FINGRID

Fingrid modelling instruction for PSS/E models –

Power Park Modules and Grid Energy Storage Systems

10.2.2026

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Change log

Date	Version	Changes
5.5.2022	1.0	First release
12.1.2024	2.0	Second release
10.02.2026	3.0	Separation from PSCAD modelling instructions and update

List of abbreviations

BESS	Battery Energy Storage System
DLL	Dynamic Linked Library
FRT	Fault Ride Through
LDC	Line Drop Compensation
LFSM	Limited Frequency Sensitivity Mode
LV	Low Voltage
MV	Medium Voltage
NDA	Non-Disclosure Agreement
Pmax	Rated power of the plant
POC	Point of Connection – The interface between plant and network

1 Introduction

1.1 Purpose and scope

This instruction describes the requirements for power park module and grid energy storage system PSS/E simulation models to be delivered to Fingrid as a part of the grid compliance monitoring process presented in the relevant valid Finnish Grid Codes, see /1/, /2/.

Delivery of a compliant model is an important precondition for demonstrating grid code compliance required to receive Interim and Final Operational Notifications for the equipment to be connected to the grid. By following this instruction, the overall quality and compatibility of the models can be ensured, which will also streamline the overall compliance monitoring process.

The requirement for PSS/E model delivery and the scope of studies to be performed for a specific project (e.g., a new power plant being built) are defined by Fingrid based on the requirements presented in the relevant grid code.

The modelling requirements are applicable as such for all greenfield projects. For retrofit projects — such as partial renewal or modification of an existing system — the exact scope of modelling shall be agreed separately.

1.2 Confidentiality

All models and related technical information given to Fingrid will be treated as confidential. Confidentiality obligations have been specified in the Main grid contract and in relevant Finnish Grid Codes, see /1/, /2/

Project specific NDAs (non-disclosure agreement) are not issued by Fingrid.

2 Modelling requirements

This chapter describes the general requirements for PSS/E models.

2.1 Version requirements

The PSS/E version as well as compiler used for project shall be compatible with the version used by Fingrid. The version information shall be inquired from models@fingrid.fi.

2.2 Intended use

The model shall accurately represent the steady-state and dynamic behavior of the plant and support the following simulation scenarios:

- Steady-state operation and control of passive components
- Setpoint changes in active and reactive power regulation
- Control mode changes for regulation of active and reactive power
- Three-phase fault in external network with an arbitrary fault impedance
- Voltage phase angle and magnitude jumps and changes to the external network impedance following events such as:
    - Disconnection of, and possible subsequent automatic reconnection of any faulty network component in the external network
    - Manual connection or disconnection (without prior fault) of any network component in the external network
- Voltage disturbances and tending voltage collapse with a duration within the required minimum simulation time
- Frequency disturbances with duration within required minimum supported simulation time)
- Simultaneous disturbances, such as combined voltage and frequency events with active/reactive power regulation
- Activation of a system protection scheme for rapid regulation of the plant's active power production according to a predefined final value and gradient.
- Interaction phenomena with other network devices and components up to the full extent of the bandwidth of positive sequence simulation solvers (usually 10 Hz around nominal value)

The project specific model is expected to be fully compatible and operable as part of large system models. To ensure this, the external dependencies such as library files etc. shall either have a unique name or version numbering, or there shall be a capability to rename the dependencies. If the model does not operate in large system models, the issues must be identified and resolved together with Fingrid. The number of model dependencies is to be kept at minimum.

Any unstable operation of the model shall not result in crashing of the simulation, and any mechanism (protection etc.) that ceases the unstable operation shall reflect the actual power plant response.

2.3 Structure and aggregation

The power plant model shall include all physical equipment that essentially affects the operation of the power plant, such as generators, transmission lines and cables, transformers, capacitor banks etc.

If the modeled power plant includes multiple similar generating units, such as wind turbines, these shall be represented as aggregated units. All generating units of the same type (identical design) shall be combined into a single aggregate. The electrical network between the power plant connection point and the main transformers shall be modelled. All main transformers shall be modelled separately. The internal electrical network, including the transmission lines, cabling, step-up transformers, capacitor banks, filters and loads behind each main transformer shall be modelled as aggregated components. Three-winding MV/LV transformers (e.g., BESS inverter transformers) can be modelled as a two-winding equivalent.

