EMT Model Specification Data Centre

Version 1.0

May 2026

EirGrid

The Oval, 160 Shelbourne Road, Ballsbridge, Dublin D04 FW28
Telephone: +353 1 677 1700 | www.eirgrid.com

Contents

Revision	Date	Description	Comments
Draft 1.0	24/02/26	Draft circulated to Data Centre owners and Grid Code Review Panel for feedback	
V1.0	18/05/26	First release incorporating feedback from Data Centre owners and independent experts	

1. Introduction

1.1. Scope & Purpose

This document has been published by the TSO to provide clarity on the electromagnetic transient (EMT) modelling requirements for Data Centres in Ireland, as specified in Grid Code (GC) clause PC.A8 (Modelling Requirements for Users) [1.], in compliance with European legislation EU 2016/1388 reflected in the Network Code on Demand Connection (Article 21) [2.]. The contents of this document are also in alignment with the recommended amendments to the existing Network Codes submitted by ACER to the European Commission in December 2023 (DCC 2.0) [3.], expected to be approved in 2026.

As the Ireland and Northern Ireland power system moves towards a net zero carbon operation; the number of Inverter-Based Resources (IBR) is expected to increase, with the amount of synchronous generation in the grid to decline, which will significantly change the dynamic characteristics of the All Island power system. In addition, the number and size of Data Centre connections in Ireland is growing rapidly. This type of Inverter-Based Load (IBL) behaves differently from conventional loads and is large enough (in aggregate) to influence the dynamic stability of the All Island power system. The aggregate effects of IBRs and IBLs are introducing new operational and reliability challenges that require detailed and accurate EMT models for impact analysis and risk mitigation.

In order to plan and operate the All Island power system in a secure and reliable manner, the TSO requires all Data Centre Users connected to, or applying for a connection to, the Transmission System to provide high-fidelity simulation EMT models of their facility following the specifications described in this document, in compliance with the requirements described in GC PC.A8[1].

The objective of this document is to provide clear and consistent guidance with regards to the level of detail, model type, model accuracy, performance, usability and interoperability requirements for EMT models of Data Centres in Ireland. Provision of EMT models compatible with these specifications will enable the TSO to effectively setup and integrate the individual Data Centre model into a larger EMT network model and conduct wide-area simulation studies related to security and stability of the All Island power system. The Data Centre owner is responsible for ensuring that the EMT model submitted to the TSO is developed and configured to meet the specifications described in this document and is accompanied by documentation demonstrating that it represents the overall Data Centre behaviour, seen at the Point of Connection (PoC), as accurately as possible.

This document describes:

- Intended use of the models.
- Components that must be included in the model.
- Structure of the model.
- Model fidelity.
- Acceptable software platforms.
- Usability and compatibility features of the model.
- Model package and submission timelines.
- Maintenance of the model.

[1] Note: The Grid Code defines obligations on all Users to submit dynamic models to the TSO (PC.A8). These obligations were introduced in 2016 with MPID 239 and did not apply retrospectively. This means that PC.A8 only applies to Users that connected (or will connect) to the power system after 1st June 2016, or to previous connections that undergo major refurbishment.

This document does not address how model validation or benchmarking should be done. Guidelines for model validation will be described in a separate document following the conclusion of an industry Working Group.

Note: it is acknowledged that, despite the fast growth of large-scale Data Centre connections around the world, currently there are no well-established industry standards for their modelling in power system analysis applications, especially in EMT. From the TSO side, there is general lack of familiarity and understanding of the many different topologies and/or components of a Data Centre facility and their impact on the dynamic performance of the power system. This document is created as a first step to provide guidance to Data Centre owners in Ireland on the level of detail expected for these models, and the component and behaviours that need to be captured, without being excessively prescriptive. Therefore, this document needs to be read as a guideline, rather than as a comprehensive specification, to start development of EMT models for Data Centres in Ireland. Future revisions of this document will refine the specifications based on gained experience and co-operation with Data Centre owners and model developers.

The following applies throughout this document:

- "***Shall***" refers to mandatory features.
- "***Should***" refers to recommended features.
- "***May***" refers to optional features.

1.2. Abbreviations

ATS	Automatic Transfer Switch
AC	Alternative Current
BESS	Battery Energy Storage System
BoP	Balance of Plant
CB	Circuit Breaker
C&P	Control and Protection
DC	Direct Current
DLL	Dynamic Link Library
EMT	Electromagnetic Transients
FRT	Fault Ride Through
GC	Grid Code
HMI	Human Machine Interface
IBL	Inverter-Based Load
IBR	Inverter Based Resource
IP	Intellectual Property
MIC	Maximum Import Capacity
MSS	Minimum System Strength
PDU	Power Distribution Unit
PED	Pre-Energisation Data
PLL	Phase-Locked Loop
PoC (*)	Point of Connection
RMS	Root Mean Square
RoCoF	Rate of Change of Frequency
SCR	Short Circuit Ratio
SLD	Single Line Diagram
SMIB	Single Machine Infinite Bus
SSCI	Sub-Synchronous Control Interaction
SSO	Sub-Synchronous Oscillation
SSR	Sub-Synchronous Resonance
SSTI	Sub-Synchronous Torsional Interaction
TSO	Transmission System Operator (EirGrid)
UPS	Uninterruptible Power Supply
VFD	Variable Frequency Drive
X/R	Reactance over Resistance ratio

(*) Note: A Data Centre demand facility may have one or more physical connection points to the main power system located in the same HV substation. The use of the PoC term in this document refers to the common HV busbar where the multiple connection points are physically connected to.

2. Intended use

This section provides clarity on the type of studies that the TSO will conduct with the EMT model submitted by the Data Centre owner in accordance with this document. The model shall be valid and accurate for these types of studies. Any simplifications or limitations in the model shall be discussed with the TSO and documented in the model user guide (section 8.3).

2.1. Context

DATA_INT_1

The EMT model of the Data Centre facility shall be capable to be integrated into a broader EMT network model, the scale of which will depend on the phenomena studied, ranging from studies of local phenomena to large-scale network simulation studies.

DATA_INT_2

The EMT model shall also be used as a **benchmark to validate the RMS model** of the Data Centre submitted to the TSO.

2.2. Studies

DATA_INT_3

The EMT model shall be used for dynamic studies within various timeframes over the entire lifetime of the Data Centre, including:

- pre-connection studies,
- transmission network planning,
- operational studies,
- system incident investigations.

