RfG

Reactive Power Capability / Excitation Limiters

[Insert Unit Name]

[Insert Three Letter Code]

Version 0.1



Contents

[1 DOCUMENT VERSION History 3](#_Toc71184951)

[2 Introduction 3](#_Toc71184952)

[3 Abbreviations 3](#_Toc71184953)

[4 unit DATA 4](#_Toc71184954)

[5 SONI Grid Code references 4](#_Toc71184955)

[6 site Safety requirements 8](#_Toc71184956)

[7 Test description and pre conditions 8](#_Toc71184957)

[7.1 Purpose of the Test 8](#_Toc71184958)

[7.2 Pass Criteria 9](#_Toc71184959)

[7.3 Instrumentation and onsite data trending 9](#_Toc71184960)

[7.4 Initial Conditions 10](#_Toc71184961)

[8 Test Steps 11](#_Toc71184962)

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# DOCUMENT VERSION History

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Document Revsion History** | | | | |
| **Revision** | **Date** | **Comment** | **Name** | **Company** |
| 0.1 | Xx/xx/xxxx | XX | User | User |
|  |  |  |  |  |
| 1.0 | Xx/xx/xxxx | Revised to Major version for onsite testing and signoff |  | SONI |

# Introduction

The Unit must submit the latest version of this test procedure as published on the SONI website[[1]](#footnote-1).

All yellow sections must be filled in before the test procedure will be approved. All grey sections must be filled in during testing. If any test requirements or steps are unclear, or if there is an issue with meeting any requirements or carrying out any steps, please contact [Generator\_Testing@soni.ltd.uk](mailto:Generator_Testing@soni.ltd.uk)

On the day of testing, suitably qualified technical personnel are required on site to assist in undertaking the tests. The personnel shall have the ability to:

1. Set up and disconnect the control system and instrumentation as required;
2. Ability to fully understand the Unit’s function and its relationship to the System;
3. Liaise with Castlereagh House Control Centre (CHCC) as required;
4. Mitigate issues arising during the test and report on system incidents.

The availability of personnel at CHCC will be necessary in order to initiate the necessary instructions for the test. CHCC will determine:

1. If network conditions allow the testing to proceed.
2. Which tests will be carried out?
3. When the tests will be carried out.

On completion of this test, the following shall be submitted to [Generator\_Testing@soni.ltd.uk](mailto:Generator_Testing@soni.ltd.uk)

|  |  |
| --- | --- |
| **Submission** | **Timeline** |
| A scanned copy of the test procedure, as completed and signed on site on the day of testing | 1 working day |
| Test data in CSV or Excel format | 1 working day |
| Test report | 10 working days |

**Note:**

**The NI Power System is a live, dynamic, constantly changing system on which major changes or disturbances can occur without warning. All testing has the potential to impact the NI Power System and must be treated as such.**

**Prior to testing taking place SONI Control Room must be informed as soon as practically possible. SONI Control Room Staff reserve the right to suspend any testing if it may have a detrimental impact on the NI Power System and/or prevailing system conditions call for it.**

**Tests must be undertaken in accordance with this procedure however should a test in the procedure:**

* **have potential for a detrimental impact on the NI Power System,**
* **result in damage to the Generator’s and/or TO’s Plant and Apparatus,**
* **does not adequately demonstrate Generator Plant performance,**

**an equivalent test procedure and/or demonstration of Generating Unit capability[[2]](#footnote-2) agreed between SONI and the Generator may be undertaken to validate Grid Code compliance.**

# Abbreviations

CHCC Castlereagh House Control Centre

HV High Voltage

MEC Maximum Export Capacity

MVAr Mega Volt Ampere – reactive

MW Mega Watt

MCR Maximum Continuous Rating / Registered Capacity

TSO Transmission System Operator

EDIL Electronic Dispatch Instruction Logger

RPM Revolutions per minute

# unit DATA

|  |  |
| --- | --- |
| Unit Test Coordinator | Unit to Specify Name, Company and contact details. |
| Unit name | Unit to Specify |
| Associated 110 kV Station | Unit to Specify |
| Unit connection point | Unit to Specify |
| Unit connection voltage | Unit to Specify |
| Unit Fuel Type: | Primary Fuel / Secondary Fuel |
| Registered Capacity / Maximum Continuous Rating | Unit to Specify |
| Contracted MEC | Unit to Specify |
| Minimum Load | Unit to Specify |

# SONI Grid Code references

CC.S1.1.3.3 A Generating Unit shall continuously control voltage at the Connection Point within its Reactive Power capability limits.

