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Technical principles and solutions of the electrical installations of the transmission system operator

Valid from 1 July 2019

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1 General part and principles of distinction

1.1 This guide describes the technical solutions and principles used in the construction of substations, lines and electrical installations of the TSO and which are used in the construction of new substations and lines owned by the TSO. This guide is applied with the connection conditions.

1.2 Not all requirements described here apply to connections in the TSO's existing electrical installations. In such cases, the technical solution will be drawn up on a case-by-case basis.

1.3 The TSO may deviate from the principles of technical solutions set out in this guide when establishing a substation if the client enters into a fixed-term network contract after the connection process (valid for no more than 25 years from energising the TSO's electrical installation built during the connection process).

1.3.1 No additional connections will be allowed to other clients for the power supply of the substation built during the temporary connection process.

1.3.2 During the temporary connection process, the construction of a tapped substation is permitted under the following conditions:

1.3.2.1 the connection substation shall not be located further than the span length of one transmission line;

1.3.2.2 the existing overhead line to which the substation will be connected must be equipped with optics (OPGW, ADSS) or, if not available, the client must pay the cost of installing the optics.

1.4 The most economically viable solution is used in preparing the connection offer for the client.

1.5 The terms for elimination of interruption in the supply of electricity at the place of consumption and the conditions for the reduction of network charges are established in the Regulation of the Minister of Economic Affairs and Communication 'Quality Requirements for Network Services and the Conditions for Reducing Network Charges in case of Breaches of Those Requirements' (hereinafter referred to as the quality regulation). A place of consumption is a set of connection points with the same or a specific voltage located within one substation.

1.6 According to the quality regulation, the TSO must eliminate the interruption caused by the failure within one hour at the point of consumption with one power supply and within 2 hours at the point of consumption with two independent power supplies.

1.7 The TSO shall ensure that the interruption caused by a failure at the point of consumption of a substation to be built or existing upon connection is eliminated within 2 hours if the point of consumption is supplied via at least two 110 kV transformers and at least two lines, and these input lines of the substation are located completely on separate supports, including line end supports.

1.8 Upon connection, the TSO shall ensure that the 2-hour interruption elimination period is maintained at the existing consumption point, the agreed term for the elimination of which is 2 hours, in the event of a failure in the following cases:

1.8.1 when increasing the consumption capacity, the power supply of this consumption point is ensured via at least two 110 kV transformers and/or at least two lines, and these lines are located on completely separate supports, including the end supports of the lines;

1.8.2 when increasing production capacity, the desired production capacity does not exceed the available consumption capacity and does not cause an increase in the capacity of the substation input lines, including the end supports of the lines.

2 Air and cable lines

2.1 General part of air lines

2.1.1 When designing and constructing new overhead lines, the routes/corridors of existing overhead lines must be used to the maximum extent.

2.1.2 Up to four-circuit supports are used in the construction of new overhead lines.

2.1.3 In the case of a multi-circuit line with different voltages, circuits with a higher nominal voltage are built higher.

2.1.4 At the intersection of the overhead contact line with main roads, railways and navigable waterways, there shall be anchor supports on both sides of the intersection with double insulator chains consisting of two sets of insulator chains independently attached to the parallel anchor support traverse. This solution must also be used if such intersection with the line is envisaged within the next ten (10) years.

2.1.5 When crossing an overhead line with a road, railway or navigable waterway, a vertical gauge of 10 m 330 kV and 8.5 m 110 kV overhead lines must be ensured at the crossing. These gauges must also be used if a given intersection with the line is planned for the next ten (10) years. In other situations, air gaps stipulated in the standard EVS-EN 50341-2-20 (‘Overhead electrical lines exceeding AC 1 kV’, part 2-20: National Normative Aspects (NNA)) for Estonia are followed.

2.1.6 The client is not allowed to add their own line circuit to the existing supports of the TSO.

2.1.7 When replacing a line with a larger cross-section line, existing supports shall be used where technically possible.

