Established by Decision No. 41-1/2019 of the Board of Elering AS of 30 May 2019

Requirements for the preparation and modelling of the electrical part project

Valid from 1 July 2019

Contents

1 Objective 2

2 General requirements for the electrical part project 2

3 Content of the electrical part project 3

4 Requirements for models 7

5 Collaboration simulation report (CSR) 11

6 Model verification 13

1 Objective

1.1 This guide sets out the requirements of the TSO for the preparation of the client's electrical part project, the simulation of cooperation between the electricity network and the power-generating module and the modelling of the power-generating modules. This guide is applied with the connection conditions.

1.2 These guidelines set out the requirements for the design of the C- and D-type power-generation modules and the consumers' electrical part project, which shall be approved by the TSO.

1.3 Chapter 3 of the guidelines sets out the common structure of both the consumption and production-oriented electrical part project, considering the general structure of the electrical part project.

1.4 Section 3.1 describes the structure of the electrical part project to be submitted upon consumption-oriented connection to the TSO.

1.5 Section 3.2 describes the structure of the electrical part project to be submitted upon production-oriented connection to the TSO.

2 General requirements for the electrical part project

2.1 The electrical part project must be prepared in a volume that enables assessment of the compliance of the electrical installation with the RFG, the Grid Code and the requirements specified in the connection contract.

2.2 The design solution must comply with the standards in force in the Republic of Estonia, whereas in the absence of the latter, the knowledge of the contracting authority of the project must be based on the relevant foreign standards or, in the absence of the latter, must be based on harmonised standards, the suitability of which must be explained by the designer if necessary.

2.3 A client can submit a production-oriented and consumption-oriented project as a single project if the installation has both production and consumption.

2.4 All drawings, diagrams, lists of signals, etc. must contain a writer's corner, which must contain the name of the client, the name of the project and the name of the designer. The SI system shall be used for units of measurement.

2.5 In the case of design changes made during the approval of the electrical part project, the change in the design must be clearly marked and the date it was made must be included. Any subsequent changes to the project will require similar action.

2.6 The electrical part project is presented digitally. Project text documents submitted in digital form must be 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 TSO must have the possibility to copy and print electronic documents.

2.7 A complete electrical part project must be submitted. Individual parts of the project must all be marked according to their project status.

2.8 Following the TSO's comments on the electrical part project, the client must introduce corrections and/or additions and resubmit the electrical part project to the TSO for coordination.

2.9 With the consent of the TSO, the design of the electrical part project may be submitted for review per the following parts as minimum:

2.9.1. a demand-oriented network connection project;

2.9.2. a production-oriented network connection project.

2.10 Final coordination shall be provided by the TSO for the electrical part project submitted in full.

2.11 An explanatory memorandum for this part shall be attached to each part to be submitted for coordination. When several parts are submitted, the explanatory statement may be common.

2.12 If the data required in the electrical part project have previously been submitted by the client to the TSO and there have been no changes thereto, the client may refrain from submitting the required materials by making reference to the previous project or letter in which the required data have been submitted.

2.13 The report of the factory acceptance test for power transformers and production units (hereinafter referred to as the FAT) does not have to be included in the initially submitted electrical part design, but must be submitted to the TSO after the relevant tests have been performed.

2.14 A FAT report is a prerequisite for final approval. In the case of the inadequacy of the electrical parameters revealed on the basis of the data presented in the FAT report, the TSO has the right to refuse to approve the project and energisation of the electrical installation.

3 Content of the electrical part project

3.1 The design of the consumption-oriented electrical part project must include the following:

3.1.1 Primary part:

3.1.1.1 The primary part of the electrical part project must include the following:

3.1.1.1.1 General – short description;

3.1.1.1.2 The primary scheme up to the connection point;

3.1.1.1.3 A one-line diagram of the electrical installation up to the connection point, showing new and existing production units, reactive energy compensation devices, intermediate transformers, distribution and protection devices and cables and connections with nominal data;

3.1.1.1.4 110 kV or 330 kV power transformers with basic parameters and a FAT report;

3.1.1.1.5 Sections of the client's 110 kV or 330 kV bays and bus arrangements if the client's electrical installation is connected to the connection point of the TSO directly through bus arrangement;

3.1.1.1.6 The results of measuring and calculating the contact voltage and step voltage (if the earthing loop of the client's electrical equipment is electrically connected to the earthing loop of the substation or line of the TSO). The source data (short-circuit values) required for the calculations shall be provided by the TSO;

3.1.1.1.7 When connecting to the 110-330 kV cable:

3.1.1.1.7.1 Cable length;

3.1.1.1.7.2 Longitudinal profile, including intersections with other structures;

3.1.1.1.7.3 Cable brand with electrical parameters;

3.1.1.1.7.4 Drawing of the connection to the cable entry and connection point, also showing sections of the cable location;

3.1.1.1.7.5 Position plan of the client's electrical installation in the protection zone of the TSO's electrical installation.

