

Proving Tests for Mid Term Reactive Power Market

Compliance Guidance Notes

September 2026

Version Control

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Contents

Version Control.....	2
Overview.....	3
1. Aim.....	3
2. Overview.....	3
3. Simulation Studies.....	3
4. Model Validation.....	6
5. Compliance Tests.....	6
Appendix A: Reactive Capability Testing Requirements.....	8
Summary of Testing Requirements.....	8
Reactive Capability Testing	8
Appendix B: Voltage Control Testing Requirements (SVC, STATCOM)	11
Summary of Testing Requirements.....	11
Voltage Control Testing	11
Appendix C: Power Oscillation Damping Simulation Requirements (Dynamic Solutions) .	16
Summary of Simulation Requirements.....	16
Simulation Requirements	17

Overview

1. Aim

The aim of this document is to provide an overview of the compliance activities and proving tests that are required to be completed as part of the Mid-Term Reactive Power Market. These tests are an important part of any tender and demonstrate the real physical capability of the solution and its compliance against the relevant sections of the GB Grid Code and Service Agreement.

This document is intended for connections which have a commercial contract in addition to a Bilateral Connection Agreement (BCA) with NESO. The User is required to demonstrate compliance successfully with the requirements stated in this document before being allowed by NESO to provide the contracted commercial services.

2. Overview

This document outlines the compliance simulations and capability tests that successful parties in any Mid-Term Market Reactive Power tender will have to complete (where required to do so) and then be approved by NESO before their scheduled service start date or Scheduled Commercial Operational Date (SCOD).

If solutions participating in Mid-Term Market tenders involve stacking with other services, the solutions must demonstrate that the stacking of other services does not impact their delivery of the Reactive Power Service contracted under the Mid-Term Reactive Power Market. Stacking with other services or different operational strategy of assets may not be allowed if this is not proven at the compliance stage. Furthermore, hybrid solutions must meet all Grid Code requirements relevant to each type of technology used in the hybrid system.

3. Simulation Studies

The simulation studies described in this document will allow for the demonstration of elements specified in the technical specification of the Service Agreement. However, if the study requirements specified in this document or in the Provider's BCA are deemed inappropriate, the Provider should contact NESO to discuss and agree an alternative program and success criteria. In general, simulation studies are required to:

1. Demonstrate an expected compliant performance ahead of connection or after any changes to the solution original design.

2. Demonstrate the model supplied is a true, accurate and up to date reflection of the equipment, as installed.
3. Demonstrate capability where it is impractical through testing as the effects on other system Users would be unacceptable.

The simulations must be based on the validated models supplied to NESO in accordance with Schedule 4 of the Service Agreement. Unless otherwise stated in individual simulation tests, all simulation test results must be shown at the Grid Entry Point or User System Entry Point. Any equipment between the solution and the Grid Entry Point that impact the solution's performance (e.g., connection transformers/cables/transmission lines) must be explicitly modelled.

The simulation tests 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. The simulation studies should be submitted in the form of a report to demonstrate compliance with the Service Agreement in sufficient time to allow NESO to review the content and validity of the report and model utilised prior to the Scheduled Commercial Operational Date (SCOD).

The simulation studies shall be carried out using the validated RMS and EMT models depending on the type of technology. The models must be supplied to NESO in accordance with the requirements specified in the most recent Mid-Term Market technical specification. Where the provider carries out tests in a FAT environment the results of these tests must be approved by NESO before any simulation studies can be conducted and submitted. This is to ensure that the correct parameters from the final accepted FAT test are reflected in any simulations completed.

The studies shall be carried out with the transmission network at its expected minimum fault level and the equipment initially operating at zero reactive power output. The simulation study shall include but it is not limited to the following topics:

Reactive capability across the voltage range*

A load flow study is required to demonstrate that the equipment can absorb maximum reactive power for 1.05pu system voltage and inject maximum reactive power for 0.95pu system voltage. Since the reactive power absorbed/injected by the reactor/capacitor is proportional to the square of its terminal voltage, reactive capability across the voltage range will not include reactors and capacitors.

