# PLANNING CODE
**(PC)**

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PC.3.4 **The Company** may provide to the **Relevant Transmission Licensees** any data which has been submitted to **The Company** by any **Users** pursuant to the following paragraphs of the **PC**. For the avoidance of doubt, **The Company** will not provide to the **Relevant Transmission Licensees**, the types of data specified in Appendix D. The **Relevant Transmission Licensees'** use of such data is detailed in the **STC**.

PC.A.2.2

PC.A.2.5

PC.A.3.1

PC.A.3.2.1

PC.A.3.2.2

PC.A.3.3

PC.A.3.4

PC.A.4

PC.A.5.1

PC.A.5.2

PC.A.5.3.1

PC.A.5.3.2

PC.A.5.4.1

PC.A.5.4.2

PC.A.5.4.3.1

PC.A.5.4.3.2

PC.A.5.4.3.3

PC.A.5.4.3.4

PC.A.7

(and in addition in respect of the data submitted in respect of the **OTSUA**)

PC.A.2.2

PC.A.2.3

PC.A.2.4

PC.A.2.5

PC.A.3.2.2

PC.A.3.3.1(d)

PC.A.4

PC.A.5.4.3.1

PC.A.5.4.3.2

PC.A.6.2

PC.A.6.3

PC.A.6.4

PC.A.6.5

PC.A.6.6

PC.A.7

PC.3.5 In addition to the provisions of PC.3.4 **The Company** may provide to the **Relevant Transmission Licensees** any data which has been submitted to **The Company** by any **Users** in respect of **Relevant Units** pursuant to the following paragraphs of the **PC**.

PC.A.2.3

PC.A.2.4

PC.A.5.5

PC.A.5.7

PC.A.6.2

PC.A.6.3

PC.A.6.4

PC.A.6.5

PC.A.6.6

PC.3.6 In the case of **Offshore Embedded Power Stations** connected to an **Offshore User System** which directly connects to an **Offshore Transmission System**, any additional data requirements in respect of such **Offshore Embedded Power Stations** may be specified in the relevant **Bilateral Agreement** with the **Network Operator** or in any **Bilateral Agreement** between **The Company** and such **Offshore Embedded Power Station**.

PC.3.7 In the case of a **Generator** undertaking **OTSDUW** connecting to an **Onshore Network Operator's System**, any additional requirements in respect of such **OTSDUW Plant and Apparatus** will be specified in the relevant **Bilateral Agreement** with the **Generator**. For the avoidance of doubt, requirements applicable to **Generators** undertaking **OTSDUW** and connecting to a **Network Operator's User System**, shall be consistent with those applicable requirements of **Generators** undertaking **OTSDUW** and connecting to a **Transmission Interface Point**.

PC.3.8 In order to comply with the requirements of ECC.6.3.17.1.5 and ECC.6.3.17.2.3 **The Company** may share relevant modelling information (to the extent available as described in ECC.6.3.17) based on the following information submitted by a **User** to another **User**:

PC.A.5.3.2(a), (b), (c), (d) and (g)

PC.A.5.4.2

PC.A.5.4.3

PC.A.9

PC.3.9 A **User** in receipt of information receved from **The Company** under PC.3.8 may only use the information to complete the analysis required by ECC.6.3.17.1 and EEC.6.3.17.2 as applicable and the **Bilateral Agreement.**

**Commented [A1]:** Original proposed change to allow ESO to provide models to Users for purposes of SSTI/SSCI simulations only.

PROPOSER'S ALTERNATIVE 1

PC.3.8 In order to comply with the requirements of ECC.6.3.17.1.5 and ECC.6.3.17.2.3 **The Company** or **Relevant Transmission Licencee** may provide the necessary information (to the extent that it is available as described in ECC.6.3.17) to a consultant employed by **The Company** or **Relevant Transmission Licencee** to carry out the analysis required by ECC.6.3.17.1 or ECC.6.3.17.2 on the behalf of a **User**. Terms for the arrangement will be agreed in the **Bilateral Agreement**.

**Commented [A2]:** Alternative suggested from WG discussions to allow model sharing with a consultant employed by ESO/TO on behalf of (and paid for) by connecting User.

PROPOSER ALTERNATIVE 2

PC.3.8 In order to comply with the requirements of ECC.6.3.17.1.5 and ECC.6.3.17.2.3 **The Company** or **Relevant Transmission Licencee** may provide the necessary information (to the extent that it is available as described in ECC.6.3.17) to a consultant employed by the **User**. Terms for the arrangement will be agreed in the **Bilateral Agreement** with the **User**. The consultant will have no affiliation with a supplier of **Plant** and **Apparatus**. The **User** is responsible for ensuring that information receved by the Consultant from **The Company** under PC.3.8 may only use the information to complete the analysis required by ECC.6.3.17.1 and EEC.6.3.17.2 as applicable and the **Bilateral Agreement.**

**Commented [A3]:** Alternative suggested from WG discussions to allow model sharing with a consultant employed by connecting User.

ALTERNATIVE – NO PROPOSER KNOWLEDGE OR EVIDENCE IF THIS IS TECHNICALLY POSSIBLE OR PRACTICAL OR ACHIEVEABLE WITH REQUIRED LEVELS OF SECURITY – REQUIRES WORK GROUP INPUT

PC.3.8 [From 1 April 2025] In order to comply with the requirements of ECC.6.3.17.1.5 and ECC.6.3.17.2.3 **The Company** or **Relevant Transmission Licencee** may provide a **User** with access to an Electro-magnetic Transient (EMT) model of an appropriate portion of the **National Electricity Transmission System** as determined by screening studies and prepared with information to the extent available as described in ECC.6.3.17. The EMT model shall be hosted by **The Company** or **Relevant Transmission Licencee** while the model of the **User Plant and Apparatus** will be provided by the User and hosted separately as arranged by **The Company** or **Relevant Transmission Licencee.** The arrangements put in place by **The Company** or **Relevant Transmission Licencee** shall as far as reasonably practical prevent the portion of the EMT model of the **National Electricity Transmission System** being visible to the **User.** A **User** may only use this access to complete the analysis required by ECC.6.3.17.1 and EEC.6.3.17.2 as applicable and the **Bilateral Agreement.**

**Commented [A4]:** Alternative suggested from WG discussions on potential technical methods of using shared hosting in PSCad so models stay hidden on an ESO/TO hosted network to which a user can apply models and run studies without seeing other models.



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**PART 2 - DETAILED PLANNING DATA**

PC.A.5.3 Synchronous Power Generating Modules, Synchronous Generating Unit and Associated Control System Data

PC.A.5.3.1 The data submitted below are not intended to constrain any **Ancillary Services Agreement**.

PC.A.5.3.2 The following **Synchronous Generating Unit** (including **Synchronous Generating Units** within a **Synchronous Power Generating Module**) and **Power Station** data should be supplied:

(a) **Synchronous Generating Unit** Parameters

Rated terminal volts (kV)

Maximum terminal voltage set point (kV)

Terminal voltage set point step resolution – if not continuous (kV)

* Rated MVA

*** Rated MW**

* Minimum Generation MW

* Short circuit ratio

Direct axis synchronous reactance

* Direct axis transient reactance

Direct axis sub-transient reactance

Direct axis short-circuit transient time constant.