* + - * 1. For Generating Units, the minimum Reactive Power capability is defined in the characteristic below, within the voltage limits specified under CC5.4.



|  |  |
| --- | --- |
| Point A | **Mvar** consumption (lead) capability of the **Generating Unit** at **Registered Capacity** and **Voltage** of 1.1 p.u. at the **Connection Point** |
| Point B | **Mvar** consumption (lag) capability of the **Generating Unit** at **Registered Capacity** and **Voltage** of 1.1 p.u. at the **Connection Point** |
| Point C | **Mvar** consumption (lead) capability of the **Generating Unit** at **Registered Capacity** and **Voltage** of 0.9 p.u. at the **Connection Point** |
| Point D | **Mvar** consumption (lag) capability of the **Generating Unit** at **Registered Capacity** and **Voltage** of 0.9 p.u. at the **Connection Point** |



|  |  |
| --- | --- |
| Point A | **Mvar** consumption (lead) capability of the **Generating Unit** at **Registered Capacity** and **Voltage** of 1.05 p.u. at the **Connection Point** |
| Point B | **Mvar** consumption (lag) capability of the **Generating Unit** at **Registered Capacity** and **Voltage** of 1.05 p.u. at the **Connection Point** |
| Point C | **Mvar** consumption (lead) capability of the **Generating Unit** at **Registered Capacity** and **Voltage** of 0.875 p.u. at the **Connection Point** |
| Point D | **Mvar** consumption (lag) capability of the **Generating Unit** at **Registered Capacity** and **Voltage** of 0.875 p.u. at the **Connection Point** |

* + - * 1. The Generating Unit shall be capable of moving to any operating point within the profiles above in appropriate timescales to target values requested by the TSO.
        2. With regard to Reactive Power below Registered Capacity, when operating at an Active Power output below Registered Capacity, the Generating Unit shall be capable of operating at every possible operating point in the Reactive Power capability of the Generating Unit, at least down to Minimum Generation. Even at reduced Active Power output, Reactive Power supply at the connection point shall correspond fully to the Reactive Power capability of that Generating Unit, taking the auxiliary supply power and the active and reactive power losses of the step-up transformer if applicable, into account.

1. Generating Units shall fulfil the following requirements relating to robustness:

(i) in the event of power oscillations, Generating Units shall retain steady-state stability when operating at any point along the characteristics defined in CC.S1.1.3.3,

(ii) without prejudice to CC8.8.6.4, Generating Units shall be capable of remaining connected to the Power System without power reduction as long as voltage and frequency remain within the limits specified in CC5,

(iii) Generating Units shall be capable of remaining connected to the Power System during single-phase or three-phase auto –reclosures on meshed network lines, if applicable to which they are connected. The details of that capability shall be subject to coordination and agreements on protection schemes and settings as referred to in CC6.4.4,

(iv) the TSO and the Generator shall enter into an agreement regarding technical capabilities of the Generating Unit to aid angular stability under fault conditions.

1. Generating Units shall fulfil the following requirements relating to voltage stability:

(i) without prejudice to CC.S1.1.9, Generating Units shall be capable of staying connected to the Power System and operating within the voltage ranges as specified in the table below;

|  |  |  |
| --- | --- | --- |
| Connection Voltage | Voltage Range | Time period for operation |
| 110 kV | 0.9 p.u. – 1.1 p.u. | unlimited |
| 275 kV | 0.9 p.u. – 1.09 p.u. | unlimited |
| 400 kV | 0.9 p.u. – 1.05 p.u. | unlimited |

it is permissible to relax the 275 kV connection voltage range requirement to 1.1 p.u. if lasting for no longer than 15 minutes,

