PLANNING CODE

(PC)

CONTENTS

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

…..

(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 September 2022 and any **Generating Unit** or **Synchronous Power Generating Module** excitation control systems subject to a control system change or **Modification** after 1 September 2022, the **Generator** should supply the control system model in accordance with PC.A.9. For the avoidance of doubt, excitation control system models as detailed in PC.A.9 maybe submitted for any **Generating Unit** regardless of **Completion Date** as an alternative to block diagrams detailed below. 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.

……

(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 September 2022 and any

Generating Unit or **Synchronous Power Generating Module** governor control systems subject to a control system change or **Modification** after 1 September 2022, the **Generator** should supply the control system model in accordance with PC.A.9. For the avoidance of doubt, governor control system models as detailed in PC.A.9 maybe submitted for any **Generating Unit** regardless of **Completion Date** as an alternative to governor block diagrams. 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.

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 ……..

(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 (as applicable)

Year for which the air density is submitted (as applicable)

Number of pole pairs (as applicable)

Blade swept area (m^2) (as applicable)

Gear box ratio (as applicable)

Mechanical drive train (as applicable)

For each **Power Park Unit**, details of the parameters of the drive train (as applicable) 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 (λ) curves for a range of blade angles (where applicable) together with the corresponding values submitted in tabular format. The tip speed ratio (λ) is defined as $\Omega R/U$ where Ω 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 September 2022 and any **Power Park Units** subject to a control system change or **Modification** after 1 September 2022 control system models in accordance with PC.A.9 should be supplied. For the avoidance of doubt, a **User** may submit control system models as detailed in PC.A.9 for any **Power Park Unit** regardless of **Power Park Module Completion Date** as an alternative to this paragraph.

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)

……

(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 September 2022 and any **Power Park Units** and/or **Power Park Module(s)** subject to a control system change or **Modification** after 1 September 2022, 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 September 2022 as 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

……

PC.A.5.4.3 DC Converter and HVDC Systems

…….

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 any **DC Converters** and **HVDC Systems** with a **Completion Date** before 1 September 2022 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** and **Generators** in respect of **OTSDUW DC Converters** who are also **EU Code Users** 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.

(b) For any **DC Converters** and **HVDC Systems** with a **Completion Date** after 1 September 2022 and any **DC Converters** and **HVDC Systems** subject to a control system change or **Modification** after 1 September 2022, control system models in accordance with PC.A.9 should be supplied covering the full functionality required under PC.A.5.4.3.2 (a).

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(a).

.....

PC.A.9 CONTROL SYSTEM MODEL REQUIREMENTS FOR USERS

PC.A.9.1 OBJECTIVE

PC.A.9.1.1 Control and protection system models, along with other **Plant** and **Apparatus** information are required by this~~e~~ **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 and protection 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 and protection 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 and protection system models shall include representation of all relevant 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. Additional guidance on relevant functionality will be published on **The Company** website.

PC.A.9.2. SCOPE

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

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) models which represent the **Users Plant and Apparatus** in 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 may include the excitation and governor control systems associated with **Synchronous Generating Units** if these impact on the types of study described on **The Company** website.

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. 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 models shall be able to calculate how aspects, (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 models 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 models in the software package specified in PC.A.9.8.1.

PC.A.9.3.4 The RMS models maybe either a User specific model or a standard open-source models, such as a standard WECC, IEEE or IEC control system model available in the software format as specified by **The Company** provided this 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 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 models structure, functionality and the **User's Plant and Apparatus** represented.

(ii) inputs/outputs and functionality,

(iii) the information described in PC.A.5 relevant to the technology modelled.

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 or request additional information concerning the RMS control system model. This should take place no later than the issuance of the FON.

PC.A.9.3.5 The performance requirements for the RMS models 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 supporting informtion shall include all material aspects of the **User's Plant and Apparatus** that affect the voltage and current outputs, including those of the control and protection response from the **User's Plant and Apparatus**. The models 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.

PC.A.9.4.2 The **User** shall provide EMT models in the software package specified in PC.A.9.9.1.

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 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 models. The details of any such rmodels will be included in the Bilateral Agreement.