DATA_INT_4

The EMT model shall be suitable for wide-area and local dynamic performance and interactions studies including, but not limited to, the following list:

- Power system stability studies (e.g. transient, voltage and frequency stability).
- Balanced and unbalanced AC fault performance studies, including ride through and post-disturbance recovery trajectory analysis.
- Sensitivity to voltage magnitude or phase-angle jumps.
- Operation under low system strength conditions.
- Voltage fluctuations.
- Sub-synchronous and super-synchronous oscillatory phenomena and control interactions analysis including (but not limited to) SSTI, SSR, SSCI and forced oscillations.
- Small signal analysis.
- Protection performance studies.
- Transient and temporary over-voltage studies (e.g. ferroresonance).

2.3. Model Capabilities

DATA_INT_5

The EMT model shall be capable of simulating the dynamic behaviour of the connected Data Centre facility, as seen at the Point of Connection (PoC), under normal operating conditions, small disturbances (e.g. voltage step change) and large disturbances (e.g. balanced/unbalanced system faults, voltage disturbances and frequency disturbances) under a wide range of credible system strength conditions.

The model shall be valid for the type of studies listed in section 2.2 and the frequency range listed in section 5.1.

DATA_INT_6

The EMT model shall accurately reproduce the Data Centre voltage ride-through behaviour and active power recovery ramp, as seen from the PoC, including tolerance to successive network faults.

DATA_INT_7

Switching events and mode change actions within the Data Centre facility such as bypassing UPS modules, engaging backup generators or energizing reactive power compensation equipment can have material impact on the wider power system and shall be accurately captured in the EMT model.

DATA_INT_8

Fast load ramping and/or cycling behaviour of the Data Centre (within the frequency range defined in section 5.1) shall be accurately reflected in the EMT model.

DATA_INT_9

The EMT model shall be capable to be used for the numerical calculation of the **frequency dependent impedance** of the facility seen from the PoC (impedance amplitude and impedance phase angle) in the frequency range that the model is valid, as defined in section 5.1.

3. Model Components

This section provides an overview of the expected Data Centre components that need to be included in the EMT model, based on the TSO's understanding of most common Data Centre architecture designs and their impact on the wider power system performance. Data Centre owners are invited to discuss with the TSO the relevance and applicability of the component listed below to their specific facilities.

3.1. Electrical Components of the Data Centre Facility

DATA_COM_1

The EMT model shall include accurate representation of all the relevant **electrical components and balance of plant equipment** (up to the PoC) which can affect the dynamic behaviour of the Data Centre into the power system. These components shall be represented in an aggregated manner as described in section 5.3. A non-exhaustive list of electrical components is given hereafter:

- Power supply and grid interface systems including Uninterruptible Power Supply (UPS), Battery Storage System (BESS), supercapacitors, E-STATCOM, flywheels, back-up/onsite generators[2] and others (where applicable).
- Power converters and DC links (including DC-link energy storage), e.g. AC/DC and DC/DC stages.
- IT loads (e.g. compute, storage and communication load), including relevant load profiles such as fast and cyclical ramping.
  - Loads that can cause fast load steps, cyclical/pulsating behaviour, or protection-driven disconnection/reconnection shall be accurately represented with a dynamic model or within an equivalent dynamic aggregate.
- Mechanical cooling loads (e.g. VFD and direct connected motors driving computer room air conditioning units, compressors and fans).
- Other relevant auxiliary loads such as Power Distribution Units (PDU) and site services.
  - Low-impact auxiliary loads may use simplified aggregates with documented justification.
- Additional reactive power/power factor control devices (e.g. STATCOM, capacitor banks, shunt reactor).
- Power transformers (Grid Connected Transformer and relevant internal transformer units), including magnetisation/saturation characteristics, vector group representation, neutral grounding and tap changer (if applicable).
- AC internal distribution system.
- Surge arresters.
- All relevant circuit breakers and automatic transfer switches (ATS).
- Passive harmonic filters, if applicable.
- Measuring equipment.

3.2. Control and Protection of the Data Centre Facility

DATA_COM_2

The EMT model shall include all the relevant **control and protection (C&P)** processes of the Data Centre facility and capture its aggregated behaviour, as seen at the PoC. All relevant non-linearities, mathematical functions, dead-bands, saturation, etc shall be correctly represented in the EMT model.

---

[2] On-site generation and storage is only expected to be included in the model if intended to operate in parallel with the power system.

A minimum list of C&P functions expected to be included is listed below (when applicable):

- Overall site supervisory control (if applicable).
- UPS C&P responsible for Fault Ride Through (FRT) behaviour, including temporary IT load decoupling from main grid supply, voltage and frequency transfer thresholds and timing, disturbance counters, staged reconnection and/or delayed recovery.
- UPS bypass control and other relevant UPS protection functions.
- Charge and discharge control logic of internal storage.
- Connection of back-up generation (if intended to operate in parallel with the power system).
- Current control and current limit logic for power converters.
- AC and DC voltage management C&P.
- Phase-Locked Loop (PLL) control.
- Signal processing, measuring methods and filtering.
- VFD controls for cooling systems.
- Active harmonic filter (if applicable).
- Active Power / Frequency control (if applicable)
- Active Power Ramp-rate limiter (if applicable)
- Control of additional active power and/or reactive power control devices (e.g. BESS, back-up generator, STATCOM, capacitor banks, shunt reactor).
- Transformer tap changer control.

DATA_COM_3

The model shall include all the relevant **protection relays** at site level and rack-level that can impact the Data Centre facility dynamic performance seen at the PoC (e.g. trip all or parts of the demand facility), including thresholds settings and delays. A typical list of functions includes, when applicable:

- Over/under voltage protection (AC & DC).
- Over current protection (AC & DC).
- Over/Under Frequency protection.
- Rate of Change of Frequency (RoCoF) protection.
- Harmonic protection.
- Negative phase sequence (voltage unbalance) protection.
- Other protection that can affect the active or reactive power drawn at the PoC under any operating condition, including tripping of cooling systems and other auxiliary loads.

DATA_COM_4

The EMT model shall include all specific measurement methods, hardware filters, communications time delays between the different devices and any others specific implementation details which may materially impact the dynamic behaviour of the Data Centre facility seen at the PoC.