Voltage control and reactive power stability*

A dynamic time series simulation study is required of a sufficiently large negative step in system voltage to cause a change in Reactive Power from zero to the maximum lagging value/injecting reactive power, and a sufficiently large positive /absorbing Reactive Power step in system voltage to cause a change in Reactive Power from zero to the maximum leading value.

Additionally, a dynamic time series simulation study result of a sufficiently large negative step in system voltage to cause a change in Reactive Power from the maximum leading value to the maximum lagging value is required.

A dynamic time series simulation study results to demonstrate control stability at the lagging Reactive Power limit by application of a -2% voltage step while operating within 5% of the lagging Reactive Power limit, and at the leading Reactive Power limit by application of a +2% voltage step while operating within 5% of the leading Reactive Power limit is required. Users which provide active power (MW) are advised to operate at **Rated MW** and unity **Power Factor** at the connection point to a 2% step increase in the voltage reference as per ECP.A.3.7.4. For storage modules the said testing must be conducted for both full active power import and export conditions.

Stacking Service Providers*

Solutions with existing Stability services contract (e.g. Inertia, Short Circuit Level) shall submit simulation studies demonstrating the simultaneous delivery of:

1. the full contracted Stability service; and
2. the full tendered leading and lagging Reactive Power (Mvar) range.

The studies shall prove that the instructed activation, deactivation or variation of the Voltage service does not reduce, delay, constrain or destabilise the delivery of the contracted Stability service and vice versa.

The simulation studies shall prove that at each Mvar operating point during Maximum and Minimum Stability service, the solution retain sufficient Mvar injection/absorption range to deliver the full tendered Voltage service at the Grid Entry Point (GEP).

***Note:** For technologies which provide active power (MW) to the system must show full contracted reactive range at their rated active power. Additionally, the storage modules must demonstrate their full contracted reactive power capability during both full active power, import and export conditions. The User must ensure that both grid code requirements and contracted reactive power capabilities are demonstrated through their simulation results.

Fault ride through and Fast fault current Injection

Based on the design of equipment and the technical requirements of each technology as specified in the Bilateral Connection Agreement (BCA) and the Service Agreement, the equipment needs to be Fault Ride Through (FRT) compliant and inject reactive current under fault conditions to help the system ride through fault events. This should be done with the physical protections enabled and set up according to site operations when applicable and demonstrating the following:

- The plant is able to ride through faults without tripping within the required operating range, and
- The plant trips correctly when outside the protection boundaries, accurately reflecting the site's actual operational behaviour.

Therefore, the User needs to supply time series simulation study results to demonstrate the capability of the equipment to meet the requirements by submission of a report.

Please note, the fault ride through studies are expected to be carried out using an EMT simulation tool in order to assess the TOV (Transient Over Voltage) impact on the power system.

4. Model Validation

The equipment owner is required to provide NESO and the Transmission Owner with a model of the solution. Based on GC0141 modification, the Grid Code specifies that all RMS and EMT models shall come implemented in the Software and version required by The Company. The model data is to be provided in a block diagram format, complete with Laplace equations and all associated parameters for the site in question. Control systems with a number of discrete states or logic elements may be provided in flow chart format if a block diagram format does not provide a suitable representation. The electrical system is to be provided as a single line diagram.

The results recorded during the compliance tests may be used to validate the model of the equipment and its control system to ensure it meets the technical requirements of the Bilateral Connection Agreement. However, the tested behaviour may be different from the behaviour predicted by the simulation studies using the provided models. Therefore, following successful tests the equipment owner or its agent shall validate the performance of the submitted model by providing overlays of recorded tests with simulations replicating as far as reasonably practical the same conditions. If the results are identical or matched very well, then the submitted model has been validated and accepted as the accurate model of the equipment. If the results are different then the owner, or his agent, i.e. consultant or equipment manufacturer, should resubmit a modified model with an explanation of the reasons that resulted in lack in alignment between results. This process will be repeated until there is close alignment with the test results and simulation results. **Note:** As per GC0141 guidance notes published for Modelling requirements; the accuracy criteria is that for 95% of the samples within the transient period, the difference between the user system model(s) response and the user system measured response shall be contained within an envelope defined by a $\pm 10\%$ deviation around the model(s) simulated response.

