FINGRID

Modelling instruction for PSS/E and PSCAD models

5.5.2022

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Change log

Date	Version	Changes
5.5.2022	1.0	First release

1 Introduction

1.1 Purpose and scope

This instruction describes the requirements for PSS/E and PSCAD simulation models to be delivered to Fingrid as a part of the grid compliance monitoring process.

Delivery of a compliant model is an important precondition for demonstrating grid code compliance required to receive Final Operational Notification 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 type of models (PSS/E, PSCAD, both or none) to be delivered and the scope of studies to be performed for a specific project (e.g. a new power plant being built) will be defined by Fingrid based on the requirements presented in the relevant valid Finnish Grid Codes, see /1/, /2/, /3/ and /4/.

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

It is highly recommended to use the latest version of this instruction as a reference for modelling requirements for a specific project at the time of the modelling studies. As per request at the time when the connection agreement is concluded, Fingrid will confirm the version of the modelling instruction to be used for a specific project.

1.2 Confidentiality

All models and related technical information given to Fingrid will be treated as confidential. Confidentiality obligations have been specified in the relevant Finnish Grid Codes.

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

2 General requirements

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

2.1 Structure and aggregation

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

If the modelled power plant includes multiple similar generating units, such as wind turbines, these should be represented as aggregated units. All generating units of the same type (identical design) should 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.

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 the simulation models. Dummy bus and zero-impedance branch shall be included only if required by plant controller.