DATA_COM_5

All relevant operating control modes and activation of specific control and protection functions shall be available in the model as for the real Data Centre facility on site, and clearly described in the model user guide (section 8.3).

4. Model Structure

This section describes a recommended harmonised model structure comprising three layers for efficient integration into a wider EMT network model.

4.1. Layer Structure

DATA_STR_1

Layer 1 defines the external electrical interface between the Data Centre facility (connected plant) model and the simulated transmission system. It should contain the PoC and the logic for current and voltage exchange with the rest of the system. This layer is illustrated in Figure 1.

DATA_STR_2

Layer 2 should act as a bridge between the TSO interface and the internal facility. It should manage plant-level control actions and should aggregate device-level feedback. This layer should also include an HMI interface with visibility and access to relevant parameters such as MW/MVAr load, UPS operation mode and FRT parameters. The HMI should provide quick access to plots and monitoring signals representative of the Data Centre facility behaviour. A high level structure of this layer is illustrated in Figure 2.

DATA_STR_3

Layer 3 should provide internal modelling of the components described in section 3. This includes electrical, physical (thermal, mechanical, etc.), control and protection functions - as represented in Figure 3. These components shall be aggregated as described in section 5.3.

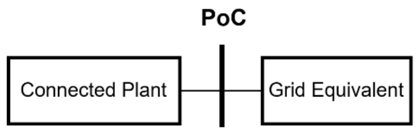

Figure 1: Layer 1 of the EMT model structure

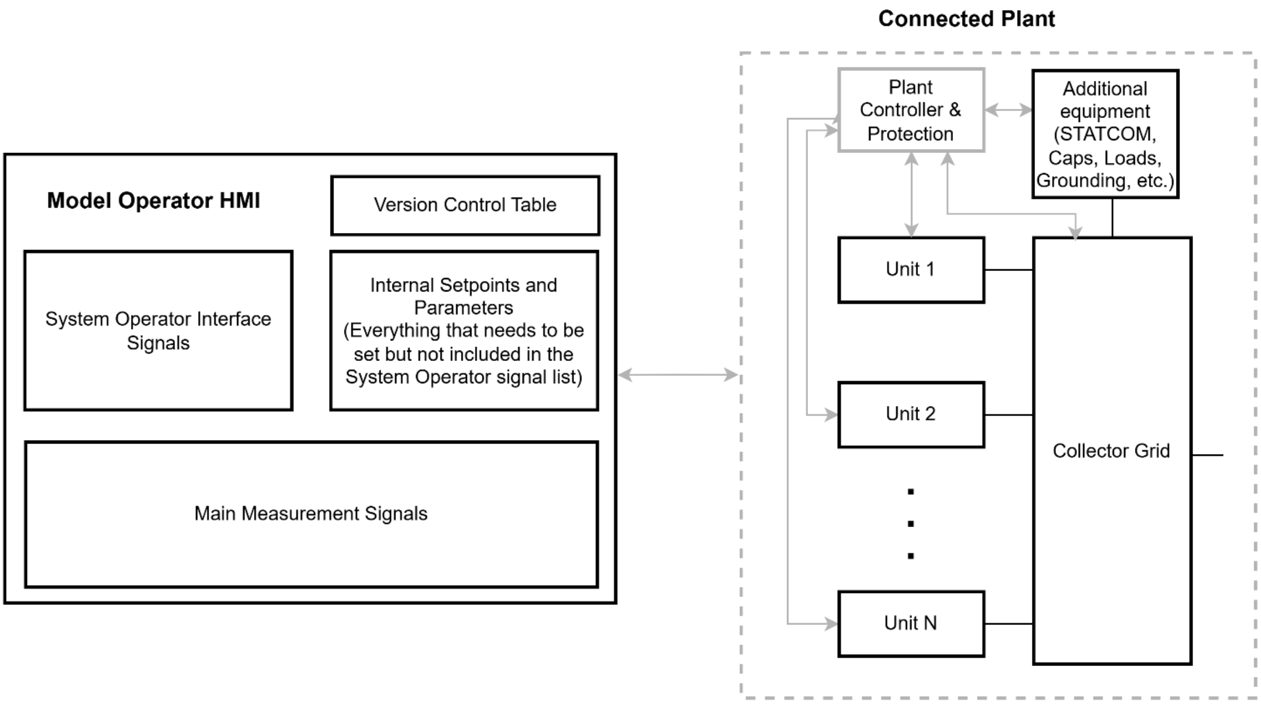

Figure 2: Layer 2 of the EMT model structure

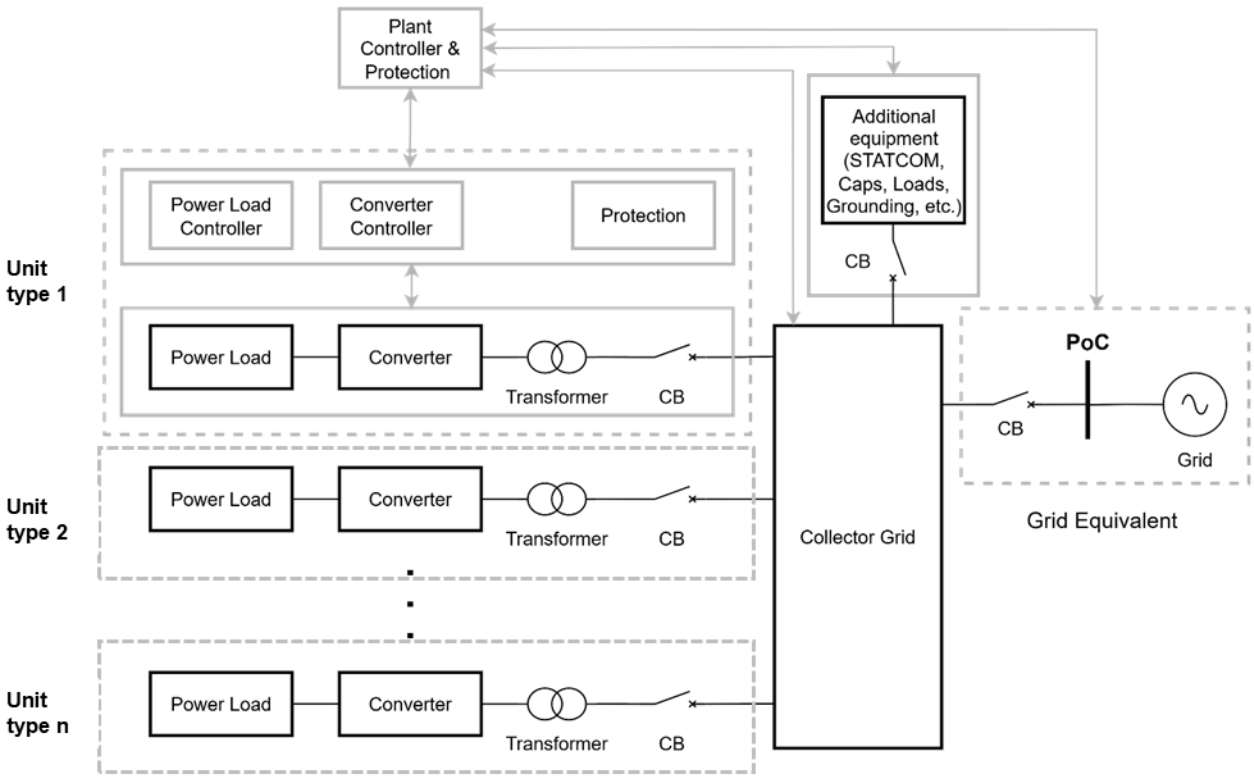

Figure 3: Layer 3 of the EMT model structure (note: similar components shall be aggregated. This figure illustrates a facility with "n" types of components)

4.2. Additional features for all Layers

DATA_STR_4

All variable parameters should be grouped for access and editing within Layer 2.

DATA_STR_5

Layer 3 devices should respond to Layer 2 signals in real time, maintaining numerical stability and control coherence.

DATA_STR_6

If any part of Layer 3 is masked, its interfaces and adjustable parameters should remain accessible via Layer 2.

DATA_STR_7

Diagnostic signals, trip indicators, and measurement outputs should be routed to Layer 2 or higher.

5. Model Fidelity

Model fidelity refers to how accurately a model represents the real-world behaviour and dynamic response of the facility. This section provides clarity on the expected model characteristics affecting its fidelity.

5.1. Accuracy

DATA_FID_1

The EMT model shall be accurate and adequate for analysis of dynamic and oscillatory behaviour of the facility in sub-synchronous and super-synchronous **frequency ranges from 0.1 Hz to 2.5 kHz**. Any limitations within this frequency range shall be clearly described and justified in the model user guide (section 8.3)

DATA_FID_2

The model shall be accurate and numerically stable for all operating conditions described in the Grid Code and for any studies listed in section 2.2, including the full range of SCR and X/R values at the connection point provided by the TSO as pre-energisation data (PED).

DATA_FID_3

All systems/components with time constant less than 100 seconds shall be included in the model. For instance, and not limited to, control and protection logics, onload tap changer controllers, and any other thermal, voltage or frequency related controller that can materially affect the dynamic behaviour seen at the PoC.

DATA_FID_4

The model should be accurate and numerically stable for a minimum **100 seconds** following any disturbance or internal event.

DATA_FID_5

