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TECHNICAL APPENDIX 2 TO THE GUIDELINES 'CONNECTING AN ELECTRICITY GENERATION INSTALLATION TO THE DISTRIBUTION NETWORK' – CONNECTING AN INSTALLATION WITH A NOMINAL RATED CAPACITY OF OVER 100 kVA

These instructions are a translation of the corresponding instructions in Finnish. In any cases of ambiguity in interpretation, the Finnish-language instructions shall be complied with.

This appendix includes technical information about connecting a generation installation with a nominal rated capacity of **over 100 kVA** to the distribution network. The purpose of this appendix together with the guidelines 'Connecting an electricity generation installation to the distribution network' is to provide information about connecting electricity generation installations to the network and to facilitate the process of connecting the installations to the network.

Chapters 1–5 and 7 of this appendix apply to all generation installation with a nominal rated capacity of over 100 kVA to be connected to the network. Chapters 1–5 deal with the general properties of the generation installations and chapter 7 provides information about the technical documentation on the generation equipment to be delivered to the system operator. In addition to these, chapter 6 sets out the separate additional requirements for installations or groups of installations with a nominal rated capacity of **over 500 kVA, but under 10,000 kVA**. Installations of over 10,000 kVA are not dealt with in this appendix, but they are subject to the specifications for the operational performance of power plants by Fingrid Oyj valid at any given time.

1. General information about the operation of an electricity generation installation in the electricity distribution network

When connecting a generation installation to the public electricity network and when using it in parallel with the public electricity network, it is of paramount importance that the generation installation is safe and will not cause any disturbances to the network and, for example, damage the electrical equipment of other electricity users. For these reasons, generation installations are subject to certain technical requirements.

A generation installation must not connect to the public electricity network unless the voltage and frequency of the electricity network are within the agreed set limits. The generation installation must not keep on feeding to the electricity network when the network is not fed from elsewhere. When the network voltage returns, the installation may connect to the network automatically or it can be connected back to the network manually if agreed with the system operator.

Larger generation installations (from about 500 kVA upwards) can have a significant impact on the structure of the entire local electricity network and their significance in terms of the entire power system is strongly emphasised as the number of installations grows. With respect to larger installations, it is essential that they are also able to operate during fluctuations of the network voltage and frequency so that they can support the operations of the power system during and immediately after possible disturbances, whenever necessary. It may also be necessary in terms of network management that the owner of a generation installation equips larger power plants with a

remote operating system which can be used for controlling the power plant operations, when necessary.

If one also wants to use a generation installation as reserve power during power cuts, the possibility of a dual connection mode must be installed in the system, with one connection to work in parallel with the network and the other in isolated operation that is completely separated from the network. This requires a separate switch and additional devices. When the electricity network is de-energised, an installation used in isolated operation must not be in connection with the electricity network. This is absolutely essential due to the safety of the fault repair and installation work on the network.

No electricity-generating equipment must cause disturbance to the network or other electrical installations. If a fault is detected in the generation installation, it is the electricity producer's responsibility to disconnect the installation from the network after detecting the fault. If a generation installation connected to the network causes disturbance elsewhere in the electricity network, the system operator will intervene and, in extreme cases, have the installation removed from the network.

The owner of the electricity generation installation is liable for any damages caused by the electricity generated by its equipment to other electricity users and the system operator if the electricity generated by the equipment does not meet the standards and other requirements.

2. Classification of equipment

Many properties of the generation installation have an impact on its operation in the electricity network. The nominal rated capacity of the generation installation is one significant matter, but other properties are also essential in terms of network use. For example, the start-up current of the installation may vary, depending on the type of equipment, from a start-up current that corresponds with the nominal rated current to one that is 8 times greater than the nominal rated current. These matters are important especially when deciding on the connection point of the generation installation.

