Grid Code

High and extra high voltage

E.ON Netz GmbH, Bayreuth

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1 Introduction

E.ON Netz GmbH, hereinafter referred to as **ENE**, is the transmission system operator for the control area below. The term **connectee** refers to those parties who operate a connection on the ENE grid, irrespective as to whether this is used for drawing or supplying electrical energy.

This grid code describes the minimum technical and organisational requirements that must be fulfilled when setting up and operating grid connections on the ENE high voltage or extra high voltage grid. Additional requirements may also be necessary for operation.

1.1 Legal framework

As a transmission system operator, ENE is responsible for the operation, maintenance and, if necessary, the development of its transmission system.

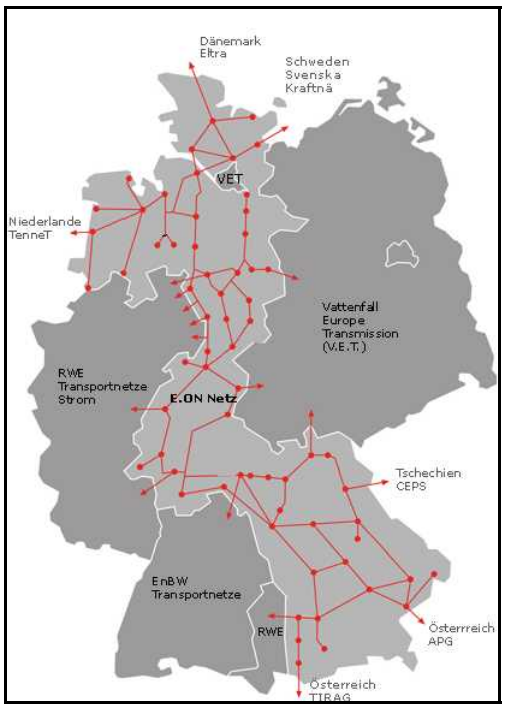


Figure 1 The *control area* of E.ON Netz GmbH (as per Jan. 2006)

According to the Energy Industry Act, operators of transmission systems have an obligation to define the minimum technical requirements for connections to these grids.

It is the connectee's obligation to adhere to the defined grid code. The connectee guarantees that those using the connection also meet this obligation. Suitable evidence of adherence must be furnished on demand.

1.2 Technical framework

ENE operates public three-phase transmission systems with different voltage levels and a frequency of nominal. 50 Hz.

The grid code defines the minimum requirements for setting up and operating one or more connections on this grid. They are aimed firstly at the objective requirements for fault-free operation of the ENE grids and secondly on the importance of plant operation in line with requirements for the connectee. They are based on the generally recognised rules of technology that are continuously being adapted in line with technical advancement, and the directives that put them into concrete form for ENE, including among others the “Technisches Handbuch Netz” [1][1].

The minimum requirements (regulations) of the Union for the Coordination of Transmission of Electricity (UCTE) [2] also form the basis for operation of the transmission system.

1.3 Scope

The grid code applies to all connections to the high and extra high voltage grid of ENE. The connectee must ensure that these grid connection regulations are also observed for connections to his network within the contractual zone, insofar as these affect operation of the ENE grids.

The grid code forms the technical basis of grid connection agreements. In this function, the grid code is part of every grid connection contract and supplements the latter both technically and organisationally.

The grid code also provides information to persons who, via operation of their plants, can influence the grid operation of ENE and must therefore adapt to them. In this context, they are aimed primarily at the operators of generating plants within the control area, irrespective of whether these are connected directly to the ENE grid or subordinate grids.

2 The grid connection concept

A prerequisite for a new grid connection or a connection change is the agreement between ENE and the connectee concerning a grid connection concept, which becomes part of the grid connection agreement.

The technical requirements and definitions described in more detail in these grid code forms the basis of the grid connection concept.

To define the grid connection concept, ENE examines on the connectee’s request whether the grid conditions (e.g. grid connection capacity, reactive power balance, short-circuit power, reliability of the capacity provision etc.) at the existing or planned grid connection point are sufficient for connecting

[1] References in square brackets can be found in Appendix C – References

and operating the connectee's plant without any unacceptable effects on the ENE grid and without impairing plant operation.

To investigate an enquiry, ENE must receives, from the connectee all the necessary data and information regarding the grid connection. If it is necessary to conduct inspections on the connectee's premises or for the design of the plant, the latter will receive the necessary data and information regarding this from ENE. The minimum scope of the data to be exchanged is listed in table form in Appendix E. The questionnaires in Appendix E must be completed in the application for the connection of a generating plant.

Besides the stipulations of this grid code, the additional criteria listed below in particular are also decisive for the investigation:

- Grid connection capacity
- Protection concept
- Reactive power exchange
- Continuous operating voltage, voltage band, voltage changes and voltage control
- Short-circuit power
- Neutral point treatment
- Static and dynamic stability
- Insulation coordination
- Parallel switching conditions
- Harmonics and flicker
- Equipment specifications
- Application of the (n-1) contingency criteria
- Behaviour in the event of grid faults, e.g. participation in the 5-step plan

If the investigations show that the grid conditions at the grid connection nodes are insufficient for correct operation of a connectee's plant, ENE defines appropriate measures in the grid connection concept for adapting the connectee's plants.

If a conversion, extension, grid reinforcement or other technical changes in the ENE grid are necessary as a result of a new connection or a modification to a connectee's plant, the necessary extension measures are stated and defined in the ENE grid connection concept.

Planned modifications to plant components affecting the grid connection are agreed between ENE and the connectee. The technical documentation must be submitted in advance.

Every grid connection must be dimensioned so that it is possible for ENE to operate the grids in accordance with the (n-1) contingency (see Appendix B).

Further regulations must be contractually agreed and must not place other connectees at a disadvantage.

Evidence of the connectee's plants with regard to

- the properties agreed between the connectee and ENE
- adherence to the grid code
- correct implementation of the grid connection concept

must be furnished in a suitable form before first commissioning. If available, certificates relating to the plant can also be used for this purpose.

3 Grid connection requirements

The requirements outlined below are minimum requirements and, unless otherwise stated, must be fulfilled by a connectee's plants at the grid connection point.

3.1 Requirements on all connectees

3.1.1 General information

A connectee's plants are, for the purpose of supplying or drawing electrical energy, connected via switching points with a disconnection function (circuit breakers and disconnectors). This connection points are defined by ENE, taking into account the prevailing grid conditions, the power and the way in which the plant operates, as well as the interests of the connectee.

Based on the grid connection concept agreed with ENE, the connectee arranges for the design of the substations for which the connectee is responsible. The switchgear must be planned, set up and operated as "closed electrical operating areas" in accordance with the relevant regulations and the recognised rules of technology.

In cases in which the connectee is the owner of the land or building, a suitable space must be available and accessible to ENE for accommodating primary and secondary technical equipment.

The connectee and ENE must exchange at least the documentation listed in Appendix E and keep this up to date for the duration of the grid connection operation. Whenever a change is made, they should be made available to the other partner.

The (n-1) contingency forms the planning basis for the high and extra high voltage grid of ENE, as described in Appendix B.

In the following cases, ENE is entitled to temporarily limit the grid connection capacity or shut down the plant:

- acts of God
- potential risk to secure system operation
- a congestion or the risk of overloading equipment
- risk of islanding

- a risk to static or dynamic grid stability
- frequency deviation putting the system at risk
- unacceptable network interactions
- maintenance, repair and construction works

3.1.2 Grid connection and plant design

In line with the grid-related and operational requirements, a connection to the ENE grid is made on the basis of one of the following alternatives:

- Connection on a line as a single or double feeder
- Connection to a busbar in a substation

Appendix D contains the standard diagrams for both alternatives. In the figures, it is shown in each case which party performs switching for each equipment and the electrical position of the transformer for the metering.

The plant concept and the key data of the equipment (e.g. rated voltage, short-circuit current capability, earthing concept, minimum dimensions etc.) are defined in the “Technisches Handbuch Netz, Chapter: Bauen und Errichten“ [1] that applies to ENE. The system configuration used for the grid access must be discussed between the connectee and ENE, and is agreed in the grid connection agreement.

ENE plants and plant components, particularly high-voltage units, must comply with the "Technisches Handbuch Netz" [1] of ENE with regard to the technical requirements and their design. Minimum requirements as laid down in the ENE specifications, for example technical electrical data, also apply to the connectee´s plants and plant components. It is also recommended to design these completely in accordance with ENE requirements.

An independent, uninterrupted power supply via a battery must be provided for all electrical auxiliary equipment (e.g. for control, communications, protection, metering or the drives of switching equipment)

3.1.3 Reactive power exchange

When active power is taken from the ENE grid, the connectee must maintain, as standard, a power factor of cos φ = 0.95 (inductive) to 1 in Quadrant I at the grid connection point. A further exchange of reactive power is only permissible if this has been separately contractually agreed.

The exchange of reactive power when feeding into the ENE grid is described in section 3.2.4.

3.1.4 Switchgear operation

The operation of electrical plants covers all technical and organisational activities that are necessary to keep the plants functional and safe. The activities include all operating measures, as well as electrical and non-electrical operations as described in the relevant specifications and regulations.

The personnel employed for operating the switchgear must be qualified in accordance with [3] and [4]. Only skilled electricians and persons trained in electrical engineering have access to the switchgear.

Appropriate instruction from ENE is required for access to ENE plants and plant components. Laypersons as defined by the specifications [3] and [4] may enter plants only when accompanied by skilled electricians or persons trained in electrical engineering.

A contact partner of the connectee with switching authorisation and responsibility for plant use at the grid connection must be available for ENE to contact at all time.

Operation of the grid connection, particularly switching actions and work on the grid connection, must be done in accordance with the "Technisches Handbuch Netz, chapter: Netzführung und Arbeiten im Netz" (NAN) [5].

If a connectee has more than one grid connection point on the ENE grid or with other grid operators, these may not be operated interconnected through the connectee's plants.

Establishing a set voltage value for normal operation and a voltage band at the grid connection point is the responsibility of ENE.

3.1.5 Operation during disturbances

Both ENE and the connectee must inform each other immediately about special events of which they become aware, insofar as such could be of concern to the other party.

Plants and grids must be designed in such a way that, if possible, faults are automatically isolated from the grid immediately and the fault is prevented from spreading.

In the event of a loss of voltage resulting from a fault, modifications to the switching status of the grid connection should only be made following consultation with the responsible switching supervisor.

To investigate the fault, ENE can request special checks, which the connectee must perform on his equipment if this equipment is electrically connected to the ENE grid.

The partners support each other in elimination and investigation of faults.

3.1.6 Network interactions and quality of supply

The connectee's electrical systems must be designed and set up in such a way that while in operation, interactions with the ENE's grid and third parties are avoided, and information and signal transmissions are not unacceptably influenced.

The requirements that apply here are specified in more detail in, for example, the relevant international standards [6]. On this basis, the connectee must keep evidence that his systems are not causing interference and, if necessary, provide remedial measures. Details are defined in the grid connection concept, taking into account the specific reaction variables in the particular individual case, and are agreed with the connectee.

The regulations published by the VDN [7] are used to assess system interactions.

3.1.7 Voltage characteristics

During normal operation, the following characteristics for the voltage in the ENE grid will be adhered to in accordance with DIN EN 50160 [8]:

- The frequency is in the range of 49.5 Hz to 50.5 Hz.
- The continuous operating voltage, for each nominal network voltage

  380-kV network: 350 – 420 kV

  220-kV network: 193 – 245 kV

  110-kV network: 96 – 123 kV

  The upper value can be exceeded for up to 30 minutes. Due to artificial pollution or other influences, lasting differing values can apply for the lower voltage value in the 110-kV grid.