3.1.1.1.8 When connecting to the 110-330 kV overhead line:

3.1.1.1.8.1 Position plan and longitudinal profile of the client's electrical installation in the protection zone of the TSO's electrical installation;

3.1.1.1.8.2 Support types (including support drawing);

3.1.1.1.8.3 Line wire and lightning rope with electrical parameters;

3.1.1.1.8.4 PSS/E model and PSCAD model shall be provided if the capacity of the electricity consumer to be connected to the single grid is over 10 MW.

3.1.2 Secondary part:

3.1.2.1 The secondary part of the project must include at least:

3.1.2.1.1 A diagram of the arrangement of the main and reserve relays of an electrical installation with a voltage of 110 or 330 kV, including a power transformer, along with measuring transformers, where the connections between the devices and the types of relays are also shown;

3.1.2.1.2 Relay protection and automatic system settings, which are needed to achieve cooperation of the client's and TSO's relays from the client's device to the connection point;

3.1.2.1.3 Control and automation in accordance with the connection conditions guide ‘Data exchange requirements related to the client’s electrical installation’;

3.1.2.1.4 Data communication parameters, IP addresses (static VPN of the concentrator, IP (RTU etc. of the devices requested by SCADA) on the side of the energy system control centre (SCADA) with a communication connection diagram and an explanatory note;

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

3.1.2.1.6 Guaranteed measurement accuracies.

3.2 When connecting power-generating modules and mixed installations and changing their consumption and/or production conditions, the client must submit a production-oriented electrical part project, in the frame of which the submitted consumption-oriented design has to be supplemented if due to the changes in the client’s electrical installation the data submitted in the consumption-oriented project have changed. In addition, the production-oriented project must include the following:

3.2.1 An explanatory note if the submitted project has differences compared with the previously submitted consumption-oriented project;

3.2.2 A position plan with the coordinates of the client’s energy park module (on a scale of 1:200 or 1:500).

3.2.2.1 Final data of the power-generating module:

3.2.2.1.1 Technical parameter data sheets issued by the manufacturer for each type of production unit in the power-generating module;

3.2.2.1.2 The basic data of the power-generating module (on the form as stipulated in subsection 1.1.2.1 of Annex 1 to the connection conditions);

3.2.2.1.3 Type test reports or certificates for each type of production unit of the power-generating module. For wind turbines according to IEC61400-21, for rotating electrical machines according to EN60034. For other types of power-generating modules, the relevant factory test reports shall be provided, including measurements and calculations of the basic electrical parameters of each type of production unit, their behaviour in the case of fault-ride, electricity quality and control capability.

3.2.2.1.4 The PQ characteristic of the power-generating module at the connection point;

3.2.2.1.5 A description of the central control system of the power-generating module, accuracy and location of measurements. Whether it is intended to monitor or control the operation of the power-generating module via the network or change settings and algorithms;

3.2.2.1.6 In the case of synchronous modules, a description of the excitation controller (application of ceiling voltage, automatic and manual control of the excitation current, block diagram, parameters), and a description of the power system stabiliser (parameters, description of signals and limitation settings) must also be provided;

3.2.2.1.7 In the case of type C and D power-generating modules, the model(s) with the planned parameters with a description and block diagrams of the control and automation of the power-generating modules (incl. for PSS/E and above 10 MW power-generating module, PSCAD models in electronic form);

3.2.2.1.8 Verified model(s) for type C and D power-generating modules (incl. PSS/E and PSCAD models for production units above 10 MW in electronic form) shall be submitted after conformity of the production unit has been confirmed;

3.2.2.1.9 FAT reports of production units;

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 (remote control of active power at a predetermined speed and range);

3.2.2.2.3 Active power control;

3.2.2.2.4 Reactive power control, automatic voltage regulation with respect to the connection point;

3.2.2.2.5 Transition to auxiliary load;

3.2.2.2.6 The ability of an electrical installation to pass through the short-term electricity network fault-ride has to be described.