The operating mode of the generation installation has an impact on contracts between the electricity producer and the system operator and on the operation and protection features required of the installations. The classification of installations in various uses and the requirements they are subject to are presented in the following table. The columns of the table show the properties that various installations require. Prevention of parallel use means that the installation is mechanically separated from operating in parallel with the distribution network. Synchronisation means that the installation is able to synchronise with the distribution network and remain in that mode. Compatibility describes the electrical compatibility of the installation and the distribution network. Prevention of isolated operation (also called Loss of Mains protection) means protection that prevents the generation installation to feed electricity into a de-energised network. Terms of contract mean the contracts between the owner of the installation and the system operator. The abbreviations refer to the following terms of contract applied to the connection and operation of the installation, recommended by Finnish Energy Industries: Terms of Network Service (VPE10), Appendix to the Terms and Conditions Concerning Network Services for Electricity Generation (TVPE11), Terms of Connection (LE05), and Terms of Network Connection for Electricity Generation (TLE11).

Table 1. Classification of generation installations according to the operating mode and purpose of the installations.

	Class	Prevention of parallel use	Synchro-nisation	Compati-bility	Loss of Mains protection	Terms of contract
Parallel use prevented mechanically	1	X				LE05 and VPE10
Electricity transmission to the distribution network prevented	2		X			LE05 and VPE10
There is no buyer for the electricity generated	3		X	X	X	LE05 and TVPE11
Producer sells electricity to a party of the electricity market	4		X	X	X	LE05 or TLE11 and TVPE11

3. Protection settings of the generation installation

Generation installations must be equipped with protection devices that disconnect the generation installation or isolated generation fed by the generation installation from the public network if the feed to the network is cut off or if the voltage or frequency at the equipment connection point deviates from the values determined by the system operator. The primary purpose of the protection settings of a generation installation is to protect the equipment from damage and to safeguard personal safety.

The set values for the protection of generation installations with a nominal rated capacity of over 100 kVA is determined separately in each case. The set values for protection are affected by many factors, such as the network structure, the connection point of the generation installation and the type and operating mode of the installation.

The properties of a power plant to be connected to the network must guarantee that the protection settings based on the above-mentioned criteria are not inconsistent with the other requirements presented in this document. Any inconsistencies must be clarified in co-operation between the system operator and the connecting party.

3.1. Set limits for under- and overvoltage and under- and overfrequency protection of the generation installation

The set limits for the under- and overvoltage and the under- and overfrequency protection of the generation installation must be in line with the permissible limits of the frequency and/or voltage deviation lasting for 30 minutes or longer, as presented in chapter 6, figure 6.1. The operating delays must be based on the generation installation's ability to operate at under- and overfrequency and at under- and overvoltage conditions. The operating delays of protection must be agreed separately with the system operator of the connection point.

Information about the protection settings of the generation installation must be delivered to the system operator of the generation installation as part of the documentation

delivered on the installation. Further information about documentation and its delivery is provided in chapter 7.

3.2. Protection to prevent isolated operation (Loss of Mains protection)

The generation installation must be equipped with protection that prevents isolated operation. A description of protection that prevents isolated operation must be delivered to the system operator of the connection point, and the protection settings must be agreed on separately with the system operator of the connection point.

4. Quality of electricity

It is the task of the distribution system operator to deliver high-quality electricity to its customers. For this reason, the quality control of electricity is very important also in issues related to small-scale generation of electricity. The quality of electricity must be regarded from the viewpoint of the quality of electricity at the connection point and the quality impacts of the generation installation.

4.1. Quality of voltage in the connection point

A generation installation to be connected to the network must be able to operate normally when the quality of voltage in the connection point of the network is within the limits determined in standard SFS-EN-50160. Momentary exceedings of the limit values referred to in the standards must not have a significant impact on the operation of the generation installation.

4.2. Impact of the generation installation on the quality of voltage in the connection point

Generation installations must meet at least the requirements on the quality of electricity set for it in the national (SFS) and international (IEC and CENELEC) standards.