3.1.8 Neutral-point treatment

The neutral-point treatment for the ENE grids is defined by ENE. This results in corresponding specification for dealing with neutral points belonging to the voltage level of the ENE grid, including when these are in the connectee's network. This applies particularly to transformers and other equipment forming neutral points that may be owned by the connectee.

The method to deal with neutral points not belonging to the ENE grid must be worked out in individual cases, and agreed in the grid connection agreement. If several neutral points are used simultaneously on one transformer, a corresponding concept must be worked out and agreed.

In all cases, each connectee must make their own provision for treating the neutral points in their plant components. This applies particularly to the compensation of earth-fault current in networks with inductively earthed neutral points.

3.1.9 Maintenance

ENE and the connectee are each responsible for the maintenance of their own equipment and plant components.

All plant components must be maintained in accordance with the state of the art in order to guarantee correct operation in line with the grid code.

Safety-relevant plant components such as circuit breakers, batteries and protective devices must be inspected regularly according to an inspection plan.

3.2 Requirements on generating plant

3.2.1 General

In addition to the "Requirements on all connectees" as outlined in chapter 3.1, the following minimum requirements also apply to the grid connection of generating plants.

With regard to technical properties, a distinction is made between **basic requirements** that must be fulfilled by every generating plant and **additional requirements** that must be fulfilled at the request of ENE in order to ensure reliable system operation above and beyond the basic requirements. The **additional requirements** are contractually agreed between ENE and the operator of the generating plant.

Unless stated otherwise, the requirements described below are **basic requirements**. The **additional requirements** are indicated.

A distinction is made below between Type 1 and Type 2 generating plant. The definitions of these types are provided in chapters 3.2.6.1 and 3.2.6.1.

The sum of rated power of all generator units at a common grid connection point is definitive for determining the rated capacity of a generating plant. This includes instances when they consist of several individual generating units.

ENE must be informed in good time about the status of the extension planning for generating plants. ENE must be informed of the technical data of a generating plant (see Chapter 2).

If occasional reversals of the load flow (infeed) occur at grid connections designed for drawing active power from the ENE grid, ENE and the connectee must agree on the conditions under which these reversed supply will take place.

If several grid connection points are present, interconnecting the connections though the connectee´s system is not permissible as a matter of principle.

3.2.2 Active power output

The connection and operation of generating plants by the connectee must not have any unacceptable effects on the grid [6].

When connecting generators, the following operating conditions must be allowed for and corresponding synchronisation and parallel switching equipment must be provided:

- Normal operation (start-up of the generating plant)
- Synchronisation after transition to auxiliary load, if this type of operation is technically possible with the generating plant
- Connection to a de-energised islanded sub-network for the purpose of energising it

Connection of a generator with a rated power of more than 50 MVA by the connectee is only permissible following approval by ENE. This is specified in more detail in the grid connection agreement.

Every generating plant must be capable of operating at a reduced power output and to allow constant power changes of 1 % of the rated power per minute across the entire range between minimum and continuous power.

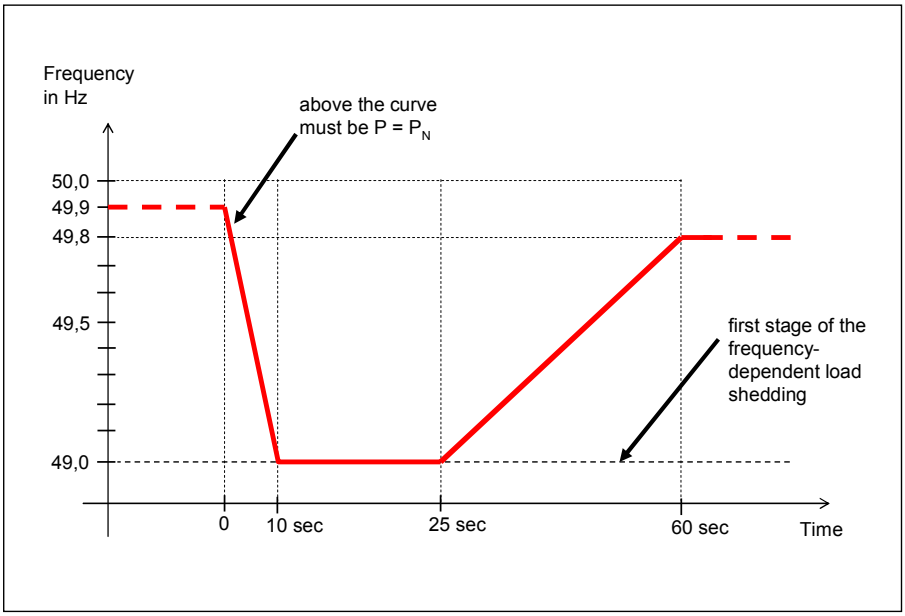


Figure 2 Frequency envelope for frequency drops in which there may be no limitation of the active power output

In the event of frequency drops above the thick line in Figure 2, the active power output must not be reduced even if the generating plant is being operated at rated power.

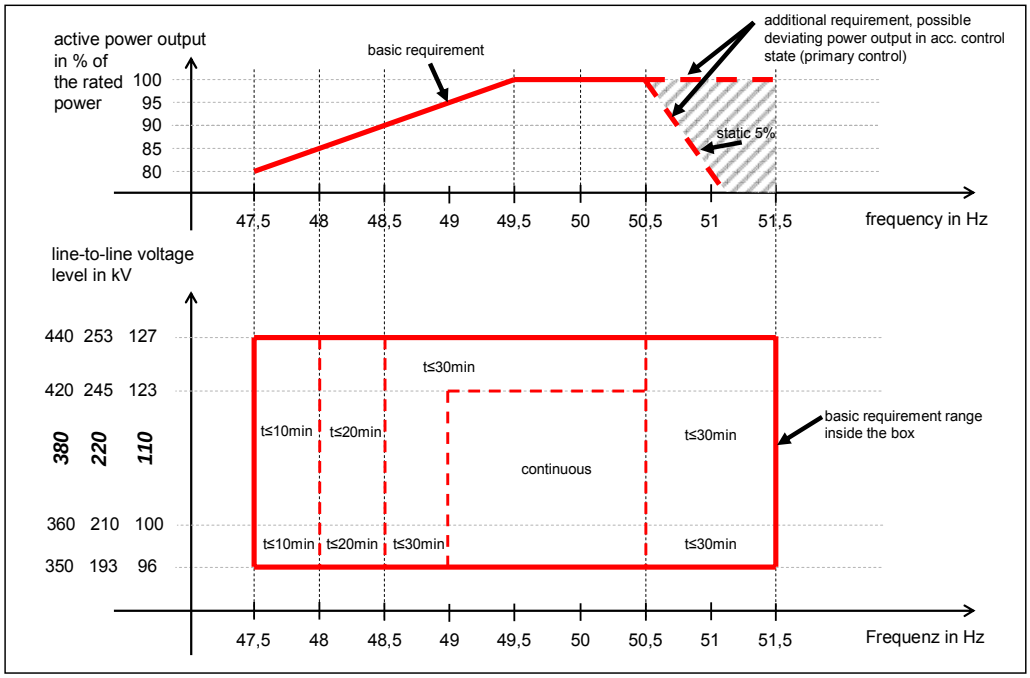


Figure 3 Requirements placed on the output power of a generating plant to the grid for certain periods, as a function of grid frequency and grid voltage (quasi-stationary observation, i.e. frequency gradient < 0.5% / min., voltage gradient 5% / min.)

The **basic requirements** shown in Figure 3 must be met. **Additional requirements** are agreed separately if necessary.

The exchange of active power by each generating plant with the grid must be technically configured to achieve ENE's specified setpoint values.

It must also be possible for ENE to control the circuit breaker connecting the generating plants.

3.2.3 Frequency stability

All generating plants meeting the necessary technical and operational requirements can be used for the provision of primary control power, secondary control power and minute reserve. To this end, a prequalification process must be passed during which details concerning the control band, ramp rate of power, period of provision, availability etc. will be determined. Consumers can also participate in secondary control power and provision of minute reserve by way of controllable loads.

Every generating plant with a rated capacity of ≥ 100 MW must be capable of supplying primary control power. This is a prerequisite for connection to the grid. ENE is entitled to exempt individual generating plants from this obligation.

Generating plants with a rated capacity of < 100 MW can, by agreement with ENE, also be used to secure the primary control .

The following requirements must be met for the primary control :

- The primary control band must be at least ± 2 % of the rated power.
- The frequency power droop characteristic must be adjustable.
- Given a quasi-stationary frequency deviation of ± 200 mHz, it must be possible to activate the total primary control power range required by the generating plant evenly in 30s and to supply it for at least 15 min.
- The primary control power must be again available 15 min after activation, provided that the setpoint frequency has been reached again.
- In the event of smaller frequency deviations, the same rate of power change applies until the required power is reached.
- The insensitivity range must be less than ± 10 mHz.

3.2.4 Reactive power exchange and voltage stability

With active power output, every generating plant must fulfil, as a **basic requirement,** at the grid connection point the range of reactive power provision shown in Figure 4. As an **additional requirement** ENE can, in justified cases, agree an extended or different reactive power exchange.

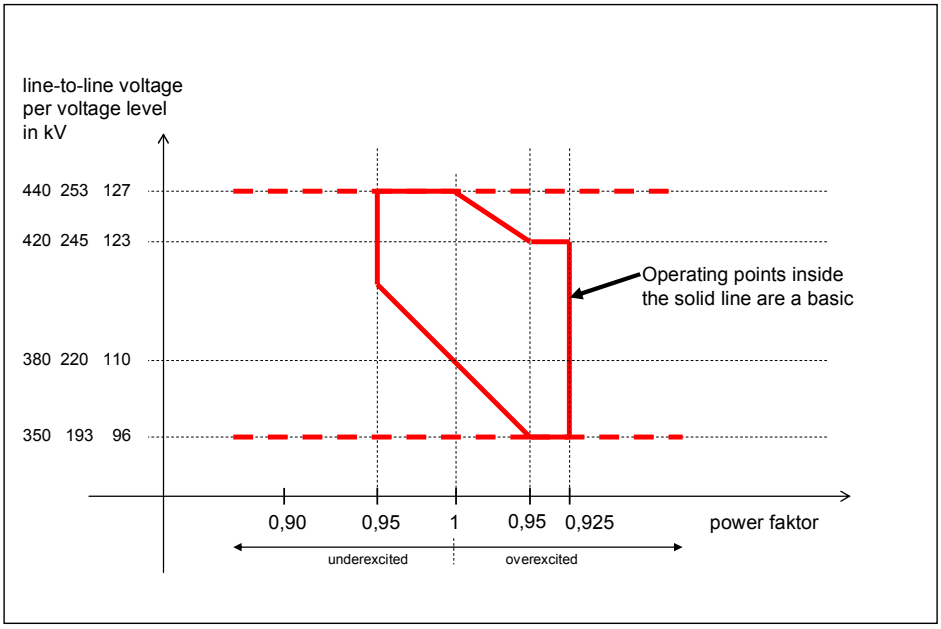


Figure 4 Requirements placed on the reactive power provision of a generating plant at frequencies between 49.5 and 50.5 Hz and without limiting the active power output

The reactive power exchange by each generating plant with the grid must be technically configured to achieve ENE's specified setpoint values.

Generally, it must be possible to pass, within a few minutes, through the agreed configuration range for the power factor at the rated active power output. The entire process must be possible as often as required.