Direct axis short-circuit sub-transient time constant.

Quadrature axis synchronous reactance

Quadrature axis sub-transient reactance

Quadrature axis short-circuit sub-transient time constant.

Stator time constant

Stator leakage reactance

Armature winding direct-current resistance.

Note: The above data item relating to armature winding direct-current resistance need only be supplied with respect to **Generating Units** commissioned after 1st March 1996 and in cases where, for whatever reason, the **Generator** or the **Network Operator**, as the case may be is aware of the value of the relevant parameter.

* Turbogenerator inertia constant (MWsec/MVA)

Rated field current (amps) at **Rated MW** and MVAr output and at rated terminal voltage.

Field current (amps) open circuit saturation curve for **Generating Unit** terminal voltages ranging from 50% to 120% of rated value in 10% steps as derived from appropriate manufacturers test certificates.

(b) Parameters for **Generating Unit** Step-up Transformers

* Rated MVA

Voltage ratio

* Positive sequence reactance (at max, min, & nominal tap)

Positive sequence resistance (at max, min, & nominal tap)

Zero phase sequence reactance

Tap changer range

Tap changer step size

Tap changer type: on load or off circuit

(c) Excitation Control System parameters

Note: The data items requested under Option 1 below may continue to be provided in relation to **Generating Units** connected to the **System** at 09 January 1995 (in this paragraph, the "relevant date") or the new data items set out under Option 2 may be provided. **Generators** or **Network Operators**, as the case may be, must supply the data as set out under Option 2 (and not those under Option 1) for **Generating Unit** excitation control systems commissioned after the relevant date, those **Generating Unit** excitation control systems recommissioned for any reason such as refurbishment after the relevant date and **Generating Unit** excitation control systems where, as a result of testing or other process, the **Generator** or **Network Operator**, as the case may be, is aware of the data items listed under Option 2 in relation to that **Generating Unit**.

For any excitation control systems associated with a **Generating Unit** or **Synchronous Power Generating Module** with a **Completion Date** after 1 April 2021 and any **Generating Unit** or **Synchronous Power Generating Module** excitation control systems subject to a control system change or **Modification** after 1 April 2021, the **Generator** should supply the control system models in accordance with PC.A.9.. The control system model of the **Excitation System** shall include but not limited to, the **PSS** if fitted, **Over-excitation Limiter**, **Under-excitation Limiter** and should have been verified as far as reasonably practicable by simulation studies as representing the expected behaviour of the control system. Additionally the data items listed under Option 2 below are also required.

Option 1

DC gain of Excitation Loop

Rated field voltage

Maximum field voltage

Minimum field voltage

Maximum rate of change of field voltage (rising)

Maximum rate of change of field voltage (falling)

Details of Excitation Loop described in block diagram form showing transfer functions of individual elements.

Dynamic characteristics of **Over-excitation Limiter**.

Dynamic characteristics of **Under-excitation Limiter**

Option 2

**Excitation System Nominal Response**

**Rated Field Voltage**

**No-Load Field Voltage**

**Excitation System On-Load Positive Ceiling Voltage**

**Excitation System No-Load Positive Ceiling Voltage**

**Excitation System No-Load Negative Ceiling Voltage**

Stator Current Limiter (applicable only to **Synchronous Power Generating Modules**)

Details of **Excitation System** (including **PSS** if fitted) described in block diagram form showing transfer functions of individual elements.

Details of **Over-excitation Limiter** described in block diagram form showing transfer functions of individual elements.

Details of **Under-excitation Limiter** described in block diagram form showing transfer functions of individual elements.

The block diagrams submitted after 1 January 2009 in respect of the **Excitation System** (including the **Over-excitation Limiter** and the **Under-excitation Limiter**) for **Generating Units** with a **Completion date** after 1 January 2009 or subject to a **Modification** to the **Excitation System** after 1 January 2009, should have been verified as far as reasonably practicable by simulation studies as representing the expected behaviour of the system.

(d) Governor Parameters

Incremental Droop values (in %) are required for each **Generating Unit** at six MW loading points (MLP1 to MLP6) as detailed in PC.A.5.5.1 (this data item needs only be provided for **Large Power Stations**)

Note: The data items requested under Option 1 below may continue to be provided by **Generators** in relation to **Generating Units** on the **System** at 09 January 1995 (in this paragraph, the "relevant date") or they may provide the new data items set out under Option 2. **Generators** must supply the data as set out under Option 2 (and not those under Option 1) for **Generating Unit** governor control systems commissioned after the relevant date, those **Generating Unit** governor control systems recommissioned for any reason such as refurbishment after the relevant date and **Generating Unit** governor control systems where, as a result of testing or other process, the **Generator** is aware of the data items listed under Option 2 in relation to that **Generating Unit**. **EU Generators** are also required to submit the data as set out in option 2. Additional data required from **EU Generators** which own or operate **Type C** or **Type D Power Generating Modules** are marked in brackets with an asterisk (eg (*)). For the avoidance of doubt, items marked as (*) need not be supplied by **GB Generators**.

For any governor control systems associated with a **Generating Unit** or **Synchronous Power Generating Module** with a **Completion Date** after 1 April 2021 and any **Generating Unit** or **Synchronous Power Generating Module** governor control systems subject to a control system change or **Modification** after 1 April 2021, control system models in accordance with PC.A.9 should be supplied. The control system model shall include but not limited to, the governor and prime mover dynamics such as steam flow, boiler, water flow which could impact on representation of the requirements required by the Grid Code. Additional the data items listed under Option 2 are also required if not included within the control system model.

Option 1

(i) Governor Parameters (for Reheat **Steam Units**)

HP governor average gain MW/Hz

Speeder motor setting range

HP governor valve time constant

HP governor valve opening limits

HP governor valve rate limits

Reheater time constant (**Active Energy** stored in reheater)

IP governor average gain MW/Hz

IP governor setting range

IP governor valve time constant

IP governor valve opening limits

IP governor valve rate limits

Details of acceleration sensitive elements in HP & IP governor loop.

A governor block diagram showing transfer functions of individual elements.

(ii) Governor Parameters (for Non-Reheat **Steam Units** and **Gas Turbine Units**)

Governor average gain

Speeder motor setting range

Time constant of steam or fuel governor valve

Governor valve opening limits

Governor valve rate limits

Time constant of turbine

Governor block diagram

The following data items need only be supplied for **Large Power Stations**:

(iii) Boiler & Steam Turbine Data

| | |
|---|---|
| Boiler Time Constant (Stored **Active Energy**) | s |
| HP turbine response ratio: | |
| proportion of **Primary Response** arising from HP turbine | % |
| HP turbine response ratio: | |
| proportion of High Frequency Response arising from HP turbine | % |

[End of Option 1]

Option 2

(i) Governor and associated prime mover Parameters - All **Generating Units** (including **Synchronous Generating Units** within a **Synchronous Power Generating Module**)

Governor Block Diagram showing transfer function of individual elements including acceleration sensitive elements.