An average-type representation is preferred (instead of a full switching representation) for power converters to improve computational efficiency in wide-area simulations. This representation shall average the switching frequency of the converters so that fast control loops are still preserved and only the switching dynamics and any pulse width modulation are omitted. This average model representation shall be able to correctly represent the dynamics between the DC side and the AC sides of the converters. Any limitations in applicability of this representation (e.g. frequency range) shall be discussed with the TSO and documented in the model user guide (section 8.3).

DATA_FID_6

The EMT model shall include the actual **hardware "real code"** for C&P functions[3]. See section 7.2 for encryption options.

DATA_FID_7

Communication and processing time delays:

- All intentional or inherent latencies (e.g., signal transmission delays between different control and protection layers) shall be modelled.

DATA_FID_8

The actual signal processing methods, as implemented in the Data Centre facility, shall be included in the model:

[3] If it is not feasible to provide hardware "real code" models for C&P or signal processing functions, the Data Centre owner shall propose an alternative representation (using native control blocks or other equivalent implementation) and provide HIL/RTS based evidence of the accuracy of the proposed EMT representation. In this case, the model shall not be encrypted and shall be fully open.

- For example: RMS calculations, all filtering processes or any other type of frequency/angle estimation and all derived quantities based on instantaneous current and voltage measurements.
- The "**real code**" of the processing method is preferred over other modelling approached based on native control blocks of the simulation tool[3]. See section 7.2 for encryption options.

5.2. Site Specific

DATA_FID_9

The EMT model shall be **specific to the equipment and the site**; generic models or parameters are not acceptable[4].

DATA_FID_10

The EMT model characteristics (electrical model, parameters, topology of the facility, etc …) shall reflect the **actual characteristics of the Data Centre facility** and not the manufacturer's default characteristics.

5.3. Aggregation

DATA_FID_11

A detailed representation of the large number of individual components that can be present in a Data Centre facility is not practical for wide-area EMT simulations. In order to reduce the size of the model and increase the speed of the simulation, **the Data Centre components shall be aggregated in the EMT model**. In this representation, all components of the same "type" (i.e. identical/similar model, type, settings and performance) are aggregated and represented as one single equivalent component. The following specifications apply:

- For Data Centre facilities with several different types of components, aggregation of each unit type shall be performed separately (e.g. centralised and distributed UPSs).
- The response of the aggregated model seen at the PoC shall be equivalent to that of the full detailed model (i.e. with all individual components explicitly represented) for the frequency range defined in section 5.1.
- The aggregated model shall preserve aggregate P/Q load, dominant time constants, and material switching/protection actions.
- Internal distribution system (i.e. LV & MV cables and transformers) shall be aggregated to provide a reasonable representation of the series impedance.
- Grid connected transformers and HV reactive compensation devices (e.g. switched shunts, harmonic filters, etc) shall be individually represented (i.e. aggregation not allowed).
- The aggregated model shall be scalable.
- Aggregate models should provide access to the component's terminal bus quantities (voltage, current, active power and reactive power) for each aggregated equivalent component.
- Descriptive information on the aggregation method and assumptions, and demonstration of accuracy (against a full detailed model) shall be provided in the Model User Guide (section 8.3).