If necessary, equipment must be provided as an additional requirement in the generating plant so that voltage and reactive power regulation can be carried out.

The operating point for the stationary steady state reactive power exchange at the active power output is defined by ENE in the grid connection agreement depending on the requirements of the grid. The definition refers to one of the following three possibilities:

- Power factor (cos φ)
- Reactive power level (Q in Mvar)
- Voltage level (U in kV), if necessary with tolerance band

The operating points are defined by the following possibilities:

- Agreement of a value or, if necessary, a schedule
- Online setpoint value specification

In the case of online specification of setpoint value, the respective new specifications for the operating point of the reactive power exchange must be realised at the grid connection point after no more than one minute.

If the reactive power exchange alters, step changes corresponding to a reactive power of more than 2.5 % of the grid connection capacity in the high voltage grid and 5 % in the extra high voltage grid are not permissible. ENE can also permit a greater range in certain justified cases.

Switching-related voltage changes at the grid connection point must not exceed 2 % in the entire operating range of the generating plant and also in the case of reactive power exchange in the limit range. For generating plants used for the base load, it is possible to agree on a higher value.

The block or power transformer must be fitted with a tap changer that must be harmonised with the properties of the generating plant (control range and step size).

If the generating plant is not running its auxiliary service requirements are covered from the ENE grid, the conditions for reactive power exchange as stated in Chapter 3.1.3 apply. In justified cases, ENE can permit a greater reactive power exchange.

3.2.5 Disconnecting the generating plant from the grid

At frequencies between 47.5 Hz and 51.5 Hz, automatic disconnection from the grid due to the frequency deviation from 50 Hz is not permissible. When 47.5 Hz or 51.5 Hz is reached, automatic disconnection from the grid must take place without delay. In individual cases, ENE can specify a different set value, e.g. for realising the 5-step plan for grid faults [9].

If the grid frequency rises to a value of more than 50.5 Hz, ENE can demand, as an **additional requirement**, a reduction of the active power output as shown in Figure 3.

If there is provision for transition to auxiliary load, when the voltage falls at the grid connection point to a value of 85 % or less of the reference voltage (380/220/110 kV, e.g. 110 kV x 0.85 = 93.5 kV), the generating plant must be disconnected from the grid after a time delay of 5 seconds. The voltage value refers to the highest value of the three line-to-line grid voltages.

In the case of Type 2 generating plants, this function must be carried out in accordance with Point 3.2.6.2.

In the event of a loss of stability, the generating plant must automatically disconnect itself from the grid in order to prevent multiple slip-through. The disconnection concept for loss of synchronism must be presented to and agreed with ENE.

The point at which the disconnection is made must be agreed with ENE within the framework of the grid connection concept.

3.2.6 Behaviour during grid disturbances

Phase swinging or power oscillations must not trigger of the generating plant protection or a capacity disconnection. Regulation of the generating plant must not stimulate phase swinging or power oscillations. Stability-related variables of turbine and generator control must be agreed between the operator of the generating plant and ENE.

For generators, equipment for damping phase swinging or power oscillations may be necessary, e.g. power system stabilizer (PSS). When required, ENE agrees with the generating plant operator the configuration of the necessary equipment. Via this measure, it must be ensured that the static stability

for every operating point within the generator power diagram is guaranteed and that steady state operation is possible when there is rated short circuit power on the high voltage side of at least four times the generating plant's rated active power and a voltage on the high voltage side of at least the network rated voltage.

Following the clearance of a fault in the ENE grid and in the case of automatic three-pole reclosure, the operator or a generating plant must expect that the voltages in ENE grids and at the connectee's grid connection can be asynchronous. The operator of the generating plant must take measures to ensure that automatic reclosure in the transmission operator's grid does not cause damage to his generating plants.

A disturbance is only considered cleared when the generating plant has resumed normal operation, and not simply after performing fault clearing.

The requirements in the event of faults in the grid must be adhered to for the range between the minimum and maximum short-circuit power present at the grid connection point, and the connectee must provide evidence of it.

3.2.6.1 Behaviour of Type 1 generating plants in the event of faults in the grid

A Type 1 generating plant refers to a synchronous generator connected directly to the grid.

Three-phase short circuits must not cause instability or a disconnection from the grid when for fault-clearing times of up to 150 ms in the entire operating range of the generating plant.

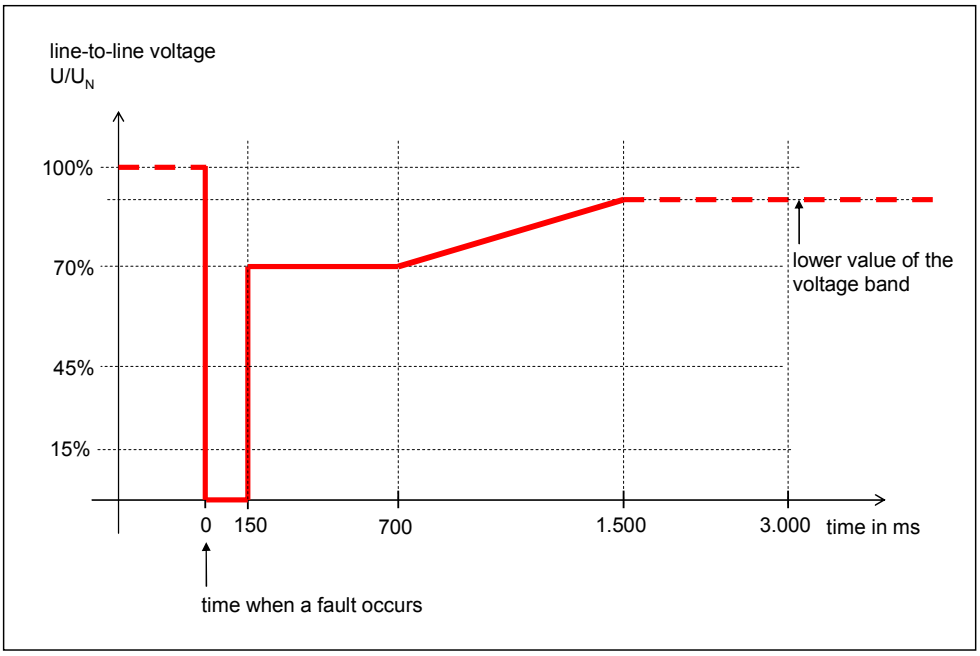


Figure 5 Limit curve for a voltage pattern at the grid connection for a Type 1 generating plant when a fault occurs in the grid

Figure 5 shows the limit curve for the voltage pattern at the grid connection in the case of a three-phase short circuit, above which Type 1 generating plants may not be disconnected from the mains

and may not become unstable. This requirement applies to the entire operating range of the generating plant.

To overcome the voltage drop for auxiliary service requirements of generating plants, by agreement with the grid operator it is permissible to use a shorter fault clearing time (at least 100 ms) at which the generating unit may disconnect itself from the grid. A prerequisite for this is that the shorter fault clearance time must be guaranteed by means of suitable protective and switching equipment that function in accordance with the concept.

> Note:
>
> In the limit range of stability, dynamic interactions between the generator and the mains can cause a voltage drop lasting longer than the fault duration at the generator terminals and when the generating plant is covering its auxiliary service requirements [10]. When determining the supply to cover the plant's auxiliary service requirements, this must be taken into account so that the above requirement is fulfilled.

In the event of three-phase short circuits with a voltage pattern above the limit curve as shown in Figure 5, even for fault clearance in the grid protection end time there must neither be a switchover for covering the plant's auxiliary service requirements nor a precautionary disconnection of the generating plant (e.g. due to the auxiliary voltage) from the grid.

3.2.6.2 Behaviour of Type 2 generating plants in the event of faults in the grid

When the conditions stated in Chapter 3.2.6.1 are not fulfilled, the generating plant is of Type 2.

In the event of faults in the grid outside the protection range of the generating plant, there must be no disconnection from the grid. A short circuit current must be fed into the grid during the period of a fault. Due to the system technology used, e.g. asynchronous generators or frequency converters, the short circuit current contribution must be agreed with ENE in each individual case.

If the voltage at the grid connection point falls and remains at a value of and below 85 % of the reference voltage (380/220/110 kV, e.g. 110 kV x 0.85 = 93.5 kV) and with a simultaneous reactive power direction to the connectee (under-excited operation), the generating plant must be disconnected from the grid after a time delay of 0.5 seconds. The voltage value refers to the highest value of the three line-to-line grid voltages. The disconnection must be made at the generator circuit breaker. This function performs the voltage support monitoring.

If the voltage on the low voltage side of each individual generator transformer falls and remains at and below 80 % of the lower value of the voltage band (e.g. 690 V x 0.95 x 0.8 = 525 V) based on a resetting ratio of 0.98, one quarter of the generators must disconnect themselves from the grid after 1.5 s, after 1.8 s, after 2.1 s and after 2.4 s respectively. The voltage value refers to the highest value of the three line-to-line grid voltages. Different time stages can be agreed in individual cases.

If the voltage on the low voltage side of each individual transformer rises and remains at over 120 % of the upper value of the voltage band (e.g. 690 V x 1.05 x 1.2 = 870 V) based on a resetting ratio of 1.02, the generator affected must disconnect itself from the grid with a time delay of 100 ms. The

voltage value refers to the lowest value of the three line-to-line grid voltages. Different time stages can be agreed in individual cases.

In addition to the requirements stated in Chapter 3.2.5, it is recommended to switch off the affected generators without a time delay on the low voltage side of each generator transformer in the event of frequency deviations below 47.5 Hz or above 51.5 Hz.

It is recommended to perform the over-frequency and under-frequency, overvoltage and undervoltage functions on the generators in one unit in each case. In general these functions, including the undervoltage function at the grid connection point, can be referred to as automatic system.

Following disconnection of a generating plant from the grid due to an overfrequency, underfrequency, undervoltage, overvoltage or after the end of isolated operation, automatic synchronisation of the individual generators with the grid is only allowed if there is a voltage at the grid connection point greater than 105 kV in the 110 kV grid, greater than 210 kV in the 220 kV grid and greater than 370 kV in the 380 kV grid. The voltage value refers to the lowest value of the three line-to-line grid voltages. After this deactivation, the increase in the active power output to the ENE grid must not exceed a maximum gradient 10 % of the grid connection capacity per minute.

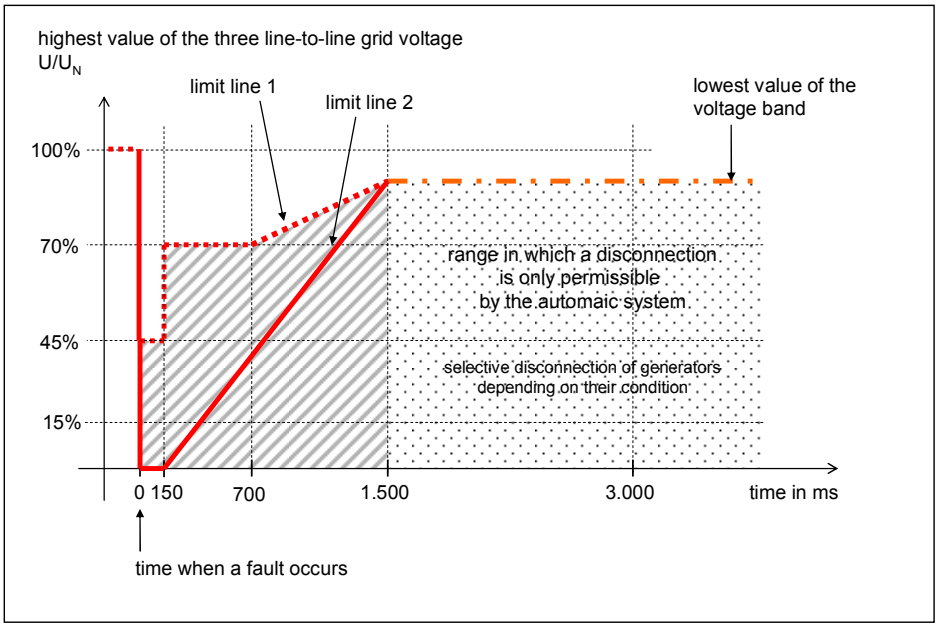


Figure 6 Limit curves for the voltage pattern at the grid connection for Type 2 generating plants in the event of a fault in the grid

Figure 6 shows the limit curves for the voltage pattern at the grid connection for Type 2 generating plants.

