

COMPLIANCE PROCESSES (CP)

APPENDIX 3 - SIMULATION STUDIES

- CP.A.3.1.1 This Appendix sets out the simulation studies required to be submitted to **The Company** to demonstrate compliance with the Connection Conditions unless otherwise agreed with **The Company**. This Appendix should be read in conjunction with CP.6 with regard to the submission of the reports to **The Company**. Where there is any inconsistency in the technical requirements in respect of which compliance is being demonstrated by simulation in this Appendix and CC.6.3 and the **Bilateral Agreement**, the provisions of the **Bilateral Agreement** and CC.6.3 prevail. The studies specified in this Appendix will normally be sufficient to demonstrate compliance. However **The Company** may agree an alternative set of studies proposed by the **Generator** or **DC Converter Station** owner provided **The Company** deem the alternative set of studies sufficient to demonstrate compliance with the Grid Code and the **Bilateral Agreement**.
- CP.A.3.1.2 **The Generator** or **DC Converter Station** owner shall submit simulation studies in the form of a report to demonstrate compliance. In all cases the simulation studies must utilise models applicable to the **Generating Unit**, **DC Converter** or **Power Park Module** with proposed or actual parameter settings. Reports should be submitted in English with all diagrams and graphs plotted clearly with legible axes and scaling provided to ensure any variations in plotted values is clear.
- CP.A.3.1.3 In the case of an **Offshore Power Station** where **OTSDUW Arrangements** apply simulation studies by the **Generator** should include the action of any relevant **OTSUA** where applicable to demonstrate compliance with the Grid Code and the **Bilateral Agreement** at the **Interface Point**.
- CP.A.3.2 Power System Stabiliser Tuning
- CP.A.3.2.1 In the case of a **Synchronous Generating Unit** the **Power System Stabiliser** tuning simulation study report required by CC.A.6.2.5.6 or required by the **Bilateral Agreement** shall contain:
- (i) the **Excitation System** model including the **Power System Stabiliser** with settings as required under the **Planning Code** (PC.A.5.3.2(c))
 - (ii) **open circuit time series simulation study of the response of the Excitation System to a +10% step change from 90% to 100% terminal voltage.**
 - (iii) on load time series dynamic simulation studies of the response of the **Excitation System** with and without the **Power System Stabiliser** to 2% and 10% steps in the reference voltage and a three phase short circuit fault applied to the higher voltage side of the **Generating Unit** transformer for 100ms. The simulation studies should be carried out with the **Generating Unit** operating at full **Active Power** and maximum leading **Reactive Power** import with the fault level at the **Supergrid HV** connection point at minimum or as otherwise agreed with **The Company**. The results should show **Generating Unit** field voltage, **Generating Unit** terminal voltage, **Power System Stabiliser** output, **Generating Unit Active Power** and **Generating Unit Reactive Power** output.
 - (iv) gain and phase Bode diagrams for the open loop frequency domain response of the **Generating Unit Excitation System** with and without the **Power System Stabiliser**. These should be in a suitable format to allow assessment of the phase contribution of the **Power System Stabiliser** and the gain and phase margin of the **Excitation System** with and without the **Power System Stabiliser** in service.

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- (iv) an eigenvalue plot to demonstrate that all modes remain stable when the **Power System Stabiliser** gain is increased by at least a factor of 3 from the designed operating value.
- (vi) gain Bode diagram f or the closed loop on load frequency domain response of the **Generating Unit Excitation System** with and without the **Power System Stabiliser**. The **Generating Unit** operating at full load and at unity power factor. These diagrams should be in a suitable format to allow comparison of the **Active Power** damping across the f frequency range specified in CC.A.6.2.6.3 with and without the **Power System Stabiliser** in service.

In the case of a Synchronous Generating Unit that may operate as demand (eg. pumped storage) the on load simulations (ii) to (vi) should also be carried out in both modes of operation.