3.2.2.3 A network and power-generating module simulation report according to chapter 5 of this guide if PSS/E and PSCAD models are required:

3.2.2.3.1 The client must submit a report on the results of the simulation of the cooperation between the electricity network and the power-generating module in both the transient and steady-state operation. If the power-generating module is built in stages, a report shall be submitted for each stage;

3.2.2.3.2 The operating principles of the power-generating module (type of power-generating module, load mode, estimated operating time per year) must be described, relevant tables, graphs, device characteristics, etc. must be submitted. The production process start-up process must be described. The shutdown process of the power-generating module must be described.

3.2.3 Secondary part project:

3.2.3.1 When submitting a production-oriented project, the client must supplement the volume of the project in the secondary part compared with the volume of the consumption-oriented project in the volume specified in clause 3.1.2.1 of these instructions for the secondary part project. Compared with what is presented in the consumption-oriented project, the additions made must be marked;

3.2.3.2 frequency and voltage protection provisions for all power-generating modules.

4 Requirements for models

4.1 The level of detail of the models depends on the capacity of the connected installation:

4.1.1 up to a capacity of 50 MW, an aggregated model shall be presented;

4.1.2 only power-generating modules of the same type may be aggregated;

4.1.3 if the installation contains several types of power-generating modules, they shall be presented by type as different aggregated power-generating modules, each of which shall characterise the production type of the corresponding type in the installation;

4.1.4 the aggregated model must reflect the capabilities of the installation and the characteristics of the control systems;

4.1.5 in an aggregated model, equipment of the same type can be equated (e.g. power transformers, lines).

4.2 For capacities of 50 MW and more, both aggregated and detailed installation models shall be provided.

4.2.1 The detailed model must model the transformers, power-generating modules, other equipment (auxiliary consumption, filters, compensation equipment, etc.) in the installation and the lines connecting them to the fullest extent;

4.2.2 The results of the simulations of the aggregated and detailed model of the installation must correspond to one another;

4.2.3 The model builder must indicate the conditions under which the models correspond to one another and the limitations to be taken into account in the case of a simplified model. It is also necessary to assess the conditions under which the simplified model cannot be used.

4.3 The power-generating modules connected to the TSO’s network must present the electrical installation models in both PSS/E (for the study of steady-state operation and electromechanical processes or dynamics) and PSCAD (for the study of electromagnetic processes and electricity quality phenomena) software.

4.4 Large electricity consumers to be connected to the TSO’s network (with a capacity of over 10 MW per unit connected to the grid, excluding DSO) whose

equipment has a significant impact on the grid must submit electrical installation models in both PSS/E and PSCAD software. The volume and accuracy of the models shall be agreed with the TSO on a project basis based on the specifics of the installation to be connected.

4.5 In the case of power-generating modules connected to distribution networks, the nominal active capacity of the power-generating module is an important indicator. The following must be taken into consideration:

4.5.1 for power-generating modules with a rated power of over 5 MW, a PSS/E model must be provided;

4.5.2 for power-generating modules with a rated power of up to 5 MW, no models need to be submitted. Only power-generating module data, basic parameters (power, voltage, cos φ, energy source, technology, etc.) and factory test reports are provided.

4.6 Models developed in PSS/E as well as PSCAD network computing software must be comparable, and the results of modelling the same processes must be close. In the case of larger differences, the model needs to be updated.

4.7 The model must be accompanied by documentation explaining the content and use of the model.

4.8 Models are built using the standard model components of network computing software databases.

4.9 If the approach described in clause 4.8.8 is not possible, black box models may be used in agreement with the TSO.

4.10 It shall be possible to do the following model calculations with the models, the most important of which are:

4.10.1 calculations of the steady-state operation of the electricity network;

4.10.2 short-circuit current calculations;

4.10.3 dynamics calculations;

4.10.4 studies related to electromagnetic transients;

4.10.5 modelling and analysis of sub-synchronous oscillations;

4.10.6 quality analysis;

4.10.7 other case studies.