2.2 330 kV overhead lines

2.2.1 The cross-section of the conductive part of 330 kV overhead lines must be at least 3x400-Al mm².

2.2.2 Free-standing supports must be used on arable land.

2.2.3 On 330 kV lines, only glass insulators are used, except in the last connection connected to the portal, where the use of composite insulators may be technically justified in traction chains. Glass insulators are fitted with corona rings and discharge horns. In addition to the insulators required due to the length of the leakage path, one additional insulator with an open profile with a diameter of at least 1.5 times the diameter of the lower insulator shall be added to the type I bearing chains.

2.2.4 Cables may be installed in the protection zone of a 330 kV overhead line no closer than 10 m from the support foundation, guy, earthing or cable projection.

2.2.5 The connection of new lines as taps to the existing 330 kV lines is not envisaged.

2.3 **110 kV overhead lines**

2.3.1 The cross-section of the conductive part of 110 kV overhead lines must be 1x240 Al mm² or 2x240 Al mm².

2.3.2 110 kV lines use either glass or composite insulators. In addition to the insulators required due to the length of the leakage path, one additional insulator with an open profile with a diameter of at least 1.5 times the diameter of the lower insulator shall be added to the type I bearing chains. The installation of composite insulators is not permitted on supports where the traverse has a downwards pointing support arm structure.

2.3.3 Cables may be installed in the protection zone of a 110 kV overhead line no closer than 5 m from the support foundation, guy, earthing or cable projection.

2.4 **110 kV cable lines**

2.4.1 Only longitudinal and radial watertight cables with a maximum permissible core operating temperature of 90 ºC shall be used, and a core operating temperature of 65 ºC shall be used for capacity calculations.

2.4.2 The cable screen is earthed at both ends.

2.4.3 When installing cables in the open method, the cables are covered with concrete slabs and the cable route is marked with a warning tape and ID marker balls.

2.4.4 As additional signs above the route, cable plugs are used along the cultivated area, in the place where the cable route runs into water, in natural parks, meadows and forests, near roads and elsewhere in similar places and places where planning, drilling or excavation work may be performed without coordination.

2.4.5 At the intersection with roads and other communications, each phase of the cable line must be installed in a separate pipe. The inside diameter of the pipe must be at least 1.5 mm outside the cable diameter, but no less than 160 mm.

2.4.6 The structures of bridges, viaducts, overpasses and other similar structures and the persons who may be present at the structure must be additionally protected against the harmful effects of electric arc, earth fault current and contact voltage in the event of cable failure.

2.4.7 It is forbidden to install additional cables in the protection zone of an existing cable.

2.5 **110 kV mixed lines**

2.5.1 When upgrading electrical installations, mixed lines (overhead lines + cable lines) are generally not built. If the construction of a mixed line proves to be economically and technically justified, the following conditions must be met:

2.5.1.1 The part of the cable section to be installed must not be located between two sections of the overhead line, i.e. the cable starts from either a substation or an existing cable;

2.5.1.2 The throughput of the cable section to be installed at 65 ºC must, as a rule, correspond to the capacity of the overhead line.

3 Principles of substation construction

3.1 As a rule, during the connection, a new substation will be built no closer than 15 km to the existing substation in a sparsely populated area and no closer than 3 km in a densely populated area. Exceptions are:

3.1.1 cases where, in the opinion of the TSO, the added capacity or some other circumstance necessitates the construction of a substation closer to the above conditions. The assessment of the TSO shall be based on a study carried out by agreement between the client and the TSO prior to the submission of the connection application, comparing the total costs of the client and the TSO for the different options. The total costs are determined for the different options, which take into account investment, operating, maintenance and other costs (e.g. losses, reliability, interruption losses) during the 15-year operating period following the expected commissioning.

3.2 When extending an existing substation of the TSO, the principle of bay uniformity is generally followed, i.e. the scheme and plan solution of the existing substation is used.

3.3 **Tapped substations**

3.3.1 The tapped substation will be connected as a tap only to the existing 110 kV overhead line.

3.3.2 The possibility to build a new tap depends on the technical feasibility (incl. location of the tap, number of existing taps on the overhead line, connection capacity).

