Modelling Information for Generators

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Part of Energy Queensland

Purpose

Certain entities are required to register with *AEMO* as a *Generator* in order to *connect* an *embedded generating system* to *Ergon Energy's* or *Energex's distribution system*. Part of the registration and *connection* process involves the prospective *Generator* providing information to *Ergon Energy* or *Energex* under *AEMO's Power System Model Guidelines*.

This fact sheet is intended to operate in conjunction with the *Power System Model Guidelines* and the *AEMO Dynamic Model Acceptance Test Guideline* and describe in more detail the specific modelling information that needs to be provided to *us*.

Required models and supporting documents

The models that need to be provided comprise:

a) a *PSS®E* model with dynamic and steady-state modelling application (including automatic and manual startup and shutdown control modules) i.e. SMIB and NEM snapshot models used for compliance studies (.sav, .sld, .dll and .dyr files) – these should meet the relevant requirements set out in *AEMO's* "Generating System Model Guidelines" in .dll or .obj/.lib in V34.5 format; and

b) A pre-validated and complete set of *PSCAD™/EMTDC™* software simulation models representing the generating system that meet the *Power System Model Guidelines*. Please note the *National Electricity Market* has transitioned to *PSCAD™* v5. As such, models will need to be submitted in v5 (refer to the [*AEMO PSCAD v5 information sheet*]). V5 Models must be compiled with Intel OneAPI Fortran Compiler: Classic 2021.x (32-bit & 64-bit). Models shall be delivered in a format that allows for maintenance for life of asset. (e.g. .dll, support files).

You must also ensure that *we* are given:

a) a *releasable user guide* for the *PSS®E* model, which should incorporate details on how to use the *PSS®E* model (including details of load flow setup of the *embedded generating system*, *embedded generating scheme voltage* control scheme, model control modes and dynamic setup with details of the model's ICONs, CONs, STATEs and VARs). This *releasable user guide* must contain sufficient information to allow entities to perform system studies with no prior knowledge of the particular *embedded generating system*;

b) an analogous document for the *PSCAD™/EMTDC™* model; and

c) a benchmarking report, demonstrating the performance of the *PSS®E* model with respect to the *PSCAD™/EMTDC™* model; and *d)* Model acceptance tests, in accordance with the latest *AEMO Dynamic Model Acceptance Test Guideline.*

The modelling parameters must be consistent with the *releasable user guide* or analogous document (as relevant).

These simulation models must:

a) fully and accurately represent the particular *embedded generating system*, that is, they must:

   i. be based on data specific to the particular manufacturer, make and model of the *embedded generating system*;

   ii. incorporate *OEM*-specific simulation models;

   iii. incorporate the particular auxiliary or supporting electrical equipment (including *instrument transformers* and any power plant controllers) that will be installed (as opposed to generic data or assumptions);

   iv. reflect the particular physical arrangement of the *embedded generating system* and its connection to our *distribution system*;

   v. include all relevant settings; and

   vi. include the *inverter* and power plant control systems complete with the controller block diagrams (so as to explain the operation of the model without compromising the model veracity);

b) fully represent the relevant part of the *power system*, including, without limitation, any other *generating systems* and *asynchronous plant* in the vicinity of the *connection point* that are either in existence or will be committed before the *embedded generating system* (unless otherwise agreed in writing by *AEMO*);

c) be based on (as appropriate), the most recent of:

   i. the preliminary design included in the *detailed response*;

   ii. the detailed data included with the *application to connect*;

   iii. the *R1 data*; and

   iv. the *R2 data*;

d) be capable of reflecting the actual performance of the *embedded generating system* under all expected or potential operating conditions; and

e) be suitable for *us*, *AEMO* and (where relevant) *Powerlink Queensland* to assess the impact of connecting the *embedded generating system* to *our distribution system* at the *connection point* (including, without limitation, relevant security and stability impacts and to prove control system performance at low *distribution system short circuit ratios*), without compromising the veracity of those simulation models.

The final *PSS®E* and *PSCAD*^{TM}*/EMTDC*^{TM} simulation models must be validated through the tests referred to in the *GPS Compliance Assessment and R2 Model Validation Test Plan*.