Three-phase short circuits or fault-related symmetrical voltage dips must not lead to instability above the Limit Line 1 in Figure 6 or to disconnection of the generating plant from the grid.

The following applies within the shaded area and above the Limit Line 2 in Figure 6:

- All generating plants should experience the fault without disconnection from the grid. If, due to the grid connection concept (plant concept including generators), a generating plant cannot fulfil this requirement, it is permitted with agreement from ENE to shift the limit line while at the same time reducing the resynchronisation time and ensuring a minimum reactive power infeed during the fault. The reactive power infeed and resynchronisation must take place so that the generating plant meets, in a suitable way, the respective requirements of the grid at the grid connection point.
- If, when experiencing the fault, the individual generator becomes unstable or the generator protection responds, a brief disconnection of the generating plant (KTE) from the grid is allowed by agreement with ENE. At the start of a KTE, resynchronisation of the generating plant must take place within 2 seconds at the latest. The active power infeed must be increased to the original value with a gradient of at least 10 % of the rated generator power per second.

A KTE from the grid is always allowed below Limit Line 2 in Figure 6. Here, resynchronisation times of more than 2 seconds and an active power increase following fault clearance of less than 10 % of the rated power per second are also possible in exceptional cases by agreement with ENE.

For all generating plants that do not disconnect from the grid during the fault, the active power output must be continued immediately after fault clearance and increased to the original value with a gradient of at least 20 % of the rated power per second.

The generating plants must support the grid voltage with additional reactive current during a voltage dip. To do this, the voltage control must be activated as shown in Figure 7 in the event of a voltage dip of more than 10 % of the effective value of the generator voltage. The voltage control must take place within 20 ms after fault recognition by providing a reactive current on the low voltage side of the generator transformer amounting to at least 2 % of the rated current for each percent of the voltage dip. A reactive power output of at least 100 % of the rated current must be possible if necessary.

After the voltage returns to the dead band, the voltage support must be maintained for a further 500 ms in accordance with the specified characteristic. The transient balancing procedures following the voltage return must be completed after 300 ms. If the generating plant's generators are too far away from the grid connection point, resulting in the voltage support being ineffective, ENE requires measurement of the voltage dip at the grid connection point and the voltage support there as a function of this measured value.

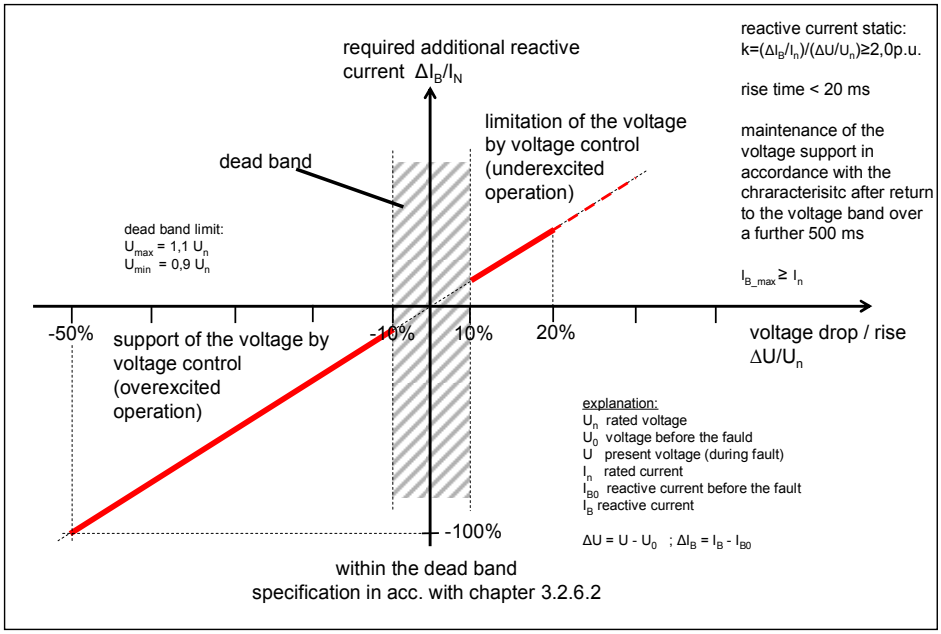


Figure 7 The principle of voltage support in the event of grid faults

Particularly in the extra high voltage grid, the voltage control can be required as continuous control also without a dead band in normal operation.

3.2.7 Electrical protection

The entire protection concept and the adjustment values for the electrical protection devices must be agreed between ENE and the operator of a generating plant and must also be followed in operation. This can give rise to stipulations for the protection of plants that are relevant to operation of the transmission system. At the grid connection point, ENE uses a protection device for the ENE equipment. ENE can also use a protection device that disconnects the generating plant from the grid in the event of unacceptable operating conditions.

The electrical protection of the generating plant is superimposed on the operational controllers, e.g. voltage regulators, excitation device and disconnects the generating plant from the grid in the event of unacceptable operating conditions.

The operator of a generating plant must ensure that switching operations, voltage fluctuations, automatic reclosing or other operations in the ENE grid do not cause damage to his plant.

The responsibility for the design, adjustment and operation of protection devices lies with the partner for whose equipment the safety devices represent the main protection.

Corresponding regulations must be agreed in the grid connection agreement for any necessary devices beyond the standard concept.

3.2.8 Restoration of supply

The generating plant must be designed for transition to auxiliary load from any operating point shown in the generator capacity diagram and Figure 3.

Transition into islanding mode must also be guaranteed when the generating plant is disconnected from the grid in accordance with the agreed protection concepts when faults occur in the grid.

After transition to auxiliary load, it must be possible to operate the generating plant for at least 3 hours only with auxiliary load.

The function of transition to auxiliary load must be proven during commissioning, and must be examined following significant modifications to the generating plant.

Every generating plant with a rated capacity of ≥ 100 MW must be capable of operation in islanding mode. The following conditions apply here:

- The generating plant must be able to regulate the frequency under the precondition that the resulting capacity deficit is not greater than the primary control reserve in the island. In the event of a capacity surplus, it must be possible to relieve the generating plant to the minimum capacity.
- It must be possible to maintain this type of islanded operation for several hours. The details must be agreed between the operator of generating plant and ENE.
- In islanded operation, the generating plant must be able to balance sudden load connections amounting to as much as 10 % of the nominal load (but maximum 50 MW). The interval between two consecutive load connections should be at least 5 minutes.

The possibility for black start capability must be realised by the operator of the generating plant as an **additional requirement** if this is required by ENE.

In the grid connection agreement, ENE will agree with the operator of a generating plant a concept for behaviour in the event of major faults. The personnel involved will be trained to perform the agreed work.

3.3 Requirements placed on REA generating plants

3.3.1 General

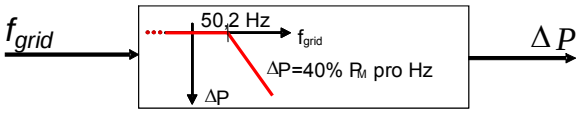
All generating plants subsidised in accordance with the "Renewable Energy Act" REA of 01.08.2004 are referred to here as REA generating plants and, in addition to the requirements described in chapters 3.1, 3.2 and 3.3:

3.3.2 Active power output

The rated power of a REA generating plant is the sum of the rated powers of all generating units combined under one grid connection.

As an additional requirement, participation in generation management may be necessary in order to ensure reliable operation and to protect equipment from damage. It must be possible to reduce the power output in any operating condition and from any operating point to a maximum power value (setpoint value) specified by ENE. This setpoint value is specified by ENE at the grid connection node

and corresponds to a percentage value referred to the grid connection capacity. The reduction of the power output to the signalled value must take place with at least 10 % of the grid connection capacity per minute, without the plant being disconnected from the grid.



$$\Delta P = 20\, P_M \frac{50{,}2\ Hz - f_{grid}}{50\ Hz} \quad \text{when } 50{,}2\ Hz \leq f_{grid} \leq 51{,}5\ Hz$$

P_M power currently available

ΔP power reduction

f_{Netz} grid frequency

In the range 47,5 Hz $\leq f_{grid} \leq$ 50,2 Hz no restriction

When $f_{grid} \leq 47{,}5$ and $f_{Netz} \geq 51{,}5$ Hz disconnection from grid

Figure 8 Active power reduction with overfrequency

All REA generating units must, when operated at a frequency of more than 50.2 Hz, reduce the current active power with a gradient of 40% of the presently available power of the generator per (Figure 8). When the frequency returns to a value of 50.05 Hz, the active power infeed may be increased again (with frequency monitoring f ≤ 50.2 Hz). This regulation is performed decentrally (at each individual generator). The insensitivity range must be less than 10 mHz.

The operator of a REA generating plant must ensure that possible islanded operation of the plant is reliably recognised and controlled when the permissible stated limits for voltage and frequency are not exceeded or have fallen below. Besides system functions such as undervoltage and overvoltage or underfrequency and overfrequency, which in most cases can indicate islanding, ENE requires that the Off auxiliary contacts of the circuit breakers on the overvoltage or undervoltage side of the grid transformer to send a shutdown and tripping command to all individual generators of the plant, so that islanded operation is ended no later than after 3 seconds. Other recognitions of islanding are also allowed, provided that they do not display any unwanted functions in the event of system faults.

3.3.3 Frequency stability

REA generating plants are exempted until further notice from the basic requirement of providing primary control power, including rated power exceeding 100 MW.

3.3.4 Restoration of supply

REA generating plants are exempted from the basic requirement of ability for islanded operation. The operator of a generating plant can offer this as an option.

4 Connection technology

4.1 Grid protection

A protection device, at least a distance protection relay, must be installed at all grid connection points.

Grid protection is of great importance for safe and reliable grid operation. Concepts and protection settings at the interfaces between ENE on one side and the connectee on the other side are jointly harmonised in such a way that risks to neighbouring grids or plants cannot arise. To this end, suitable protective devices and circuit breakers must be provided at the grid connection point.

The connectee is responsible for the reliable protection of his plants. To ensure constant functional capability, the protective devices of ENE and those of the connectee should be examined at regular intervals. Evidence of the protection inspections and their results is provided in the form of inspection records. Significant changes of the protective devices and their settings are to be agreed in good time between ENE and the connectee. All information necessary for fault clearance must be exchanged between ENE and the connectee.