3.3.3 In the case of a tapped substation, the TSO cannot guarantee less than 120 hours for the elimination of power outages caused by the failure.

3.3.4 The tapped station must be expandable in the future with an H-scheme substation.

3.4 **Substations with two sections (including with an H-scheme)**

3.4.1 Up to four connections are connected to the substation busbars with an H-scheme.

3.4.2 Over four connections are connected to the substation busbars with two sections.

3.4.3 Connections between lines and power transformers are usually made with disconnector-circuit breakers.

3.4.4 Each section must have the possibility to expand for one line bay if the electricity network development plan does not provide for more bays.

3.5 **110 kV substations with two bar systems**

3.5.1 In a substation with two bar systems, all connections (lines, power transformers) are connected with disconnectors to both systems and the TSO can ensure the elimination time of the power failure caused by the failure for 2 hours.

3.5.2 The client's bay may also be connected to only one system, provided that the client does not want an interruption time shorter than 120 hours or the client has another connection point in the same substation of the TSO, which is connected to both bar systems.

3.5.3 The dual bar system is used:

3.5.3.1 in 330/110 kV substations in 110 kV switchgears;

3.5.3.2 in substations where the existing systems ensure the security of supply of clients in the event of an emergency when one bar system is in repair mode;

3.5.3.3 in substations to which important 110 kV transit lines are connected.

3.5.4 The connection between the systems is made with a disconnect switch with earthing switches and a power switch.

3.5.5 Each system must have the ability to expand for at least one bay.

3.6 **Principles of 330 kV substation schemes**

3.6.1 The mesh scheme is used for three connections with the possibility to build a substation with a duplex scheme in the future.

3.6.2 The duplex scheme is used for four or more connections.

3.6.3 All lines of the TSO shall be connected with two circuit breakers to each bar.

3.6.4 Client bays are connected either with one power switch for one bar or with two power switches for two bars.

3.6.5 If the client's bay is connected to one bar with one circuit breaker, the possibility of installing another circuit breaker must remain.

3.6.6 For future additional lines or power transformers, the possibility of expanding the switchgear is envisaged according to the electricity network development scheme, but no less than for two connections.

4 Substation buildings and facilities

4.1 Real estate of substations of the TSO, incl. the land under the bays established for the client's connection and necessary for servicing, including access roads, fences, communications, etc., belongs to the TSO.

4.2 Depending on the location and the approval of the local government, the substation switchgear can be either an open type (external switchgear) or a closed type switchgear, including a gas-insulated switchgear.

4.3 The gas-insulated switchgear solution is applied only in cases when it is not possible to use other economically and technically more favourable solutions.

4.4 In the case of an external switchgear, the TSO shall always set up a separate control building.

4.5 Substation control buildings must be expandable.

4.6 The installation of equipment belonging to the client in the control building or switchgear of the TSO is not intended.

4.7 No common fire and security systems will be installed for the TSO's and client's buildings.

4.8 The TSO's lightning protection equipment is not intended to protect the client's equipment. The client must provide a separate lightning protection system to protect their equipment.

5 Solutions of the AC systems of the substation

5.1 The TSO and client shall have separate AC centres.

5.2 The AC centre of the TSO usually has two sections and has a backup switching circuit between the power inputs to ensure power reliability.

6 DC systems of the substation

6.1 The TSO and client shall have separate DC centres.

6.2 In the 330 kV substations of the TSO, a 110 V DC auxiliary voltage system is used in the 220 kV substations and in the 110 kV substations.

6.3 All substations must have at least one battery centre.

6.4 The minimum capacity of one battery must be 100 Ah in 10 h discharge mode.

7 Principles of relay protection and automatics design

7.1 The relay protection is designed to be fast, sensitive, selective and reliable and cover all electrical equipment.

7.2 The choice of relay protection devices takes into account the requirements of the stability of the electrical system, and the devices to be installed must ensure compliance with the requirements of the RfG.