(ii) the TSO may specify shorter periods of time during which Generating Units shall be capable of remaining connected to the Power System in the event of simultaneous overvoltage and underfrequency or simultaneous undervoltage and overfrequency,

(iii) wider voltage ranges or longer time periods for operation may be agreed with the TSO and Generator. If wider voltage ranges or longer minimum times for operation are economically and technically feasible, the Generator shall not unreasonably withhold an agreement,

1. with regard to the voltage control system;
2. the parameters and settings of the components of the voltage control system shall be agreed between the Generator and the TSO;
3. the agreement referred to in (a) shall cover the specifications and performance of an automatic voltage regulator (AVR) with regard to steady-state and transient voltage control and the specifications and performance of the excitation control system. The latter shall include:
   * + - * bandwidth limitation of the output signal to ensure the highest frequency of response cannot excite torsional oscillations on other Generating Units connected to the Power System;
         * an underexcitation limiter to prevent the AVR from reducing the Generation Units excitation to a level which would endanger synchronous stability;
         * an overexciatation limiter to ensure that the alternator excitation is not limited to less than the maximum value that can be achieved whilst ensuring that the Generating Unit is operating within its design limits;
         * a stator current limiter; and
         * a power system stabiliser function to attenuate power oscillations, this will be assessed by the TSO on a case by case basis.

CC.S1.1.3.4 The TSO may specify supplementary Reactive Power capability to be provided if the connection point of a Generating Unit is neither located at the high-voltage terminals of the step-up transformer to the voltage level of the connection point nor at the Generating Unit terminals if no step-up transformer exists. This supplementary Reactive Power shall compensate the Reactive Power demand of the high-voltage line or cable between the high-voltage terminals of the step-up transformer of the Generating Unit or its alternator terminals, if no step-up transformer exists, and the connection point and shall be provided by the responsible owner of that line or cable.

**Glossary:**

|  |  |
| --- | --- |
| **Active Power or MW** | The product of the components of alternating current and voltage that equate to true power which is measured in units of watts and standard multiples thereof, for example:  1000 Watts = 1 kW; 1000 kW = 1 **MW**; 1000 **MW** = 1 GW. |
| **Automatic Voltage Regulator** or **AVR** | A continuously acting automatic excitation system to control the voltage of a **Generating Unit** as measured at the **Generator Terminals**. |
| **Connection Point** | A **Bulk Supply Point** or a point at which a **User's Plant** and/or **Apparatus** connects to the **Transmission System**, which in the case of an **Interconnector** is the connection point specified in the relevant **Connection Agreement**. |
| **Generating Unit** | Other than in the case of **Wind Farm Power Stations**, a turbine generator within a **Power Station**, together with all **Plant** and **Apparatus** at that **Power Station** up to the high voltage bushings at the **Generator Transformer** which relate exclusively to the operation of that turbine generator (which in the case of a steam turbine will include the boiler and heat exchanger and in the case of a gas turbine will include the gas generator/combustion turbine). In the case of **Power Park Modules,** a generator within a **Power Park Module**, together with all **Plant** and **Apparatus** (including any step-up transformer) which relates exclusively to the operation of that generator. It will be either a **Synchronous Generating Unit** or a **Non-Synchronous Generating Unit**. |
| **Generator** | A **Power Station** or person who generates electricity under a **Licence** or exemption under the **Order** and who is subject to the **Grid Code** either by virtue of a **Licence** or exemption or pursuant to any agreement with the **TSO** or otherwise. |
|  |  |
| **Reactive Power** or **Mvar** | The product of voltage and current and the sine of  the phase angle between them measured in units of  volt-amperes reactive and standard multiples  thereof, i.e.:  1000 var = 1 kvar  1000 kvar = 1 Mvar |
| **Registered Capacity** | The normal **Full Load** capacity of a **Generating Unit** in **MW** measured as at the **Connection Point** and in relation to a **Power Park Module,** the normal **Full Load** capacity of the collection of one or more **Generating Unit (s)** taken together in aggregate**,** in **MW** measured as at the **Connection Point** of the **Power Park Module**. |
| **Voltage Control** | The retention of the voltage on the **System** within acceptable limits. |