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

4.11.1 An internal network consisting of the following elements:

4.11.2 transformers;

4.11.3 lines;

4.11.4 compensation equipment (reactors, condensers);

4.11.5 filters;

4.12 For the synchronous module:

4.12.1 Generator;

4.12.2 main station (turbine, internal combustion engine, etc.);

4.12.3 turbine speed controller;

4.12.4 exciter;

4.12.5 over and under-excitation limiters;

4.12.6 power system stabiliser;

4.12.7 relay protection (under and over frequency, undervoltage and overvoltage);

4.12.8 control systems;

4.12.9 the model of the turbine/prime mover must be able to describe its behaviour as the frequency and load change.

4.13 In the case of a power park module (power-generating module connected via a converter):

4.13.1 converter and its control systems;

4.13.2 generator, solar panel, etc.

4.14 Regarding auxiliary electrical installation, a description and types shall be submitted and they should be modelled with the corresponding models.

4.15 If the electrical installation uses appropriate devices to compensate for reactive power or if large engines are present in the installation, they must also be modelled.

4.16 The models presented must include all relevant control systems and their components and describe the modes of electrical installation that affect or are affected by electromechanical processes such as:

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

4.16.2 all frequency and active power control modes;

4.16.3 the model shall be capable of configuring at least those basic electrical control settings that can be changed or activated through the local user interface or the remote control system (SCADA);

4.16.4 relay protection, control systems and other equipment directly related to, affected by or installed in connection with compliance with the technical requirements;

4.17 In the PSCAD software, the simplified model must be available with a calculation time step of 25 μs and the PSS/E standard models must be available with a calculation time step of 5 ms. The basic values used in the PSS/E model shall be the same as those used by the TSO.

4.18 Specification and detail of models according to the calculations to be performed:

4.18.1 steady-state operation and short-circuit current calculations;

4.18.2 the purpose of the steady-state operation calculation is to find the modes of the electricity system that limit the production unit and the measures necessary to remove the restrictions. As a result, the power-generating unit must be able to develop (within its capacity limits) any capacity under all possible grid load conditions without being subject to the operating restrictions of the operating system;

4.18.3 the purpose of the short-circuit calculation is to determine the relay protection settings as precisely as possible to provide source information for the selection and design of network equipment and the earthing system;

4.18.4 Data required for calculations:

4.18.4.1 positive sequence and zero sequence parameters of elements;

4.18.4.2 capacity and operating limits of power-generating units;

4.18.4.3 active and reactive loads of the installation;

4.18.4.4 rated currents and operating voltages of existing and planned equipment;

4.18.4.5 earthing method and earthing resistances.

4.19 Electromechanical processes of the electrical system:

4.19.1 the purpose is to analyse dynamic stability, check the settings of the control systems, find the lengths of the critical switching times, etc.

4.19.2 Data required for calculations:

4.19.2.1 data describing steady-state operation and short-circuit power;

4.19.2.2 sub-transient reactive resistances, time constants and other required values of power-generating modules and loads;

4.19.2.3 values describing the physical characteristics of generators and loads;

4.19.2.4 the generator model must take into account the effect of saturation, i.e. a generator model that takes into account saturation characteristics must be used;

4.19.2.5 block diagrams describing control algorithms;

4.19.2.6 main drive control system and parameters;

4.19.2.7 the excitation system must consist of a terminal voltage transducer, a load compensator, excitation control elements, an exciter, a power system stabiliser (PSS), a voltage/frequency (V/Hz) limiter (V/Hz limiter) and the under and over-excitation limiter;

4.19.2.8 the turbine model must be able to describe its behaviour during frequency and load changes;

4.19.2.9 when modelling steam turbines and their control, a constant vapour pressure at the inlet is assumed. It is not necessary to model the boiler model and its control system if it is not present in the combined turbine and speed controller model;

4.19.2.10 hydroturbine models must take into account the non-elastic water column in the pressure pipe without the impact of the reservoir;

4.19.2.11 characteristics of relay protection models.

4.19.3 The dynamics models presented for the study of electromechanical processes must be able to describe both the processes related to the fundamental frequency and the operating modes in which the frequency oscillations of the synchronous generator rotor occur at a frequency of ~0.1…3.0 Hz.

4.19.4 The duration of the transients to be analysed is determined by the equipment/parts/controllers of the electrical installation depending on the time and time constants of their commissioning. Depending on the scope specified, the models submitted for dynamic stability analysis shall be able to cover the following post-disturbance transition periods:

4.19.4.1 The first 30 seconds (short-term);

4.19.4.2 900 seconds (long-term).