Model comparison analysis

You must also ensure that *we* are given a tabulated summary of the different model types required (*PSCAD*^{TM}*/EMTDC*^{TM}, *PSS®E* and *HiL*) for simulation purposes, which includes an overview of the suitability of each of those model types (having regard to the accuracy and reproducibility of the relevant simulation) for a range of simulation test cases, including, but not limited to, cases examining the following:

a) *voltage* changes due to lightning, switching or faults (whether synchronous, transient or sub-transient), or single phasing, or any other similar changes, or due to the operation of any protective or auto-reclosing device in the *distribution system*, including for relevant time periods such as:

   i. during the *voltage* change;

   ii. just after the *voltage* change;

   iii. just after a successful reclose operation; and

   iv. just after an unsuccessful reclose operation,

   including information on the capability of the *embedded generating system* to remain in *continuous uninterrupted operation* following such changes;

b) start-up/shutdown of any *asynchronous plant* (e.g. sunrise, sunset and planned maintenance shutdowns);

c) active power/reactive power setpoint changes;

d) converter or *inverter* stability;

e) *synchronous condenser* (or similar electrical plant if installed) stability;

f) trip limits;

g) demonstrating anti-islanding functionality;

h) demonstrating interactions between the power plant controller, *synchronous condenser*, dynamic *reactive power* plant and any *asynchronous plant* (as applicable); and

i) power plant control.

Certifications

We also require *you* and the *OEM* to certify:

a) that the *PSS®E* simulation models are valid for the *embedded generating system*;

b) that any *PSCAD™/EMTDC™* simulation model represents the fully detailed inner control loops, phase locked loops, fault ride-through controllers, internal and external voltage controllers, plant level controllers and all relevant protection systems of the *embedded generating system*, and, where possible, embeds the actual hardware code;

c) the minimum fault level (synchronous and sub-transient) and *short circuit ratio* at which the *PSCAD™/EMTDC™* simulation model is valid;

d) the minimum fault level (synchronous and sub-transient) and *short circuit ratio* at which the *embedded generating system* can reliably operate, and what margins of operation are recommended; and

e) whether the *embedded generating system* is capable of operating down to a minimum *short circuit ratio* of 3.0 at the *connection point*.

This certification must be supported by a stability limit assessment where the number of items of *asynchronous plant* are varied within the relevant simulation to the point of instability (or a recommended margin from the point of instability) at the *connection point*, using a *PSCAD™/EMTDC™* simulation model.

Measurement results

You must also ensure that *we* are given measurement results (from an equivalent facility and plant performance from other installations with similar network fault level and *X/R ratio* characteristics, laboratory tests, *HiL*, etc.) confirming:

a) the validity of:

   i. the *PSCAD™/EMTDC™* simulation model vs the *HiL* simulation model; and

   ii. the *PSCAD™/EMTDC™* simulation model vs the *PSS®E* simulation model,

   and demonstrating that the *PSCAD™/EMTDC™* and *PSS®E* simulation models show the same behaviour as the relevant physical *embedded generating system*; and

b) where no other equivalent installation or laboratory test measurement results are available to assess system performance at the proposed fault levels, *X/R ratio* and *system strength* characteristics experienced in the relevant part of the *distribution system*, then *HiL* testing must be undertaken.

These tests must, where requested by *us*, *AEMO* or any other relevant *Network Service Provider*, include the following:

a) **(test set 1)** three phase faults close to the *connection point* simulated with a low fault impedance (approx. 5 ohms) and clearing time of 430 ms;

b) **(test set 2)** three phase faults close to the *connection point* simulated with a high fault impedance (approx. 50 ohms) and clearing time of 430 ms;

c) **(test set 3)** three phase faults which simulate a high fault impedance and clearing time of 2,000 ms to assess the control transition from the power plant controller to the *asynchronous plant* during fault ride-through (FRT);

d) undertaking test sets 1-3 at 100%, 50% and 5% P_{max} respectively and Q_{max} (lagging) and Q_{min} (leading) respectively;

e) application of 25% and 75% active power step changes to the active power reference point

f) a check of the response by changing V_{ref} by ±5% at P_{max}, 50% P_{max} and 5% P_{max} respectively;

g) a check of the high voltage ride through (HVRT) response as per S5.2.5.4 of the *NER* for Q_{max} (lagging) and Q_{min} (leading) at 100% P_{max};

h) injection of different rates of change of *frequency* to assess the phase lock loop sensitivity (±4 Hz/sec. for 0.25 s, ±1 Hz/s for the remainder of the time until the *frequency* reaches 52 Hz or 47 Hz);

i) application of +/- 20° (or more depending on the point of connection) grid angle change at point of connection; and

j) testing to demonstrate the capability of the *embedded generating system* to remain *connected* in accordance with S5.2.5.6 of the *NER* (that is, during times when the harmonic *voltage* distortion, *voltage* fluctuation and *voltage* unbalance conditions reach levels specified by the compatibility levels in S5.1a.5, S5.1a.6 and S5.1a.7 of the *NER*.