For the extra high voltage grids, the protection concepts valid at ENE provide for the following criteria:

- First-zone time protection for 100 % of all components (fault clearance times ≤ 150 ms)
- 100 % selectivity
- Circuit breaker failure protection system
- Single-phase automatic reclosure on overhead lines with an interval of 1.0 to 1.2 seconds

For high voltage grids with phase-to-earth fault compensation, the protection concepts valid at ENE provide for the following criteria:

- 100 % first-zone time protection for transformers (fault clearance times ≤ 150 ms)
- For lines, an overlapping of the distance protection with one-time three-phase automatic reclosure with interval of 0.4 to 0.8 seconds and, if necessary, subsequent triggering according to the time grading schedule
- No separate busbar protection and no circuit breaker failure protection

For high voltage grids with low-resistance neutral point earthing, the protection concepts valid at ENE provide for the following criteria:

- 100 % first-zone time protection for transformers (fault clearance times ≤ 150 ms)
- For lines, an overlapping of the distance protection with one-time single-phase automatic reclosure with interval of 0.4 to 0.8 seconds and, if necessary, subsequent triggering according to the time grading schedule
- No separate busbar protection and no circuit breaker failure protection

The protection concepts realised by the connectee at the grid connection point must be the same as the ENE concepts with regard to triggering times, availability, redundancy etc. Here, when selecting his protection concepts, the connectee must assume and be prepared that

- ENE will specify the permissible back-up times at the grid connection point, while the back-up times in the primary grid can, if necessary, be set lower than in the secondary grid,
- The functions of ENE's remote back-up protection cannot always be guaranteed for the connectee's plants, and particularly not for faults on the low voltage side of transformers (on the connectee's side),
- For the purpose of fulfilling the 5-step plan in the event of grid faults [9], ENE can demand the use of frequency relays at the grid connection point and can stipulate their settings,
- In the extra high voltage grid, fault clearance times much longer than 150 ms can result in the event of failure of a protective device or of a circuit breaker.

4.2 Real-time data processing

ENE and the connectee must install technical equipment in order to transfer the following information for the power system management systems furnished with a real-time stamp:

- Commands and responses from switching equipment, e.g. circuit breakers, disconnectors, earthing switches and tap changers, if required for operation or for system evaluation
- Measured values, e.g. current, voltage, frequency, active power, reactive power
- Protection, operating and warning messages
- Commands, responses, messages and measured values for an agreed load control and the control of compensation systems
- Setpoint and adjustment values from and for generating plants

To this end, the internal standards valid at ENE must be considered, as contained in the currently valid "Technisches Handbuch Netz, chapter: Bauen und Errichten" [1] and the technical requirements for the grid management systems. In particular, attention must be paid to the process data interfaces and the reaction times.

The exact scope of the process data being exchanged will be jointly defined.

4.3 Transfer metering facilities

ENE specifies the technical standards that are required for correct transfer metering facilities that conform to the legal requirements. The transfer metering facilities must be built and operated in accordance with the guideline [11].

ENE defines the location of the installation of the transfer metering facilities. Normally, a suitable location close to the property boundary is selected for this purpose.

The transfer metering facilities basically consist of account and comparative metering facilities.

The following are the minimum requirements for the technical equipment of transfer metering facilities:

- Only calibrated Class 0.2 (or better) transformers are used for transfer metering facilities.
- A separate calibrated meter set must be provided for both account and comparative metering.
- The account and comparative metering must be the same in technical terms.
- Class 0.2 active energy meters and Class 2.0 reactive energy meters are used at the extra high voltage level.
- At least Class 0.5 (in new plants Class 0.2) active energy meters and Class 2.0 reactive energy meters are used at the high voltage level.
- Separate current transformer cores and at least two separate voltage transformer windings must be provided for accounting and comparative metering.
- The metered values of accounting and comparative metering are registered.
- The registered values are remotely transmitted to ENE for further processing and invoicing.
- The registration period is a quarter of an hour.

A metering point designation (ID code) is issued by ENE for each transfer measuring point.

5 Operation planning and power system management

Operation planning and power system management at ENE are part of the obligations that must be fulfilled for correct grid operation. They encompass all planning tasks for grid operation and the system balance, as well as power system management and system control.

5.1 Operation planning

The operation planning ensures that events that occur in the short and medium term, such as maintenance and repair work on equipment, building work, in the grids or transmissions announced at short notice are planned into the daily work schedule and are reliably mastered by the power system management.

In contrast to grid expansion planning and the reliability that must be considered there, operation planning takes into account grid security, e.g. by observing actual failure situations and planned shutdowns.

The basis of operation planning for the period under consideration is all transmissions in accordance with the grid utilisation conditions, including reserve infeeds and the planned grid condition. The basic grid condition includes planned shutdowns of grid equipment and generating plants.

Deviation from the (n-1) security is possible if this is necessary for operational work and grid conversions. Operational shutdowns of important grid components are agreed in good time with the affected party (neighbouring grid operator, connectee).

To maintain the (n-1) security in the event of planned shutdowns of grid equipment, ENE can agree adjusted power transport with the connectees (e.g. restricting the grid connection and / or the use of generating plants).

5.2 Power system management

The most important power system management tasks include the system services (frequency stability, voltage stability and restoration of supply), grid monitoring, ensuring grid security in conjunction with static and transient stability, and also neutral point treatment, the instruction and carrying out of switching operations and the carrying out of reactive power voltage control.

Power system management follows the stipulations of operation planning and, as part of the continuous security observation using the available equipment, ensures that the effects of faults are mastered and limited.

The respective responsible power system control centre at ENE is authorised to provide general instructions to connectees and in terms of switching orders for the safe operation of the grid and in order to fulfil the system service obligations.

Faulty operation includes all system states that deviate from normal operation. Within the framework of fault management, ENE has the obligation to carry out the measures necessary for fault limitation and for system restoration. This means that secure system operation and its restoration take precedence over the interests of connectees.

If corrective measures are not successful or if there is still a risk the fault spreading, ENE is entitled to briefly shut down grid areas in order to maintain secure system operation and for fast system restoration. In the event of a fault, the corresponding instructions from ENE must be implemented without delay.

Operational data, measured values, records etc. can be exchanged in order to clear the fault.

5.3 System management agreement

A system management agreement must be concluded. The system management agreement covers the following points in particular:

- Nomination of the responsible contact partners for plant use and switching operation who are available at all times
- Instruction authorisations of ENE with regard to the way in which the connectee's plant is run (active and reactive power) and for switching operations

- Description of the responsibilities for power system management between the connectee and ENE
- Performing switching operations in normal operation and in the case of faults and for trial switching operations
- The applicable regulations and safety provisions
- Granting of supplementary access authorisations

Appendix A - Glossary

Account metering

Transformers, meters with a recording device including the applicable auxiliary installations for recording electrical energy at the grid connection.

Additional requirement

A minimum technical requirement placed on plants that must be fulfilled if demanded by ENE. Supplements basic requirements.

Automatic reclosure

A brief single-phase or three-phase disconnection of a system component caused by the tripping of one or more circuit breakers followed by automatic reclosure after a defined interval.

Auxiliary service

The auxiliary service of a substation or generating plant is the electrical power required for operating its auxiliary systems (e.g. for water treatment, steam generator water feed, fresh air and fuel supply, flue gas cleaning), plus the power losses of the transformers. A distinction is made between the auxiliary service load in operation, when the plant is not running and for start-up.

Basic requirement

A minimum technical requirement that must be met by all plants. It can be supplemented by additional requirements.

Black start capability

The ability of a generating plant to independently resume operation without auxiliary service “from outside“ (black start). Every TSO must ensure that there is a sufficient number of generating units in his area with black start capability.

Brief disconnection of the generating plant from the grid (KTE)

Brief (for less than 2 seconds) disconnection - via a circuit breaker or power electronics of the machine’s stator - from the grid until the fault has been cleared.

Certificate

A certificate is issued by an authorised institute for particular plant components and is accepted in place of individual evidence for specified properties.

Common-mode failure

Common-mode failure is the simultaneous failure of several components due to the same cause.

Comparative metering

Transformers, meters and (if necessary) a recording device, including the applicable auxiliary installations for recording electrical energy at the grid connection. Used as comparative metering for account metering.

Connectee

A connectee is the party whose plant is connected to a grid of E.ON Netz GmbH. A

distinction is made between consumers and generators, based on the load flow.

Consumer

See connectee

Continuous capacity

The continuous capacity of a generating plant is the maximum capacity possible with correct operation and without a time restriction. Note: The continuous capacity can, for example, fluctuate with the seasons (e.g. due to cooling water conditions).

Control area

The control area is the area for whose primary control, secondary control and minute reserve a TSO is responsible within the framework of the UCTE. Each control area is physically established by the locations of the interchange measuring systems of the secondary controller.

Disconnection from the grid

In the sense used here, disconnection from the grid means switching off the circuit breaker, particularly when faults occur in the grid.

Distribution

Distribution is the transmission of electrical energy in a limited region for feeding into distribution stations and for supplying connectees. Distribution is normally accomplished via the high voltage, medium voltage and low voltage grid.

Distribution network

The distribution network is used within a limited region to distribute electrical energy for feeding stations and the plants of connectees. In distribution networks, it is largely the connectees that determine the power flow. In Germany, low voltage, medium voltage and high voltage networks (≤ 110 kV) are classified as distribution networks. In special cases, a 380 and 220 kV network section can be regarded as a distribution network.

ENE

E.ON Netz GmbH

Extra high voltage grid

At ENE, this comprises the voltage levels 220 kV and higher.

Fault clearance time

The fault clearance time is the time required for identifying and disconnecting a fault identified in the grid.

Frequency stability

Frequency stability refers to the control of frequency deviations arising from imbalances between generation and consumption (active power control) and is provided by the primary and secondary control, and also the use of minute reserve in the power stations.

Generation management

The generation management is part of the power system management system at ENE and its purpose is controlling the output power of generating plants. The aim of generation management is to avoid a capacity-related termination of production, to use the existing network infrastructure as optimally as possible and to protect against infeed-related

overloads of grid equipment.

Generating plant

A generating plant (power station) is a plant intended for generating electrical energy and feeding it into the grid. It can consist of one or more generating units. It also covers all the associated auxiliary equipment and plants. The term generating plant also covers additional infeeds of electrical energy from high-voltage d.c. (HVDC) links.

A Type 1 generating plant exists when a synchronous generator is connected to the grid either directly or via transformers. If this condition is not fulfilled, the generating plant is of Type 2.

Generating plant type

See generating plant

Generating unit

A generating unit for electrical energy is a plant that can be defined according to certain criteria. For example, it can be a power station block, a busbar power station, a gas and steam plant, the machine set of a hydroelectric power station, a fuel cell stack, a wind farm or a solar module.

Generator transformer

The generator transformer is the connecting link between the generator and the grid (also see: grid transformer).

Gradient

A gradient describes the change to an electrical variable within a certain time interval. The average gradient applies to this time interval and does not have to undergo linear change.

Grid

The electricity supply grid is the whole interconnected system for transmitting or distributing electrical energy. For differentiation purposes, it can be named on the basis of - among other things - tasks, method of operation, voltages or ownership. Uniform rated voltage and current type (direct current or alternating / three-phase current) are frequently used as additional criteria for the classification.

Grid connection

The grid connection refers to the technical connection between connectees' plants and the general electricity supply grid.

Grid connection capacity

The grid connection capacity is the apparent power that depends on the load flow direction available to the connectee at the grid connection node or point for a defined voltage range and for a defined reactive power exchange for the transport of electric energy. Additionally, other characteristics such as reliability, short circuit power, reserve availability etc. are assigned to the grid connection capacity.

Grid connection node

The combination of all grid connecting points that exist at a location and on a voltage level.

Grid connection point

The grid connection point is the point at which the plant of a connectee is connected to the

grid, normally switchgear. Connectees can be connected to the transmission or distribution grid at one or more points.