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CP.A.3.2.2 In the case of **Onshore Non-Synchronous Generating Units, Onshore DC Converters and Onshore Power Park Modules** and **OTSDUW Plant and Apparatus** at the **Interface Point** the **Power System Stabiliser** tuning simulation study report required by CC.A.7.2.4.1 or required by the **Bilateral Agreement** shall contain:

- (i) the **Voltage Control System** model including the **Power System Stabiliser** with settings as required under the **Planning Code** (PC.A.5.4) and **Bilateral Agreement**.
- (ii) on load time series dynamic simulation studies of the response of the **Voltage Control System** with and without the **Power System Stabiliser** to 2% and 10% steps in the reference voltage and a three phase short circuit fault applied to the **Grid Entry Point** or the **Interface Point** in the case of **OTSDUW Plant and Apparatus** for 100ms. The simulation studies should be carried out operating at full **Active Power** and maximum leading **Reactive Power** import condition with the fault level at the **Supergrid HV** connection point at minimum or as otherwise agreed with **The Company**. The results should show appropriate signals to demonstrate the expected damping performance of the **Power System Stabiliser**.
- (iii) any other simulation as specified in the **Bilateral Agreement** or agreed between the **Generator** or **DC Converter Owner** or **Offshore Transmission Licensee** and **The Company**.

CP.A.3.3 Reactive Capability across the Voltage Range

CP.A.3.3.1 The **Generator** or **DC Converter station** owner shall supply simulation studies to demonstrate the capability to meet CC.6.3.4 by submission of a report containing:

- (i) a load f low simulation study result to demonstrate the maximum lagging **Reactive Power** capability of the **Synchronous Generating Unit, DC Converter, OTSUA or Power Park Module** at **Rated MW** when the **Grid Entry Point** or **User System Entry Point** if **Embedded** or **Interface Point** (in case of **OTSUA**) voltage is at 105% of nominal.
- (ii) a load f low simulation study result to demonstrate the maximum leading **Reactive Power** capability of the **Synchronous Generating Unit, DC Converter, OTSUA or Power Park Module** at **Rated MW** when the **Grid Entry Point** or **User System Entry Point** if **Embedded** or **Interface Point** (in case of **OTSUA**) voltage is at 95% of nominal.

CP.A.3.3.2 In the case of a **Synchronous Generating Unit** the terminal voltage in the simulation should be the nominal voltage for the machine. Where necessary to demonstrate compliance with CC.6.3.4 and subject to compliance with CC.6.3.8 (a) (v), the **Generator** shall repeat the two simulation studies with the terminal voltage being greater than the nominal voltage and less than or equal to the maximum terminal voltage. The two additional simulations do not need to have the same terminal voltage.

CP.A.3.3.3 In the case of a **Synchronous Generating Unit** the **Generator** shall supply two sets of simulation studies to demonstrate the capability to meet the operational requirements of BC2.A.2.6 and CC.6.1.7 at the minimum and maximum short circuit levels when changing tap position. Each set of simulation studies shall be at the same system conditions. None of the simulation studies shall include the **Synchronous Generating Unit** operating at the limits of its **Reactive Power** output.

The simulation results shall include the **Reactive Power** output of the **Synchronous Generating Unit** and the voltage at the **Grid Entry Point** or, if **Embedded**, the **User System Entry Point** with the **Generating Unit** transformer at two adjacent tap positions with the greatest interval between them and the terminal voltage of the **Synchronous Generating Unit** equal to

- its nominal value; and
- subject to compliance with CC.6.3.8 (a) (v), its maximum value.

CP.A.3.3.4 In the case of a **Power Park Module** where the load flow simulation studies show that the individual **Power Park Units** deviate from nominal voltage to meet the **Reactive Power** requirements then evidence must be provided from factory (e.g. in a **Manufacturer's Data & Performance Report**) or site testing that the **Power Park Unit** is capable of operating continuously at the operating points determined in the load flow simulation studies.