# site Safety requirements

The following is required for the EirGrid/SONI witness to attend site:

|  |  |
| --- | --- |
| Personal Protective Equipment Requirements   1. Site Safety boots 2. Hard Hat with chin strap 3. Hi Vis 4. Arc Resistive clothing 5. Safety Glasses 6. Gloves | 1. Yes / No 2. Yes / No 3. Yes / No 4. Yes / No 5. Yes / No 6. Yes / No |
| Site Induction requirements | Yes / No  (If Yes, WFPS to specify how and when the induction must carried out) |
| Any further information | Unit to specify |

# Test description and pre conditions

## Purpose of the Test

The purpose of this test is to demonstrate the stable operation of the Unit at the MW/MVar levels as per Grid Code requirements.

This test shall also demonstrate the stable operation of the unit while under the control of automatic excitation limiters.

## Pass Criteria

The following is the pass criteria for the test. Any subsequent report for this test will be assessed against each of these criteria.

1. The Unit power output shall be within the required band.
2. The Unit is capable of stable operation while under the control of the under-excitation limiter.
3. The Unit is capable of stable operation while under the control of the over-excitation limiter.

## Instrumentation and onsite data trending

All of the following trends must be recorded by the Unit during the test. Failure to provide any of these trends will result in test cancellation.

|  |  |  |  |
| --- | --- | --- | --- |
| **No.** | **Data Trending and Recording** | **Resolution** | **Check On Day Of Test** |
| 1 | Active power at Connection (MW) | Unit to specify, 100ms or as agreed with TSO | Unit to specify |
| 2 | Reactive power at Connection point (MW) | Unit to specify, 100ms or as agreed with TSO | Unit to specify |
| 3 | Active Power at Generator Terminals (MW) | Unit to specify, 100ms or as agreed with TSO | Unit to specify |
| 4 | Reactive Power at Generator Terminals (Mvar) | Unit to specify, 100ms or as agreed with TSO | Unit to specify |
| 5 | Generator Voltage (kV) | Unit to specify, 100ms or as agreed with TSO | Unit to specify |
| 6 | Turbine Speed (RPM) | Unit to specify, 100ms or as agreed with TSO | Unit to specify |
| 7 | Generator Transformer Tap setting | Unit to specify, 100ms or as agreed with TSO | Unit to specify |
| 8 | System Voltage | Unit to specify, 100ms or as agreed with TSO | Unit to specify |
| 9 | System Frequency | Unit to specify, 100ms or as agreed with TSO | Unit to specify |
| 12 | Other signals as required by the unit or by [Generator\_Testing@soni.ltd.uk](mailto:Generator_Testing@soni.ltd.uk). | Unit to specify | Unit to specify |
| 13 | Alarm/Event page | Screenshot alarms/events for duration of the test. | |
| 14 | Generator Overview Screen | Screenshot at appropriate milestones during the test i.e. Before, during at regular intervals and after test from generator overview page on DCS | |
| 15 | EDIL instructions | Screenshot as logged during the test. | |

## Initial Conditions

Should “No” be answered to any of the following, contact the EirGrid/SONI Test Coordinator and agree next steps in advance of making any corrective actions.

|  |  |  |
| --- | --- | --- |
| **No.** | **Conditions** | **Check on day of test** |
| 1 | Test Profiles have been submitted and approved by [neartime@soni.ltd.uk](mailto:neartime@soni.ltd.uk). | Yes/No |
| 2 | Unit Fuel Type: Primary Fuel / Secondary Fuel. | Yes/No |
| 3 | Correction curves (Temperature, humidity, atmospheric pressure) have been provided to [Generator\_Testing@soni.ltd.uk](mailto:Generator_Testing@soni.ltd.uk) | Yes/No |
| 4 | Frequency Response mode On / Off. | Yes/No |
| 5 | Unit is on load and stable in agreement with CHCC. | Yes/No |
| 6 | Normal start up support auxiliary systems are aligned and in service. | Yes/No |
| 7 | Required signals, as described in section 7.3 are available. | Yes/No |