The system operator determines the criteria for the permitted disturbance levels of the generation installation. The permitted disturbance levels are determined so that a generation installation to be connected to the network will not substantially impair the quality of voltage in the connection point of the installation. The generation installation's connections to the network must be implemented so that the impact of the connections on the voltage of the connection point will remain as small as possible. The impacts of the connections to the voltage can be verified, for example, in connection with test runs.

5. Electrical safety

According to the general electrical safety regulations, a generation installation must be equipped with a disconnecting device with a position indicator or a visible clearance between open contacts and to which the system operator has free access. The switch must also have a locking option. The disconnecting device is needed to ensure the safety of electrical work.

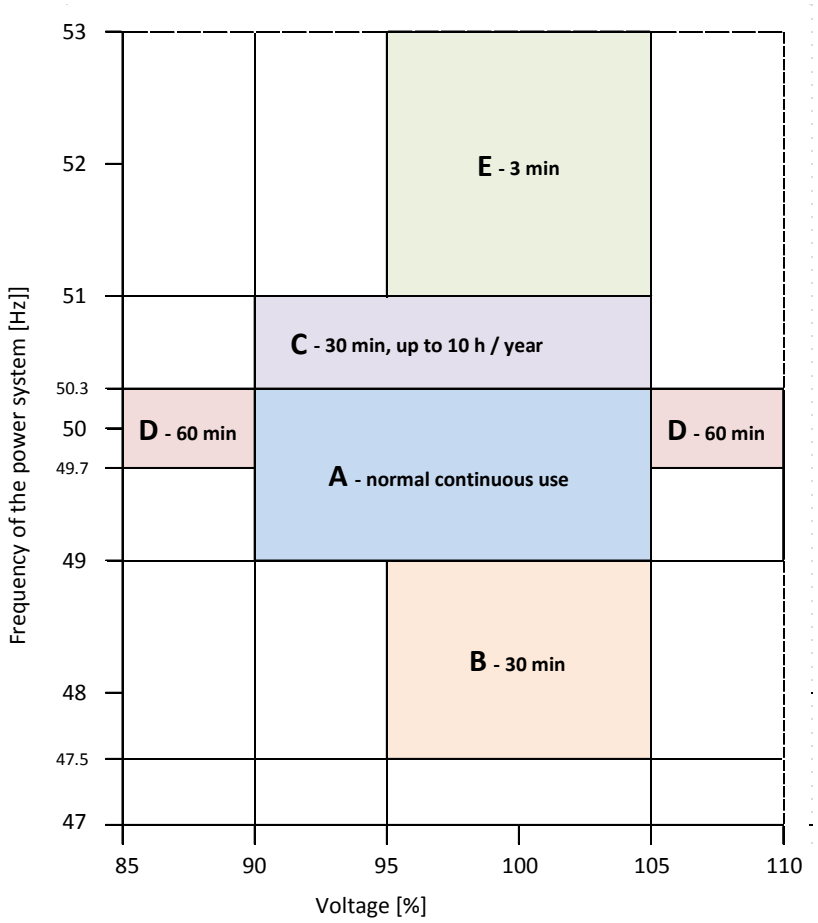
6. Specifications for the operational performance of installations of over 500 kVA

Generation installations with a nominal rated capacity of over 500 kVA may have a significant impact on the operation of the local electricity network and their impact on the electricity system of the entire country is strongly emphasised as the number of installations grows. For this reason, they are subject to specifications for their operational performance presented in this chapter in addition to the above-mentioned requirements.

6.1. Frequency and voltage operating range

The frequency and voltage of the electricity network and the power system formed by the electricity users and electricity generation installations vary constantly in a normal operating situation from the impact of constant fluctuation in loads and production and as a result of constant changes taking place in the electricity network transmission situation. Both the frequency and the voltage can significantly deviate from their nominal values in connection with occasional disturbances in the power system and temporarily as a result of them. It is important in connection with the voltage and frequency disturbances that the components of the power system, including the generation installations, are able to carry on their operations in a normal way and, if necessary, support the functioning of the electricity network during and after the disturbance.