Grid operator

An actual or legal person or a legally independent organisational unit of an energy supply company that performs the task of transmitting or distributing electricity and is responsible for the operation, maintenance or, if necessary, the expansion of the grid in a certain area and, when applicable, the connecting lines to other grids.

The operator of a transmission system also regulates transmission via the grid, paying attention to the exchange with other transmission grids. He provides the system services (frequency stability, voltage stability, supply restoration, operational management) and in so doing ensures the reliability of the supply.

Grid security

Grid security in the sense of "supply security" and "secure system operation" refers to the ability of an electric supply system to fulfil its supply task at a certain point in time.

Grid short circuit power

This quantity (√3x grid rated voltage x initial symmetrical short circuit current) is used as a calculation quantity for three-phase short circuits. It is independent of the transformation ratio and must not be confused with the power converted in an arc at the short circuit point.

Grid transformer

Transformer directly at the grid connection point (also see: generator transformer).

Grid utilisation

The use of a transmission or distribution grid for transporting electrical energy.

High voltage grid

At ENE, this comprises the voltage levels 60 to 110 kV.

Insensitivity range

The insensitivity range is the range defined by the frequency limit values, in which the controller does not respond. This key variable describes the interaction of the primary controller and machine.

Interconnected system

The interconnected system is the whole synchronously connected transmission systems.

Interruption of supply

An interruption of supply is the failure-related interruption in the supply of one or more connectees lasting longer than 1 second.

Islanded operation capability

Islanded operation is the operation of asynchronous sub-grids that can arise for example as a result of grid faults. In islanded operation, a sub-grid is fed from at least one generating plant. The control of the generating plant must be designed so that a secure transition to any partial load is mastered as securely as transition to auxiliary load. A time restriction must be avoided if possible. It must be possible to maintain islanded operation of this type for several hours.

Limit value violation

A limit value violation occurs when the observed electrical quantity leaves a permissible range.

Load

Utilised power is referred to as “load“ in the electric power industry. This can mean the sum of the power presently being drawn from one, several or all grids of a control area for the purpose of consumption.

Main components of generating plants

The main components and their key data include generators stating the type, rated voltage, voltage range, rated apparent power, capacity diagram, x_d and x_d''; transformers stating rated apparent powers, rated voltages, transformation ratios, vector group, short circuit voltage and control range; own power requirements; series and shunt compensation means; lines and cables stating the types and lengths; direct current transmission technology with specific plant data; description of the normal switching state.

Maintenance

Maintenance consists of the inspection and servicing work carried out regularly in order to prevent failures and to keep the equipment in good order, and repair work such as repairing or replacing a defective part.

Major fault

A major fault is present if there is a loss of voltage

- in the entire transmission system or
- in several systems of neighbouring grid operators or
- in grid sections of one or more neighbouring transmission and distribution grids.

Medium voltage

At ENE, medium voltage comprises the voltage levels less than 60 kV and greater than 1 kV.

Meter

A meter determines - on the basis of the secondary measuring transformer quantities of the currents and voltages - the active energy in one or both directions and, if necessary, the reactive energy. The energy quantities are output in ”quantised“ form as a pulse or digital value.

Metering facility

The term metering covers the meter itself and all associated system components such as transformers, cables, power supply, registration etc. A distinction is made between accounting and comparative metering.

Minimum power

The minimum power of a generating plant is the power that cannot be reduced further in continuous operation for plant-specific or equipment-related reasons. If the minimum power does not refer to continuous operation but instead to a shorter time span, this must be clearly highlighted.

Minute reserve

The minute reserve should be available without delay after a power failure occurs and must take over from the primary control after no more than 15 minutes, in accordance with the

currently valid recommendation of the European integrated organisation "Union for the Coordination of Transmission of Electricity " (UCTE). The minute reserve is mainly provided by the thermal power stations operating under secondary control and through the use of storage and pumped storage power stations, as well as gas turbines. Depending on the size of the power station system, a quick-starting reserve may also be necessary; the entire minute reserve available under secondary control and manually must be at least as great as the power of the largest power station block, so that frequency deviations caused by failures can be balanced out sufficiently quickly.

Normal operation

Normal operation means the following:

All customers supplied

All limit values adhered to (e.g. no overloads),

Sufficient power station and transmission reserves.

Operational management

Operational management is the generic term for power system management and the maintenance and repair of all grid equipment.

"Operational management as a system service" includes all tasks in the framework of the coordinated use of power stations (e.g. for frequency stability) and power system management, as well as the national / international interconnected operation by central control centres, each responsible for itself.

Partial load

A generating plant is operated at partial load when its power is between minimum power and continuous power.

Phase swings

Phase swings in the system occur during changeover from one system state to a new system state, e.g. as a result of a switching action or a fault. As long as this does not cause any limit value violations and the transient phenomenon is adequately damped, this has no significant consequences.

Power system management

The operative monitoring and control of a grid by a switching supervisor or grid control centre.

Power System Stabilizer (PSS)

The generators can be equipped with a power system stabilizer (oscillation suppression) to improve the damping of transient phenomena.

Prequalification

Processes with which generating plants are inspected with regard to their capability to provide various properties, particularly system services.

Primary control

The primary control is the stabilising active power control of the entire interconnected synchronously operated three-phase network automatically acting in the instantaneous range. It is created from the active contribution of the power stations when the grid frequency

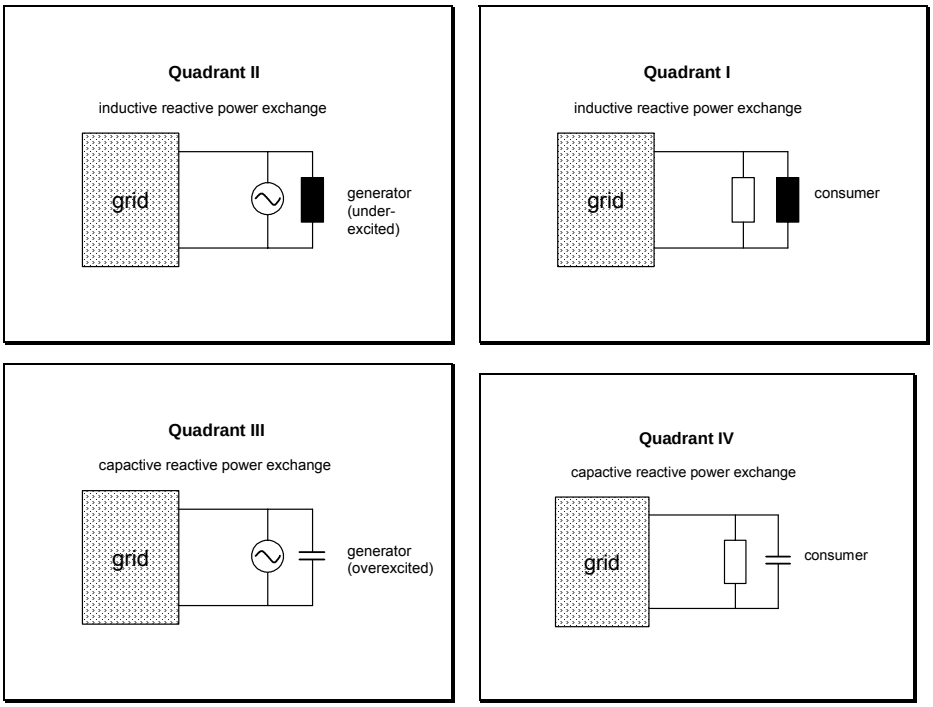
changes, and is supported by the passive contribution of the loads that are dependent on the grid frequency (self-regulatory effect).

Primary control band

The primary control band is the adjustment range of the primary control power within which the primary controllers can act automatically in both directions in the event of a frequency deviation. The term primary control band can be used for every machine, for every control area and for the entire interconnected network.

Quadrant

Depending on the direction of flow active and reactive power, a distinction is made between four quadrants for the exchange of power between the connectee and the grid.



Rated power / current

The rated power of a generating, transmission and consumption plant is the continuous power rating ordered in accordance with the delivery agreements. If the rated power cannot be clearly determined from the order documentation, a power value that can be achieved under normal conditions must be determined for the new plant on a one-off basis. In the case of combined heat and power plants, the rated power is the rated electric power.

Real-time data processing

The control and instrumentation technology processing of signals for check-back, control, warning messages, measured values etc.

Registration device

A device for storing, for a defined time interval, energy quantities recorded with a meter. Also referred to as a recording device.

Reliability

The reliability (of the supply) is the capability of an electricity supply system to perform its correct task under specified conditions over a particular time period.

Reserve power

The reserve power is the power that is supposed to balance out deviations in the power balance between the expected and the actual conditions, or that is kept available for actual, plannable situations.

Resynchronisation

The process of synchronous reclosure following disconnection from the grid by the protection facility.

Secondary control

The secondary control is the area-based control of generating plants belonging to a supply system for the purpose of maintaining the desired energy exchange of the area (control area) with the rest of the interconnected power system, and with the simultaneous integral support of the frequency. In the European integrated organisation "Union for the Coordination of Transmission of Electricity" (UCTE), the secondary control is performed by power / frequency control.

The power / frequency control refers to a control method by which TSOs maintain the electrical quantities agreed among themselves at the limits of their control areas in normal operation and particularly in the event of a fault. Here, every TSO aims - via an appropriate contribution from his own control area - to maintain both the exchange power relative to the other control areas within the agreed limits and also the grid frequency near the setpoint value.

Secondary control band

The secondary control band is the adjustment range of the secondary control power, within which the secondary controller can act automatically in both directions from the working point of the secondary control power (instantaneous value).

Secondary control reserve

The secondary control reserve is the positive part of the secondary control band, from the working point to the maximum value of the secondary control band. The part of the secondary control band that is already in use at the working point is known as the secondary control power.

Sequential trip

If a fault is eliminated through the intentional disconnection of the equipment affected by the fault and if this results in additional cascading protective tripping, these consequential events are called “sequential trips".

Stability

The term stability is used here as a generic term for static or transient stability: Stability is the capability of the electricity supply system to maintain synchronous operation of the generators. Synchronous operation of a generator in the practical sense occurs when no pole slips and no sustained oscillations occur. Transient stability is guaranteed with respect to the type, location and duration of a fault when all generators overcome this fault without synchronism loss.

5-step plan

A concept of measures that is applied when frequency deviations occur.

Supply restoration

Supply restoration describes the technical and organisational measures that are carried out to limit the fault and, after it has occurred, to maintain and restore the supply quality. Supply restoration also includes measures for equipping generating plants and power systems as a precaution against possible major faults (restoration concepts).

Switching authorisation

The authorisation to perform switching operations.

Switching authority

Responsibility for performing operational measures, e.g. switching operations.

Switching operation

Carrying out switching actions in network control centres and substations, and the monitoring of electricity grids.

Switching order authorisation

The authorisation to issue switching orders, i.e. giving the instruction to carry out switching operations.

System interactions

System interactions are line-bound interference variables in the form of voltage changes, voltage fluctuations, flicker, harmonics, intermediate harmonics and voltage asymmetries resulting from the connection to the grid of devices, plant or equipment with a non-linear current / voltage characteristic or with non-stationary operating behaviour. The occurrence of system interactions influences the quality of voltage and signal transmission, and can cause faults or interruptions to the supply of connected devices or plants.

System services

In electricity supply, system services describe those services that the grid operator provides for the connectees and that are in some cases essential for the system's functionality, and therefore determine the quality of electricity generation.

The most important of these system services are:

- Frequency stability
- Voltage stability
- Supply restoration
- Operational management

Transfer metering facilities

Generic term for account and comparative metering.