7.3 The TSO's relay protection equipment is not intended as the main protection of the client's equipment.

7.4 The client must install a separate basic relay to protect their equipment and the installation.

7.5 The TSO shall install a separate limit switch cabinet in its substation, where the following measuring and control circuits (copper circuits) shall be provided for the client's basic protection and automatics:

7.5.1 circuits from the protection winding of the current transformer of the connection bay (accuracy class 5P);

7.5.2 voltage circuits from the voltage transformer of the connection bay and/or from the busbar voltage transformer(s) of the corresponding voltage class (accuracy class 0.5);

7.5.3 control circuits for switching off the circuit breaker of the 110 or 330 kV connection bay belonging to the TSO (in case of connection to the line, also the switching circuits of the circuit breaker for the client's reclosing automatics).

7.6 All circuits are limited by the terminal blocks of the limit terminal box. The length of the test and control cables connected by the client to the limit switch cabinet to the client's basic protection must not exceed 1000 m and must not pass through real estate owned by third parties. Thus the basic protection of the client must be located on a neighbouring immovable in relation to the TSO's substation or in a separate building on the TSO's substation property, to which a personal right of use must be established. If this is not possible, the client procures the necessary 110 or 330 kV measuring transformers and a power switch and installs them in their electrical installation. If the accuracy of the voltage and current measurements provided by the TSO does not meet the client's needs, the client must procure and install suitable measuring transformers in their electrical installation.

7.7 The TSO shall supplement the relay protection and monitoring equipment of the existing substation if a category D power-generating module is connected to the distribution network.

7.8 If the total installed production capacity of the power-generating modules connected to the existing distribution system operator's connection point at the TSO's substation exceeds the class D limit, the TSO shall, if necessary, supplement the relay protection and monitoring equipment available at that substation.

8 Power transformers

8.1 General

8.1.1 No automatic fire extinguishing system shall be built for outdoor power transformers.

8.1.2 In all power transformers at least one of the windings must be triangularly connected.

8.1.3 All devices connected to the power transformer (measuring transformers, circuit breakers, medium voltage cables) must be installed in accordance with EVS-EN 61936-1 clause 8.7.2.1. requirements.

8.1.4 Fire protection walls are installed on power transformers according to the standard EVS-EN 61936-1 clause 8.7.

8.2 330 kV power transformers

8.2.1 330 kV power transformers must be conventional transformers.

8.2.2 Selection criteria of a power transformer:

8.2.2.1 Nominal voltage: 347/117.5/21 kV;

8.2.2.2 Rated power: 200/200/60 MVA;

8.2.2.3 The diverter switch of the power transformer shall be located on the 330 kV side.

8.2.2.4 Steps of the diverter switch ±6 × 1.33%.

8.2.2.5 The 330 kV and 110 kV windings of conventional transformers may operate with a rigidly earthed neutral (including through a neutral switch), a neutral connected through a reactor or an isolated neutral.

8.2.2.6 The insulation level of the neutral taps of conventional transformers 110 kV must be equal to the insulation level of the phase.

8.2.2.7 The insulation level of the 330 kV neutral terminals and winding of conventional transformers must be at least 245 kV.

8.3 **110 kV power transformers**

8.3.1 Selection criteria of a power transformer:

8.3.1.1 nominal voltage: 115/(38.5; 22; 16.5; 11; 6.6) kV;

8.3.1.2 rated power: 63 MVA, 40 MVA, 25 MVA, 16 MVA, 10 MVA, 6.3 MVA, 2.5 MVA;

8.3.1.3 steps of the diverter switch ±9 × 1.67%;

8.3.1.4 the diverter switches of the power transformer shall be located on the 110 kV side;

8.3.1.5 the insulation level of the neutral taps must be equal to the insulation level of the phase;

8.3.1.6 neutral must be earthed with an earthing switch.

9 Shunt reactors

9.1 Parameters of new shunt reactors:

9.1.1 nominal voltage: 21 kV;

9.1.2 rated power: per switchable unit: 20 MVAr, 30 MVAr or 50 MVAr.

10 Capacitor banks

10.1 Parameters of new capacitor banks:

10.1.1 operating voltage: 123 kV;

10.1.2 rated power at 115 kV: 20 MVAr, 30 MVAr, 50 MVAr;

10.1.3 the capacitor bank (or battery pack - for example 20 + 30 Mvar) is connected to a 110 kV switchgear.

