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Requirements for the Preparation and Modelling of Electrical Design Documentation

Valid from 31.07.2025

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1 Objective

1.1 This guide sets out the requirements established by the transmission system operator for the preparation of the Client's electrical design documentation, for the simulation of interaction between the power network and the generating unit, and for the modelling of generating units. The guide shall be applied together with the standard terms and conditions for connecting to the electricity transmission system of Elering AS (hereinafter the Connection Conditions).

1.2 The guide establishes the requirements for the electrical design documentation of type C and D generating modules and consumers, which are subject to coordination with the transmission system operator.

1.3 Chapter 3 of the guide sets out the general structure of the electrical design documentation, covering the common parts of both consumption- and generation-oriented designs.

1.4 Section 3.1 describes the structure of the electrical design documentation to be submitted when connecting to the transmission system operator in a consumption-oriented manner.

1.5 Section 3.2 describes the structure of the electrical design documentation to be submitted when connecting to the transmission system operator in a generation-oriented manner.

2 General requirements for the electrical design documentation

2.1 The electrical design documentation shall be prepared to the extent necessary to assess the compliance of the electrical installation with the Requirements for Generators (RfG), the Grid Code, and the requirements set out in the connection contract.

2.2 The design solution must comply with the standards applicable in the Republic of Estonia; in the absence of such standards, relevant foreign standards known to the Client shall be applied, or, if these are also unavailable, harmonised standards shall be used, the suitability of which must be explained by the designer if necessary.

2.3 The Client may submit a single design project for both generation- and consumption-oriented connection if both generation and consumption take place within the same installation.

2.4 All drawings, diagrams, lists of signals, and other documents must include a title block containing the Client's name, the name of the design project, and the designer's name. The SI system of measurement units must be used.

2.5 In case of any changes made during the coordination of the electrical design documentation, the changes must be clearly marked in the design and the date of the change must be added. Any later changes to the design must be marked similarly.

2.6 The electrical design documentation must be submitted in digital form. Text documents must be submitted in .docx, .doc, or .pdf format; tables and data volume tables in .xlsx or .xls format; and diagrams and drawings in .dwg and .pdf format. The Transmission System Operator must be able to copy and print electronic documents.

2.7 The complete electrical design documentation must be submitted. Each part of the design project must be clearly marked as belonging to the overall Design.

2.8 After receiving comments from the transmission system operator on the electrical design documentation, the client is obliged to make the necessary corrections and/or additions and resubmit the updated documentation to the transmission system operator for coordination.

2.9 With the transmission system operator's consent, the electrical design documentation may be submitted for review in at least the following parts:

2.9.1. design for a consumption-oriented grid connection;

2.9.2. design for a generation-oriented grid connection;

2.10 Final coordination shall be granted by the transmission system operator only for the completely submitted electrical design documentation.

2.11 Each part of the electrical design documentation submitted for coordination must be accompanied by an explanatory memorandum concerning that part. If several parts are submitted together, a single explanatory memorandum may cover them.

2.12 If the data required in the electrical design documentation have been previously submitted by the client to the Transmission System operator and there have been no changes thereto, the client may choose to not submit the required materials and instead refer to the previous design or letter in which the required data have been submitted.

2.13 *The factory acceptance test (FAT) report for power transformers and generating units does not need to be included in the initially submitted electrical design document; instead, it must be submitted to the transmission system operator after the corresponding tests have been carried out*

2.14 The FAT report is a prerequisite for obtaining final coordination. If the electrical parameters presented in the FAT report are found to be unsuitable, the transmission system operator shall have the right to refuse coordination of the design and authorisation to energise the electrical installation.

3 Content of the electrical design documentation

3.1 The consumption-oriented electrical design documentation must include the following:

3.1.1 Primary part:

3.1.1.1 The primary part of the electrical design documentation must include:

3.1.1.1.1 General part – brief description;

3.1.1.1.2 Primary single-line diagram of the electrical installation up to connection point;

3.1.1.1.3 Single-line diagram of the electrical installation from the client's medium-voltage equipment (<110kV)) up to the connection point (110 or 330 kV), indicating new and existing power generation and storage units, reactive energy compensation devices, interconnecting transformers, protection relays, as well as cables and connections with their rated data;

3.1.1.1.4 Power transformers (110 kV or 330 kV) with main parameters and the FAT report;

3.1.1.1.5 Cross-sections of the client's 110 kV or 330 kV bays and busbars, if the client's electrical installation is connected directly to the busbar at the transmission system operator's connection point;

3.1.1.1.6 Contact voltage calculation results, if the client's electrical equipment ground loop is electrically connected to the substation or line ground loop of the transmission system operator. The transmission system operator shall provide the input data necessary for the calculations (short-circuit currents).