Governor Time Constant (in seconds)

**Speeder Motor Setting Range** (%)

Average Gain (MW/Hz)

**Governor Deadband** (and **Governor Insensitivity Governor Deadband***) need only be provided for **Large Power Stations** (and both **Governor Deadband** and **Governor Insensitivity** should be supplied in respect of **Type C** and **D Power Generating Modules** within **Large Power Station** and **Medium Power Stations** excluding **Embedded Medium Power Stations** not subject to a **Bilateral Agreement***)

| | |
|---|---|
| - Maximum Setting | ±Hz |
| - Normal Setting | ±Hz |
| - Minimum Setting | ±Hz |

Where the **Generating Unit** governor does not have a selectable **Governor Deadband** (or **Governor Insensitivity***) facility as specified above, then the actual value of the **Governor Deadband** (or **Governor Insensitivity***) need only be provided.

The block diagrams submitted after 1 January 2009 in respect of the Governor system for **Generating Units** with a **Completion date** after 1 January 2009 or subject to a **Modification** to the governor system after 1 January 2009, should have been verified as far as reasonably practicable by simulation studies as representing the expected behaviour of the system.

(ii) Governor and associated prime mover Parameters - **Steam Units**

HP Valve Time Constant (in seconds)

HP Valve Opening Limits (%)

HP Valve Opening Rate Limits (%/second)

HP Valve Closing Rate Limits (%/second)

HP Turbine Time Constant (in seconds)

IP Valve Time Constant (in seconds)

IP Valve Opening Limits (%)

IP Valve Opening Rate Limits (%/second)

IP Valve Closing Rate Limits (%/second)

IP Turbine Time Constant (in seconds)

LP Valve Time Constant (in seconds)

LP Valve Opening Limits (%)

LP Valve Opening Rate Limits (%/second)

LP Valve Closing Rate Limits (%/second)

LP Turbine Time Constant (in seconds)

Reheater Time Constant (in seconds)

Boiler Time Constant (in seconds)

HP Power Fraction (%)

IP Power Fraction (%)

(iii) Governor and associated prime mover Parameters - **Gas Turbine Units**

Inlet Guide Vane Time Constant (in seconds)

Inlet Guide Vane Opening Limits (%)

Inlet Guide Vane Opening Rate Limits (%/second)

Inlet Guide Vane Closing Rate Limits (%/second)

Fuel Valve Constant (in seconds)

Fuel Valve Opening Limits (%)

Fuel Valve Opening Rate Limits (%/second)

Fuel Valve Closing Rate Limits (%/second)

Waste Heat Recovery Boiler Time Constant (in seconds)

(iv) Governor and associated prime mover Parameters - Hydro Generating Units

Guide Vane Actuator Time Constant (in seconds)

Guide Vane Opening Limits (%)

Guide Vane Opening Rate Limits (%/second)

Guide Vane Closing Rate Limits (%/second)

Water Time Constant (in seconds)

[End of Option 2]

(e) Unit Control Options

The following data items need only be supplied with respect to **Large Power Stations**:

Maximum **Droop** %

Normal **Droop** %

Minimum **Droop** %

Maximum **Governor Deadband** (and **Governor Insensitivity***) ±Hz

Normal **Governor Deadband** (and **Governor Insensitivity***) ±Hz

Minimum **Governor Deadband** (and **Governor Insensitivity***) ±Hz

Maximum output **Governor Deadband** (and **Governor Insensitivity***) ±MW

Normal output **Governor Deadband** (and **Governor Insensitivity***) ±MW

Minimum output **Governor Deadband** (and **Governor Insensitivity***) ±MW

**Frequency** settings between which Unit Load Controller **Droop** applies:

- Maximum Hz
- Normal Hz
- Minimum Hz

State if sustained response is normally selected.

(* **GB Generators** which are not required to satisfy the requirements of the **European Connection Conditions** are not required to supply **Governor Insensitivity** data).

(f) Plant Flexibility Performance

The following data items need only be supplied with respect to **Large Power Stations**, and should be provided with respect to each **Genset**:

# Run-up rate to **Registered Capacity**,

# Run-down rate from **Registered Capacity**,

# **Synchronising Generation**,

Regulating range

Load rejection capability while still **Synchronised** and able to supply **Load**.

Data items marked with a hash (#) should be applicable to a **Genset** which has been **Shutdown** for 48 hours.

* Data items marked with an asterisk are already requested under partx1, PC.A.3.3.1, to facilitate an early assessment by **The Company** as to whether detailed stability studies will be required before an offer of terms for a **CUSC Contract** can be made. Such data items have been repeated here merely for completeness and need not, of course, be resubmitted unless their values, known or estimated, have changed.

(g) Generating Unit Mechanical Parameters

It is occasionally necessary for **The Company** to assess the interaction between the **Total System** and the mechanical components of **Generating Units**. For **Generating Units** (including **Synchronous Generating Units** within a **Synchronous Power Generating Module**) with a **Completion Date** on or after 01 April 2015, the following data items should be supplied:

The number of turbine generator masses.

Diagram showing the Inertia and parameters for each turbine generator mass ($kgm^2$) and Stiffness constants and parameters between each turbine generator mass for the complete drive train (Nm/rad).

Number of poles.

Relative power applied to different parts of the turbine (%).

Torsional mode frequencies (Hz).

Modal damping decrement factors for the different mechanical modes.

ALTERNATIVE

(g) Generating Unit Mechanical Parameters

It is occasionally necessary for **The Company** to assess the interaction between the **Total System** and the mechanical components of **Generating Units**. For **Generating Units** (including **Synchronous Generating Units** within a **Synchronous Power Generating Module**);

-with a **Completion Date** on or after 01 April 2015, or;

-with a **Completion Date** before 01 April 2015 when requested by **The Company** in accordance with good industry practice,

-the following data items should be supplied:

The number of turbine generator masses.

Diagram showing the Inertia and parameters for each turbine generator mass ($kgm^2$) and Stiffness constants and parameters between each turbine generator mass for the complete drive train (Nm/rad).

Number of poles.

Relative power applied to different parts of the turbine (%).

Torsional mode frequencies (Hz).

Modal damping decrement factors for the different mechanical modes.

PC.A.5.4 Power Park Module, Non-Synchronous Generating Unit and Associated Control System Data

PC.A.5.4.1 The data submitted below are not intended to constrain any **Ancillary Services Agreement**

PC.A.5.4.2 The following **Power Park Unit**, **Power Park Module** and **Power Station** data should be supplied in the case of a **Power Park Module** not connected to the **Total System** by a **DC Converter** or **HVDC System** (and in the case of PC.A.5.4.2(f) any **OTSUA**):

Where a **Manufacturer's Data & Performance Report** exists in respect of the model of the **Power Park Unit**, the **User** may subject to **The Company's** agreement, opt to reference the **Manufacturer's Data & Performance Report** as an alternative to the provision of data in accordance with PC.A.5.4.2 except for:

(1) the section marked thus # at sub paragraph (b); and

**Commented [A5]:** Original proposal before October WG meeting

**Commented [A6]:** Alternative wording for (g) sasking for older plant torsional data "by request". Option added for consideration following October WG meeting

**Commented [A7]:** Added following October WG meeting

(2) all of the harmonic and flicker parameters required under sub paragraph (h); and

(3) all of the site specific model parameters relating to the voltage or frequency control systems required under sub paragraphs (d) and (e),

which must be provided by the **User** in addition to the **Manufacturer's Data & Performance Report** reference.