[4] When site-specific models of non-critical/non-dominant components (e.g. mechanical cooling load representing low % of the facility load) are not available, the User should propose a suitable generic model and demonstrate that it can reproduce the expected dynamic behaviour of the equipment with reasonable accuracy.

6. Software Platforms

This section provides clarity on the software platforms and versions accepted by the TSO for the EMT models.

6.1. Simulation Software

DATA_SOF_1

Grid Code PC.A8.8 specifies that the User must provide models in the software packages defined by the TSO.

The TSO will accept EMT models in any of the following software packages and versions:

- PSCAD version 5.
- EMTP version 4.5.
- PowerFactory version 2025.

Any changes to the above software packages or versions will be advised to the Data Centre owner.

DATA_SOF_2

No additional toolboxes or third party software shall be required to run the model without agreement with the TSO.

DATA_SOF_3

This EMT model specification is intended to be “software agnostic”, however some commercial tools have specific features that can affect the compatibility and performance of the model.

If the PSCAD software is used to deliver the model, the following additional specifications shall be fulfilled:

- Be compatible with Intel Fortran Complier version 19.2 and higher, and Visual studio 2019 and newer, compatible with 32-bit and 64-bit systems. It must also be executable with other versions of Intel Fortran – models that require GNU FORTRAN exclusively will not be accepted.
- Support the PSCAD “time snapshot” and “multiple run” features. In case the "snapshot" function is used, the model must provide the same response with or without snapshot usage.
- Not utilise multiple layers in the PSCAD environment, including ‘disabled’ layers.

If the EMTP software is used to deliver the model, the use of masks is encouraged to facilitate the usability of the model.

7. Usability and Compatibility

This section provides clarity on aspects related to usability and compatibility of the models to ensure smooth and efficient integration into a larger wide-area EMT model and allow users configure the model, run simulations and analyse results.

7.1. Performance

DATA_USA_1

The model shall be accurate for **simulation time steps** within a range from 10 µs to 50 µs, with 10 µs discrete steps (i.e. only time steps of 10, 20, 30, 40 and 50 µs are acceptable[5]).

The model shall not be restricted to running at one single defined time step and shall allow the TSO to have the flexibility to change the simulation time step.

Any accuracy limitations at larger time steps shall be clearly flagged to the TSO in the model documentation.

DATA_USA_2

The model shall be capable of **self-initialization**. EMT models shall initialize and ramp to the expected operating point without external input/actions from the user. Any slower control functions included in the model (such as switched shunt controllers, transformer tap changers and other slow controls) should also accept initial condition variables if required.

DATA_USA_3

The model shall **initialise** correctly and reach stable steady-state to any user defined and valid operating point **in less than 3 seconds** of simulation time for the full operating range of the Data Centre facility (MW and MVAr) and PoC voltage range defined in the Grid Code. This performance specification applies to initialisation of the "sample case" in a Single Machine Infinite Bus (SMIB) setup, as described in section 8.5, with a time-step of 10 µs.

DATA_USA_4

The voltage (RMS), frequency, active and reactive power measured at the PoC shall remain constant (≤ 0.1% oscillatory behaviour) after the initialisation period during dynamic solution runs with no disturbances.

DATA_USA_5

The model should accurately represent the Data Centre facility for simulation times up to **5 minutes**.

DATA_USA_6

Any unstable operation of the dynamic behaviour of the Data Centre facility shall not result in crashing of the simulation, and any mechanism (protection etc.) that ceases the unstable operation shall reflect the actual behaviour of the Data Centre facility.

7.2. Encryption

DATA_USA_7

The TSO has a preference for **unencrypted** (and fully accessible to the TSO) EMT models for all Data Centre components.

If black-boxing/encryption is required for IP reasons, **the "real code" IEEE/CIGRE DLL** format and interface modelling method, as defined by Cigre TB 958 [4.], shall be used for confidential C&P functions and signal processing only[3]. All other components shall be open (unencrypted) and accessible.

[5] Time steps smaller than 10 µs shall be agreed with the TSO.

7.3. Functionality

DATA_USA_8

It should be possible to copy the Data Centre model, as defined in Layer 1 (Figure 1), and paste it into any other schematic implemented within the same EMT software without requiring any manual adaptation by the user to integrate the model into the new environment.

DATA_USA_9

Any number of the connected Data Centre models can be placed in the same scheme with the following rules:

- Multiple instances of the connected Data Centre model should be able to run with or without parallel computing.
- It should be done without any manual adaptation of the model required by the user of the different instances in the simulation environment.
- Independent parametrisation shall be possible for each model instance.

DATA_USA_10

The use of global variables defined in the simulation environment is forbidden. Variables can be defined in external configuration files (.txt or .csv), with associated documentation and namespace rules.

7.4. Inputs, Configuration & Tuning

DATA_USA_11

Relevant control and protection parameters, time delays, thresholds and hardware settings shall be accessible to the user. The user shall be capable of enabling and disabling relevant control and protection functions in the model.

DATA_USA_12

The model shall be able to accept external reference variables. This functionality shall be supported during both initialization and dynamic simulation, enabling seamless set-point changes at runtime without compromising numerical stability or control accuracy. Where applicable, all models shall allow adjustment — both prior to and during a simulation run — of, at a minimum, the following parameters:

- DC link voltage (if applicable).
- P (MW) and Q (MVAr) load value from each type of component: IT, cooling and auxiliaries.
- Voltage reference values for voltage control modes (if applicable)
- Parameters determining FRT activation / load transfer and load recovery.
- Other Control and protection modes and associated activation as listed in section 3.2.

DATA_USA_13

The model shall be submitted with all control modes and parameter settings defined to reflect the actual configuration of the Data Centre facility on site.

Any user-settable option shall reflect real hardware capabilities and must only expose control configurations that are valid at the actual site being modelled.

7.5. Outputs & Diagnostics

DATA_USA_14

The EMT model shall provide at the PoC and relevant internal nodes (e.g. UPS terminals), at a minimum, the following measurement signals and internally calculated by the measuring system of the Data Centre facility (when applicable/available):

- V(t), I(t): 3 phase instantaneous and RMS AC voltage and current
- V_{DC}, I_{DC}: DC voltage and current
- Vpos, Vneg, Vzero: Positive, negative and zero sequence voltages
- Ipos, Ineg, Izero: Positive, negative and zero sequence currents
- P, Q: Active and reactive power
- freq: Measured absolute frequency
- RoCoF: Calculated rate-of-change-of-frequency
- PLL input and output signals: frequency and angle

Note: All voltage signal values shall be provided in kV, current kA, active power in MW, reactive power in MVAR and measured frequency in Hz.