3.1.1.1.7 If connecting via 110–330 kV cable:

3.1.1.1.7.1 Cable length;

3.1.1.1.7.2 Longitudinal profile including crossings with other structures;

3.1.1.1.7.3 Cable brand with electrical parameters;

3.1.1.1.7.4 Drawing showing the interface and connection of the cable line to the connection point, including cross-sections of the cable route;

3.1.1.1.7.5 Site plan of the client's electrical installation located within the protection zone of the transmission system operator's electrical installation.

3.1.1.1.8 If connecting via 110–330 kV overhead line:

3.1.1.1.8.1 Site plan and longitudinal profile of the client's electrical installation located within the protection zone of the transmission system operator's electrical installation;

3.1.1.1.8.2 Types of towers (including tower drawing);

3.1.1.1.8.3 Phase wire and lightning protection cable brand with electrical parameters;

3.1.1.1.8.4 Model of the electrical installation in accordance with Chapter 4 of this guide.

3.1.2 Secondaries:

3.1.2.1 The secondaries of the design must include at least the following:

3.1.2.1.1 Layout diagram of primary and backup protections of an electrical installation with 110 or 330 kV voltage level, including metering transformers, with indication of interconnections and protection types;

3.1.2.1.2 Relay protection and automation provisions of the client's electrical installation necessary for protection coordination between the client and the transmission system operator, from the client's equipment up to the connection point;

3.1.2.1.3 Control and automation in accordance with the guideline "Requirements for Data Exchange Related to the Client's Electrical Installation";

3.1.2.1.4 Data communications parameters: IP addresses (static for VPN concentrator, IP for SCADA-accessible devices such as RTUs, etc.), and a communication diagram towards the energy system control centre (SCADA), with an explanatory memorandum;

3.1.2.1.5 RTU data volumes (measurements, controls, and position signals);

3.1.2.1.6 Guaranteed measurement accuracies.

3.2 In the case of the connection of generating units and mixed installations or the amendment of their generation and/or consumption conditions, the Client must submit a generation-oriented electrical design documentation. This design must supplement the previously submitted consumption-oriented design if the modifications to the client's electrical installation have affected the data previously submitted, and in addition, the generation-oriented design must include the following:

3.2.1 Explanatory memorandum if the submitted design differs from the previously submitted consumption-oriented design;

3.2.2 Site plan with coordinates of the client's power park module (scale 1:200 or 1:500). For electric wind turbines, the site plan must show the location and coordinates of each wind turbine; for solar plants, the site plan must indicate the area of the power-generating facilities.

3.2.2.1 Final data of the generating unit:

3.2.2.1.1 data sheets of technical parameters issued by the manufacturing plant for each specific type of power-generating facility of the generating unit;

3.2.2.1.2 Basic data of the generating unit (in the form provided in section 1.1.2 of Appendix 1 to the Connection Conditions);

3.2.2.1.3 Type test reports or certificates for each type of generating unit in the power-generating facility. For electric wind turbines, according to the IEC61400-21 standard, for rotating electrical machines, according to the requirements of the EN60034 standard. For other types of generating units, relevant factory test reports shall be provided, in which the main electrical parameters of each type of power-generating facility, their behavior during voltage dips, power quality and controllability have been measured and calculated.

3.2.2.1.4 PQ characteristics of the generating unit at the connection point, and separately for the entire group of power-generating facilities of each type;

3.2.2.1.5 Description of the generating unit's central control system, accuracy and location of measurements. Whether remote monitoring, control, or modification of settings of the generating unit's operation and algorithms via the network is foreseen;

3.2.2.1.6 For synchronous power-generating modules, a description of the excitation controller (voltage control, automatic/manual excitation current control, block diagram, parameters) and power system stabiliser (PSS) (parameters, signal and limit setting description);

3.2.2.1.7 In the case of generating units, model(s) with planned parameters, together with a description in accordance with Chapter 4 of this guide, and block diagrams of the control and automation of the generating units;

3.2.2.1.8 In the case of production units, verified model(s) (including PSCAD models in electronic form in the case of PSS/E and type D generating modules), to be submitted after confirmation of conformity of the generating unit;

3.2.2.1.9 FAT reports for power-generating facilities.

3.2.2.1.10 Dependence of output active power on climatic and environmental conditions;

3.2.2.2 Function descriptions with settings and block diagrams.

3.2.2.2.1 Primary control;

3.2.2.2.2 Secondary control (active power control performed via remote control at a defined rate and within a specified range);

3.2.2.2.3 Active power control;

3.2.2.2.4 Reactive power control, automatic voltage control relative to the connection point;

3.2.2.2.5 Transition to auxiliary load;

3.2.2.2.6 Description of the capability of the electrical installation to withstand short-duration fault ride-throughs of the power network.