11 Substation short-circuit currents and earthing circuit

11.1 All primary equipment of a 330 kV substation must withstand a short-circuit current of at least 40 kA for 1 s.

11.2 All primary equipment of a 110 kV substation must withstand a short-circuit current of at least 25 kA for 1 s.

11.3 The minimum cross-section of the substation earthing circuit is Cu 50 mm².

11.4 The client must provide an earthing installation for their equipment, which must be connected to the TSO’s earthing installation via at least two beams that correspond to the cross-section of the TSO’s earthing circuit.

12 Substation control and data acquisition

12.1 To control and monitor the substation, special telematics equipment for the substation (RTU – Remote Terminal Unit, control computer, data communication equipment, etc.) will be installed.

12.2 The TSO and the client must have separate and independent telematics equipment.

13 Network analysis equipment

13.1 **External alarm recorder**

13.1.1 To ensure the measurement of short-circuit currents and to analyse the effects of relay protection, external alarm recorders are installed in 110 kV and 330 kV bays.

13.2 **Electricity quality measurement**

13.2.1 The quality of electricity is measured at all new 110 kV or 330 kV connection points between the TSO and the client.

13.2.2 At existing connection points of the TSO with the distribution system operator, electricity quality measurement shall be added if a class D power-generating module is connected to the distribution network or if the total installed capacity of the power-generating modules connected to this connection point according to the normal scheme exceeds the class D limit.

1.3.2.3 Only EVS-EN 61000-4-30 class A type electricity quality measuring devices and capacitive measuring transformers with harmonic sensors suitable for this purpose shall be used for quality measurements.

13.3 **PMU (Phasor Measurement Unit)**

13.3.1 PMU equipment is installed in all bays of 330 kV lines and in bays of producers connected to the 330 kV network (wind, solar, co-generation plants, etc.). At a voltage of 110 kV, PMU equipment is installed in the bays of the most important clients (affecting the quality of the network) connected to the electricity network.

14 Measurement of transmitted electricity

14.1 The volume of network service and the amount of electricity are measured at the client's connection point, except at the TSO's existing connection points with the distribution system operator, where it is not reasonable to update the measurement points in the power transformer's medium voltage bays. In this case, a commercial measuring point is built in the 110 kV bay of the power transformer and a loss factor is used to determine the losses of the network (transformer) between the measuring and connection points.

14.2 All AC electricity measuring instruments used in the transaction must comply with the Metrology Act of the Republic of Estonia.

14.3 Only inductive voltage transformers may be used for commercial measurement. The use of capacitive voltage transformers is not permitted.

14.4 Intermediate current transformers and summation of secondary currents of current transformers are not used in the measuring circuits. Additional resistances may be used in measuring circuits only in exceptional cases where other technical solutions are not possible. The measuring wiring must not be installed in a common duct, rack or piping with high voltage conductors. To avoid affecting the measurement results, all terminals of the measuring circuits and the equipment in them must be covered and sealed. Meters and their accessories must be located in a separate measuring board.

14.5 Meters used for commercial measurements at 6-330 kV must be able to measure active and reactive energy in both directions with a measurement period of at least 15 minutes.

15 Conditions for connecting power-generating modules

15.1 Irrespective of the capacity of the electricity network of the TSO, the maximum transmitted power per connection point is 350 MVA in order to ensure the measurement accuracy of commercial measurements at 330 kV. In the case of higher capacity, more than one connection point must be established at the TSO's substation and the power-generating modules must be divided between the connection points. From the three production-oriented connection bays in the same 330 kV substation, at least one connection bay must be built with a duplex circuit in order to maintain the connection of at least two production bays in the event of substation equipment failure.

15.2 The equipment of the connection point between the TSO and the client shall be built according to the maximum network connection capacity specified in the connection contract. The measurements and compliance of the TSO's SCADA are based on the capacity fixed in the connection contract.

15.3 The TSO shall implement an automation system to monitor the contracted power-generating capacity, which shall function when the connection point is switched off.