Transition into islanding mode

Transition into islanding mode means that following a sudden disconnection from the grid, a generating plant immediately assumes an operating state in which it can continue supplying its auxiliary service requirements and is available for reconnection.

Transmission system

The transmission system is used for transmitting electrical energy to subordinate distribution grids and for incorporating large power stations. A transmission system is characterised in that the power flow in the grid is mainly determined by the use of power stations. Generally,

German transmission systems are limited to the voltage levels 220 and 380 kV. In special cases, a 110 kV grid can also be a transmission system in terms of its task.

TSO

Transmission system operator

UCTE

Union for the Coordination of Transmission of Electricity, an amalgamation of all European transmission system operators

Voltage band

The voltage band is determined for each voltage level by a lower and an upper value for the amount of operating voltage.

Voltage stability

The purpose of voltage stability is to maintain an acceptable voltage profile in the entire grid. This is achieved by means of a balanced reactive power balance as a function of the respective reactive power demand of the grid and the connectees.

Voltage support

The voltage support is a static reactive power provision that makes reactive power available in the event of voltage dips.

Appendix B - The (n-1) contingency

1. The (n-1) contingency in the ENE extra high voltage grid (380 kV and 220 kV) is met when the following effects can be excluded after fault-related failures of grid operating equipment:
   a) Permanent limit value violations with regard to grid operating quantities (operating voltages, voltage bands, grid short circuit capacities) and equipment stresses (current load) endangering secure system operation or leading to the destruction of the equipment or unacceptable shortening of its expected service life.
   b) Permanent supply interruptions, despite the incorporation of the redundancies presently available in the subordinate grids and in the connectees' plants.
   c) Sequential tripping through the excitation of other protection devices of equipment not directly affected by the fault, with the risk of propagating the fault.
   d) The loss of stability in generating plants.
   e) The need to change and, if necessary, interrupt transmissions.

   On the grid side, the single failure of overhead lines, cable power circuits and network transformers is generally included here.

   When busbars and line cross-arms fail (e.g. common-mode failure of overhead line power circuits), the large-area grid transmission function can only be maintained by the joint utilisation of technical grid redundancies in neighbouring transmission systems.
2. The (n-1) contingency in the ENE high voltage grid (110 kV grid groups) is fulfilled when the following effects can be excluded after fault-related failures:
   a) Permanent limit value violations with regard to grid operating quantities (operating voltages, voltage bands, grid short circuit capacities) and equipment stresses (current load) endangering secure system operation or leading to the destruction of the equipment or unacceptable shortening of its expected service life.
   b) Permanent supply interruptions, despite the incorporation of grids of the same voltage level, subordinate grids and redundancies presently and instantaneously available in connectees' plants.
   c) Sequential tripping through the excitation of other protection devices of equipment not directly affected by the fault, with the risk of propagating the fault.
   d) The need to change and, if necessary, interrupt transmissions.

   On the grid side, the single failure of overhead lines, cable power circuits and network transformers is generally included here.

To assess the technical grid (n-1) security, the supply situations expected for the time period being investigated must be taken into account. The shutdown of generating plants is considered here insofar as significant effects on supply security can be expected.

Appendix C - References

[1] "Technisches Handbuch Netz, Kapitel: Bauen und Errichten“,
E.ON Netz GmbH, Bayreuth, updated regularly

[2] "Operation Handbook"
union for the co-ordination of transmission of electricity (UCTE), Jun. 2004

[3] DIN VDE 0105-100 "Betrieb von elektrischen Anlagen"
Deutsches Institut für Normung (DIN), Berlin, June 2000

[4] BGV A3 "Elektrische Anlagen und Betriebsmittel",
Berufsgenossenschaft der Feinmechanik und Elektrotechnik, Jan. 2005

[5] "Technisches Handbuch Netz, Kapitel: Netzführung und Arbeiten im Netz" for short: NAN,
E.ON Netz GmbH, Bayreuth, updated regularly

[6] e.g. IEC publications 61000-... and standards series DIN EN 61000-...

[7] "Technische Regeln zur Beurteilung von Netzrückwirkungen" D-A-CH-CZ
Verband der Netzbetreiber - VDN – e.V. at VDEW, Oct. 2004

[8] DIN EN 50160 "Merkmale der Spannung in öffentlichen Elektrizitätsversorgungsnetzen"
Deutsches Institut für Normung (DIN), Berlin, March 2000

[9] "Netzwiederaufbaustrategie" und "Durchführung von Maßnahmen für die Versorgung im Störungsfall“, E.ON Netz GmbH, Bayreuth, updated regularly

[10] "Verhalten thermischer Kraftwerke bei Netzstörungen",
Deutsche Verbundgesellschaft (DVG), January 1990

[11] "Metering Code",
Verband der Netzbetreiber - VDN – e.V. at VDEW, April 2004

If the connectee does not have the above documentation and that produced by E.ON Netz GmbH, they are available for inspection at any time at ENE. They conform to the generally accepted rules of technology and must be adhered to by the connectee.

Appendix D - Grid connection and plant design figures

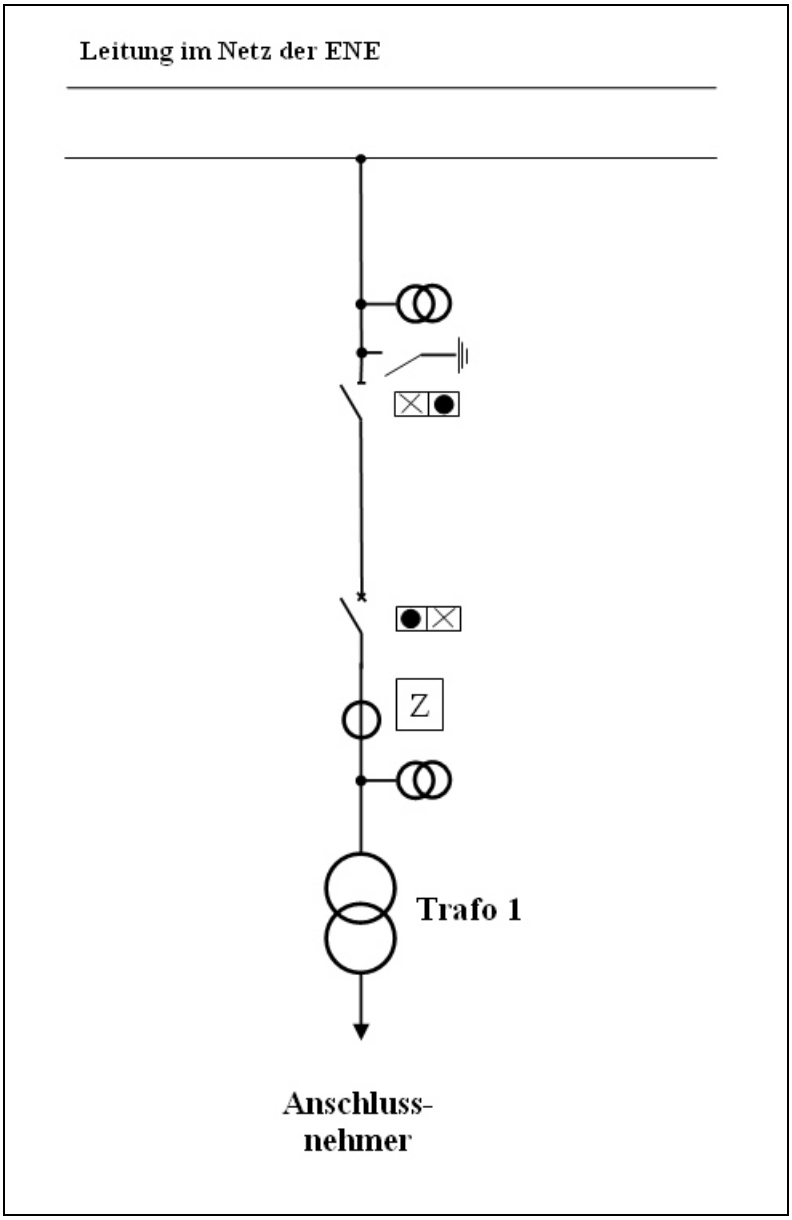


Figure D1: Connection to a line as a single radial feeder

Legende:

