SUPPLY OF REACTIVE POWER AND MAINTENANCE OF REACTIVE POWER RESERVES

1.1.2021

Contents

1 INTRODUCTION 2

2 PRINCIPLES OF THE SUPPLY OF REACTIVE POWER 2
2.1 Supply point for reactive power 2
2.2 Output and input limits of reactive power at the connection point 2
2.2.1 Reactive power limits for consumption 3
2.2.2 Reactive power limits for production 3
2.2.3 Reactive power window 4
2.2.4 Reactive power window for energy storage connections 6
2.2.5 Reporting of the net power generation capacity of a power plant and the maximum power of an energy storage 7
2.3 Adjustment of the supply limits for reactive power 7

3 MONITORING OF REACTIVE POWER USE AND DETERMINATION OF FEES 7

4 REACTIVE POWER PRICING 8

5 ABATEMENTS IN THE INVOICING OF REACTIVE POWER 9
5.1 Reactive power of power generating units 9
5.2 Other abatements in invoicing 9

6 NETTING 10

7 REACTIVE POWER RESERVES 11
7.1 Method of voltage control for power generating units 11
7.2 Reserve requirements imposed on power generating units 11
7.3 Maintenance of activated reserve 11
7.4 Voltage support in fault, disturbance and maintenance situations 11
7.5 Monitoring of reserve maintenance 12

8 MEASUREMENTS OF REACTIVE POWER 12

9 REACTIVE POWER OF DIRECT CURRENT CONNECTIONS 12

Reactive power and maintenance of reactive power reserves

1 INTRODUCTION

This application instruction is applied for the supply and monitoring, and for calculating the supply limits, of reactive power transmitted via the Customer's connection points in the main grid. The application instruction additionally specifies the guidelines for the maintenance of reactive power reserves in power generating units[1].

In so far as the measures presented in this application instruction concern a power generating unit or network connected directly or indirectly to the Customer's network, the Customer shall agree on the measures specified in this application instruction with the operator of the power generating unit or the network connected to the Customer's grid.

2 PRINCIPLES OF THE SUPPLY OF REACTIVE POWER

2.1 Supply point for reactive power

The supply point for reactive electricity is the Customer's connection point as stated in the Main Grid Contract. Invoicing is based on energy measurements. If the measuring point is on the lower voltage side of the Customer's transformer, the reactive power consumed by the transformer is calculated for invoicing based on the transformer data provided by the customer and the power transferred through the transformer. The reactive power produced or consumed by the connection line is not taken into account when the measurement is at the Customer's own substation.

The Customer has the right to obtain the measurement data necessary for monitoring of the Contract. Fingrid shall report to the Customer on the use of reactive power at an individual connection point in Fingrid's extranet service.

2.2 Output and input limits of reactive power at the connection point

The connection point's reactive power output and input limits are set in normal switching and operational situations on the basis of the annual output energy of active power transmitted via the connection point and on the basis of the combined net power generation capacity for power plants and the combined maximum power of energy storage systems beyond the connection points. Typical mean values are used for peak consumption hours. Output energy is calculated for the previous 12-month period. During outages and other exceptional situations, the electric power of an assumed normal operational situation covering the same period is used. For the connection of a new customer, the assumed electric power according to normal operations is used.

The output and input limits of reactive power at the connection point are set according to whether active power is produced or consumed in the main grid's connection points.

The output and input limits of connection points connected to over 110 kV are set case by case.

---

[1] For the purposes of this document, power generating unit refers to power plants and converter-connected grid energy storage systems.

If the main grid has a longer-term need for reactive power produced or consumed by the Customer to support voltage control, and this makes sense technically and economically, the supply of reactive power is agreed on separately.

The filter capacitors of the rail service substations connected to the customer's electricity network do not increase the calculated Q_{D1} and Q_{G1} limits of the Customer's connection point.

2.2.1 Reactive power limits for consumption

In active power consumption, the connection point's reactive power output limit Q_D and input limit Q_{D1} are applied.

<u>The connection point's reactive power output limit Q_D</u>

The connection point's reactive power output limit Q_D (MVAr) is calculated as follows:

$$Q_D = 0.16 \times \frac{W_{output}}{t_k} + 0.1 \times \frac{P_{net}}{0.9}$$

W_{output} = the connection point's output energy in one year (MWh)
t_k = 7,000 h (peak consumption hours, process industry)
t_k = 5,000 h (peak consumption hours, other consumption)
P_{net} = sum (MW) of net power generation capacity for power plants and maximum power for grid energy storage systems beyond the connection point, chapter 2.2.4
- if the power generating unit's power is max. 1 MW, its P_{net} = 0
- if the power generating unit's combined power P_{net} is higher than 450 MW, it will not increase the reactive power window, i.e. max. (0.1 x P_{net} / 0.9) = 50.0 MVAr

A minimum size is set for the reactive power window such that the minimum value Q_D for the reactive power output limit is 2 MVAr in a transmission line connection and 4 MVAr in a substation connection. The reactive power output limit Q_D is, however, at most 50 MVAr.

<u>The connection point's reactive power input limit Q_{D1}</u>

The connection point's reactive power input limit Q_{D1} (MVAr) is calculated using the formula:

$$Q_{D1} = -0.25 \times Q_D$$

2.2.2 Reactive power limits for production

In active power production, the connection point's reactive power output limit Q_G and input limit Q_{G1} are applied.