(a) **Power Park Unit** model

A mathematical model of each type of **Power Park Unit** capable of representing its transient and dynamic behaviour under both small and large disturbance conditions. The model shall include non-linear effects and represent all equipment relevant to the dynamic performance of the **Power Park Unit** as agreed with **The Company**. The model shall be suitable for the study of balanced, root mean square, positive phase sequence time-domain behaviour, excluding the effects of electromagnetic transients, harmonic and sub-harmonic frequencies.

The model shall accurately represent the overall performance of the **Power Park Unit** over its entire operating range including that which is inherent to the **Power Park Unit** and that which is achieved by use of supplementary control systems providing either continuous or stepwise control. Model resolution should be sufficient to accurately represent **Power Park Unit** behaviour both in response to operation of **Transmission System** protection and in the context of longer-term simulations.

The overall structure of the model shall include:

(i) any supplementary control signal modules not covered by (c), (d) and (e) below.

(ii) any blocking, deblocking and protective trip features that are part of the **Power Park Unit** (e.g. "crowbar").

(iii) any other information required to model the **Power Park Unit** behaviour to meet the model functional requirement described above.

The model shall be submitted in the form of a transfer function block diagram and may be accompanied by dynamic and algebraic equations.

This model shall display all the transfer functions and their parameter values, any non wind-up logic, signal limits and non-linearities.

The submitted **Power Park Unit** model and the supplementary control signal module models covered by (c), (d) and (e) below shall have been validated and this shall be confirmed by the **Generator**. The validation shall be based on comparing the submitted model simulation results against measured test results. Validation evidence shall also be submitted and this shall include the simulation and measured test results. The latter shall include appropriate short-circuit tests. In the case of an **Embedded Medium Power Station** not subject to a **Bilateral Agreement** the **Network Operator** will provide **The Company** with the validation evidence if requested by **The Company**. The validation of the supplementary control signal module models covered by (c), (d) and (e) below applies only to a **Power Park Module** with a **Completion Date** after 1 January 2009 or **Power Park Modules** within a **Power Generating Module**.

(b) **Power Park Unit** parameters

* Rated MVA
* **Rated MW**
* Rated terminal voltage
* Average site air density (kg/m$^3$), maximum site air density (kg/m$^3$) and minimum site air density (kg/m$^3$) for the year

Year for which the air density is submitted

Number of pole pairs

Blade swept area (m$^2$)

Gear box ratio

Mechanical drive train

For each **Power Park Unit**, details of the parameters of the drive train represented as an equivalent two mass model should be provided. This model should accurately represent the behaviour of the complete drive train for the purposes of power system analysis studies and should include the following data items:-

Equivalent inertia constant (MWsec/MVA) of the first mass (e.g. wind turbine rotor and blades) at minimum, synchronous and rated speeds

Equivalent inertia constant (MWsec/MVA) of the second mass (e.g. generator rotor) at minimum, synchronous and rated speeds

Equivalent shaft stiffness between the two masses (Nm/electrical radian)

Additionally, for **Power Park Units** that are induction generators (e.g. squirrel cage, doubly-fed) driven by wind turbines:

* Stator resistance
* Stator reactance
* Magnetising reactance.
* Rotor resistance.(at starting)
* Rotor resistance.(at rated running)
* Rotor reactance (at starting)
* Rotor reactance (at rated running)

Additionally for doubly-fed induction generators only:

The generator rotor speed range (minimum and maximum speeds in RPM)

The optimum generator rotor speed versus wind speed submitted in tabular format

Power converter rating (MVA)

The rotor power coefficient ($C_p$) versus tip speed ratio ($\lambda$) curves for a range of blade angles (where applicable) together with the corresponding values submitted in tabular format. The tip speed ratio ($\lambda$) is defined as $\Omega$R/U where $\Omega$ is the angular velocity of the rotor, R is the radius of the wind turbine rotor and U is the wind speed.

The electrical power output versus generator rotor speed for a range of wind speeds over the entire operating range of the **Power Park Unit**, together with the corresponding values submitted in tabular format.

The blade angle versus wind speed curve together with the corresponding values submitted in tabular format.

The electrical power output versus wind speed over the entire operating range of the **Power Park Unit**, together with the corresponding values submitted in tabular format.

Transfer function block diagram, including parameters and description of the operation of the power electronic converter and fault ride through capability (where applicable). For any **Power Park Unit**s in a **Power Park Module** with a **Completion Date** after 1 April 2021 and any **Power Park Units** subject to a control system change or **Modification** after 1 April 2021 control system models in accordance with PC.A.9 should be supplied.

For a **Power Park Unit** consisting of a synchronous machine in combination with a back to back **DC Converter** or **HVDC System**, or for a **Power Park Unit** not driven by a wind turbine, the data to be supplied shall be agreed with **The Company** in accordance with PC.A.7.

(c) Torque / speed and blade angle control systems and parameters

For the **Power Park Unit**, details of the torque / speed controller and blade angle controller in the case of a wind turbine and power limitation functions (where applicable) described in block diagram form showing transfer functions and parameters of individual elements.

(d) Voltage/**Reactive Power**/**Power Factor** control system parameters

For the **Power Park Unit** and **Power Park Module** details of voltage/**Reactive Power**/**Power Factor** controller (and **PSS** if fitted) described in block diagram form showing transfer functions and parameters of individual elements.

(e) **Frequency** control system parameters

For the **Power Park Unit** and **Power Park Module** details of the **Frequency** controller described in block diagram form showing transfer functions and parameters of individual elements.

(f) **Protection**

Details of settings for the following **Protection** relays (to include): Under **Frequency**, over **Frequency**, under voltage, over voltage, rotor over current, stator over current, high wind speed shut down level.

(g) Complete **Power Park Unit** model, parameters and controls

(i) For any **Power Park Unit**s in a **Power Park Module** with a **Completion Date** after 1 April 2021 and any **Power Park Units** and/or **Power Park Module(s)** subject to a control system change or **Modification** after- 1 April 2021, control system models in accordance with PC.A.9 should be supplied covering the full information required under PC.A.5.4.2 (a), (b), (c), (d), (e) and (f).