3.2.2.3 Co-operation simulation report for the power network and the generating unit in accordance with Chapter 5 of this guide, if PSS/E and PSCAD models are required;

3.2.2.3.1 The client must submit a report of the generating unit's co-operation simulation results for both transient and steady-state conditions. If the generating unit is built in stages, a separate report must be submitted for each stage.

3.2.2.3.2 Description of the operating principles of the generating unit (type of generating unit, operating regime, estimated annual operating time), including relevant tables, diagrams, device characteristics, etc. Describe the shutdown process of a generating unit.

3.2.3 Secondaries design:

3.2.3.1 When submitting a generation-oriented design, the client must expand the scope of the secondaries accordingly, compared to the consumption-oriented design, to the full extent set out in section 3.1.2.1 of this guide. Any additions compared to the previous consumption-oriented submission must be clearly marked;

3.2.3.2 frequency and voltage protection provisions for all generating units.

4 Requirements for models

4.1 When connecting to the transmission system operator's network, the following shall be submitted:

4.1.1 In the case of a generating unit smaller than type D, a model of the electrical installation in PSS/E software;

4.1.2 In the case of a type D generating module, a model of the electrical installation in both PSS/E and PSCAD software;

4.1.3 In the case of a large electricity consumer whose individual current-using equipment to be connected to the power network exceeds 15 MW (excluding distribution system operators), a model of the electrical installation in PSS/E software;

4.1.4 In the case of a large electricity consumer where the capacity of the equipment connected via voltage transducers exceeds 15 MW (excluding distribution system operators), a model of the electrical installation in PSS/E or PSCAD software, as appropriate. The requirement to submit such a model shall be assessed on a project-specific basis.

4.2 When connecting to the distribution system operator's network, the following must be submitted to the transmission system operator:

4.2.1 In the case of a type B generating module, the data and main parameters of the generating unit (power, voltage, cos φ, energy source, technology, etc.) and factory test protocols;

4.2.2 From type C generating modules onwards, a verified model of the electrical installation in PSS/E software.

4.3 The models created in PSS/E and PSCAD power system calculation software must be comparable, and the results of modelling the same processes must be consistent. In the case of significant discrepancies, the model must be revised.

4.4 The submitted model must be accompanied by documentation explaining its content and how it is to be used.

4.5 When creating the models, standard model components from the software databases of power system calculation tools shall be used.

4.6 If the approach described in section 4.5 is not feasible, it is possible, in agreement with the transmission system operator, to use “black box” models; however, by the verification stage at the latest, the model presented in PSS/E software must be constructed from the standard model components provided by the software.

4.7 Only units of the same brand and model may be aggregated in the model;

4.8 If the installation includes units of different brands and/or models, they must be submitted as separately aggregated units by brand and model, each representing that specific type of unit within the installation;

4.9 The model must reflect the capabilities of the installation and the characteristics of its control systems;

4.10 Identical types of equipment may be modelled as equivalent components in the model (e.g. power transformers, lines);

4.11 The models must enable the execution of the following calculations, the most important of which are:

4.11.1 calculations of steady-state operation of the power network;

4.11.2 short-circuit current calculations;

4.11.3 dynamics calculations;

4.11.4 studies related to electromagnetic transition processes;

4.11.5 modelling and analysis of subsynchronous oscillations;

4.11.6 power quality analysis;

4.11.7 other case-specific studies.

4.12 The client’s installation model must include the following elements:

4.12.1 Internal network consisting of the following elements:

4.12.2 Transformers;

4.12.3 Lines;

4.12.4 Compensation devices (reactors, capacitors);

4.12.5 Filters.

4.13 For synchronous power-generating modules:

4.13.1 Generator;

4.13.2 Prime mover (turbine, internal combustion engine, etc.);

4.13.3 Turbine speed governor;

4.13.4 Exciter;

4.13.5 Over- and underexcitation limiters;

4.13.6 Power system stabilizer;

4.13.7 Relay protection (under and over frequency, under and over voltage);

4.13.8 Control systems;

4.13.9 The model of the turbine/speed governor (*prime mover*) must be capable of describing its behaviour under frequency and load variations.