Figure 6.1 presents the frequency and voltage limits (voltage value 100% and frequency 50 Hz refer to the nominal values) in relation to which the generation installations must be able to continue their operations in a normal way either without a separate time limit or temporarily for the period presented in figure 6.1 or for a similar period of time.



A: Normal continuous use – reduction in the production ability of active and reactive power due to the voltage and/or frequency of the power system is not permitted

B: 30 min continuous use – power reduction permitted so that the greatest permitted reduction at the 49 Hz level is 0% and at the 47.5 Hz level 15% in the frequency area remaining between this, the permitted reduction is determined in a linear way on the basis of permitted reductions in the limit frequencies

C: 30 min continuous use totally a maximum of 10 hours per year - 10% power reduction is permitted if it does not set restrictions to continue operations at full capacity after frequency returns below the level of 50.3 Hz

D: 60 min continuous use – a maximum of 10% power reduction is permitted from full power

E: 3 min continuous use – high power reduction is permitted

Outside the above-mentioned operating ranges, the operation shall be continued within the limits permitted by the technology, direct disconnection is not permitted

Figure 6.1 Frequency and voltage ranges within which a generation installation of over 500 kVA must be able to operate

The operating delays of protection must be agreed separately with the system operator of the connection point. The system operator of the connection point must be notified of the protection data, which is to be described as part of the power plant documentation on the generation installations to be delivered to the system operator. The documentation is described in further detail in chapter 7.

6.2. Reactive power capacity and the reactive power control of the generation installation

In order to improve the utilisation of the network transmission capacity and to maintain reliable operations in the electricity network, the generation installations must be able to take part in the maintenance of network voltage by producing or consuming reactive power, depending on the voltage and load level of the network. Therefore, a generation installation to be connected to the network must have a certain reactive power capacity to maintain the reactive power balance between the network and the generation installation and the voltage level in various uses of the network. Moreover, the generation installation must be able to dynamically control the reactive power of the installation to utilise the reactive power capacity.

6.2.1. Reactive power capacity of the generation installation

The generation installation must be able to produce reactive power on the overvoltage side of the generator transformer, i.e. at the points indicated in figures 6.2 and 6.3, and at least within the limits indicated in figure 6.4.

When the production efficiency of the generation installation fluctuates with the target value of reactive power control being 0 kVar, the variation permitted for reactive power around the 0 kVar level is in the region corresponding to 5% of the nominal rated capacity of the generation installation as reactive capacity (i.e. $\Delta Q = \pm 0.025 \times S_N$ [kVar]). The variation of reactive power must not momentarily exceed the level that corresponds to 10% of the nominal rated capacity of the generation installation (i.e. $\Delta Q = \pm 0.05 \times S_N$ [kVar]).

The reactive power capacity of the generation installation must not be restricted artificially, but it must be based on the natural reactive power capacity of the generator(s) in addition to the limits presented in figure 6.4.

The system operator of the connection point is entitled to utilise the reactive power capacity of the generation installation in a way permitted by the reactive power control properties of the generation installation (see section 6.2.2), for example, for the compensation of voltage changes taking place across the connection cable of the generation installation. Examples of possible ways of utilising the reactive power capacity of the generation installation are presented in figure 6.4.