(ii) For any **Power Park Units** in a **Power Park Module** with a **Completion Date** before 1 April 2021 as ~~An~~ an alternative to PC.A.5.4.2 (a), (b), (c), (d), (e) and (f), is the submission of a single complete model that consists of the full information required under PC.A.5.4.2 (a), (b), (c), (d), (e) and (f) provided that all the information required under PC.A.5.4.2 (a), (b), (c), (d), (e) and (f) individually is clearly identifiable. For the avoidance of doubt, a **User** may submit control system models as detailed in PC.A.9 for any **Power Park Unit** or **Power Park Module** regardless of **Completion Date** as an alternative to this clause.

(h) Harmonic and flicker parameters

When connecting a **Power Park Module**, it is necessary for **The Company** to evaluate the production of flicker and harmonics on the **National Electricity Transmission System** and **User's Systems**. At **The Company's** reasonable request, the **User** (a **Network Operator** in the case of an **Embedded Power Park Module** not subject to a **Bilateral Agreement**) is required to submit the following data (as defined in IEC 61400-21 (2001)) for each **Power Park Unit**:-

Flicker coefficient for continuous operation.

Flicker step factor.

Number of switching operations in a 10 minute window.

Number of switching operations in a 2 hour window.

Voltage change factor.

Current Injection at each harmonic for each **Power Park Unit** and for each **Power**

**Park Module**

* Data items marked with an asterisk are already requested under part 1, PC.A.3.3.1, to facilitate an early assessment by **The Company** as to whether detailed stability studies will be required before an offer of terms for a **CUSC Contract** can be made. Such data items have been repeated here merely for completeness and need not, of course, be resubmitted unless their values, known or estimated, have changed.

PC.A.5.4.3 DC Converter and HVDC Systems

PC.A.5.4.3.1 For a **DC Converter** at a **DC Converter Station** or an **HVDC System** or **Power Park Module** connected to the **Total System** by a **DC Converter** or **HVDC System** (or in the case of **OTSUA** which includes an **OTSDUW DC Converter**) the following information for each **DC Converter**, **HVDC System** and **DC Network** should be supplied:

(a) **DC Converter** and **HVDC System** parameters

* **Rated MW** per pole for transfer in each direction;

* **DC Converter** type (i.e. current or voltage source (including a **HVDC Converter** in an **HVDC System**));

* Number of poles and pole arrangement;

* Rated DC voltage/pole (kV);

* Return path arrangement;

(b) **DC Converter** and **HVDC System** transformer parameters

Rated MVA

Nominal primary voltage (kV);

Nominal secondary (converter-side) voltage(s) (kV);

Winding and earthing arrangement;

Positive phase sequence reactance at minimum, maximum and nominal tap;

Positive phase sequence resistance at minimum, maximum and nominal tap;

Zero phase sequence reactance;

Tap-changer range in %;

number of tap-changer steps;

(c) **DC Network** parameters

Rated DC voltage per pole;

Rated DC current per pole;

Single line diagram of the complete **DC Network** and **HVDC System**;

Details of the complete **DC Network**, including resistance, inductance and capacitance of all DC cables and/or DC lines and **HVDC System**;

Details of any DC reactors (including DC reactor resistance), DC capacitors and/or DC-side filters that form part of the **DC Network** and/or **HVDC System**;

(d) AC filter reactive compensation equipment parameters

Note: The data provided pursuant to this paragraph must not include any contribution from reactive compensation plant.

Total number of AC filter banks.

Type of equipment (e.g. fixed or variable)

Single line diagram of filter arrangement and connections;

**Reactive Power** rating for each AC filter bank, capacitor bank or operating range of each item of reactive compensation equipment, at rated voltage;

Performance chart showing **Reactive Power** capability of the **DC Converter** and **HVDC System**, as a function of MW transfer, with all filters and reactive compensation plant, belonging to the **DC Converter Station** or **HVDC System** working correctly.

Note: Details in PC.A.5.4.3.1 are required for each **DC Converter** connected to the **DC Network** and **HVDC System**, unless each is identical or where the data has already been submitted for an identical **DC Converter** or **HVDC System** at another **Connection Point**.

Note: For a **Power Park Module** and **DC Connected Power Park Module** connected to the **Grid Entry Point** or (**User System Entry Point** if **Embedded**) by a **DC Converter** or **HVDC System** the equivalent inertia and fault infeed at the **Power Park Unit** should be given.

DC Converter and HVDC System Control System Models

PC.A.5.4.3.2 The following data is required by **The Company** to represent **DC Converters** and associated **DC Networks** and **HVDC Systems** (and including **OTSUA** which includes an **OTSDUW DC Converter**) in dynamic power system simulations,

(a) For any **DC Converters** and **HVDC Systems** with a **Completion Date** after 1 April 2021 and any **DC Converters** and **HVDC Systems** subject to a control system change or **Modification** after 1 April 2021, control system models in accordance with PC.A.9 should be supplied covering the full functionality required under PC.A.5.4.3.2 (b).

(b) For any any **DC Converters** and **HVDC Systems** with a **Completion Date** before 1 April 2021 ~~as~~ in which the AC power system is typically represented by a positive sequence equivalent, ~~,~~ it is acceptable to represent **DC Converters** and **HVDC Systems** ~~are represented~~ by simplified equations rather than ~~and are not modelled~~ to the switching device level.

(i) Static $V_{DC}$-$I_{DC}$ (DC voltage - DC current) characteristics, for both the rectifier and inverter modes for a current source converter. Static $V_{DC}$-$P_{DC}$ (DC voltage - DC power) characteristics, for both the rectifier and inverter modes for a voltage source converter. Transfer function block diagram including parameters representation of the control systems of each **DC Converter** and of the **DC Converter Station** and the **HVDC System**, for both the rectifier and inverter modes. A suitable model would feature the **DC Converter** or **HVDC Converter** firing angle as the output variable.

(ii) Transfer function block diagram representation including parameters of the **DC Converter** or **HVDC Converter** transformer tap changer control systems, including time delays

(iii) Transfer function block diagram representation including parameters of AC filter and reactive compensation equipment control systems, including any time delays.

(iv) Transfer function block diagram representation including parameters of any **Frequency** and/or load control systems.

(v) Transfer function block diagram representation including parameters of any small signal modulation controls such as power oscillation damping controls or sub-synchronous oscillation damping controls, that have not been submitted as part of the above control system data.

(vi) Transfer block diagram representation of the **Reactive Power** control at converter ends for a voltage source converter.

In addition and where not provided for above, **HVDC System Owners** shall also provide the following dynamic simulation sub-models

(i) **HVDC Converter** unit models

(ii) AC component models

(iii) DC Grid models

(iv) Voltage and power controller

(v) Special control features if applicable (eg power oscillation damping (POD) function, subsynchronous torsional interaction (SSTI) control;

(vi) Multi terminal control, if applicable

(vii) **HVDC System** protection models as agreed between **The Company** and the **HVDC System Owner**

**HVDC System Owners** are also required to supply an equivalent model of the control system when adverse control interactions may result with **HVDC Converter Stations** and other connections in close proximity if requested by **The Company**. The equivalent model shall contain all necessary data for the realistic simulation of the adverse control interactions.

For the avoidance of doubt a **User** may submit control system models as detailed in PC.A.9 for any **DC Converters** and **HVDC Systems** regardless of **Completion Date** as an alternative to PC.A.5.4.3.2(b).