4.14 For power park modules (generating units connected via a converter):

4.14.1 Converter and its control systems;

4.14.2 Generator, solar panel, etc.

4.15 The client must provide a description of internal auxiliary loads of the electrical installation, specify their types, and model them using appropriate models.

4.16 If the electrical installation uses reactive power compensation devices or includes large motors, these must also be modelled.

4.17 The submitted models must include all essential control systems and their components, and must describe the various operating modes of the electrical installation that influence or are influenced by electromechanical processes, such as:

4.17.1 all voltage and reactive power control modes (including power system stabilisers);

4.17.2 all frequency and active power control modes;

4.17.3 the model must allow configuration of at least the main control settings of the electrical installation that can be changed or activated via the local user interface or the remote control system (SCADA);

4.17.4 relay protection, control systems, and other equipment that is directly related to, affected by or installed in connection with the fulfillment of technical requirements.

4.18 The simplified model in PSCAD software must be usable with a time step of 25 µs, and the standard models in PSS/E must be usable with a time step of 5 ms. The base values used in the PSS/E model must match those used by the transmission system operator.

4.19 Specification and level of detail of models according to the required calculations:

4.19.1 Calculations of steady-state operation and short-circuit currents;

4.19.2 The purpose of steady-state operation calculations is to determine the power system operating modes that constrain the power-generating facility and to identify the measures required to eliminate such constraints. As a result, the power-generating facility must be capable of generating (within its capacity limits) any

amount of power under all foreseeable network loading conditions without being subject to operational restrictions imposed by the power system;

4.19.3 The purpose of short-circuit current calculations is to accurately determine relay protection provisions and to provide input for the selection and design of network equipment and earthing systems.

4.19.4 Data required for calculations:

4.19.4.1 Positive and zero sequence parameters of elements;

4.19.4.2 Power and operational limits of power-generating facilities;

4.19.4.3 Active and reactive loads of the installation;

4.19.4.4 Rated currents and voltages of existing and planned equipment;

4.19.4.5 Earthing method and earth resistances.

4.20 Electromechanical processes in the power system:

4.20.1 The objective is to analyse dynamic stability, verify control system settings, determine critical switching times, etc.

4.20.2 Data required for calculations:

4.20.2.1 Data characterising steady-state operation and short-circuit power;

4.20.2.2 Subtransient reactances, time constants, and other necessary values for generating units and loads;

4.20.2.3 Quantities describing the physical properties of generators and loads;

4.20.2.4 The generator model must take into account saturation effects, i.e., a generator model including saturation characteristics must be used;

4.20.2.5 Block diagrams describing control algorithms;

4.20.2.6 Parameters and control systems of the prime mover;

4.20.2.7 The excitation system must include: terminal voltage transducer; load compensator; excitation control system (elements); exciter; power system stabiliser (PSS); voltage/frequency (V/Hz) limiter; over- and underexcitation limiters.

4.20.2.8 The turbine model must be capable of describing its behaviour under frequency and load variations;

4.20.2.9 In the case of steam turbines, a constant inlet steam pressure is assumed during modelling. The boiler model and its control system may be omitted from the modelling if not included in the combined turbine and speed governor model.

4.20.2.10 Hydro turbine models must account for the pressure in the non-elastic water column in the penstock, excluding reservoir effects;

4.20.2.11 Characteristics of relay protection models.

4.20.3 Dynamic models submitted for the analysis of electromechanical processes must be capable of representing both fundamental frequency-related phenomena and

operating modes where the rotor frequency of a synchronous generator oscillates in the range of approximately 0.1…3.0 Hz.

4.20.4 The duration of the transients to be analysed depends on the activation time and time constants of the electrical installation's components, devices, and controllers. The models submitted for dynamic stability analysis must be capable of covering the following post-disturbance transient mode periods:

4.20.4.1 First 30 seconds (short-term);

4.20.4.2 900 seconds (long-term).

4.21 Electromagnetic processes in the power system:

4.21.1 To study power quality, insulation coordination, resonances caused by harmonics, interactions between control systems, and interactions between the connecting electrical installation and other installations connected to the power network.

4.22 Modelling of torsional oscillations and subsynchronous resonance

4.22.1 Objective: to analyse the interaction between the electrical installation and direct current connections or series compensation.