Example topologies for power plants with one and two main transformers are presented in Figure 1 and Figure 2. This topology principle shall be used in simulation models. Dummy bus and zero-impedance branch at the Point Of Connection (POC) shall be included. The Thevenin impedance representing the background network shall be modelled as a separate branch instead of a source impedance of the infinite bus machine.

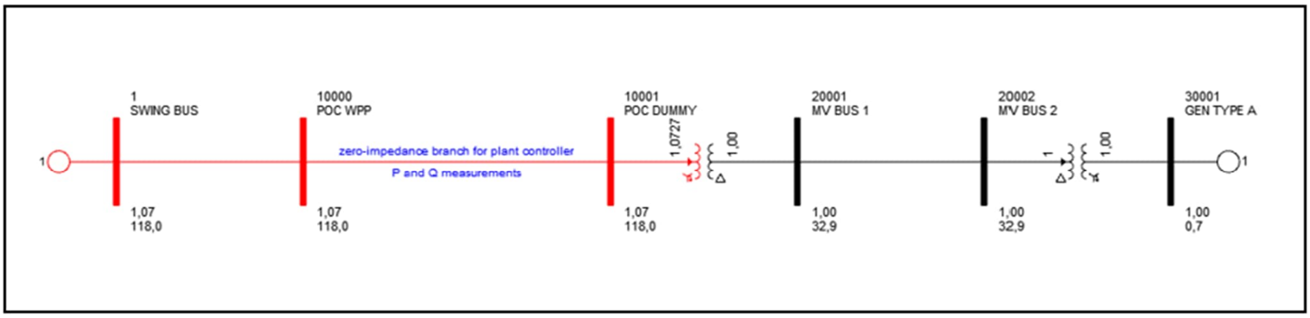

FIGURE 1. EXAMPLE TOPOLOGY OF AN AGGREGATED MODEL WITH ONE MAIN TRANSFORMER

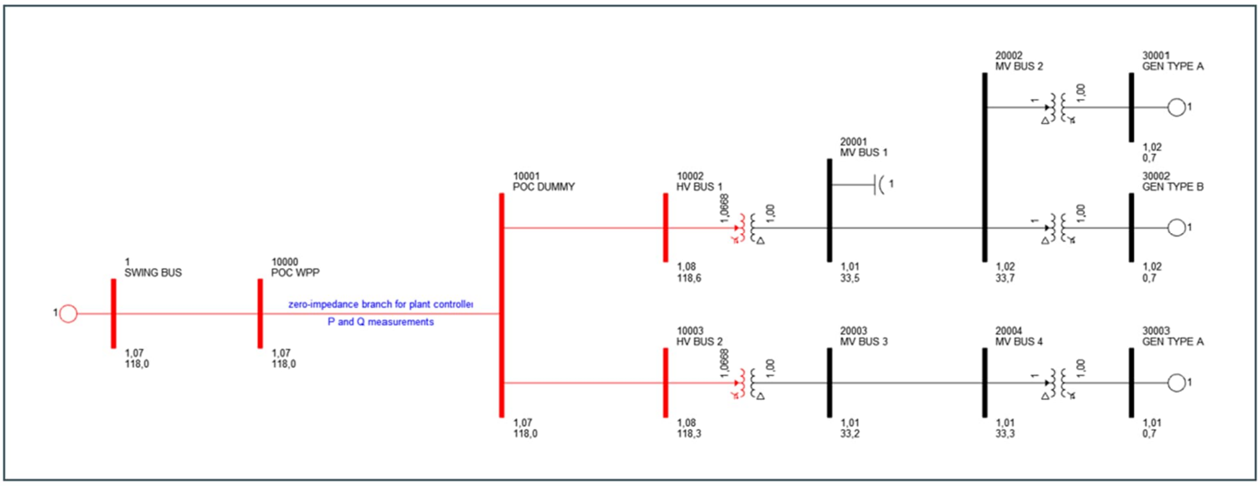

FIGURE 2. EXAMPLE TOPOLOGY OF AN AGGREGATED MODEL WITH TWO MAIN TRANSFORMERS AND TWO TYPES OF GENERATORS

2.4 Modelling of house loads

The house load of the plant exceeding 1% of the rated power (Pmax) shall be included in the model. The modelling of house loads and exceeding 5 MW shall be agreed separately with Fingrid.