5. Compliance Tests

Tests will be required to demonstrate that the reactive compensation equipment meets the relevant provisions of the Bilateral Connection Agreement and Mid-Term Market Service Agreement. The tests are carried out by the owner of the equipment or by their agent, and not by NESO. Tests shall be completed following the test procedures supplied by the equipment owner or

by their agent. The test procedures are required to be submitted well in advance to the device connecting to the network to ensure NESO has enough time to review and comment.

For solutions without dynamic reactive power capability:

- The tests required with their associated data, as well as example of testing procedure is presented in the Appendix A Table 2. Tests for Reactors and Capacitors.

For solutions with dynamic reactive power capability:

- The provision of an Electro-Magnetic Transient (EMT) model in addition to an RMS model is required as mentioned in the technical specifications, for this please refer to the EMT Guidance Notes.
- For GBGF-S¹ solutions, the relevant sections of the Grid Code must be followed.
- For additional guidance for Synchronous Condensers please refer to the Synchronous Condenser Guidance Note.
- For additional guidance for Power Park Modules please refer to the Power Park Modules Guidance Note
- For GBGF-I² solutions, the relevant sections of the Grid Code must be followed for the host technology as well as additional testing detailed in ECP.A.9 and ECC.6.3.19.5. For more detail, please refer to the GB Grid Forming Guidance Notes and the GB Grid Forming Best Practice Guide.
- For additional guidance for Synchronous Generators refer to the Synchronous Generators Guidance Notes
- For additional guidance for Electrical Storage refer to the Electrical Storage Guidance Notes
- For STATCOM and SVCs, the tests required with their associated data, as well as examples of testing procedures are shown in the Appendices A and B.
- Information on Grid Code connections compliance process can be found on NESO's website: <https://www.neso.energy/industry-information/connections/compliance-process>

¹ GBGF-S: Great Britain Grid Forming – Synchronous: Is a Synchronous Power Generating Module, Synchronous Electricity Storage Module or Synchronous Generating Unit with a Grid Forming Capability.

² GBGF-I: Great Britain Grid Forming – Inverter: Is any Power Park Module, HVDC System, DC Converter, OTSDUW Plant and Apparatus, Non-Synchronous Electricity Storage Module, Dynamic Reactive Compensation Equipment or any Plant and Apparatus (including a smart load) which is connected or partly connected to the Total System via an Electronic Power Converter which has a Grid Forming Capability.

Note: In order for NESO engineers to make an accurate assessment of the connection it is crucial that the controller's working logic, architecture and key parameters are explained in detail and if more information is required, the User must provide them upon NESO's request.

Appendix A: Reactive Capability Testing Requirements

Summary of Testing Requirements

The Reactive Capability requirements for static and dynamic solutions are specified in the Mid-Term Reactive Power Market Service Agreement.

The dynamic equipment shall be capable of delivering its reactive power range across a variation in system voltage.

With reference to ECC.6.1.4.1, all Users connected at voltage levels greater than 300kV shall operate within $\pm 5\%$ of the nominal value unless abnormal conditions prevail. The minimum voltage is -10% and the maximum voltage is $+10\%$ unless abnormal conditions prevail for example, but not limited to, situations such as System Restoration, but voltages between $+5\%$ to $+10\%$ will not last longer than 15 minutes unless abnormal condition prevails.

Table 1. Voltage Requirements

National Electricity Transmission System Nominal Voltage	Normal Operating Range		Time period for Operation
	Voltage (percentage of Nominal Voltage)	Pu (1pu relates to the Nominal Voltage)	
Greater than 300kV	V -10% to $+5\%$ V $+5\%$ to $+10\%$	0.90pu- 1.05pu 1.05pu- 1.10pu	Unlimited 15 minutes
110kV up to 300kV	V $\pm 10\%$	0.90- 1.10pu*	Unlimited

*Upper limit for 275kV is 1.09pu and for 132kV is 1.1 pu.