DATA_USA_15

The EMT model shall provide access to the relevant signals needed to analyse the behaviour of the Data Centre facility, while preserving confidential IP. In general, the following output signals shall be available in the HMI in Layer 2 (Figure 2) (when applicable/available):

- Positions of UPS by-pass switches.
- Positions of all other relevant circuit breakers/switches.
- UPS mode of operation (e.g. normal, by-pass, other).
- Input and output signals of relevant C&P functions, including FRT.
- Transformer tap changer position (when applicable).
- Diagnostic signals (e.g., flags to show UPS entering into FRT mode or triggering of protection functions) and should clearly identify why a control or protection function triggers during simulations.

DATA_USA_16

Appropriate and clear warnings should be generated whenever the operating point violates defined thresholds or enters invalid operating condition.

8. Model Package

This section provides clarity on the scope of the model package (i.e. model files and associated documentation) and the timeliness for submission.

8.1. Contents

DATA_PAC_1

The **preliminary model package** submission shall include:

- Model files (section 8.2)
- Model user guide (section 8.3)
- Additional technical documentation related to the Data Centre facility (section 8.4)
- Model sample case (section 8.5)
- Model checklist (section 8.6)

DATA_PAC_2

The **final model package submission** (post energisation) shall include:

- As-built model files (section 8.2)
- As-built model user guide (section 8.3)
- As-built technical documentation related to the Data Centre facility (section 8.4)
- As-built model sample case (section 8.5)
- Model checklist (section 8.6)
- Model validation report (guidelines for model validation will be provided in a separate document)

DATA_PAC_3

All files submitted in the model package shall be identified with a name that includes a unique version identifier. When the model package is resubmitted for whatever reason (e.g. following an update), all corresponding files shall be renamed with a new unique identifier.

DATA_PAC_4

When a new model version is submitted, the model package shall contain all items listed in DATA_PAC_2, with updated documentation reflecting the changes made to the model structure and/or parameters.

8.2. Model Files

DATA_PAC_5

The EMT model shall be delivered in one single folder and include all files required to run a simulation.

DATA_PAC_6

The following additional specifications apply:

- Precompiled elements are forbidden (such as .lib, .obj, etc.), only DLL files are accepted for encrypted control and protection functions.
- The EMT model shall be configured to run without any manual adaptation by the user. For instance, location of any external references and files shall be specified with relative paths.

DATA_PAC_7

If the Data Centre includes additional equipment - (e.g. STATCOM, auxiliary generation, energy storage, etc.), these components shall be represented according to their own applicable specification described in a separate document accessible in the TSO's website. However, all components shall be integrated into a single Data Centre EMT model (i.e. one single EMT model representing the behaviour of the facility and all its components, seen from the PoC).

8.3. Model User Guide

The Data Centre owner shall submit a comprehensive site-specific **EMT Model User Guide** (Grid Code PC.A8.3) including:

DATA_PAC_8

Name, location (i.e. connection point) and MIC of the Data Centre facility.

DATA_PAC_9

The name and version of the model.

DATA_PAC_10

Version history of the model - including versioned filenames and a brief change log.

DATA_PAC_11

Software requirements and version compatibility.

DATA_PAC_12

List and description of all the files required to run the EMT model.

DATA_PAC_13

Declaration by the Data Centre owner confirming site-specific representation, including credible loading and cycling profiles expected at the PoC.

DATA_PAC_14

Detailed description of the overall Data Centre EMT model structure (including single line representation), functionality and representation of individual components, including assumptions and limitations.

Include a classification table of auxiliaries/IT load blocks by modelling method (explicit, dynamic aggregate, static aggregate, omitted) with assumptions and justification.

DATA_PAC_15

Description of any possible limitations of the model for the required simulation time step range defined in section 7.1, applicability frequency range described in section 5.1 and studies described in section 2.2.

DATA_PAC_16

Model applicability boundaries, including minimum system strength (SCR) below which the model is no longer stable and, minimum/maximum X/R ratio outside which the model is no longer stable.

DATA_PAC_17

Description of model aggregation method (section 5.3), including assumptions and limitations. The document shall demonstrate the equivalence between a "full detailed"[6] and the "aggregated" model responses over a representative range of operating conditions and disturbances[7].

[6] Submission of the "full detailed" model to the TSO is not required.

[7] Representative operating points and disturbances for demonstrating adequacy of "model aggregation" and "average switching" representation shall be discussed with the TSO.

DATA_PAC_18

Description of the average representation of the power converters (section 5.1) highlighting any limitations in its accuracy within the frequency range specified in section 5.1. The document shall illustrate the dynamic behaviour of the "average" model in comparison to the reference "full switching"[8] model for a representative range of operating conditions and disturbances[7].

DATA_PAC_19

List of encrypted C&P functions (section 7.2). Include some level of description of the C&P functions while protecting IP.

DATA_PAC_20

Description of FRT functionality implementation in the model, including how to parametrise the model and description of all signals and flags available for the user to understand its behaviour.

DATA_PAC_21

Description of all other protection and control functions implemented in the model (e.g. protection relays), including trip signals and activation flags available for the user to understand its behaviour.

DATA_PAC_22

Clear mapping of implemented vs. missing Data Centre facility functions and/or control modes (including transition logic, if applicable). Any missing logic, protection or control mode that can materially affect the PoC behaviour must be flagged and justified to the TSO.

DATA_PAC_23

Mapping between model parameters and real equipment settings on site, highlighting any differences (with explanations).

DATA_PAC_24

Tabular list of model parameters and control modes accessible to the user (including description of each parameter), highlighting parameters affecting FRT and recovery behaviour. Include valid range of values for each model parameter. If parameters are defined in "per unit", the relevant base value should be included.

DATA_PACK_25

List and description of output signals available to the user in the model operator HMI (Layer 2 - Figure 2). The description should include signal name, unit, measurement point, base value, and variable type.

DATA_PAC_26

Guidance on simulation platform setup.

DATA_PAC_27

Instructions for model setup and initialization, including how to change the load profile (if applicable).