4.20 Electromagnetic processes in the power system:

4.20.1 the aim is to study the quality of electricity, insulation coordination, interactions due to harmonics and control systems and the interaction between the connected electrical installation and other installations connected to the electricity network.

4.21 Modelling of torsional oscillations and sub-synchronous resonance:

4.21.1 the aim is to investigate the interaction between the electrical installation and DC connections or longitudinal compensation.

4.21.2 Data required for modelling:

4.21.2.1 number of different masses in the model (on the shaft):

4.21.2.2 inertia H [kgm2] for each mass;

4.21.2.3 stiffnesses between masses K [Nm/rad];

4.21.2.4 damping factors D;

4.21.2.5 number of generator poles;

4.21.2.6 the relative power S [r.u.] of the different turbine parts;

4.21.2.7 mechanical oscillation frequencies between different masses calculated by the manufacturer.

5 Collaboration simulation report (CSR)

5.1 A CSR shall be submitted for all power-generating modules connected to the electricity network.

5.2 The network computing software PSS/E and PSCAD are used for the study.

5.3 In agreement with the TSO, the use of other known network calculation software is permitted.

5.4 In the case of the use of other network calculation software, an agreement is reached with the TSO on how the electrical installation will be modelled, how the study will be carried out and how the results will be evaluated.

5.5 Only models approved by the TSO may be used to perform a CSR.

5.6 Purpose:

5.6.1 to analyse the behaviour of the electrical installation and assess the ability of the power-generating module to meet the established requirements;

5.6.2 to analyse the cooperation and interaction of the power-generating module with nearby electrical installations.

5.7 Studies covered by the report (this list is not exhaustive):

5.7.1 An overview of the connected electrical installation;

5.7.2 The possibility of loading the electrical installation based on the ambient temperature and other temperatures;

5.7.3 The active and reactive power flows of the power-generating module occur at different operating points and the accompanying voltage changes in the internal network of the production unit and at the connection point;

5.7.4 PQ curves for the power-generating module and production unit;

5.7.5 Simulation of different points on the U-Q/P_{max} graph according to RfG requirements;

5.7.6 A 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 The effect of the excitation controller;

5.7.12 Power system stabiliser adjustment and operation;

5.7.13 The ability to pass the fault-ride;

5.7.14 An analysis of the electricity quality of the power-generating module and compliance with the limit values;

5.7.15 An analysis of harmonics according to the impedance characteristics issued by the TSO;

5.7.16 Selection of filter parameters, impact analysis (if filters are used to attenuate harmonics);

5.7.17 Mains overvoltages;

5.7.18 Transient and temporary overvoltages;

5.7.19 Lightning surges;

5.7.20 Ferroresonance;

5.7.21 Insulation coordination;

5.7.22 Sub-synchronous oscillation processes, possible countermeasures;

5.7.23 Blind start analysis;

5.7.24 The effect of relay protection and automation;

5.7.25 Noise study.

5.8 The exact scope of the study will depend on the technology and location of the connected installation in the electricity system and will be agreed with the TSO.

5.9 The results must be presented in the form of a report describing the study bases, models and results.

5.10 The report shall include the necessary references to supporting documentation.

5.11 The results must be presented in a clear and comprehensible manner.

5.12 An explanation must be added to the figures and tables.

5.13 The report shall compare the results of the study with the Grid Code, the RfG and the agreed technical requirements.

5.14 The report is submitted electronically in .pdf format 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 performed tests on the electrical installation, the results of which shall be used to assess the conformity of the model.

6.3 The scope of the verification is offered by the customer, indicating for which test results the verification is performed.

6.4 The scope of the verification is agreed; it usually includes the verification of control functions:

6.4.1 primary regulation control;

6.4.2 secondary regulation control;

6.4.3 reactive power control;

6.4.4. voltage control;

6.4.5 gradual change of voltage setpoint during generator idle operation ±10% Un;

6.4.6 passing a fault-ride;

6.4.7 in exceptional cases, technology based control functions.

6.5 As a result of the verification, a separate report shall be submitted containing at least the following:

6.5.1 a comparison of test results and model simulation results;

6.5.2 a comparison of the results of simulations of models presented in different software (also a comparison of the results of aggregated and detailed models);

6.5.3 the changes made to the models.

6.6 final documentation of the models, including at least:

6.6.1 the final parameters;

6.6.2 a description of the control functions and their impact on model behaviour;

6.6.3 Instructions for using the model, what changes can be made in the control functions during the simulations and how.