CP.A.3.4 Voltage Control and Reactive Power Stability

CP.A.3.4.1 In the case of a power station containing **Power Park Modules** and/or **OTSUA** the **Generator** shall provide a report to demonstrate the dynamic capability and control stability of the **Power Park Module**. The report shall contain:

- (i) a dynamic time series simulation study result of a sufficiently large negative step in **System** voltage to cause a change in **Reactive Power** from zero to the maximum lagging value at **Rated MW**.
- (ii) a dynamic time series simulation study result of a sufficiently large positive step in **System** voltage to cause a change in **Reactive Power** from zero to the maximum leading value at **Rated MW**.
- (iii) a dynamic time series simulation study result 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.
- (iv) a dynamic time series simulation study result to demonstrate control stability at the leading **Reactive Power** limit by application of a +2% voltage step while operating within 5% of the leading **Reactive Power** limit.

(v) a dynamic time series simulation study result of a sufficiently negative step in **System** voltage to cause a change in **Reactive Power** from the maximum leading value to the maximum lagging value at **Rated MW**.

The **Generator** should also provide the voltage control study specified in CP.A.3.7.4.

CP.A.3.4.2 All the above studies should be completed with a nominal network voltage for zero **Reactive Power** transfer at the **Grid Entry Point** or **User System Entry Point** if **Embedded** or, in the case of **OTSUA**, **Interface Point** unless stated otherwise and the fault level at the **HV** connection point at minimum as agreed with **The Company**.

CP.A.3.4.3 **The Company** may permit relaxation from the requirements of CP.A.3.4.1(i) and (ii) for voltage control if the **Power Park Modules** are comprised of **Power Park Units** in respect of which the **GB Code User** has in its submissions to **The Company** referenced an appropriate **Manufacturer's Data & Performance Report** which is acceptable to **The Company** for voltage control.

CP.A.3.4.4 In addition **The Company** may permit a further relaxation from the requirements of CP.A.3.4.1(iii) and (iv) if the **GB Code User** has in its submissions to **The Company** referenced an appropriate **Manufacturer's Data & Performance Report** for a **Power Park Module** mathematical model for voltage control acceptable to **The Company**.

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CP.A.3.5 Fault Ride Through

CP.A.3.5.1 The **Generator**, (including where undertaking OTSDUW) or **DC Converter Station** owner shall supply time series simulation study results to demonstrate the capability of **Non-Synchronous Generating Units, DC Converters, Power Park Modules** and **OTSUA** to meet CC.6.3.15 by submission of a report containing:

- (i) a time series simulation study of a 140ms solid three phase short circuit fault applied on the nearest point of the **National Electricity Transmission System** operating at **Supergrid** voltage to the **Non-Synchronous Generating Unit, DC Converter, Power Park Module** or **OTSUA**
- (ii) time series simulation study of 140ms unbalanced short circuit faults applied on the nearest point of the **National Electricity Transmission System** operating at **Supergrid** voltage to the **Non-Synchronous Generating Unit, DC Converter, Power Park Module** or **OTSUA**. The unbalanced faults to be simulated are:
 - 1. a phase to phase fault
 - 2. a two phase to earth fault
 - 3. a single phase to earth fault.

For a **Non-Synchronous Generating Unit, DC Converter, Power Park Module** or **OTSUA** the simulation study should be completed with the **Non-Synchronous Generating Unit, DC Converter, Power Park Module** or **OTSUA** operating at full **Active Power** and maximum leading **Reactive Power** import and the fault level at the **Supergrid HV** connection point at minimum or as otherwise agreed with **The Company**.

- (iii) time series simulation studies of balanced **Supergrid** voltage dips applied on the nearest point of the **National Electricity Transmission System** operating at **Supergrid** voltage to the **Non-Synchronous Generating Unit, DC Converter, Power Park Module** or **OTSUA**. The simulation studies should include:
 - 1. 30% retained voltage lasting 0.384 seconds
 - 2. 50% retained voltage lasting 0.71 seconds
 - 3. 80% retained voltage lasting 2.5 seconds
 - 4. 85% retained voltage lasting 180 seconds.