During system incidents (i.e., the voltage is $<95\%$ or $>105\%$) the dynamic equipment should deliver the maximum (lagging or leading respectively) reactive power possible, whilst remaining within its design limits.

Reactive Capability Testing

The following procedures are provided for Reactors, Capacitors, SVC and STATCOM connected under normal system condition to demonstrate their specified value (Reactor/Capacitor) or the

maximum reactive capability provided in the Bilateral Connection Agreement (BCA) and Service Agreement, which might aid the equipment owner to draft their own test procedures.

Table 2. Tests for Reactors and Capacitors

Test No	Step	Description	Notes
1	1	Record steady state for 2 minutes	
2	2	Switch in the Reactor/Capacitor	
	3	Record the steady state for 5 minutes	
3	4	Switch out the Reactor/Capacitor	
	5	Record the steady state for 3 minutes	

Table 3. Tests for SVC, STATCOM

Test No	Step	Description	Notes
1	1	Operation in normal system condition	
	2	Target Voltage (*) selected to generate a maximum continuous lagging Reactive Power for 60 minutes.	
2	3	- Return Target Voltage to the value required to achieve zero reactive power. - Retain zero reactive power for 3-5 Mins subject to System Operators' Approval	
3	4	Operation in normal system condition	
	5	Target Voltage (*) selected to generate a maximum continuous leading Reactive Power for 60 minutes.	
4	6	- Return Target Voltage to the value required to achieve zero reactive power. - Retain zero reactive power for 3-5 Mins subject to System Operators' Approval	

Appendix B: Voltage Control Testing Requirements (SVC, STATCOM)

Summary of Testing Requirements

The reactive compensation equipment (SVC, STATCOM) is required to meet the performance requirements with regards to voltage control in the Service Agreement. Since the reactive power absorbed by reactor/capacitor is proportional to the square of its terminal voltage and it is not able to adjust its voltage reference, voltage control tests will not include reactors and capacitors.

Voltage Control Testing

The voltage control testing for reactive compensation equipment should be by injection to the control system reference (altering the setpoint voltage) and tapping of an upstream grid transformer. The following generic procedure is provided.

Starting with the equipment providing zero reactive power, voltage steps changes corresponding to $\pm 1\%$, $\pm 2\%$, and $\pm 4\%$ shall be applied to the voltage reference.

Table 4. Voltage Control Testing

Test No	Step	Description of injection	Notes
		Set the Target Voltage to the value required to achieve zero Reactive Power output	
1		- Record steady state 3 to 5 minutes - Inject $+1\%$ step to SVC/STATCOM voltage setpoint - Hold for at least 3 minutes - Remove the voltage step by returning the voltage setpoint to 1 p.u of nominal voltage. - Hold for at least 3 to 5 minutes	
2		- Record steady state for 3 to 5 mins. - Inject -1% step to SVC/STATCOM voltage setpoint - Hold for at least 3 minutes	

		- Remove the voltage step by returning the voltage setpoint to 1 p.u of nominal voltage. - Hold for at least 3 to 5 mins.	
3		- Record steady state for 3 to 5 minutes - Inject +2% step to SVC/STATCOM voltage setpoint - Hold for at least 3 minutes - Remove the voltage step by returning the voltage setpoint to 1 p.u of nominal voltage. - Hold for at least 3 to 5 minutes	
4		- Record steady state for 3 to 5 minutes - Inject -2% step to SVC/STATCOM voltage setpoint - Hold for at least 3 minutes - Remove the voltage step by returning the voltage setpoint to 1 p.u of nominal voltage. - Hold for 3 to 5 minutes	
5		- Record steady state for 3 to 5 minutes - Inject +4% step to SVC/STATCOM voltage setpoint - Hold for at least 3 minutes - Remove the voltage step by returning the voltage setpoint to 1 p.u of nominal voltage. - Hold for at least 3 to 5 minutes	
6		- Record steady state for 3 to 5 minutes - Inject -4% step to SVC/STATCOM voltage setpoint - Hold for at least 3 minutes - Remove the voltage step by returning the voltage setpoint to 1 p.u of nominal voltage. - Hold for at least 3 to 5 minutes	

Note: Please note that while conducting voltage control tests with positive and negative step changes continuously the stabilisation period in between the step changes should be between 3 to 5 minutes in case of automatic tap changers and 10 minutes in case of manual tap changers at the grid transformer, to avoid any adverse impact on the Grid. The time periods mentioned in the table above refer to the tests being conducted in standalone manner.