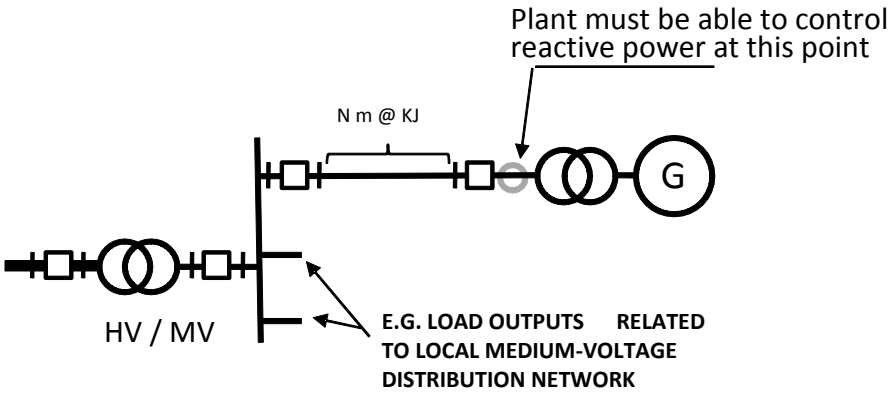


Figure 6.2 The point where the requirement set for the reactive power production capacity must be met with respect to a power plant formed by an individual generator and a generation unit

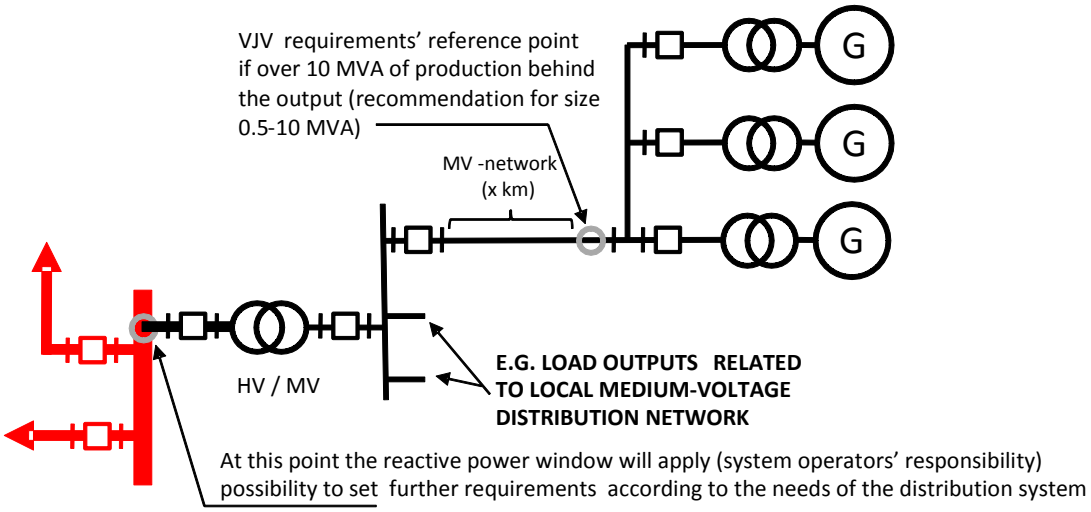


Figure 6.3 The point where the requirement set for the reactive power production capacity must be met with respect to a power plant formed by several generators and a generation unit