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## PC.A.9 CONTROL SYSTEM MODEL REQUIREMENTS FOR USERS

### PC.A.9.1 OBJECTIVE

PC.A.9.1.1 Control system models, along with other **Plant and Apparatus** information are required by thise **PC**, with supporting documentation provided to **The Company** in order for **The Company** and **Transmission Licensees** to assess the impact of the **User's Plant and Apparatus** on the transient performance, security and stability of the **Transmission System**.

PC.A.9.1.2 The control system models submitted by the **User** shall be representative of the **User's Plant and Apparatus** at the **Connection** Point appropriate to the type of model eg. RMS or EMT. All control system models must take into account all communication, controller and processing delays relevant to modelling the performance of the **User's Plant and Apparatus**. If all **Power Park Units** or **DC Convertors** or **HVDC Converters** contained within the **Users Plant and Apparatus** are not identical, the control system model shall account for this by accurately representing the overall performance of the **Users Plant and Apparatus** at the **Connection Point**.

PC.A.9.1.3 The control system models shall include representation of all functionality required by the Grid Code including services provided to **The Company**. For example, this includes voltage control, LFSM-O, LFSM-U, frequency response, fault ride through, fast fault current injection, protection and automatic switching of shunt devices. Where modes of operation are selectable, the ability to select the mode of operation shall be included within the control system model.

### PC.A.9.2. SCOPE

PC.A.9.2.1 All **Users** shall provide root mean-square (RMS) control system models which represent the **Users Plant and Apparatus** and controllers in balanced, RMS, positive phase-sequence, time domain studies.

**Commented [A8]:** Added in response to Siemens comments

PC.A.9.2.2 All **Generators**, **HVDC Convertor Station Owners**, or **HVDC System Owners** directly connected to the **Transmission System** or **Generators** with **Large Power Stations** and **HVDC Convertor Station** Owners or **HVDC System Owners** with **DC Converter Stations** or **HVDC Systems** embedded within a **User** system which employ convertors/invertors to import or export power to or from the **System** shall provide Electro-Magnetic Transient (EMT) control and protection system models which represent the **Users Plant and Apparatus** in ~~three phase~~ electromagnetic transient studies on the transmission and distribution system. For the avoidance of doubt this includes **Generators** who own and operate a **Power Park Module** comprising doubly fed induction generators and excludes the excitation and governor control systems associated with **Synchronous Generating Units** provided suitable detailing of voltage and frequency measurements have been included in the transfer block diagrams submitted under PC.A.5.3.2.

PC.A.9.2.3 **The Company** may specify requirements for other models in the **Bilateral Agreement** if required for specific connections in accordance with good industry practice. ~~F~~for example Real Time Dynamic Simulator (RTDS) Models may be required for protection co-ordination.

PC.A.9.3 Balanced Root Mean Squared (RMS) Control System Model

PC.A.9.3.1 The balanced, root mean-square positive sequence time-domain control system model shall be able to calculate how quantities, (including but not limited to; **Active Power** and **Reactive Power)** of the **User's Plant and Apparatus** vary due to changes in **System Frequency** and voltage at the **Connection Point**.

PC.A.9.3.2 The RMS control system model shall include all electrical and mechanical phenomena that impact on the **Active Power** and/or **Reactive Power** of the **User's Plant and Apparatus** for sub-transient, transient and synchronous dynamics within the context of an RMS study assumptions up to and including **Primary** and **Secondary Response** timeframes or when post-event steady state conditions have been achieved.

PC.A.9.3.3 The User shall provide RMS control system models in the software package DIgSILENT PowerFactory. **The Company** shall publish on **The Company** website acceptable software versions.

PC.A.9.3.4 The RMS control system model maybe either a User specific model or a standard open-source control system model, such as a standard WECC, IEEE or IEC control system model available in the software format as specified by **The Company** provided this control system model represents the **User's Plant and Apparatus** at the **Connection Point**. Where the **User** is referencing a standard model, the **User** will submit an unambiguous reference to the model and a full set of parameters for the control system model representing the control system performance of the real **Plant and Apparatus**.

PC.A.9.3.4.1 Where a **User** specific model is provided sufficient information shall be provided by the **User** to allow for **The Company** to redevelop RMS models in the event of future software environment changes or version updates. All control system models shall be accompanied with appropriate documentation with sufficient detail as specified and deemed complete by **The Company** (such agreement not to be unreasonably withheld).

PC.A.9.3.4.2 Where a **User** specific model is provided the **User** shall provide information:

(i) a full description of the control system model structure and functionality the **Users Plant and Apparatus** represented.

(ii) inputs/outputs and functionality,

**Commented [A9]:** Added in response to SHETL comment

**Commented [A10]:** Reference to harmonic studies removed in response to comments. Purposes for use of model in description referenced in PC.A.9.4.2

**Commented [A11]:** Added from October WG meeting

**Commented [A12]:** Added in response to NGIC comments

**Commented [A13]:** Added in response to Siemens comments

~~(iii) transfer block diagrams (e.g. Laplace diagrams)~~

~~(iv) a description of the controller's functionality of all levels of control on the **Users Plant and Apparatus**.~~the information described inPC.A.5 relevant to the technology modelled.

Commented [A14]: Altered in reponse to Siemens comments

PC.A.9.3.5 **The Company** may, when necessary, require the **User** to provide details of the proper operation of its complete RMS system representation or to facilitate its understanding of the results of a RMS dynamic simulation. **The Company** may, when necessary, request additional information concerning the RMS control system model, which may include control system model documentation or source code of one or more routines in the RMS control system model.

PC.A.9.3.5 The performance requirements for the RMS control system model are included in Appendix PC.A.9.8

PC.A.9.4 **Electromagnetic Transient (EMT) Model**

PC.A.9.4.1 The three-phase electromagnetic transient control and protection system model shall include all material aspects of the **User's Plant and Apparatus** that affect the voltage and current outputs from the **User's Plant and Apparatus**. The control system model shall represent phenomena that materially affect the voltage and **Frequency** on the **Total System** over timeframes of sub-cycle up to 50 cycles including, but not limited to, switching electronic devices, transformer saturation and equipment energisation.

Commented [A15]: Added in response to Siemens and SHETL comments

PC.A.9.4.2 The **User** shall provide EMT control system models in software package PSCad. **The Company** shall maintain a list of acceptable software versions, and compiler version which shall be published on **The Company** website. The Company shall also publish on **The Company** website a description of the types of study that **The Company** and **Transmission Licensees** will use the EMT control system models in.

PC.A.9.4.3 The performance requirements for the EMT control system model are included in Appendix PC.A.9.9

PC.A.9.5 ~~not used, to be removed~~Replica Control Systems, RTDS, RScad

PC.A.9.5.1 Where required by the Bilateral Agreement, the **User** shall provide replica and/or suitable Real Time Dynamic Simulator control and protection control system models. The details of any such rmodels will be included in the Bilateral Agreement.