For a **Non-Synchronous Generating Unit, DC Converter, Power Park Module** or **OTSUA** the simulation study should be completed with the **Non-Synchronous Generating Unit, DC Converter, Power Park Module** or **OTSUA** operating at full **Active Power** and zero **Reactive Power** output and the fault level at the **Supergrid HV** connection point at minimum or as otherwise agreed with **The Company**. Where the **Non-Synchronous Generating Unit, DC Converter** or **Power Park Module** is **Embedded** the minimum **Network Operator's System** impedance to the **Supergrid HV** connection point shall be used which may be calculated from the maximum fault level at the **User System Entry Point**.

For **DC Converters** the simulations should include the duration of each voltage dip 1 to 4 above for which the **DC Converter** will remain connected.

CP.A.3.5.2 In the case of **Power Park Modules** comprised of **Power Park Units** in respect of which the **GB Code User's** reference to a **Manufacturer's Data & Performance Report** has been accepted by **The Company** for Fault Ride Through, CP.A.3.5.1 will not apply provided:

- (i) the **Generator** or **DC Converter Station** owner demonstrates by load flow simulation study result that the faults and voltage dips at either side of the **Power Park Unit** transformer corresponding to the required faults and voltage dips in CP.A.3.5.1 applied at the nearest point of the **National Electricity Transmission System** operating at **Supergrid** voltage are less than those included in the **Manufacturer's Data & Performance Report**,

or;

- (ii) the same or greater percentage faults and voltage dips in CP.A.3.5.1 have been applied at either side of the **Power Park Unit** transformer in the **Manufacturer's Data & Performance Report**.

CP.A.3.5.3 In the case of an **Offshore Power Park Module** or **Offshore DC Converter** the studies may instead be completed at the **LV Side of the Offshore Platform**. For fault simulation studies described in CCA.8.5.1(i) and CCA.8.5.1(ii) a retained voltage of 15% or lower may be applied at the **LV Side of the Offshore Platform** on the faulted phases. For voltage dip simulation studies described in CP.A.3.5.1(iii) the same voltage levels and durations as normally applied at the **National Electricity Transmission System** operating at **Supergrid Voltage** will be applied at the **LV Side of the Offshore Platform**.

CP.A.3.5.3

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CP.A.3.6 Load Rejection

CP.A.3.6.1 In respect of **Generating Units** or **DC Converters** or **Power Park Modules** with a **Completion Date** on or after 1 January 2012, the **Generator** or **DC Converter Station** owner shall demonstrate the speed control performance of the plant under a part load rejection condition as required by CC.6.3.7(c)(i), through simulation study. In respect of **Generating Units** or **DC Converters** or **Power Park Modules**, including those with a **Completion Date** before 1 January 2013, the load rejection capability while still supplying load must be stated in accordance with PC.A.5.3.2(f).

CP.A.3.6.2 For **Power Park Modules** comprised of **Power Park Units** having a corresponding generically verified and validated model included in the **Manufacturer's Data & Performance Report** this study ~~is may not be required by The Company~~ if the correct **Manufacturer's Data & Performance Report** reference has been submitted in the appropriate location in the **Data Registration Code**.

CP.A.3.6.3 The simulation study should comprise of a **Generating Unit, DC Converter** or **Power Park Module** connected to the total **System** with a local load shown as "X" in figure CP.A.3.6.1. The load "X" is in addition to any auxiliary load of the **Power Station** connected directly to the **Generating Unit, DC Converter** or **Power Park Module** and represents a small portion of the **System** to which the **Generating Unit, DC Converter** or **Power Park Module** is attached. The value of "X" should be the minimum for which the **Generating Unit, DC Converter** or **Power Park Module** can control the power island frequency to less than 52Hz. Where transient excursions above 52Hz occur the **Generator** or **DC Converter Owner** should ensure that the duration above 52Hz is less than any high frequency protection system applied to the **Generating Unit, DC Converter** or **Power Park Module**.