# Test Steps

|  |  |  |  |
| --- | --- | --- | --- |
| **Step No.** | **Action** | **Time** | **Comments** |
| 1 | Unit operator begins data recording for all trends noted in Section 7.3. |  |  |
|  | **OVER EXCITED TESTS** |  |  |
| 2 | Unit operator contacts CHCC and requests permission to begin test and a dispatch instruction to **Registered Capacity** via EDIL. |  | Registered Capacity: \_\_\_\_ MW |
| 3 | Unit operator receives EDIL instruction, dispatches the Unit to **Registered Capacity** and allows the Unit to stabilise for 10 mins. |  |  |
| 4 | With the Unit at Registered Capacity the operator adjusts the Mvars to the rated value for Lagging Mvars on the Generator Capability Curve and allows the Unit to thermally stabilise. |  |  |
| 5 | With the Unit at Registered Capacity and the generator thermally stabilised run for an additional 30 minutes and record all data. |  |  |
|  |  |  |  |
| 6 | Adjust the generator terminal voltage to 110% rated (Transmission connected generation) |  | 110% rated voltage: \_\_\_\_\_ kv |
| 7 | With theUnit at Registered Capacity and the Generator terminal voltage at XX% rated adjust the Mvars to the rated value for Lagging Mvars on the Generator Capability Curve and allow it to thermally stabilise. |  |  |
| 8 | With theUnit at Registered Capacity and the Generator terminal voltage at XX% rated and the generator thermally stabilised run for an additional 30 minutes and record all data. |  |  |
| 9 | With theUnit at Registered Capacity adjust the PF to unity. |  |  |
|  |  |  |  |
| 10 | Adjust the generator terminal voltage to 90% rated (Transmission connected generation) |  | 90% rated voltage: \_\_\_\_\_ kv |
| 11 | With theUnit at Registered Capacity and the Generator terminal voltage at XX% rated adjust the Mvars to the rated value for Lagging Mvars on the Generator Capability Curve and allow it to thermally stabilise. |  |  |
| 12 | With theUnit at Registered Capacity and the Generator terminal voltage at XX% rated and the generator thermally stabilised run for an additional 30 minutes and record all data. |  |  |
| 13 | With theUnit at Registered Capacity adjust the PF to unity. |  |  |
| 14 | Command a 5% increase to the AVR and hold for 10 seconds. Confirm that the OEL alarm comes in. Allow unit to stabilise for 5 mins. |  |  |
| 15 | Adjust theAVR OE settings and then adjust GSU tap changer to confirm OEL activates and adjusts AVR response |  |  |
| 16 | Return the AVRsettings to normal and allow unit to stabilise for 10 minutes |  |  |
| 17 | With theUnit at Registered Capacity adjust the Mvars to the rated value for Lagging Mvars on the Generator Capability Curve in preparation for the AVR Ceiling Test |  |  |
| 18 | Command a 10% increase to the AVR and hold for 0.1 seconds. |  |  |
| 19 | Return the AVRsettings to normal and allow unit to stabilise for 10 minutes |  |  |
| 20 | Unit operator contacts CHCC and requests permission to begin test and a dispatch instruction to 75% **Registered Capacity** via EDIL. |  | 75% Registered Capacity: \_\_\_\_MW |
| 21 | Unit operator receives EDIL instruction, dispatches the Unit to 75% **Registered Capacity** and allows to stabilise for 10 mins. |  |  |
| 22 | With the Unit at 75% Registered Capacity the operator adjusts the Mvars to the rated value for Lagging Mvars on the Generator Capability Curve and allows the Unit to thermally stabilise. |  |  |
| 23 | With the Unit at 75% Registered Capacity and thermally stabilised run for an additional 30 mins and record all data. |  |  |
|  |  |  |  |
| 24 | Unit operator contacts CHCC and requests permission to begin test and a dispatch instruction to Designed Minimimum Operating Level (DMOL)via EDIL. |  | 35% Registered Capacity: \_\_\_\_MW |
| 25 | Unit operator receives EDIL instruction, dispatches the Unit to DMOLand allows the Unit to stabilise for 10 mins. |  |  |