Commented [A16]: Added in response to SHETL comment

PC.A.9.6 CONFIDENTIALITY AND SHARING OF CONTROL SYSTEM MODELS

PC.A.9.6.1 The control system model, supporting documentation and associated data are provided to **The Company** in order to carry out its duties to meet its **Transmission Licence** and Grid Code obligations. In that regard, **the Company** is entitled to share the control system models, supporting documentation and associated data with the **Transmission Licensees**. **The Company** and/or **Transmission Licensees** may share the control system model with companies/contractors employed by **the Company** or **Transmission Licensees** to carry out licensed activities. Where such data is shared with third parties working with **The Company** or **Transmission Licensees**, this data will be shared and protected under the confidentiality conditions of the **Transmission Licence**.

PC.A.9.6.2 It is the responsibility of the **User** to provide the control system models, supporting documentation and associated data to **The Company**. **The Company** will accept the models, supporting documentation and associated data from a manufacturer as a **Manufacturers Data and Performance Report** (See CP.8). **The Company** will only accept this information from a third party manufacturer provided the third party manufacturer agrees to enter into **The Company's** standard confidentiality agreement for **User**s for sharing of the model as outlined above. In the event the third party manufacturer is unable to enter into **The Company's** standard confidentiality agreement, the **User** shall be responsible for the provision of the control system models, supporting documentation and associated data to **The Company**.

PC.A.9.6.3 It may also be necessary for **The Company** to share a representative control system model with another **User** to comply with ECC.6.3.17.1.5 and ECC.6.3.17.2.3. For these purposes the **User** must recorded in the **Compliance Statements** either:

(i) A declaration that the control system model submitted for compliance purposes may be shared; or,

(ii) provide an equivalent encrypted version of the model that maybe shared. In this event the **User** shall demonstrate that the performance of the control system model and the encrypted model are comparable.

PC.A.9.6.4 The **User** shall notify **The Company** of any changes to control system models in accordance with PC.A.1.2. Unless specified otherwise in the **Bilateral Agreement**, RMS and EMT control system models must be submitted:

(i) at least 3 months prior to date requested for issue of the **Interim Operational Notification**

(ii) at least 1 month prior to date of issue of a **Limited Operational Notification**

for the **Users Plant and Apparatus**.

PC.A.9.7 VALIDATION

PC.A.9.7.1 The **User** shall submit evidence that the control system models have been validated demonstrating that the control system model under simulation conditions is representative of the **User's Plant and Apparatus** under equivalent conditions. Validation of control system models before commissioning may be against test results at other comparable sites, Factory Acceptance Tests of comparable equipment, or type test results to show that the responses shown by the control system models are representative of the **Users Plant and Apparatus** ~~under laboratory test conditions~~. Results from model validation in accordance internationally recommended standards (for example IEC) where applicable are also acceptable.

PC.A.9.7.~~1~~2 Where Factory Acceptance Testing has been completed prior to installation on site, the **User** shall carry out dynamic simulations using the control system models such that responses shown by the control system models can be compared against measurements from Factory acceptance testing to ensure the control system model responses are representative of the **Users Plant and Apparatus**. Tests should include steady state reactive capability, voltage control, **Fault Ride Through** and frequency response.

**Commented [A17]:** Removed in response to SHETL comment

**Commented [A18]:** Added in response to ITP Energised comments

PC.A.9.7.~~1~~3 After final compliance testing as required under the **CP** or **ECP**, the **User** shall complete dynamic simulations using the control system models such that responses shown by the control system models can be compared against measurements from final compliance testing to ensure the control system model responses are representative of the **Users Plant and Apparatus**. Tests may include but are not limited to steady state reactive capability, voltage control, and **Frequency** response.

PC.A.9.7.~~1~~4 If these tests show the control system models are not representative of the **User's Plant and Apparatus**, the **User** shall provide updated control system models, supporting documentation and associated data to ensure the responses shown by the control system models is representative of the responses shown by **User's Plant and Apparatus** during testing.

PC.A.9.7.~~1~~5 In the event **The Company** identifies through lifetime monitoring (OC5) that that the response of the models are not representative of the **User's Plant and Apparatus**, **The Company** shall notify the **User**. The **User** shall provide the revised control system models, supporting documentation and associated data whose response is representative of the **Users Plant and Apparatus** as soon as reasonably practicable, but in any case no longer than 54 days after notification by **The Company**. In the event of revised control system models not being made available a **Limited Operational Notification** (as detailed in CP.9 or ECP.9 as applicable) may be issued with appropriate restrictions.

PC.A.9.7.~~1~~6 The **User** is responsible for ensuring the control system models remain representative of the **User's Plant and Apparatus** throughout the operational lifetime of the **User's Plant and Apparatus**. In the event of the **User** modifying hardware/software which affects the control and/or operation of the **Users Plant and Apparatus**, the **User** shall provide **The Company** with updated control system models, supporting documentation and associated data to enable **The Company** to assess the impact of the modification of the **Users Plant and Apparatus** on the **Total System**. Such changes may require other compliance activity as described in the **CP** or **ECP** as applicable.

PC.A.9.7.~~1~~7 The **User** shall demonstrate that the representation of a **User's Plant and Apparatus** and models perform correctly in a sample network model published by **The Company** before being accepted. The **User** should represent the **User's Plant and Apparatus** modelled in accordance with the **Single Line Diagram** and parameters submitted under the **Planning Code** and **DRC** in Schedules 1, 5 or 18 aggregating multiple **Power Park Units** and the collector grid to a single **Power Park Unit** representing a **Power Park Module**.

PC.A.9.8 RMS MODEL PERFORMANCE SPECIFICATION - DIGSILENT POWERFACTORY

PC.A.9.8.1 The models provided for DIgSILENT PowerFactory must be compatible with Objetives as outlined in Grid Code PC.A.9.1.

PC.A.9.8.2 GENERAL

PC.A.9.8.2.1 User RMS control system models shall interface with the DIgSILENT PowerFactory software in a manner that is consistent with the behaviour of standard library models.

PC.A.9.8.2.1 The control system models shall use standard PowerFactory library functional blocks representing using standard Laplace block diagram format to the extent practicable. Use of DIgSILENT Simulation Language (DSL) expressions to represent functions that could otherwise be represented by standard PowerFactory library macro block definitions should be avoided to the extent practicable. Where user defined functional blocks have been submitted the **User** must provide **The Company** with the relevant documentation for the model including transfer block diagrams and an explanation of any DSL coding to the satisfaction of **The Company**.

PC.A.9.8.2.2 The use of any "black boxes" encrypted code or external DLLs is not acceptable.

PC.A.9.8.2.3 The **User** shall specify the operating ranges for the control system model and shall be consistent with the real physical values and the actual performance of the **Plant and Apparatus**. This may include reactive power limits and allowable voltage ranges with control mode and droop settings configured according to the usual operation. This information shall be provided either on the appropriate per unit base or in physical units.