4.22.2 Data required for modelling:

4.22.2.1 Number of various masses in the (shaft) model;

4.22.2.2 Inertia (H [kgm2]) for each mass;

4.22.2.3 Shaft stiffness (K [Nm/rad]) between the masses;

4.22.2.4 Damping factors (D);

4.22.2.5 Number of generator poles;

4.22.2.6 Relative power of various turbine sections (S in p.u.);

4.22.2.7 Manufacturer-calculated mechanical natural frequencies between the masses.

5 Co-operation simulation report (CSR)

5.1 A report shall be submitted for all generating units connecting to the transmission system.

5.2 For conducting the studies, the power system calculation software PSS/E and PSCAD shall be used.

5.3 Subject to agreement with the transmission system operator, the use of other well-known power system calculation software is permitted.

5.4 In the case of other software being used, the modelling of the electrical installation, performance of the studies, and the evaluation of results must be agreed upon with the transmission system operator.

5.5 Only models coordinated with the transmission system operator may be used for conducting the CSR.

5.6 Objective:

5.6.1 to analyse the behaviour of the electrical installation and assess the generating unit's ability to comply with the applicable requirements;

5.6.2 to analyse the co-operation and mutual impact of the generating unit and nearby electrical installations.

5.7 Scope of studies to be covered in the report (non-exhaustive list):

5.7.1 Overview of the connecting electrical installation;

5.7.2 Capability of the electrical installation to operate under ambient temperature and other environmental conditions;

5.7.3 Active and reactive power flows at various operating points of the generating unit, including associated voltage changes within the power-generating facility's internal network and at the connection point;

5.7.4 PQ curves of the generating unit and of the power-generating facility;

5.7.5 Simulation of various points on the U-Q/Pmax-profile in accordance with RfG requirements;

5.7.6 Description of control functions;

5.7.7 Frequency control capability;

5.7.8 Active power control capability;

5.7.9 Voltage control capability;

5.7.10 Reactive power control capability;

5.7.11 Performance of the excitation controller;

5.7.12 Tuning and effect of the power system stabiliser;

5.7.13 Fault ride-through capability;

5.7.14 Power quality analysis of the generating unit and compliance with limit values;

5.7.15 Harmonics analysis based on the impedance characteristics provided by the transmission system operator;

5.7.16 Selection and impact analysis of filter parameters (if harmonic filters are used);

5.7.17 Power frequency overvoltages;

5.7.18 Transient and temporary overvoltages;

5.7.19 Lightning overvoltages;

5.7.20 Ferroresonance;

5.7.21 Insulation coordination;

5.7.22 Subsynchronous oscillations and potential countermeasures;

5.7.23 Black start capability analysis;

5.7.24 Relay protection and automation effect;

5.7.25 Noise studies.

5.8 The exact scope of studies depends on the technology of the connecting installation and its location within the power system, and shall be agreed upon with the transmission system operator.

5.9 The results shall be documented in a report that includes description of the assumptions, models, and results of the studies;

5.10 References to relevant supplementary documentation;

5.11 clear and comprehensible presentation of results;

5.12 Figures and tables must be accompanied by explanations;

5.13 Comparison of the study results with the Grid Code, RfG, and the agreed technical requirements;

5.14 The report shall be submitted electronically in .pdf format, along with the models used in the CSR studies.

6 Model verification

6.1 The purpose of model verification is to ensure that the models correspond to the actual electrical installation;

6.2 Verification shall be based on successfully conducted tests of the electrical installation, the results of which are used to assess the conformity of the model;

6.3 The client shall propose the scope of verification by specifying which test results will be used as the basis for verification;

6.4 The scope of verification shall be agreed upon with the transmission system operator and generally includes the verification of the following control functions:

6.4.1 Primary control;

6.4.2 Secondary control;

6.4.3 Reactive power control;

6.4.4. Voltage control;

6.4.5 Stepwise change of the voltage setpoint during generator no-load operation within ±10% of the rated voltage (Un);

6.4.6 Fault ride-through;

6.4.7 In exceptional cases, technology-specific control functions.

6.5 The result of the verification shall be documented in a separate report, which must include at least the following:

6.5.1 Comparison between test results and simulation results from the models;

6.5.2 Comparison of simulation results obtained from different software platforms, as well as comparison between aggregated and detailed model results;

6.5.3 Any modifications made to the models.

6.6 The final model documentation must include at least:

6.6.1 Final parameter values;

6.6.2 Description of control functions and their impact on model behaviour;

6.6.3 User manual for the model, including instructions on how and to what extent the control functions can be modified during simulations.