| 26 | With the Unit at DMOL the operator adjusts the Mvars to the rated value for Lagging Mvars on the Generator Capability Curve and allows the Unit to thermally stabilise. |  |  |
| 27 | With theUnit at DMOL and thermally stabilised run for an additional 30 minutes and record all data |  |  |
|  | **UNDER EXCITED TESTS** |  |  |
| 28 | Unit operator contacts CHCC and requests permission to begin test and a dispatch instruction to **Registered Capacity** via EDIL. |  | Registered Capacity: \_\_\_\_ MW |
| 29 | Unit operator receives EDIL instruction, dispatches the Unit to **Registered Capacity** and allows the Unit to stabilise for 10 mins. |  |  |
| 30 | With theUnit at Registered Capacity adjust the Mvars to the rated value for leading Mvars on the Generator Capability Curve and allow it to thermally stabilise. |  |  |
| 31 | With theUnit at Registered Capacity and the generator thermally stablised run for an additional 30 minutes and record all data. |  |  |
| 32 | With theUnit at Registered Capacity adjust the Mvars to the less than the rated value for leading Mvars on the Generator Capability Curve and allow it to thermally stabilise. |  |  |
| 33 | Adjust the UEL settings to just below operating levels |  |  |
| 34 | Command a 2% reduction to the AVR and hold for 10 seconds. Confirm that the UEL alarm comes in and allow the Unit to stabilise for 5 mins. |  |  |
| 35 | With theUnit at Registered Capacity adjust the Mvars to the rated value for leading Mvars on the Generator Capability Curve and allow it to stabilise for 5 minutes. |  |  |
| 36 | Restore the unit to pre-test MW and Mvar levels. Allow unit to stabilise for 5 mins |  |  |
| 37 | Unit operator contacts CHCC and requests permission to begin test and a dispatch instruction to 75% **Registered Capacity** via EDIL. |  | 75% Registered Capacity: \_\_\_\_MW |
| 38 | Unit operator receives EDIL instruction, dispatches the Unit to 75% **Registered Capacity** and allows to stabilise for 10 mins. |  |  |
| 39 | With the Unit at 75% Registered Capacity the operator adjusts the Mvars to the rated value for Lagging Mvars on the Generator Capability Curve and allows the Unit to thermally stabilise. |  |  |
| 40 | With the Unit at 75% Registered Capacity and thermally stabilised run for an additional 30 mins and record all data. |  |  |
| 41 | Unit operator contacts CHCC and requests permission to begin test and a dispatch instruction to 50% **Registered Capacity** via EDIL. |  | 50% Registered Capacity: \_\_\_\_MW |
| 42 | Unit operator receives EDIL instruction, dispatches the Unit to 50% **Registered Capacity** and allows the Unit to stabilise for 10 mins. |  |  |
| 43 | With the Unit at 50% Registered Capacity the operator adjusts the Mvars to the rated value for Lagging Mvars on the Generator Capability Curve and allows the Unit to thermally stabilise. |  |  |
| 44 | With theUnit at 50% of Registered Capacity and thermally stabilised run for an additional 30 minutes and record all data |  |  |
| 45 | Unit operator contacts CHCC and notifies them that the test is complete. |  |  |
| 46 | Unit operator follows CHCC instruction. |  | Instruction from CHCC \_\_\_\_\_\_ |
| 47 | Unit operator ends data recording for all trends noted in Section 7.3 |  |  |

|  |
| --- |
| **Comments:** |
| Unit Witness signoff that this test has been carried out according to the test procedure, above.  Signature: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date / Time: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ |
| SONI Witness signoff that this test has been carried out according to the test procedure, above.  Signature: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date / Time: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ |

1. https://www.soni.ltd.uk/how-the-grid-works/grid-codes/ [↑](#footnote-ref-1)
2. For example a simulation model of the Generator performance characteristics under the test procedure [↑](#footnote-ref-2)