maximum reactive power export** (i.e. lagging mode or reactive power injection).	Simulate frequency event to increase from 50Hz to 51Hz with RoCoF of 1Hz/s.

4	Figure 3	Pre-event voltage at the Grid Entry Point equal to 1p.u. If applicable, solution operating at **maximum active power import** (demand). Solution operating at **maximum reactive power import** (i.e. leading mode or reactive power absorption).	Simulate frequency event to increase from 50Hz to 51Hz with RoCoF of 1Hz/s.
5	Figure 3	Pre-event voltage at the Grid Entry Point equal to 1p.u. Solution operating at **zero** active power output. Solution operating at **maximum reactive power export** (i.e. lagging mode or reactive power injection).	Simulate frequency event to drop from 50Hz to 49Hz with RoCoF of 1Hz/s.
6	Figure 3	Pre-event voltage at the Grid Entry Point equal to 1p.u. Solution operating at **zero** active power output. Solution operating at **maximum reactive power import** (i.e. leading mode or reactive power absorption).	Simulate frequency event to drop from 50Hz to 49Hz with RoCoF of 1Hz/s.
7	Figure 3	Pre-event voltage at the Grid Entry Point equal to 1p.u. Solution operating at **zero** active power output. Solution operating at **maximum reactive power export** (i.e. lagging mode or reactive power injection).	Simulate frequency event to increase from 50Hz to 51Hz with RoCoF of 1Hz/s.
8	Figure 3	Pre-event voltage at the Grid Entry Point equal to 1p.u. Solution operating at **zero** active power output. Solution operating at **maximum reactive power import** (i.e. leading mode or reactive power absorption).	Simulate frequency event to increase from 50Hz to 51Hz with RoCoF of 1Hz/s.
9	Figure 3	Pre-event voltage at the Grid Entry Point equal to 1p.u. Solution operating at **zero** active power output. Solution operating at **zero** reactive power output.	Simulate a frequency **step** event from 50Hz to 49Hz lasts for 0.5s.

Table 3: Test 2: Simulations required for each solution

Number of simulations for each solution: 9 for solutions with non-zero MW capability and 5 (Steps 5-9) for zero MW solutions.

Active Inertia Power must be provided without activating current limiting functions for a Rate of Change of System Frequency (RoCoF) whose magnitude is of less than or equal to 1Hz/s.

Network Configurations for Frequency and RoCoF tests

Figure 3 illustrates the single-line diagram of the system to be simulated in Test 2. The equivalent system impedance (Z_{sys}) for each location has been provided by NGESO at the time of tender launch.

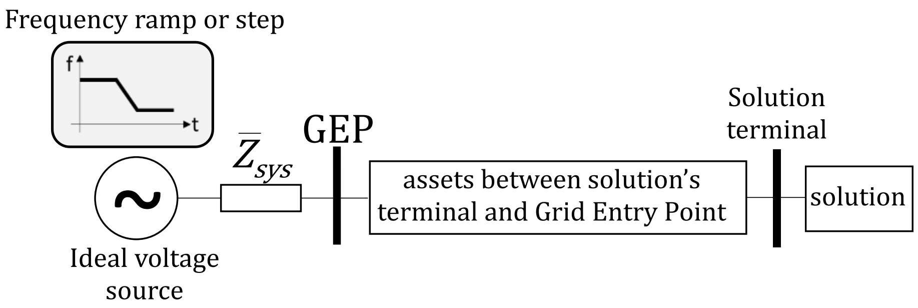


Figure 3. Network configuration for Test 2

The inertia values should also be demonstrated from simulations based on the Active Inertia Power computed for each frequency event.

For all solutions, the inertia value to be used in the tender assessment and contract should be the lowest value demonstrated from Steps 1 to 8.
For all solutions, the inertia values in MW.s should be computed through Equation 1. For each event, the **Active Inertia Power** (ΔP in Equation 1) should be based on an average across all the recorded samples over the duration of the frequency ramp event.

$$\textbf{Inertia} = \frac{\Delta P\, f_0}{2 \times RoCoF} \qquad \text{Equation 1}$$

Where:

ΔP is the **Active Inertia Power** of the **Grid Forming Plant** for a frequency event of 1Hz/s (MW)

RoCoF is the **Rate of Change of Frequency** in Hz/s

f0 is the pre-fault System **Frequency** (Hz)

For the avoidance of doubt ΔP should be calculated as follows:

ΔP = [Average MW provided by the solution at GEP across all recorded samples over the frequency ramp period (1 second)] – [Initial MW provided by the solution prior to the event].

Test 3. Voltage angle change events

The purpose of this test is to understand how a solution will behave under extreme voltage angle changes at the Grid Entry Point.

The voltage phase jump event must be modelled as a step change in the grid source voltage phase angle. Using other methods such as fault impedance will not be accepted.

3.1 Test conditions

The Tenderer must note any limitations and observations related to the performance of their solutions.