CP.A.3.6.4 At the start of the simulation study the **Generating Unit, DC Converter** or **Power Park Module** will be operating maximum **Active Power** output. The **Generating Unit, DC Converter** or **Power Park Module** will then be islanded from the **Total System** but still supplying load "X" by the opening of a breaker, which is not the **Generating Unit, DC Converter** or **Power Park Module** connection circuit breaker (the governor should therefore, not receive any signals that the breaker has opened other than the reduction in load and subsequent increase in speed). A schematic arrangement of the simulation study is illustrated by Figure CP.A.3.6.1.

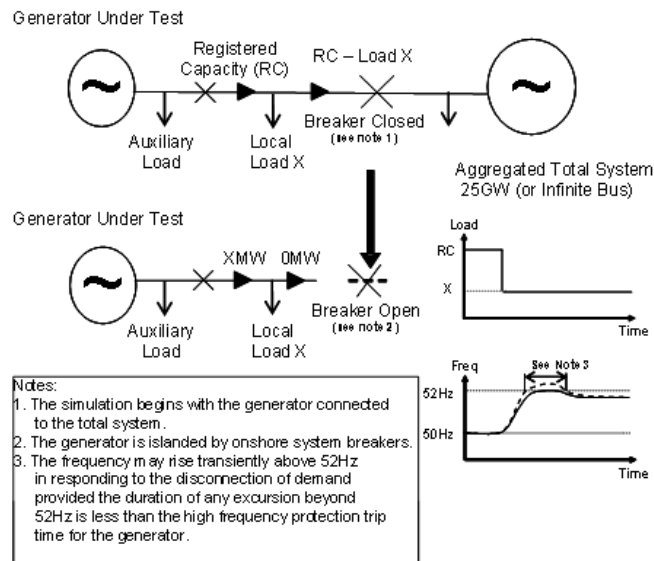


Figure CP.A.3.6.1 – Diagram of Load Rejection Study

- CP.A.3.6.5 Simulation study shall be performed for both control modes, **Frequency Sensitive Mode (FSM)** and **Limited Frequency Sensitive Mode (LFSM)**. The simulation study results should indicate **Active Power** and **Frequency** in the island system that includes the **Generating Unit, DC Converter or Power Park Module**.
- CP.A.3.6.6 To allow validation of the model used to simulate load rejection in accordance with CC.6.3.7(c)(i) as described a further simulation study is required to represent the largest positive **Frequency** injection step or fast ramp (BC1 and BC3 of Figure 2) that will be applied as a test as described in OC5.A.2.8 and OC5.A.3.6.
- CP.A.3.7 Voltage and Frequency Controller Model Verification and Validation
- CP.A.3.7.1 For **Generating Units, DC Converters or Power Park Modules** with a **Completion Date** after 1 January 2012 or subject to a **Modification** to a **Excitation System**, voltage control system, governor control system or **Frequency** control system after 1 January 2012 the **Generator or DC Converter Station** owner shall provide simulation studies to verify that the proposed controller models supplied to **The Company** under the **Planning Code** are fit for purpose. These simulation study results shall be provided in the timescales stated in the **Planning Code**. For **Power Park Modules** comprised of **Power Park Units** having a corresponding generically verified and validated model in a **Manufacturer's Data & Performance Report** **The Company** may permit the simulation studies detailed in CP.A.3.7.2, CP.A.3.7.4 and CP.A.3.7.5 to be replaced by submission of the correct **Manufacturer's Data & Performance Report** reference in the appropriate location in the **Data Registration Code**.
- CP.A.3.7.2 To demonstrate the **Frequency** control or governor/load controller/plant model the **Generator or DC Converter Station** owner shall submit a simulation study representing the response of the **Synchronous Generating Unit, DC Converter or Power Park Module** operating at 80% of **Registered Capacity**. The simulation study event shall be equivalent to:
- (i) a ramped reduction in the measured **System Frequency** of 0.5Hz in 10 seconds followed by
 - (ii) 20 seconds of steady state with the measured **System Frequency** depressed by 0.5Hz followed by

- (iii) a ramped increase in measured **System Frequency** of 0.3Hz over 30 seconds followed by
- (iv) 60 seconds of steady state with the measured **System Frequency** depressed by 0.2Hz as illustrated in Figure CP.A.3.7.2 below.