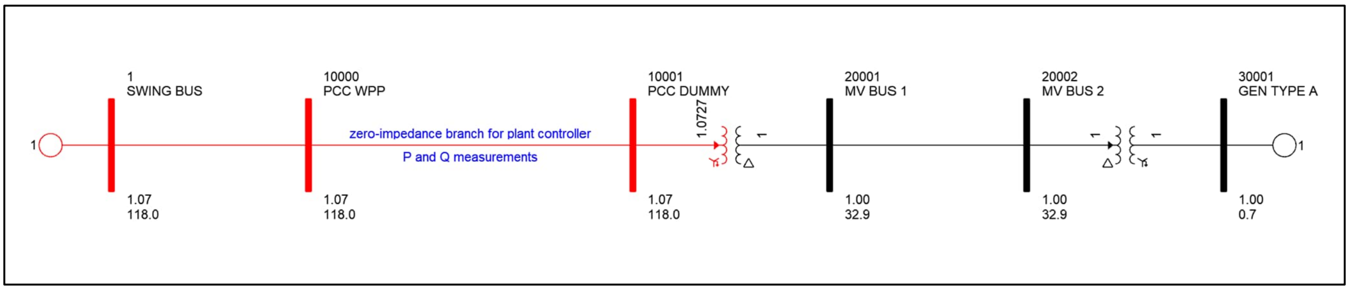

FIGURE 1. EXAMPLE TOPOLOGY OF AN AGGREGATED MODEL WITH ONE MAIN TRANSFORMER

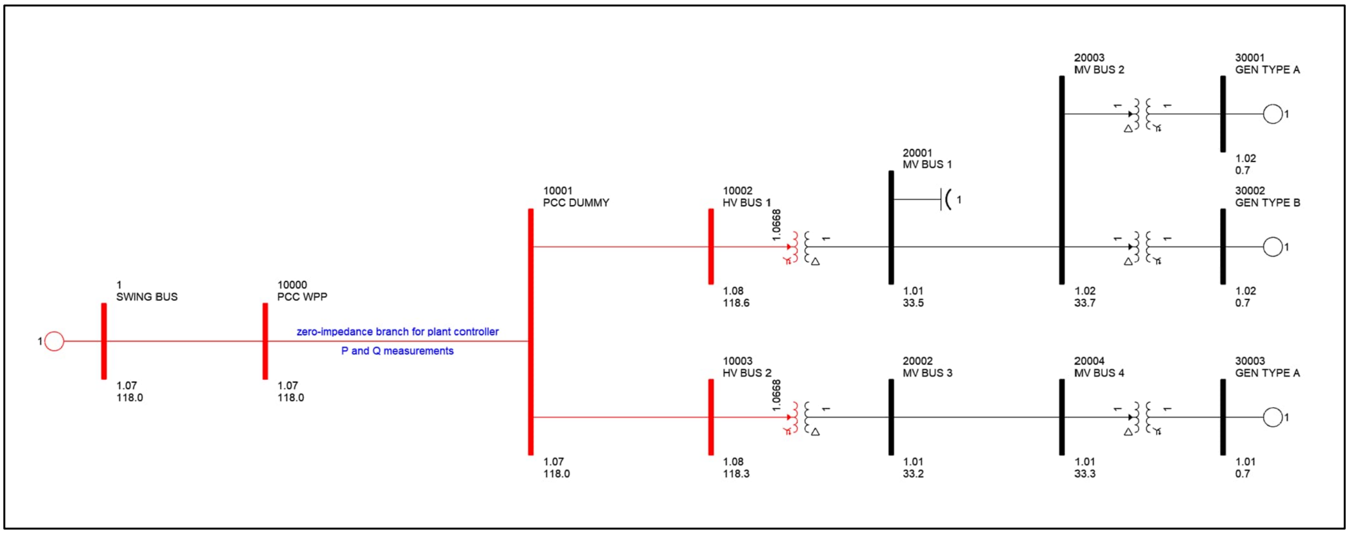

FIGURE 2. EXAMPLE TOPOLOGY OF AN AGGREGATED MODEL WITH TWO MAIN TRANSFORMERS AND TWO TYPES OF GENERATORS

2.2 Functionalities

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.

The model shall include all generator protection functionalities relevant from the power system perspective. 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 functionalities.

2.3 Usability

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 unique version numbering, or there should 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 are recommended 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.

The model shall not require use of specific operating system settings, such as specific decimal separator.

2.4 Other requirements

2.4.1 Modelling of synchronous generators

If the power generating facility is identified by Fingrid as having a risk or contributing to sub-synchronous oscillation phenomena particularly subsynchronous torsional interaction and subsynchronous resonance, detailed EMT model in format usable by PSCAD simulation tools shall be delivered. The model shall include turbine-generator shaft, Power System Stabilizer (PSS), Exciter and Automatic Voltage regulator model. The shaft shall be modeled with multi-shaft mass torsional interface. Key parameters including Inertia constant for each mass and the spring constant between adjacent masses, torque share and respective damping coefficient parameter must be included as listed in Table 1 below.

Parameter	Unit
Inertia Constant	Kgm^2
Shaft Spring Constant	Nm/rad
Turbine Torque Share	P.U.
Self Damping	Nms/rad
Mutual Damping	Nms/rad
Speed Variation Damping Factor	P.U.

TABLE 1. INITIAL DATA FOR MODELLING OF THE SHAFT OF A TURBINE GENERATOR.

Project specific turbine governor model shall also be provided. The model shall cover project specific frequency control functions and functions related to island mode operation. Related documentation depicting the control block diagram, possible modes of operation, model parameters which reflect actual project specific installed settings in the field (not manufacturer default parameter) shall be delivered. The model provided shall also be able to replicate the characteristics of the turbine dynamics up to the level relevant for grid studies.

2.4.2 Modelling of house loads

The house load of the generating facility exceeding 1% of the rated power (Pmax) shall be included in the model. The house loads shall be modelled as passive components (R, L, C) or with suitable load block. The modelling of house loads and process loads of integrated manufacturing facilities exceeding 5MW shall be agreed separately with Fingrid.

2.5 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.
- Compatibility, including what PSS/E and PSCAD versions the model supports. For PSCAD models, the compatible version of the Intel Fortran Compiler shall be specified.
- Requirements for the simulation environment. This includes the minimum and maximum simulation time steps and other relevant parameters.
- List of dependencies in PSCAD. The list of all dependencies, such as library files, that are required to run the model shall be listed.
- List of library files or DLLs in PSS/E. The list of all needed files that are required to run the model shall be listed.
- Limitations of the project specific model performance. Defined as the model response matching actual power plant performance. This shall include:
  - minimum SCR at turbine level and point of common coupling
  - model bandwidth and observable oscillation frequencies.
- 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, subsynchronous damping circuit and control logic of mechanically switched capacitor banks.

- Transfer functions and bode diagram of the possible power system stabilizer and/or power oscillation damping functionality.