Further Information

The following reference documents may provide additional helpful information:

- STNW1175 Standard for High Voltage Embedded Generation Connections
- Connection Application Checklist
- Registration (R1 Checklist)

Prospective *Generators* may contact their *Project Sponsor* to obtain further specific information.

Glossary

Any terms that are used, but not defined, in this Fact Sheet have the meaning given to them in the *NER*.

AEMO or Australian Energy Market Operator: The agency responsible for the day to day management of wholesale and retail energy market operations and emergency management protocols for the *NEM*, on-going *NEM* development required to incorporate new rules, infrastructure and participants, and long-term *NEM* planning through demand forecasting data and scenario analysis.

asynchronous plant includes asynchronous *generating units* and dynamic *reactive power* support plant that uses phase-locked loops (for example, *static VAR compensators* and *STATCOMs*);

connection point: The physical point at which the *embedded generating system* will be *connected* to *Ergon Energy's* or *Energex's distribution system*;

detailed response means the relevant "detailed response" (as that term is defined in rule 5.3A.2(a) of the *NER*);

distribution system: The distribution system (as that term is defined in the *NER*) owned and operated by *Ergon Energy*.

embedded generating system: The *generating system* to be *connected* to the *distribution system*.

Ergon Energy: In this Fact Sheet, refers to Ergon Energy Corporation Limited as a *Local Network Service Provider*.

Energex: In this Fact Sheet, refers to Energex Limited as a *Local Network Service Provider*.

GPS Compliance Assessment and R2 Model Validation Test Plan means *AEMO's* document entitled: "GPS Compliance Assessment and R2 Model Validation Test Plan Template for power electronic interfaced non-synchronous generation technologies", published to facilitate the processes referred to in rules 5.8.4 and S5.2.4(d) of the *NER*;

HiL means hardware-in-the-loop simulation;

inverter means a device that uses semiconductor devices to transfer power between a direct current (DC) source or load and an alternating current (AC) source or load;

LNSP or Local Network Service Provider: A *Network Service Provider* within a local geographical area, which has the relevant jurisdictional authority (such as *Ergon Energy* or *Energex*).

NEM: National Electricity Market: The wholesale electricity market operating in relation to the interconnected electricity network in Queensland, NSW, ACT, Tasmania, Victoria and South Australia.

NER: National Electricity Rules: The rules under which the *National Electricity Market* operates.

Network Service Provider: Has the meaning given to that term in the *NER*.

OEM means original equipment manufacturer;

Power System Model Guidelines: The guidelines of that name promulgated by *AEMO*;

Powerlink Queensland means Queensland Electricity Transmission Corporation Limited ABN 82 078 849 233, being the relevant *Transmission Network Service Provider*;

Project Sponsor: An *Ergon Energy* representative who has been allocated to the prospective *Generator* to facilitate the *connection*;

PSCAD™/EMTDC™ means a software package developed by the Manitoba-HVDC Research Centre that comprises a power systems computer-aided design package which includes an electromagnetic transients (including DC) simulation engine, and which is used to carry out electromagnetic transient type studies;

PSS®E means Power Systems Simulator for Engineering, being a software package used to carry out root mean square studies;

R1 data has the meaning given to that term in S5.5.2 of the *NER* (essentially, a category of Registered data (as referred to in S5.5.2(b) of the *NER*) that encapsulates the measured performance and behaviour of an *embedded generating system* and which confirms and validates the modelled system across a range of potential study conditions and is supported by a long term monitoring program particularly for particular system fault conditions, events and fault ride through conditions);

R2 data has the meaning given to that term in S5.5.2 of the *NER* (essentially, a category of Registered data (as referred to in S5.5.2(a) of the *NER*) that is derived from manufacturers' data, detailed design calculations, off-site tests (i.e. other *generating system* sites), factory tests or site tests);

short circuit ratio is an analytical metric that normalises the *system strength* in MVA using synchronous fault levels at the *connection point* to the aggregate *nameplate rating* of any *embedded generating systems*;

system strength broadly refers to the stability of the *distribution system* and broader *power system*. It:

is typically measured by the available short circuit current or characterised by an analytical metric such as the *short circuit ratio* at any given location; and

relates to the size of the change in *voltage* for a change to the generation (or load) at a *connection point* (which can be affected by adjacent *asynchronous plant*).

System strength can be impacted where there is *asynchronous plant* in the area. Strong *distribution systems* exhibit better *voltage* control in response to small and large *power system* disturbances during both normal and contingency events, whilst weak *distribution systems* are more susceptible to *voltage* instability or collapse and the incorrect operation of protection systems; and

X/R ratio is the ratio of system inductive to resistive impedance.