2.5 The model documentation

The model documentation shall include:

- Version history of the complete plant model. If any changes to the model are required after the initial delivery, these changes shall be listed in the version history.
- Information on which PSS/E versions the model is compatible with.
- Requirements for the simulation environment. This includes the minimum and maximum simulation time steps and other relevant parameters.
- List of library files or DLLs in PSS/E. The list of all files needed that are required to run the model shall be listed.
- Limitations of the project specific model performance.
- Description of protection functions and tripping signals. This includes the description of what protection signals are available to the user, and how to view these signals.

- Description of the modelled additional functionalities such as power oscillation damping, control logic of mechanically switched capacitor banks and on-load tap changers of transformers.

- The following model usage instructions:

  - How to change the control mode and the setpoints of each available control mode.

  - How to parametrize the dynamic model in case of bus number changes.

  - A full list of ICONs, CONs, STATEs and VARs and other relevant parameters with descriptions.

2.6 Power flow model

The system base (SBASE) of the simulation model shall be 100 MVA. The machine bases (MBASE) shall not be arbitrary. The base voltage for the buses must be set as defined in Table 2. Note that the base voltages defined in Table 2 are only for modelling purposes and e.g. the reference value for voltage control is based on local conditions and relevant grid code requirements according to /1/, /2/.

TABLE 2. SELECTING THE BASE VOLTAGE OF THE BUSES

Normal operating voltage	Base voltage for buses
395–420 kV	400 kV
215–245 kV	220 kV
105–123 kV	110 kV
<105 kV	Normal operating voltage

In power flow, the reactive power capability of the plant shall be modelled using machine capability curve (gcp) file. The file shall correspond to PQ diagram for terminal voltage of 1.0 pu. If the modelled capability curve cannot accurately follow the actual PQ diagram due to a limited number of gcp data points, the data points shall be selected so that the error resulting from the interpolation between the adjacent points is no more than 5% of the reactive power value provided in the actual PQ diagram. The reactive power capability of all the aggregated units shall be modelled in a single gcp file. Possible compensation devices must be modelled separately and the control mode in the power flow shall be locked.

In power flow, generator P_{max} and P_{min} shall be set such that active power in POC corresponds to the rated capacity specified in the connection agreement or otherwise determined by the relevant network operator and the plant owner. If the rated active power has been limited, for example due to an insufficient reactive power capability, P_{max}

and P_{min} shall reflect the limited values. This does not apply to hybrid power plants where the total active power might have been limited.

Bus numbering can be selected freely, however, small bus numbers below 100 shall be avoided.

2.7 Model initialization

The initializing of the models shall not cause initial condition suspects. Model flat-run simulation shall not present any changes from the steady state if reactive and active power are within their respective limits in power flow.

For power park modules, if the plant active power is dependent on the availability of primary energy source, and the model is initialized with partial power, the model shall assume that it is the maximum available active power. The user must be able to change the available active power during the simulation. For example, when in limited frequency sensitive mode for underfrequency (LFSM-U) plant shall not be able to raise active power in case it is already operating at the limit of the available active power. In case available power is also increased, the active power shall rise in LFSM-U situation.

2.8 Dynamic model

2.8.1 Dynamic model naming

Dynamic model names (i.e., the name of the subroutine called by PSS/E during the simulation) shall include version numbering. Version numbers ensure that any changes and updates that affect the model internal structure are traceable and different versions of the model can be integrated into same large network model without conflicts.

2.8.2 Functional requirements

The model shall use a voltage source type grid interface with the network solver, and additionally, also have representation of the dynamic behaviour of inner control loops and synchronization elements such that the entire model can remain valid up to the full extent of the bandwidth of positive sequence simulation solvers (usually 10 Hz around nominal value).