The following model usage instructions:

- For PSS/E and PSCAD models, how to change the control mode and the setpoints of each available control mode.
- For PSCAD models, how to transfer the power plant model to another simulation project (for example to large network model), including for example how to set up the required dependencies, settings etc.
- For PSS/E models, how to parametrize the dynamic model in case of bus number changes
- For PSS/E models, a full list of ICONs, CONs, STATEs and VARs with descriptions.

3 Simulation program specific requirements

3.1 PSCAD models

3.1.1 Version requirements

The model shall be compatible with PSCAD 4.6 or 5.0.

The model shall be compatible with Intel Visual Fortran Compiler 12 or later.

3.1.2 Functional requirements

The model should work accurately with simulation time step of 10 microseconds or greater. If the model requires smaller time step, justification and evidence as to why 10 microsecond or higher time step cannot achieve the same level of accuracy shall be provided.

The model shall include overvoltage protection devices (e.g. Surge Arresters) and filters. The saturation of the transformers shall be modelled. The control logic of the relevant auxiliary equipment, such as mechanical switched capacitor banks, shall be modelled. The topology principles described in chapter 2.1 shall be used, however the dummy bus is not required in the PSCAD models.

The model shall work with the ‘snapshot’ and ‘multiple run’ features of the PSCAD. The model shall not use global variables or multiple layers.

The model shall initialize to any user defined and valid operating point in less than 3 seconds. The fault current injection during the faults (FRT mode) shall be modelled.

The models of the inverter-based resources shall have a full power transistor representation or use an average representation that maintains the accuracy of the inner controls and DC side protection schemes. It is highly recommended to embed the hardware code used in the real equipment into the PSCAD model.

The model shall have the following output signals available for plotting:

- Active power, reactive power and frequency at power plant level and at the generating unit level.
- Voltage and current (both RMS and 3-phase instantaneous values) at power plant level and at the generating unit level.
- All the tripping protection signals
- Activation of the FRT mode
- Output of possible active damping functions such as subsynchronous damping controllers

3.2 PSS/E models

3.2.1 Powerflow model

The base MVA of the powerflow case shall be 100 MVA. 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. reference value for voltage control is based on local conditions and relevant grid code requirements acc. to /1/, /2/, /3/, /4/.

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

TABLE 2. SELECTING THE BASE VOLTAGE OF THE BUSES

The generator shall have Q_{min} and Q_{max} set as the limits during P=max and U_{LV}=1.0 pu operation. Possible compensation devices must be modelled separately.

In case the dynamic model measures power flow from the power plant, a dummy bus must be included before the point of common coupling. There shall not be any measurements over the branch representing the background network i.e. from swing bus to study network.

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

3.2.2 Dynamic model

3.2.2.1 Type requirements

Dynamic models which include calls into CONEC and CONET subroutines are not allowed. Only table driven models shall be used.

In addition to project specific custom models, parameters for generic library models of the PSS/E 35 should be delivered (e.g. WECC models for renewables) if available by vendor. It is known that generic library models cannot be parametrized to exactly match the response of a custom model in all areas. Generic library models for inverter-based resources should be parametrized to prioritize the following (given in the order of precedence):

- Voltage control performance
- Fault current contribution
- Active and reactive power fault recovery

3.2.2.2 Version requirements

The model shall be compatible with PSS/E 35. In case dynamic model source code is delivered it must be developed in FORTRAN 90 or higher.

To make sure the models work in large network model, version and sub-version numbering shall be included in the dynamic model's name.

3.2.2.3 Functional requirements

For the dynamic models following requirements must be fulfilled:

- Models shall be able to run multiple disturbances in the same simulation
- Model flat-run simulation shall not present any changes from steady state
- Models shall have stable operation for simulation times up to 5 minutes.
- The initializing of the models shall not cause initial condition suspects.

- The models shall be able to work with time step from 1 to 10 ms. Accuracy of the model based on the time step shall be described.

Linearized models that are accurate only for a single operating point are not acceptable. In case power plant includes compensation devices, inclusion of the switching logic in the model is preferred.

4 References

/1/ Grid Code Specifications for Demand Connections, KJV
/2/ Grid Code Specifications for Power Generating Facilities, VJV
/3/ Grid Code Specifications for Grid Energy Storage Systems, SJV
/4/ Grid Code Specifications for High Voltage Direct Current Systems, HVDC

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