As described testing should also be by tapping of an upstream grid transformer. Where steps can be initiated using network tap changers, the equipment (SVC/STATCOM) will need to coordinate with the host Transmission or Distribution Network Operator. Consideration should also be given to switching the associated tap changer Automatic Voltage Control (AVC) from auto to manual for the duration of the test.

Table 5. Voltage Control Testing

Test No	Step	Description of Tap change	Notes
		Set the Target Voltage to the value required to achieve zero Reactive Power output	
1		- Record steady state for 20 seconds. - Tap up 1 position on external upstream tap changer (1 positions from starting position) - Hold for at least 3 minutes	
2		- Record steady state for 10 seconds - Tap up 1 position on external upstream tap changer (2 positions from starting position) - Hold for at least 3 minutes	
3		- Record steady state for 10 seconds - Tap down 1 position on external upstream tap changer (1 positions from starting position) - Hold for at least 3 minutes	
4		- Record steady state for 10 seconds - Tap down 1 position on external upstream tap changer (at starting position) - Hold for at least 3 minutes	
5		Record steady state for 10 seconds	

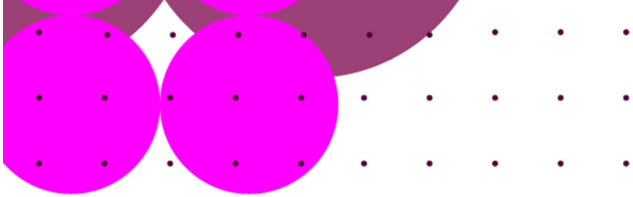
		- Tap down 1 position on external upstream tap changer (1 positions from starting position) - Hold for at least 3 minutes	
6		- Record steady state for 10 seconds - Tap down 1 position on external upstream tap changer (2 positions from starting position) - Hold for at least 3 minutes	
7		- Record steady state for 10 seconds - Tap up 1 position on external upstream tap changer (1 positions from starting position) - Hold for at least 3 minutes	
8		- Record steady state for 10 seconds - Tap up 1 position on external upstream tap changer (at starting position) - Hold for at least 3 minutes	

Note: The time periods mentioned in the table above refer to the tests being conducted in standalone manner.

Where the voltage control system includes discretely switched shunt capacitors/reactors to provide part of the reactive capability the test program should demonstrate the performance when these are switched.

Table 6. Voltage Control Testing

Test No	Step	Description	Notes
		Adjust voltage setpoint to a suitable operating point below switching threshold for shunt device.	
1		- Record steady state for 10 seconds - Inject a step to the equipment (SVC/STATCOM) reference of sufficient size and polarity to switch in shunt device. - Hold for at least 10 seconds	



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2		• Remove injection with a step of sufficient size to switch out the switched device • Repeat step 1 immediately (with minimum delay)	
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Appendix C: Power Oscillation Damping Simulation Requirements (Dynamic Solutions)

Summary of Simulation Requirements

These simulations will establish if the dynamic asset is meeting reactive and/or active power oscillation damping capability as specified in the technical specification.

GBGF-S Plant, SVC and STATCOM, must be able to:

1. Detect system voltage oscillations in the sub-synchronous frequency range 0.3-2Hz
2. Upon detecting oscillations, inject reactive current adequately in antiphase to achieve a reduction in voltage oscillation at the Grid Entry Point
3. Change the amount of reactive current injection proportional to the amplitude of the oscillations.
4. Limit the influence of these subsidiary control actions at 10% of the primary function.
5. Achieve 1-4 whilst keeping the solution stable and not compromise other aspects of the technical specification.