DATA_PAC_28

Guidance on the interpretation of error messages and troubleshooting

DATA_PAC_29

Instructions to change control modes (including all the intermediate steps) and parameter settings.

DATA_PAC_30

Instructions for scaling the rating of the aggregated components.

[8] Submission of the "full switching" model to the TSO is not required.

DATA_PAC_31

Instructions for integrating the Data Centre model in a wider EMT network model.

DATA_PAC_32

Instructions for creating multiple instances of the Data Centre model in the same project with different parametrisation.

8.4. Additional Technical Documentation

Supporting technical documentation shall be provided in appendices to the **EMT Model User Guide**, including:

DATA_PAC_33

Single-line diagram (SLD) showing the Data Centre architecture and main electrical components up to the PoC.

DATA_PAC_34

Comprehensive description of the FRT design of the Data Centre facility, including temporary IT load decoupling from main grid supply, voltage and frequency transfer thresholds and timing, disturbance counters, staged reconnection and/or delayed recovery.

DATA_PAC_35

UPS technical documentation, including manufacturer, model and ratings.

DATA_PAC_36

IT load technical documentation, including load profiles, cyclic behaviour and ramping rates.

DATA_PAC_37

Cooling load technical documentation.

DATA_PAC_38

Description of all relevant C&P functions and protection relays at facility and device level, including transfer function block diagrams.

DATA_PAC_39

P,Q,U operational capabilities of the Data Centre facility.

DATA_PAC_40

Lengths and electrical characteristics of HV and internal distribution circuits.

DATA_PAC_41

Transformers datasheets including nameplate and saturation data, power frequency impedances calculated from short circuit and open circuit tests for all applicable tap changer positions.

DATA_PAC_42

Surge arresters data sheet.

DATA_PAC_43

Harmonic filter data sheet (if applicable).

DATA_PAC_44

Technical documentation of other relevant components (e.g. BESS, STATCOM, on-site generators, etc).

8.5. Model Sample Case

DATA_PAC_45

The delivery of the EMT model shall be accompanied by a **sample case** such that the model can be tested before being integrated into the wide area model of the All Island network (Grid Code PC.A8.8). The sample case and associated documentation shall illustrate how to use the model with clear guidelines and results to compare.

- The sample case model shall be configured according to the site-specific real equipment configuration and parameters up to the PoC.
- The sample case shall use a Single Machine Infinite Bus (SMIB) representation of the power system, as seen at the PoC using the Minimum System Strength (MSS) data provided by the TSO.
- A table with model parameters used for each step of the sample case shall be provided.
- Time step used for the sample case simulation shall be clearly indicated.
- All waveforms of signals shall be accessible to the user in the HMI (Layer 2).

DATA_PAC_46

The sample case shall be configured to simulate two types of disturbances:

- a 100 milliseconds three-phase fault at PoC of the Data Centre facility,
- a 150 milliseconds single-line-to-ground fault at PoC of the Data Centre facility.

8.6. Model Checklist

DATA_PAC_47

A complete checklist (see Appendix A) shall be submitted to the TSO confirming compliance with the modelling specifications described in this document.

8.7. Submission Timelines

DATA_PAC_48

Preliminary model package (see section 8.1):

- **12 months** before first energization of the Data Centre facility[9].

DATA_PAC_49

Final model package (see section 8.1):

- **1 month** after energization of the Data Centre facility[9].

DATA_PAC_50

In accordance with GC PC.A8.6, the TSO will conduct regular studies and ongoing validation against data recorded during system incidents in order to ensure that the EMT model submitted by the Data Centre owner is representative of the facility through its operational lifetime. If the measured data indicates that the EMT model is not valid in one or more respects, the Data Centre owner shall provide an updated EMT model package whose behaviour corresponds to the observed on-site behaviour according to the timeline below:

- 90 business days after the date of request by TSO.

[9] Alternative timelines shall be discussed with the TSO in cases where the Data Centre facility is energised in phases. These timelines must allow for TSO's review of the submitted model (and model resubmission when necessary) and TSO's impact assessments of the proposed Data Centre connection on the transmission system.

9. Maintenance of Model

This section provides clarity on the GC PC.A8.7 requirement for the Data Centre owner to provide maintenance and updates of the EMT model to ensure it remains accurate over the lifetime of the Data Centre facility.

9.1. General

DATA_MAI_1

Model providers should confirm that they have model maintenance and support frameworks in place with vendors / suppliers for the duration of the Data Centre facility operational lifetime to provide model updates and technical support to the TSO (GC PC.A8.7). Should this requirement be not achievable either in practical or commercial terms, then further discussions with the TSO are required to seek alternative means of continued model maintenance and support.

9.2. Technical Support

DATA_MAI_2

Technical support from the model supplier shall be made available to help the TSO in setup and running simulation analysis and solve any relevant issues in case of non-compliance with any item of this EMT model specification.

9.3. Model Maintenance

DATA_MAI_3

All Models provided to the TSO must be maintained and updated to accurately reflect the operational performance of the User's plant over its lifetime (Grid Code PC.A8.7). In the event of any changes to the Data Centre facility which may materially affect the accuracy or capability of the submitted EMT model to reproduce the dynamic behaviour of the Data Centre facility under the conditions described in this document, the Data Centre owner shall submit a new model package with updated model and associated documentation. The timelines for submission shall be agreed with the TSO (typically, no later than 1 month after modifications have been implemented on site).

DATA_MAI_4

Any update of the model submitted shall comply with the most up-to-date EMT model specification published by the TSO.

DATA_MAI_5

The TSO may from time-to-time request that the models be updated to be compatible with changes in the TSO's computing environment, namely software version and/or compiler version. The Data Centre owner shall ensure that such updated models are provided without undue delay or in any event, within 90 Business Days of the date of the request. (Grid Code PC.A8.8)

10. References

[1.] EirGrid Grid Code v16 (October 2025).

[2.] Commission Regulation (EU) 2016/1388 of 17 August 2016 establishing a Network Code on Demand Connection.

[3.] ACER proposes amendments to the electricity grid connection network codes | www.acer.europa.eu

[4.] CIGRE/IEEE Technical Brochure 958 “Guidelines for use of real-code in EMT models for HVDC, FACTs and inverter based generators in power systems analysis”. February 2025. Available online at: https://www.e-cigre.org/publications/detail/958-guidelines-for-use-of-real-code-in-emt-models-for-hvdc-facts-and-inverter-based-generators-in-power-systems-analysis.html

[5.] ESIG Large Loads Task Force “Large Load Modelling for Dynamic Studies”: Current Practices and Recommendations (March 2026).