For all solutions, please refer to Table 4 for a description of the tests required. Please note that only Steps 3-6 are required for solutions that do not have the capability to export or import MW with setting 0MW in all the steps. However, for numbering consistency, please keep numbering the steps as Steps 3-6 even if other steps are not performed.

For each **solution**, the tests described in Table 4 are required:

Step	Network Configuration	Initial Conditions	Simulated Event
1	Figure 4	Pre-event voltage at the Grid Entry Point equal to 1p.u. Solution operating at **maximum active power export** (generation). Solution operating at **maximum reactive power export** (i.e. lagging mode or reactive power injection).	Simulate 60 degrees drop at the Grid Entry Point, sustained for 0.5s after the event.
2	Figure 4	Pre-event voltage at the Grid Entry Point equal to 1p.u. Solution operating at **maximum active power export** (generation). Solution operating at **maximum reactive power import** (i.e. leading mode or reactive power absorption).	Simulate 60 degrees drop at the Grid Entry Point, sustained for 0.5s after the event.
3	Figure 4	Pre-event voltage at the Grid Entry Point equal to 1p.u. Solution operating at **maximum active power import** (demand). Solution operating at **maximum reactive power export** (i.e. lagging mode or reactive power injection).	Simulate 60 degrees drop at the Grid Entry Point, sustained for 0.5s after the event.
4	Figure 4	Pre-event voltage at the Grid Entry Point equal to 1p.u. Solution operating at **maximum active power import** (demand). Solution operating at **maximum reactive power import** (i.e. leading mode or reactive power absorption).	Simulate 60 degrees drop at the Grid Entry Point, sustained for 0.5s after the event.
5	Figure 4	Pre-event voltage at the Grid Entry Point equal to 1p.u. Solution operating at **maximum active power export** (generation). Solution operating at **maximum reactive power export** (i.e. lagging mode or reactive power injection).	Simulate 90 degrees drop at the Grid Entry Point, sustained for 0.5s after the event.
6	Figure 4	Pre-event voltage at the Grid Entry Point equal to 1p.u. Solution operating at **maximum active power export** (generation).	Simulate 90 degrees drop at the Grid Entry Point, sustained for 0.5s after the event.

		Solution operating at **maximum reactive power import** (i.e. leading mode or reactive power absorption).	
7	Figure 4	Pre-event voltage at the Grid Entry Point equal to 1p.u. Solution operating at **maximum active power import** (demand). Solution operating at **maximum reactive power export** (i.e. lagging mode or reactive power injection).	Simulate 90 degrees drop at the Grid Entry Point, sustained for 0.5s after the event.
8	Figure 4	Pre-event voltage at the Grid Entry Point equal to 1p.u. Solution operating at **maximum active power import** (demand). Solution operating at **maximum reactive power import** (i.e. leading mode or reactive power absorption).	Simulate 90 degrees drop at the Grid Entry Point, sustained for 0.5s after the event.

Table 4: Test 3: Simulations required for each solution

Number of simulations for each solution: 8 for solutions with non-zero MW capability and 4 (Steps 3-6 with setting 0MW) for zero-MW solutions.

The Tenderer must demonstrate the performance of their solution(s) under various voltage angle changes. Solutions that do not demonstrate the capability to withstand a voltage phase jump of 60 degrees will not pass the assessment. If a solution can withstand a voltage phase jump of 60 degrees but fails to withstand voltage angle change of 90 degrees, it will still pass the assessment; however, a detailed explanation on the solutions' limitations must be provided. Solutions must be modelled in detail to capture limitations such as inverter blocking and controller saturation.

Network configurations for voltage angle change tests

Figure 4 shows the single-line diagram of the system to be simulated in Test 3. The equivalent system impedance (Z_{sys}) for each location has been provided by NGESO at the time of tender launch.

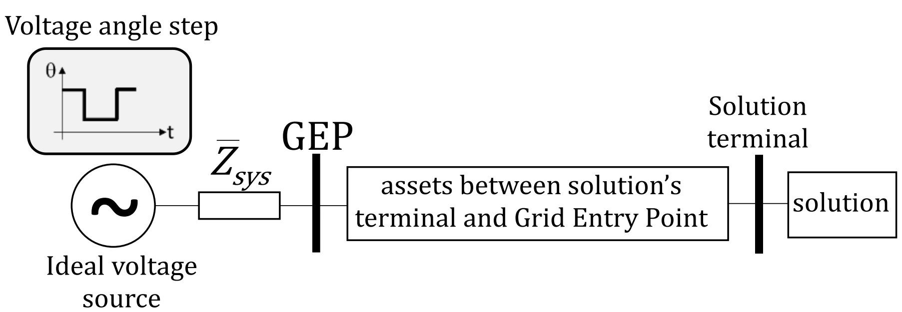


Figure 4. Network configuration for Test 3