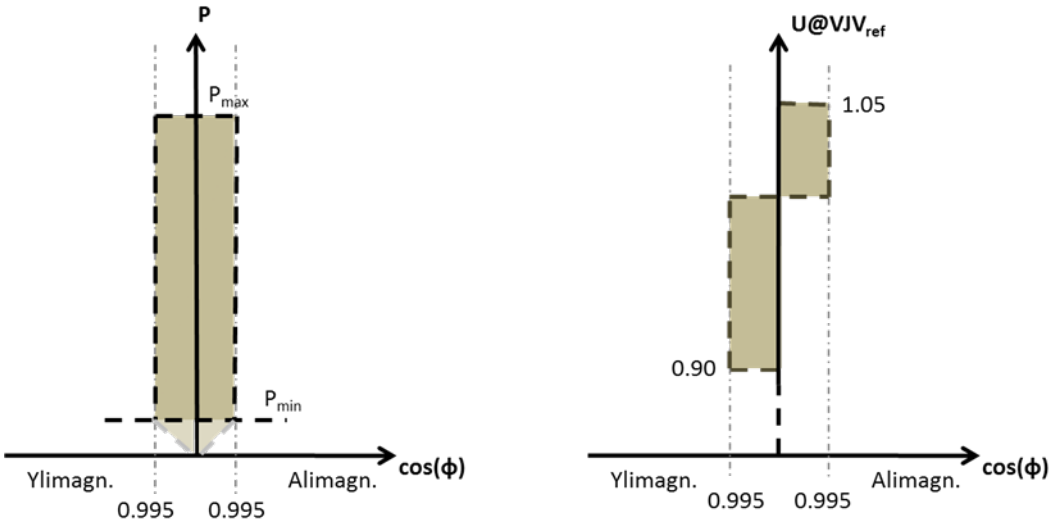


Figure 6.4 The requirement for reactive power capacity set for the generation installation. U@VJV$_{ref}$ refers to the voltage in the reference point defined in Fingrid Oyj's technical requirements for the power system (VJV).

6.2.2. Reactive power control properties of the generation installation

The generation installation must have at least one of the following two functionalities related to reactive power control: standard reactive power control or standard power factor control.

The reactive power control must enable the utilisation of the generation installation's reactive power capacity in the way described in section 6.2.1. The control operations must not be disturbed by changes in the network voltage or frequency or by momentary voltage disturbances. Changes in the control function status and the operating points must take place without significant sudden changes or repeated, significant fluctuations in the power produced by the installation.

If the basic properties of the generation installation include more than one functionality related to reactive power control or the option to control the reactive power produced by the generator on the basis of network voltage (standard voltage control), the system operator of the connection point is entitled to require utilisation of this functionality within the scope of the natural reactive power capacity when the generation installation produces active power to the network.

The system operator of the connection point is entitled to define a point deviating from the reference points presented in figures 6.2 and 6.3 as the reference point of the reactive power control or separately required voltage control, for example an electric point corresponding to the medium-voltage feeder of the generator or generation installation.

The operating mode of the reactive power control of the generation installation is defined by the system operator of the connection point on the basis of the reactive power control properties of the generation installation.

6.3. Active power control of the generation installation

Generation installations with a nominal rated output of under 10,000 kVA (both individual generation units and power plants consisting of several generation units) need not have

automatic functionalities of active power control related to, for example, frequency variation in addition to the normal functionalities required for the control of production output and the maintenance of power level and, in the case of synchronous machines, rotation speed control.

However, if the basic properties of the generation installation include functionalities related to the control of active power and/or frequency, the system operator of the connection point in co-operation with the grid company is entitled to require utilisation of the functionalities related to the active power control of the generation installation, for example, in case of network disturbances. An example of this functionality is a momentary automatic restriction of active power production increase during an overvoltage disturbance in the power system.

6.4. Commissioning tests

In connection with the commissioning and/or test runs of the generation installation, the following properties must be verified with measurements:

1) The momentary impact of the start-up and stopping of the generation installation to the voltage level
2) Verifying the highest production output of the generation installation
3) Compliant reactive power capacity
4) The generation installation's ability to maintain the reactive power constant in accordance with the requirements presented in section 6.2.1
5) Operation of reactive power control and any standard voltage control and change in the operating point without significant sudden changes
6) Quality of electricity

With respect to the above-mentioned properties, the commissioning record including the variables verified by measurement and the time of the measurements shall be delivered to the system operator of the connection point.

With respect to sections 2, 3, 5 and 6, the commissioning measurements may be replaced by a type testing report or a similar document if it is not possible to carry out the tests related to these sections, for example, due to conditions having an impact on production or the operating situation of the electricity network.

Measurements related to the quality of electricity (section 6) can be replaced, for example, with a testing report complying with standard IEC 61400-21 or a similar testing report describing the quality of electricity in an installation to be connected to the network.