PC.A.9.6 CONFIDENTIALITY AND SHARING

PC.A.9.6.1 CONFIDENTIALITY AND SHARING RMS TYPE MODELS

PC.A.9.6.1.1 The models, 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 models, supporting documentation and associated data with the **Transmission Licensees**. **The Company** and/or **Transmission Licensees** may share the models 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 as provided in GC.12.

PC.A.9.6.1.2 It is the responsibility of the **User** to provide the RMS 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 ECP.10). **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 in PC.A.9.6.1. 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 RMS models, supporting documentation and associated data to **The Company**.

PC.A.9.6.1.3 It may also be necessary for **The Company** to share a representative RMS model with another **User** to comply with applicable Grid Code requirements (e.g. ECC.6.3.17.1.5 and ECC.6.3.17.2.3) and Bilateral Agreement. For these purposes the **User** must recorded in the **Compliance Statements** either:

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

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

PC.A.9.6.1.4 The **User** shall notify **The Company** of any changes to RMS models in accordance with PC.A.1.2. Unless specified otherwise in the **Bilateral Agreement**, RMS 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.9.6.2 CONFIDENTIALITY AND SHARING EMT TYPE MODELS

PC.A.9.6.2.1 The EMT 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 EMT models, supporting documentation and associated data with the **Transmission Licensees**. **The Company** and/or **Transmission Licensees** may share the EMT 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 as provided in GC.12.

PC.A.9.6.2.2 It is the responsibility of the **User** to provide the EMT models, supporting documentation and associated data to **The Company**. **The Company** will accept the EMT models, supporting documentation and associated data from a manufacturer as a **Manufacturers Data and Performance Report** (See ECP.10). **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 in PC.A.9.6.2. 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 EMT models, supporting documentation and associated data to **The Company**.

PC.A.9.6.2.3 It may be necessary for **The Company** to share a representative EMT model with another **User** to comply with applicable Grid Code requirements (e.g. ECC.6.3.17.1.5 and ECC.6.3.17.2.3) and Bilateral Agreement. For these purposes the **User** must record in the **Compliance Statements** either:

(i) a declaration that the EMT model submitted for compliance purposes (PC.A.9.6.2.1) may be shared with another **User** for the purpose of fulfilling relevant Grid Code requirements; or,

(ii) provide an equivalent EMT model that maybe shared with another **User** for the purpose of fulfilling relevant Grid Code requirements. In this event the **User** shall declare that the performance of the equivilent EMT model is adequate for the purposes of fulfilling relevant Grid Requirements as published on **The Company** website.

PC.A.9.6.2.4 Where it is necessary for **The Company** to share a representative EMT model with another **User**, the **User** in receipt of the model shall:

(i) limit of the use of the EMT model to a specific purpose agreed with **The Company** (e.g. simulation requirements to demonstrate compliance with Grid Code including ECC.6.3.17.1 and ECC.6.3.17.2 and Bilateral Agreement)

(ii) control access to the EMT model to only those individuals who are strictly necessary for the execution of the specific purpose.

(iii) establish and maintain security measures to restrict access to and prevent distribution of the EMT model (e.g. single computer terminal containing the EMT model and restricting access to file areas where the model resides)

(iv) ensure any publication is only for demonstrating compliance with the specific purpose agreed with **The Company** and shall not include any data directly derived from the EMT model

(v) not disclose the EMT model

(vi) destroy all copies of the EMT model and supporting material in a confidentially secure manner after the execution of the specific purpose is complete. Destruction of the EMT model and supporting material shall be confirmed to **The Company** in writing.

PC.A.9.6.2.5 The **User** shall notify **The Company** of any changes to EMT models in accordance with PC.A.1.2. Unless specified otherwise in the **Bilateral Agreement**, EMT 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 models have been validated demonstrating that the models under simulation conditions is representative of the **User's Plant and Apparatus** under equivalent conditions. Validation of 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 models are representative of the **Users Plant and Apparatus**. Results from model validation in accordance internationaly recommended standards (for example IEC) where applicable are also acceptable.