GBGF-I and Hybrid Plants must be able to:

1. Detect system voltage and active power oscillations in the sub-synchronous frequency range 0.3Hz to 2Hz.
2. Upon detecting voltage oscillations, inject/absorb reactive current adequately in antiphase to achieve a reduction in voltage oscillation at the Grid Entry Point
3. Upon detecting active power oscillations, inject/absorb active current adequately in antiphase to achieve a reduction in active power oscillations at the Grid Entry Point
4. Change the amount of reactive current injection proportional to the amplitude of the voltage oscillations
5. Change the amount of active current injection proportional to the amplitude of the active power oscillations
6. Limit the influence of these subsidiary control functions at 10% of the primary function
7. Achieve 1-6 whilst keeping the solution stable and not compromise other aspects of the technical specification.

Simulation Requirements

Tables 7 and 8, shows the procedure of power oscillation damping simulations. The report/results must explain any limitations on damping over the frequency range 0.3Hz to 2Hz based on the tuning. Also, all solutions must provide a table showing the angle between reactive power and voltage and if applicable active power and frequency.

Table 7. Voltage Oscillations Simulation Steps

Test No	Step	Description	Notes
1	1	Set Plant MW and Mvar to zero.	
	2	- Inject 0.3Hz oscillations in system voltage. The 0.3Hz oscillations should be superimposed to the fundamental frequency (50 Hz) voltage. - The amplitude of the oscillation must be 5% of the rated voltage at the Grid Entry Point. If 5% is not sufficiently large to demonstrate damping capability, increase further until able to demonstrate the solutions contribution to damping. - Record for at least 20s.	
	3	Observe differences with and without the plant connected on the contribution towards damping of the reactive power oscillations. Explain the Plant's behaviour and any observations.	
	4	Repeat step 1 to 3 by increasing oscillation frequencies with steps of 0.1Hz up to 2Hz.	

Additional test defined in Table 8 must be undertaken by GBGF-I and Hybrid Plants.

Table 8. Active Power Oscillations Simulation Steps

Test No	Step	Description	Notes
1	1	Set Plant MW and Mvar to zero.	
	2	- Inject 0.3Hz oscillations in system frequency. The 0.3Hz oscillations should be superimposed to the fundamental frequency (50 Hz) value. - The amplitude of the oscillation must be 0.5% of the rate frequency at the Grid Entry Point. If 0.5% is not sufficiently large to demonstrate the damping capability, increase further until the amplitude is able to demonstrate the solutions contribution towards damping. - Record for at least 20s.	
	3	- Observe differences with and without the plant connected on the contribution towards damping of the active power oscillations. - Explain the Plant's behaviour and any observations	
	4	Repeat step 1 to 3 by increasing oscillation frequencies with steps of 0.1Hz up to 2Hz.	

Note: For the Power Oscillation tests, the system should be represented as in the figure below. The equivalent system impedance (Z_{sys}) will be provided by NESO at the time of tender launch (unless otherwise stipulated).

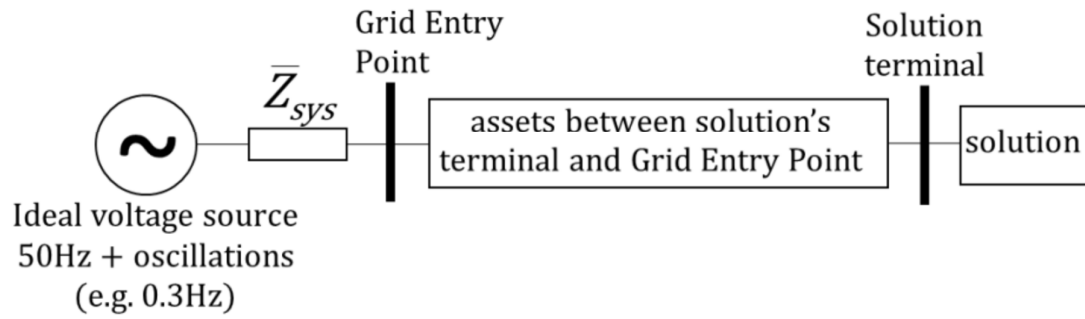


Figure 1: Network Configuration for Simulations in Table 7 and 8