Steuerung und Rückmeldung ENE
Rückmeldung Anschlussnehmer

Steuerung und Rückmeldung Anschlussnehmer
Rückmeldung ENE

Z Einbauort der Übergabezählung

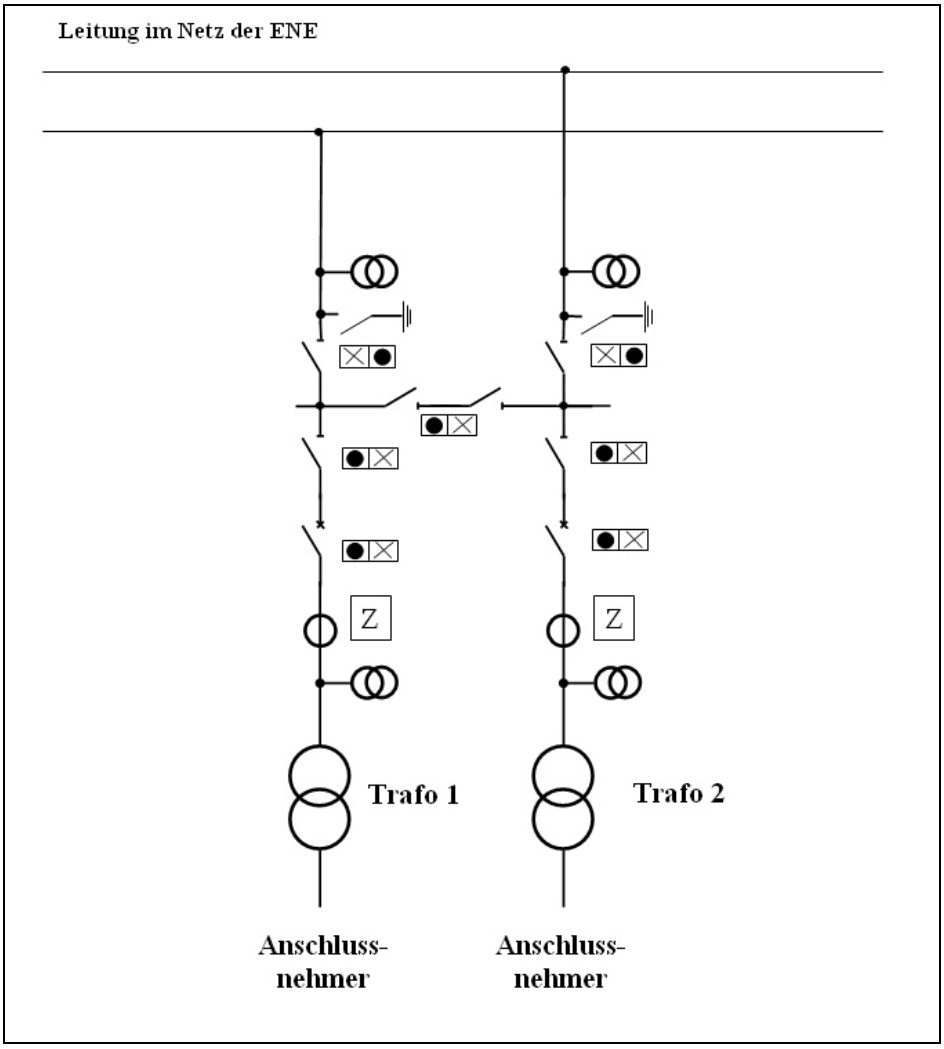


Figure D2: Connection to a line as a double radial feeder

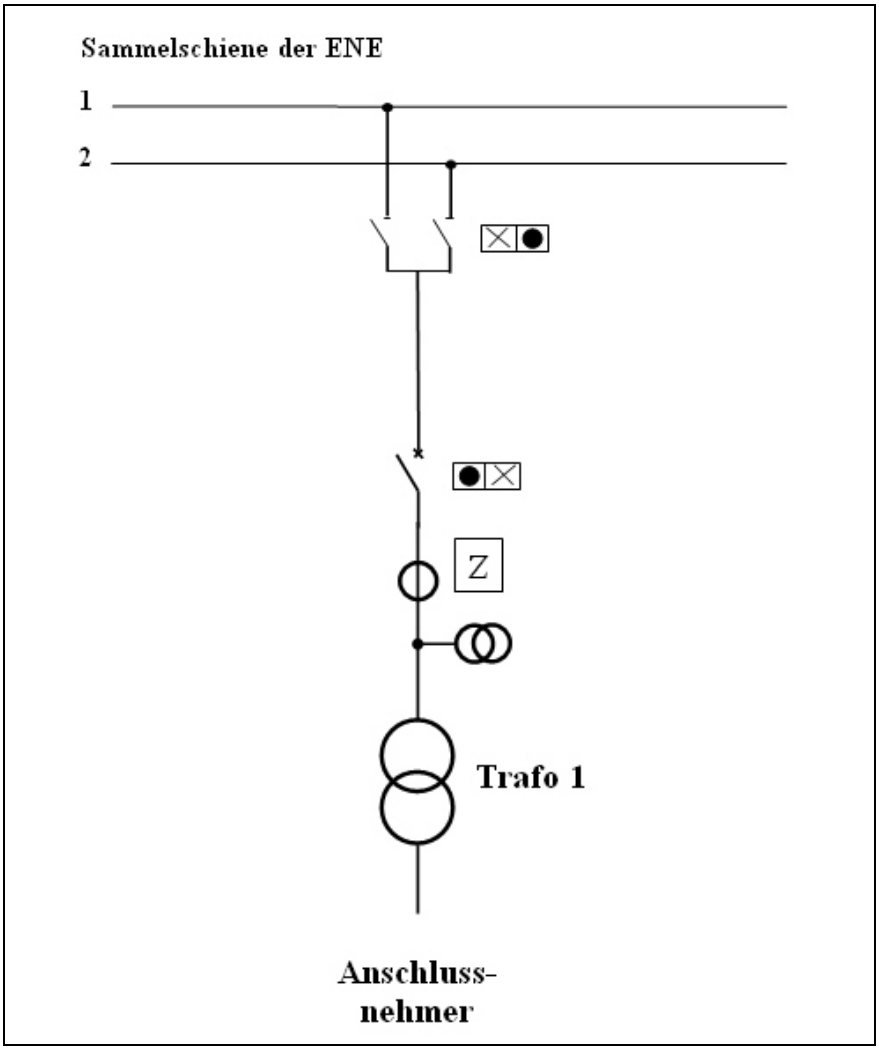


Figure D3: Connection to a busbar in a substation

Appendix E - Exchange of data and documentation

Table T1 – Load grid connection
Minimum scope of the technical information and documentation to be exchanged between ENE and connectees (consumers)

Project phase	Responsible Party	Documentation / data to be provided
Feasibility	Connectee	• Connection request • Naming a desired grid connection point • Main connection data (e.g. connection capacity, max. active power, power factor, site plan etc.) • Single line circuit diagram conforming to standard • Approximate project schedule • Official approvals and permissions, if required
	ENE	• Non-binding preliminary information on power consumption • Provision of general information on the grid connection point, such as node name, voltage band, neutral point connection of the grid • Min. and max. short circuit current from the ENE grid and series impedance
Stationary (Steady state) study and inspection of the plant and connection concept	Connectee	• Connection capacity, load, load development • Switchgear and transformer key data • Protection concept • Details of system interactions
	ENE	• Definition of actual requirements on the generating plant at the grid connection
Determination of the connection concept	Connectee	• Presentation of a binding connection concept • Site plans • Other official approvals, if required
	ENE	• Defining the limits of ownership • Additional / special requirements • Plant-related stipulations, equipment specifications • Process data list • Measurement, protection, metering • Final description of the “grid connection concept" and grid connection offer
Conditions for commissioning	Connectee	• Commissioning program and schedule • Plant documentation (construction plans, circuit diagrams, documents for the primary and secondary engineering etc.) • Protection adjustment data, incl. reserve protection • Evidence of agreed properties / requirements • Evidence that the plants behave on the grid in accordance with the grid code • Inspection protocols, certificates • Other official approvals, if required • Successful acceptance and approval for commissioning
	ENE	• Grid connection agreement with technical specification and system management agreement • Approval for commissioning

Table T2 – Generation grid connections
Minimum scope of the technical information and documentation to be exchanged between ENE and connectees (operators of generating plants)

Project phase	Responsible Party	Documentation / data to be provided
Feasibility	Connectee	• Connection request, stating power station type and primary energy type and also how the plant is to be operated • Naming a desired grid connection point or geographical position of the generating plant • Main connection data (e.g. connection capacity, rated power, min. / max. active power etc.) • Approximate schedule, stating medium-term / long-term development • Official approvals, if required
	ENE	• Non-binding preliminary information on power consumption • Provision of general information on the grid connection point, such as node name, voltage band, neutral point connection of the grid • Min. and max. short circuit current from the ENE grid and series impedance
Stationary (Steady state) study and inspection of the plant and connection concept	Connectee	• Connection capacity, load and operating method, load development • Connection capacity for auxiliary load and for start-up • Single line circuit diagram conforming to standard • Connection of the generating plant in the normal switching state, giving the key values for the main components [2] • Switchgear key technical data • Contribution to the short circuit current into the ENE grid and also data on load flow and short circuit current calculation • Questionnaire from Appendix E of the grid code • Details of system interactions
	ENE	• Definition of actual requirements on the generating plant at the grid connection
Determination of the connection concept	Connectee	• Presentation of a binding connection concept • Protection concept for grid connection and generating plant • Details of the possibility of providing system services such as primary / secondary control and minute reserve, reactive power provision • Site plans • Other official approvals, if required
	ENE	• Defining the limits of ownership • Additional / special requirements • Plant-related stipulations, equipment specifications • Process data list • Measurement, protection, metering • Final description of the “grid connection concept" and grid connection offer
Dynamic system studies	Connectee	• Confirmation of the design data provided for the stationary steady state study • Adjustment values and block circuit diagram of the control model (voltage / reactive power / frequency / oscillation damping / turbine / speed control, compensation equipment) • Dynamic equivalent circuit diagram of the generators • Dynamic equivalent circuit diagram of the motors for auxiliary load • Adjustment values for components for the automatic system and description of its behaviour in the event of frequency and voltage deviations • Concept for auxiliary load • Other data relevant to the system
	ENE	• Stating the requirements on control devices with regard to grid security and grid compatibility

. . .

[2] The main components and their key data include generators stating the type, rated voltage, voltage range, rated apparent power, power diagram, xd and xd"; Transformers stating rated apparent powers, rated voltages, transformation ratio, vector group, short circuit voltage and control range; own requirement; series and shunt compensation means; lines and cables stating types and lengths; direct current transmission technology with specific plant data; description of the normal switching state

. . .

Conditions for commissioning	Connectee	• Commissioning program and schedule • Plant documentation (construction plans, circuit diagrams, documents for the primary and secondary engineering etc.) • Protection adjustment data, incl. reserve protection • Evidence of agreed properties / requirements • Evidence that the plants behave on the grid in accordance with the grid code • Inspection protocols, and if necessary certificates • Other official approvals, if required • Successful acceptance and approval for commissioning
	ENE	• Grid connection agreement with technical specification and system management agreement, subject to evidence of the properties in test operation as required by ENE • Approval for commissioning in test operation • Following evidence of the properties and, if necessary, troubleshooting or improvement for permanent operation approval

Questionnaire for **Connection of a generating plant to the E.ON Netz GmbH grid**	
Project: Plant: Connectee:	Date: Page: Author:

Connection point: Transformer station : ..... *)

Line: ..... *)

Grid transformer:

HV side	Rated voltage:	U_{n1}	=	..... kV	
	Rated power:	S_{n1}	=	..... MVA	
	Tap changer max.	U_{max1}	=	..... kV	
	Tap changer min.	U_{min1}	=	..... kV	
LV1 side	Rated voltage:	U_{n2}	=	..... kV	
	Rated power:	S_{n2}	=	..... MVA	
LV2 side	Rated voltage:	U_{n3}	=	..... kV	*)
	Rated power:	S_{n3}	=	..... MVA	*)

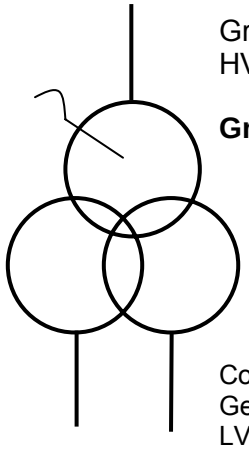
Vector group .....

Short circuit voltages:

HV-LV1 uk_{12} = ... %

HV-LV2 uk_{13} = ... % *)

LV1-LV2 uk_{23} = ... % *)



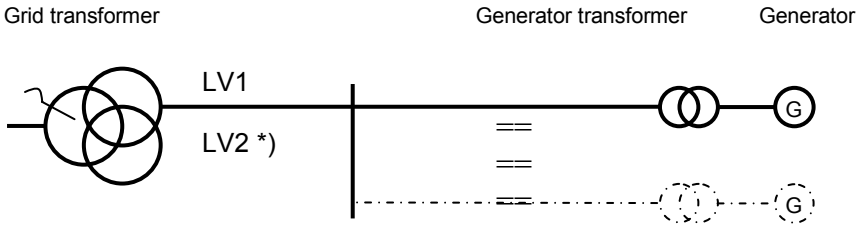
Medium voltage network:

Total cable length at LV1: ..... km Type: ..... Diameter: .....

Total cable length at LV2: ..... km *) Type: ..... Diameter: .....

*) delete that which does not apply

Questionnaire for **Connection of a generating plant to the E.ON Netz GmbH grid**	
Project: Plant: Connectee:	Date: Page: Author:



Generating plants (please fill in a sheet for each type of generating plant)

Manufacturer ..... Type: .....

Rated power S_{nG} = ... MVA Number of units n = ... ea.

Generator type Asynchronous machine ☐

Synchronous machine ☐

Concept (please give brief description of converter concept etc.)

.....

.....

.....

Short circuit characteristics (with a 3-phase fault on the low voltage side of the generator transformer)

Ratio of sub-transient short-circuit current / rated current I''_{k3} / I_n
or ratio of starting current / rated current I_{An} / I_n = ... p. u.

Inspections / certificates (if available):

Inspection report Author .....
No. .....

Certificate Author .....
No. .....

Generator transformer:

Rated power S_{nT} = ... MVA

Short circuit voltage uk = ... %

Vector group .....

Decoupling devices:

For measuring purposes, the decoupling devices are connected to the

Medium voltage grid ☐ the generator ☐

Manufacturer: ..... Type: .....

Setting: Frequency increase ..... Hz ..... s **)
Frequency reduction ..... Hz ..... s **)
Voltage increase ..... p. u. ..... s **)
Voltage reduction ..... p. u. ..... s **)

**) Total disconnection time (decoupling device + switch)