PC.A.9.7.2 A User may request agreement from **The Company** on the process for validating the models. In particular, for **Users Plant and Apparatus** where Factory Acceptance Testing is to be carried out details of any additional model validation at this stage should be agreed in a timely manner prior to the testing being carried out. Tests should generally include steady state **Reactive Power** capability, voltage control, **Fault Ride Through** and **Frequency** response.

PC.A.9.7.3 After final compliance testing as required under the **CP** or **ECP**, the **User** shall carry out validation of the model simulation results against measurements from final compliance testing in accordance with CP.A.3 or ECP.A.3, to ensure the model responses are representative of the **Users Plant and Apparatus.**

PC.A.9.7.4 If these tests show the models are not representative of the **User's Plant and Apparatus**, the **User** shall provide updated models, supporting documentation and associated data to ensure the responses shown by the model is representative of the responses shown by **User's Plant and Apparatus** during testing.

PC.A.9.7.5 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 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 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.9.7.6 The **User** is responsible for ensuring the 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 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.9.7.7 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

PC.A.9.8.1 The RMS models shall be provided in the format required by **The Company**. **The Company** shall publish on **The Company** website acceptable software versions. **The Company** will act reasonable in determining acceptable software versions or compatible formats. In accordance with good industry practice **The Company** will consult with the industry prior to changing the format required. Prior to the start of model development the **User** may request formal agreement from **The Company** of the software version.The RMS models shall be compatible with Objectives as outlined in Grid Code PC.A.9.1 Additional guidance on RMS model is published on **The Company** website.

PC.A.9.8.2 GENERAL

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

PC.A.9.8.2.1 The models shall use standard library functional blocks representing using standard Laplace block diagram format 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 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. An additional RMS model with these features maybe provided for comparison but for the avoidance of doubt does not meet the requirements of PC.A.9.

PC.A.9.8.2.3 The **User** shall specify the operating ranges for the 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 The RMS model must compile without errors. Warnings must be kept to a minimum.

PC.A.9.8.3 INITIALISATION

PC.A.9.8.3.1 The RMS model shall be self contained. The combined load-flow and dynamic model shall solve with minimal 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 model shall automatically initialise its parameters from load flow simulations without errors and with minimal warnings , must not result in run time errors and run with minimal warnings , and there must not be any interactions or conflicts with other models. The RMS models initialisation shall be invariant to simulation start time (i.e. not require the simulation to be initialised at a particular time). External software or automation routines to initialise the model are not acceptable.

PC.A.9.8.3.3 The RMS 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 It is not acceptable for the models to crash catastrophically and provide no documentary evidence as to why the simulation failed.

PC.A.9.8.4.2 RMS 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 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 models 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 should be agreed with **The Company**. In this case, an alternative model may be requested according to PC.A.9.8.3.3, if required.

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

PC.A.9.9.1 The **User** shall provide EMT models in the format required by **The Company**. **The Company** shall maintain a list of acceptable software versions, and compiler version which shall be published on **The Company** website. **The Company** will act reasonable in determining acceptable software versions or compatible formats. In accordance with good industry practice **The Company** will consult with the industry prior to changing the format required. The EMT models shall be compatible with Objectives as outlined in Grid Code PC.A.9.1 and **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. Additional guidance on EMT model is also published on **The Company** website.

PC.A.9.9.2 The EMT 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 objectives 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 model shall:

i) have adjustable operational control parameters. For example this would be expected to include setpoints, control drops, operational limits, relay thresholds. The **User** may seek agreement from **The Company** on the list of adjustable parameters prior to submission of the model.

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

iii) include all control systems from outer loop control down to inner and switching functions

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

v) 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.

vi) Allow **Plant** and **Apparatus** to be scaled where appropriate in accordance with good industry practice. For example representation of multiple **Power Park Units** by a single equivalent unit.

vii) 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.

viii) 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.

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

x) Be capable of self initiation to **User** defined terminal conditions within 4 seconds of the simulation time when connected to an equivalent Thevenin source. In the case of complex models **The Company** may agree a self initiation simulation time within 6 seconds.

xi) Warn the **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.

xii) Be able to be initialised from a snapshot of network conditions