Models shall be delivered with control modes and setpoints that will primarily be used in normal operation. The model operating range shall reflect the actual power plant operating range, and the model shall include all limiters that restrict the operation of the power plant. The limiters shall represent the actual power plant response.

The model shall have the capability to change the control mode to any control mode possible in the actual power plant, such as voltage droop control, reactive power control and power factor control. The setpoints of these control modes, such as active power, reactive power, and voltage setpoints shall also be changeable during the simulation. The modification of the essential control parameters (e.g., voltage regulator settings, fault current infeed, power ramp rates) must be available for the user.

At least following parameters must be adjustable during simulation:

- active power setpoint
- available active power, either adjusting it directly or indirectly by adjusting primary energy sources such as wind speed or solar irradiation.
    - If wind speed or solar irradiation etc. is used to adjust the power, the dependency of active power vs. wind speed/solar irradiation shall be provided.
- reactive power setpoint
- voltage setpoint
- power factor setpoint
- reactive power control mode
- active power control mode
- active power ramp rates

The model shall include all generator protection functionalities relevant from the power system perspective as well as all relevant plant level protections. Protection settings used in the model shall correspond to the ones to be used on site. The model shall announce the type of protection in case of tripping. Protection functions shall be modelled within the limits of simulation program capabilities.

The model shall include limited frequency sensitive mode for overfrequency and underfrequency (LFSM-O and LFSM-U) and those shall be enabled by default. In addition to limited frequency sensitive mode, the frequency sensitive mode (FSM) shall be available to be enabled by the user. The model shall be built so that all frequency control modes can be enabled and disabled individually for each frequency control range. It shall be possible to have different droop settings for each frequency range.

For the dynamic models following requirements must be fulfilled:

- The models shall be manufacturer-specific, i.e., no generic PSS/E library models are accepted. Auxiliary models such as tap changer and protection models may be modelled using PSS/E library models, provided that the library models can represent the real functionality with sufficient accuracy.
- The models shall be able to work with time steps from 1 to 5 ms.

- Models shall be able to run multiple disturbances in the same simulation.
- Models shall have stable operation for simulation times up to 5 minutes.
- Models shall have stable operation when simulating with network frequency dependence (NETFRQ) enabled.
- Linearized models that are accurate only for a single operating point are not acceptable.
- There shall not be any measurements over the branch representing the background network, i.e., from the swing bus to the study network.
- The models shall include the control logic of the relevant auxiliary equipment, such as mechanical switched capacitor banks and on-load tap changer of the transformers.
- All delays that affect plant's performance such as communication and measurement delays shall be included in the model.
- Tap changer dynamic models shall be parametrized with the same setpoints and delays as in the physical device.
- The models shall not print excessively into the PSS/E Progress output during the simulation. It is allowed to have a more verbose output for debugging purposes, but it shall be possible to switch it off in normal use.
- The models shall have signals (VARs) representing activation/deactivation of Fault Ride Through (FRT) modes.
- The models shall have a proper implementation of PSS/E dynamic simulation control flag MODE for values 6 (DYDA) and 8 (descriptions for CONs, ICONs, VARs and STATEs).

3 Reporting and model review by Fingrid

Fingrid tests the models to ensure that the model fulfills requirements set in the grid code and complies with this modelling instruction. Template explaining the test set currently used by Fingrid for PSS/E is provided in attachments list on page "Modelling instructions". When delivering the model package, the template shall be included with the last column filled in showing that the model provider ensures that the model complies with the requirements presented in this instruction. A separate report including e.g. visualization of each test is not required.

In addition to the test set provided in the template, Fingrid will test that model can be integrated as part of the larger network model. Fingrid will also evaluate the similarity of the PSCAD and PSS/E models. Differences due to program characteristics in the transient state are evaluated separately in each case.

4 References

/1/ Grid Code Specifications for Power Generating Facilities, VJV
/2/ Grid Code Specifications for Grid Energy Storage Systems, SJV