PC.A.9.8.2.4 Inclusion of multiple (unique) equipment control functions within a single macro block definition should be avoided. The number of lines of code within a single macro block definition - excluding parameter definitions, initial conditions and comments – should generally not exceed 30. The intent of this requirement, in conjunction with PC.A.9.8.2.1, is to provide guidance to the model developer and to improve macro code readability and model usability (it is not intended to result in increased complexity of macro equations or detract from macro code readability).

PC.A.9.8.2.5 In DIgSILENT PowerFactory, each controller is linked to a "slot". To enable the complete dynamic model to be removed from service without the need to remove each of the controllers from service, the "Main Slot" checkbox should be selected for the slot which relates to the generator element (e.g. the synchronous machine).

PC.A.9.8.2.6 RMS control system model parameters should have parameter names, descriptions and units defined in the DIgSILENT Simulation Language (DSL) models, for example "Kp Proportional gain [pu]".

PC.A.9.8.2.7 The DIgSILENT PowerFactory DSL model must compile to C code without warnings or errors.

PC.A.9.8.3 INITIALISATION

PC.A.9.8.3.1 The RMS control system model shall be self contained. The combined load-flow and dynamic model shall solve without warnings without the need for manual adjustment or to run external software routines that adjust parameters in either the load-flow case or the dynamic case or both. External software or automation routines to integrate the model are not acceptable.

PC.A.9.8.3.2 The RMS control system model shall automatically initialise its parameters from load flow simulations without warnings or errors, must not result in initialisation or run time warnings or errors, and there must not be any interactions or conflicts with other models. The RMS control system model initialisation shall be invariant to simulation start time (i.e. not require the simulation to be initialised at a particular time). The RMS control system model parameters need not be recalculated at each time step, the DSL commands selfix(), limfix() and outfix() must be used instead of select(), limits() and output() so that they are only calculated at initialisation. External software or automation routines to initialise the model are not acceptable.

PC.A.9.8.3.3 The RMS control system model is expected to be numerically stable and must adequately represent the expected equipment behaviour over the operational range of the **Plant and Apparatus** at the **Connection Point**. This includes the full load and reactive power range of the **Plant and Apparatus**, the range of system voltage and **frequency** operating range (described in Grid Code CC.6.1/ECC.6.1), short circuit levels and X/R ratio at the **Connection Point** where it would be in operation. These values maybe requested from **The Company or** the **Distribution Network Owner** during the compliance process. If necessary, the **User** shall provide a supplementary model for specific conditions. All information on the model capabilities shall be addressed in the model documentation provided to **The Company**.

PC.A.9.8.4 OUTPUT MESSAGES

PC.A.9.8.4.1 The RMS control system model shall not fill the progress monitoring files with content that is not relevant to monitoring the technical behaviour of the dynamic simulation. Control system models shall not spuriously report to the monitoring file during normal operation. Control system models that experience instability during simulation should report to the progress monitoring file. It is not acceptable for the control system model to crash catastrophically and provide no documentary evidence as to why the simulation failed.

PC.A.9.8.4.2 RMS control system models shall allow all appropriate internal variables to be requested for output for the duration of the simulation.

PC.A.9.8.4.3 In the case where the **User's Plant** trips during simulation, the relevant RMS control system models shall set the flag that indicates that the **User's Plant** has tripped.

PC.A.9.8.4.4 For protection events (e.g. crow bar controller operation) the simulation events, including initial detection, operation, and time-out, should be reported to the PowerFactory output window during the simulation.

PC.A.9.8.5 Integration time step

PC.A.9.8.5.1 The dynamic model must support time domain simulations with a minimum integration step size of 0.01 s.

PC.A.9.8.5.2 The control system model must not include algorithms that require use of a particular integration step size (for example the control system model should not fail to solve, or the response be materially different for an integration step size of 0.005 s).

PC.A.9.8.5.3 Time constants below 0.01 s should only be included if their inclusion is critical to the performance of the dynamic model and are required to meet the accuracy requirements.

PC.A.9.8.5.4 Internal integration algorithms should only be included if their inclusion is critical to meeting the accuracy requirements, and should not materially detract from model simulation speed performance.

PC.A.9.9 EMT MODEL PERFORMANCE SPECIFICATION - PSCAD

PC.A.9.9.1 The EMT control system models provided for PSCAD versions and compliers and must be compatible with simulation methods as published on **The Company** website (PC.A.9.4.2). EMT Models should not be:

i) dependent on a particular version of Intel Fortran, or not be:

ii) compiled in or requiring GNU Fortran or Compaq visual Fortran to run.

iii) dependent or require access to other external references or software.

PC.A.9.9.2 The EMT control system models must be open, unencrypted to similar level provided for RMS control system models i.e. **Power Park Module** controllers and **Power Park Unit** controllers. Detailed representations of convertor controllers and phase locked loops (PLL's) at the switching level maybe encrypted.

ALTERNATIVE

PC.A.9.9.2 The EMT control and protection system models maybe encrypted. The scope, behaviour and performance of all encrypted elements must be documented. Documentation should include behaviour and performance of all encrypted inner and outer loop control functionality such as voltage control, frequency control, protection systems, convertor controls and phase locked loop controllers (PLL). Aspects of the control system may be omitted provided the study ojectives published by **The Company** in accordance with PC.A.9.-4.2 are met in which case the documentation should explain any functionality not included in the EMT control system model.

PC.A.9.9.3 The EMT control and protection system model shall:

i) have adjustable control parameters. For example this would include all setpoints, control drops, operational limits, relay thresholds

ii) have a bandwidth of at least continuous to 10kHz and settle to the correct final value for the applicable power system conditions and applied disturbances

iii) be based on plant design and validated against testing of the **Plant and Apparatus** (See Model Validation )

iv) include inner and outer loop control systems

vi) represent all electrical, mechanical and control features appropriate for the **Plant** and **Apparatus** including switching algorithums of power convertors applicable to ~~EMT and harmonic type studies~~studies described by the Company.

vii) Have all appropriate protection systems modelled for power system transient stability analysis including balanced and unbalanced fault conditions, **Frequency** and voltage disturbances configured to match the site specific installation of the **Plant** and **Apparatus**. Any protections which relate to multiple disturbances should have an option to be disabled.

**Commented [A19]:** Response to suggestion from SHETL

**Commented [A20]:** Response to comments from Siemens and SHETL

viii) Allow **Plant** and **Apparatus** to be scaled. For example representation of multiple **Power Park Units** by a single equivalent unit.

ix) Have time steps which must be appropriate for the accurate representation of the switching algorithms used in the **Plant and Apparatus**~~.~~ and compatible with study time steps down to 10us.

x) Be portable between network models which may be any size between a single machine infinite bus power system representation and a full multi node power system network depending on the studies that need to be undertaken.

xi) Allow multiple instances within a network and be compatible with other control system models within a network.

xii) Be capable of self initiation to **User** defined terminal conditions within 3 seconds of the simulation time.

xiii) Warn the **~~U~~user** by way of an output message when **System** conditions exceed the operational limits of the **Plant** and **Apparatus** or are not valid for continued operation.

**Commented [A21]:** Response to SHETL comments and discussions at October Work Group.