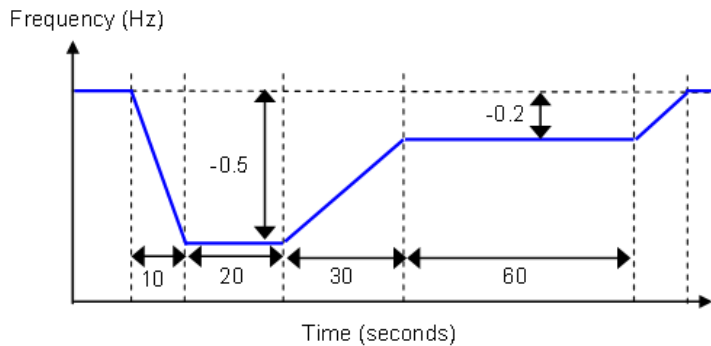


Figure CP.A.3.7.2

The simulation study shall show **Active Power** output (MW) and the equivalent of **Frequency** injected.

CP.A.3.7.3 To demonstrate the **Excitation System** model the **Generator** shall submit simulation studies representing the response of the **Synchronous Generating Unit** as follows:

- (i) operating open circuit at rated terminal voltage and subjected to a 2% step increase in terminal voltage reference.
- (ii) operating at **Rated MW**, nominal terminal voltage and unity power factor subjected to a 2% step increase in the voltage reference. Where a **Power System Stabiliser** is included within the **Excitation System** this shall be in service.

The simulation study shall show the terminal voltage, field voltage of the **Generating Unit**, **Active Power**, **Reactive Power** and **Power System Stabiliser** output signal as appropriate.

CP.A.3.7.4 To demonstrate the Voltage Controller model the **Generator** or **DC Converter Station** owner shall submit a simulation study representing the response of the **Non-Synchronous Generating Unit**, **DC Converter** or **Power Park Module** operating at **Rated MW** and unity power factor at the connection point to a 2% step increase in the voltage reference. The simulation study shall show the terminal voltage, **Active Power**, **Reactive Power** and **Power System Stabiliser** output signal as appropriate.

CP.A.3.7.5 To validate that the excitation and voltage control models submitted under the **Planning Code** are a reasonable representation of the dynamic behaviour of the **Synchronous Generating Unit**, **DC Converter Station** or **Power Park Module** as built, the **Generator** or **DC Converter Station** owner shall repeat the simulation studies outlined above but using the operating conditions of the equivalent tests. The simulation study results shall be displayed overlaid on the actual test results.

CP.A.3.7.7 For **Generating Units** or **DC Converters** with a **Completion Date** after 1 January 2012 or subject to a **Modification** to the governor system or **Frequency** control system after 1 January 2013 to validate that the governor/load controller/plant or **Frequency** control models submitted under the **Planning Code** is a reasonable representation of the dynamic behaviour of the **Synchronous Generating Unit** or **DC Converter Station** as built, the **Generator** or **DC Converter Station** owner shall repeat the simulation studies outlined above but using the operating conditions of the equivalent tests. The simulation study results shall be displayed overlaid on the actual test results.

- CP.A.3.8 Sub-synchronous Resonance Control and Power Oscillation Damping Control for DC Converters
- CP.A.3.8.1 To demonstrate the compliance of the sub-synchronous control function with CC.6.3.16(a) and the terms of the **Bilateral Agreement**, the **DC Converter Station** owner or **Generator** undertaking **OTSDUW** shall submit a simulation study report.
- CP.A.3.8.2 Where power oscillation damping control function is specified on a **DC Converter** the **DC Converter Station** owner or **Generator** undertaking **OTSDUW** shall submit a simulation study report to demonstrate the compliance with CC.6.3.16(b) and the terms of the **Bilateral Agreement**.
- CP.A.3.8.3 The simulation studies should utilise the **DC Converter** control system models including the settings as required under the **Planning Code** (PC.A.5.3.2). The network conditions for the above simulation studies should be discussed with **The Company** prior to commencing any simulation studies.

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