Moreover, if the power plant has, for example, control properties referred to in sections 6.2 and 6.3.3, the system operator of the connection point is also entitled to require testing of these properties in connection with test runs of the power plant.

6.5. Metering information

Metering information on the connection point defined by the system operator must be delivered from the power plant. With respect to plants of over 1,000 kVA, electricity transmission system operator Fingrid requires delivery of hourly energy metering data.

7. Required documentation on plants over 50 kVA

The general and electrical engineering data on the generation installation must be documented, and the documents must be delivered to the system operator of the connection point. The technical documentation to be delivered must include the data required by the system operator.

The delivery form and method of the data are discretionary on condition that the documents to be delivered are clear and unambiguous in terms of their spelling and structure. A list of requirements related to the documentation is presented in Table 7.1. The list is presented in a general form and it shall be applied case-specifically according to the nature of the power plant project.

Table 7.1 Information to be delivered on the power plant (an example)

Information on the power plant to be delivered to the system operator	
1	Power plant structure and location
1,1	Main circuit diagram
1,2	Structure
	Power plant type (e.g. Wind power, solar power, biomass...)
	Basic information (e.g. of a wind turbine: height of tower, rotor diameter etc.)
1,3	Location data
2	Technical data of power plant transformer/s
2,1	Number of power plant transformers
2,2	Nominal values of power plant transformers
	Power [MVA], current [A], voltage [V]
	Transformer ratio [primary/secondary]
	Tap change control range and tapping step [%,%]
	Number of steps and selected step in tap changes [number, position data]
3	Technical data of the power system of the power plant
3,1	Number of generator units
3,2	Supplier/s of generator units
3,3	Type/s of generator units
3,4	Nominal values of generator units
	Output (nominal output [MVA] and highest production output [MW])
	Current [A], voltage [V], frequency [Hz]
	Electrical parameters of synchronous machines (resistances, reactances and related time standards)
3,5	Production output's dependency on operating conditions (e.g. wind velocity, temperature)
3,6	Any used compensation equipment and/or equipment that are used in repair of power factor
	Number and type/s
	Nominal values (output, voltage, frequency)
	If utilised in filtering of harmonics, information on structure and tuning frecuency
4	Power plant properties
The following sections can be replaced, e.g. with manufacturer's equipment documents, testing documentation complying with standard IEC61400-21 or other testing documentation	
4,1	Description of reactive power production capacity (e.g. so-called PQ-diagrams)
4,2	Description of power plant's ability to operate at under- and overvoltage
4,3	Description of power plant's ability to operate at under- overfrequency
4,4	Description of power plant's ability to operate in frequency disturbances (FRT operations)
4,5	Description of any control properties of the power plant
4,6	Description of the power plant's impact on the quality of electricity
5	Power plants protection data
5,1	Power plant's relay protection diagram
5,2	Power plant's relay protection settings
5,3	Description of the Loss of Mains protection
6	Commissioning documents
6,1	Commissioning documents
6,2	Final settings and operating status of reactive power control
6,3	Final relay protection settings of the power plant
7	Other documentation
7,1	Calculation models

7.1. Delivery of power plant documentation in different stages of the project

Information about the power plant must be delivered to the system operator of the connection point throughout the power plant project. Information to be delivered to the system operator of the connection point in different stages of the power plant project, above all, as the initial data for network design, is presented in Table 7.2. Figures 1–7 in Table 7.2 refer to the items numbered in Table 7.1.

Table 7.2 Delivery of power plant documentation to the system operator during different stages of the project

	Information to be delivered in different stages of the project (numbers refer to Table 7.1)						
	1	2	3	4	5	6	7
Preliminary planning	X						
Design		X	X	X			
Construction	P	P	P	P			
Before the start of test runs					X		X
Normal use (after test runs)	P	P	P	P	P	X	P
X = information to be delivered							
P = update to previously supplied information							