[6.] Electromagnetic Transient Modeling of Large Data Centers for Grid-Level Studies. Pacific Northwest National Laboratory. January 2026.

[7.] FINGRID-modelling-instruction-for-PSCAD-models – Data Centers (March 2026).

[8.] ERCOT Dynamic Modelling of Crypto-Miner Load in PSCAD, version 7, November 2025. https://www.ercot.com/about/grit/large-load-modeling

[9.] Electranix PSCAD Model Requirements Rev 13 (February 2025).

[10.] NGESO Guidance Notes for Electro-Magnetic Transient (EMT) Models. Issue 2.0, Sep 2025.

[11.] AEMO Power System Modelling Guidelines (July 2023).

[12.] CAISO EMT Modelling Requirements (April 2021).

[13.] REE Requisitos de los modelos EMT (June 2023).

[14.] ENERGINET REQUIREMENTS FOR GENERATORS (RFG) – SIMULATION MODEL REQUIREMENTS (September 2024).

[15.] French Grid code for PPM - "Cahier des charges des capacités constructives – Conditions générales – arc non synchrones de générateurs" Section 3.11.2 available online: https://servicesrte.com/files/live//sites/services-rte/files/documentsLibrary/20241225_DTR_7401_f

11. Appendix

11.1. Appendix A: Model Checklist

This appendix is a EMT model checklist which must be completed by the Data Centre owner and submitted alongside the EMT model.

PlantFacility model identification		
Model submission Date		
Data Centre project name		
Data Centre Maximum Import Capacity (MIC)		
Data Centre connection point HV substation name		
Primary contact information for model related questions		
List of EMT model files submitted		
List of documents submitted		
Facility model specification checklist		
2. Intended use		**Model Complies? (Y, N, N/A, comments)**
2.1	DATA_INT_1	
2.1	DATA_INT_2	
2.2	DATA_INT_3	
2.2	DATA_INT_4	
2.3	DATA_INT_5	
2.3	DATA_INT_6	
2.3	DATA_INT_7	
2.3	DATA_INT_8	
2.3	DATA_INT_9	
3. Model Components		**Model Complies? (Y, N, N/A, comments)**
3.1	DATA_COM_1	

3.2	DATA_COM_2	
3.2	DATA_COM_3	
3.2	DATA_COM_4	
3.2	DATA_COM_5	
4. Model Structure		**Model Complies? (Y, N, N/A, comments)**
4.1	DATA_STR_1	
4.1	DATA_STR_2	
4.1	DATA_STR_3	
4.2	DATA_STR_4	
4.2	DATA_STR_5	
4.2	DATA_STR_6	
4.2	DATA_STR_7	
5. Model Fidelity		**Model Complies? (Y, N, N/A, comments)**
5.1	DATA_FID_1	
5.1	DATA_FID_2	
5.1	DATA_FID_3	
5.1	DATA_FID_4	
5.1	DATA_FID_5	
5.1	DATA_FID_6	
5.1	DATA_FID_7	
5.1	DATA_FID_8	
5.2	DATA_FID_9	
5.2	DATA_FID_10	
5.3	DATA_FID_11	
6. Software Platforms		**Model Complies? (Y, N, N/A, comments)**
6.1	DATA_SOF_1	
6.1	DATA_SOF_2	
6.1	DATA_SOF_3	
7. Usability and Compatibility		**Model Complies? (Y, N, N/A, comments)**
7.1	DATA_USA_1	
7.1	DATA_USA_2	
7.1	DATA_USA_3	
7.1	DATA_USA_4	
7.1	DATA_USA_5	
7.1	DATA_USA_6	

7.2	DATA_USA_7	
7.3	DATA_USA_8	
7.3	DATA_USA_9	
7.3	DATA_USA_10	
7.4	DATA_USA_11	
7.4	DATA_USA_12	
7.4	DATA_USA_13	
7.5	DATA_USA_14	
7.5	DATA_USA_15	
7.5	DATA_USA_16	
8. Model Package		**Model Complies? (Y, N, N/A, comments)**
8.1	DATA_PAC_1	
8.1	DATA_PAC_2	
8.1	DATA_PAC_3	
8.1	DATA_PAC_4	
8.2	DATA_PAC_5	
8.2	DATA_PAC_6	
8.2	DATA_PAC_7	
8.3	DATA_PAC_8	
8.3	DATA_PAC_9	
8.3	DATA_PAC_10	
8.3	DATA_PAC_11	
8.3	DATA_PAC_12	
8.3	DATA_PAC_13	
8.3	DATA_PAC_14	
8.3	DATA_PAC_15	
8.3	DATA_PAC_16	
8.3	DATA_PAC_17	
8.3	DATA_PAC_18	
8.3	DATA_PAC_19	
8.3	DATA_PAC_20	
8.3	DATA_PAC_21	
8.3	DATA_PAC_22	
8.3	DATA_PAC_23	
8.3	DATA_PAC_24	

8.3	DATA_PAC_25	
8.3	DATA_PAC_26	
8.3	DATA_PAC_27	
8.3	DATA_PAC_28	
8.3	DATA_PAC_29	
8.3	DATA_PAC_30	
8.3	DATA_PAC_31	
8.3	DATA_PAC_32	
8.4	DATA_PAC_33	
8.4	DATA_PAC_34	
8.4	DATA_PAC_35	
8.4	DATA_PAC_36	
8.4	DATA_PAC_37	
8.4	DATA_PAC_38	
8.4	DATA_PAC_39	
8.4	DATA_PAC_40	
8.4	DATA_PAC_41	
8.4	DATA_PAC_42	
8.4	DATA_PAC_43	
8.4	DATA_PAC_44	
8.5	DATA_PAC_45	
8.5	DATA_PAC_46	
8.6	DATA_PAC_47	
8.7	DATA_PAC_48	
8.7	DATA_PAC_49	
8.7	DATA_PAC_50	
9. Maintenance of Model		**Model Complies? (Y, N, N/A, comments)**
9.1	DATA_MAI_1	
9.2	DATA_MAI_2	
9.3	DATA_MAI_3	
9.3	DATA_MAI_4	
9.3	DATA_MAI_5	