The reactive power limits for production (Q_G and $Q_{G1)}$ are voltage dependent. This means that when the connection point controls the voltage of the main grid accordingly, the reactive power may be produced or consumed indefinitely. Voltage-dependent limits are valid at all connection points. The voltage-dependent limits are discussed in more detail in chapter 2.2.3.

If the energy measurement of the customer's connection point is done on the lower voltage side of the transformer or voltage information is not available from the connection point, the voltage-dependent limits cannot be applied. In this case, normal reactive power limits are used.

The connection point's reactive power output limit Q_G

The connection point's reactive power output limit Q_G (MVAr) is calculated as follows:

$$Q_G = 0.1 \times \frac{P_{net}}{0.9}$$

P_{net} = sum (MW) of net power generation capacity for power plants and maximum power for grid energy storage systems beyond the connection point

A minimum size is set for the reactive power window such that the minimum value Q_G for the reactive power output limit is 2 MVAr in a transmission line connection and 4 MVAr in a substation connection. The reactive power output limit Q_G is, however, at most 50 MVAr.

The connection point's reactive power input limit Q_{G1}

The connection point's reactive power input limit Q_{G1} (MVAr) is calculated using to the formula:

$$Q_{G1} = -Q_G$$

2.2.3 Reactive power window

The reactive power window specifies the volume of reactive power that can be delivered to and received from the main grid through individual connection points without separate compensation.

The reactive power window of the converter-connected grid energy storage systems connected directly to the main grid are discussed in Chapter 2.2.4. The reactive power window of the converter-connected grid energy storage systems connected directly to the main grid is different from other types of connections, as the electrical storages are instructed to control the voltage with a constant voltage control even when consuming active power.

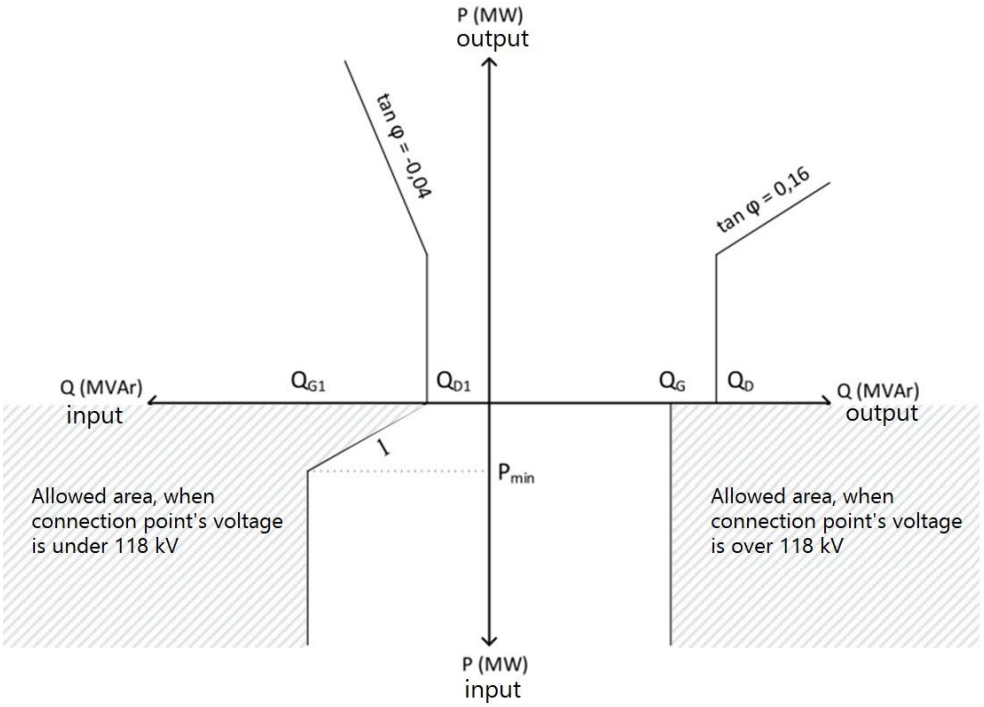

Figure 1. The reactive power window specifies the volume of reactive power that can be delivered to and received from the main grid through individual connection points without separate compensation. Additionally, output of reactive power is not invoiced when active power is transferred into the main grid and the voltage at the connection point exceeds 118 kV. Similarly, input of reactive power is not charged when active power is transferred into the main grid and the voltage at the connection point is less than 118 kV.

The delivery of reactive power is considered to take place according to the reactive power window when the reactive power output from the main grid and input into the main grid takes place according to the following conditions:

- In active power consumption, the connection point's output of reactive power from the main grid is at most equal to the Q_D value specified in chapter 2.2.1 or 16% of the active power output from the main grid, and the input of reactive power into the main grid is at most equal to the Q_{D1} value specified in chapter 2.2.1 or 4% of the active power output from the main grid.

- In active power production, the connection point's output of reactive power from the main grid is not invoiced when the voltage at the connection point exceeds 118 kV. Similarly, the input of reactive power into the main grid is not charged when the voltage at the connection point is less than 118 kV. During the rest of the time, the output of reactive power from the grid is at most equal to the Q_G value specified in 0chapter 2.2.2, and the input of reactive electricity into the grid is at most equal to the Q_{G1} value specified in chapter 2.2.2 however less than the limit value, which is calculated using the formula:

$$l = Q_{D1} + P \times \frac{Q_{G1} - Q_{D1}}{P_{min}}$$

Q_{D1} = reactive power input limit when consuming active power
P = average power produced into the grid (MW)
Q_{G1} = reactive power input limit when producing active power
P_{min} = −0,1 x P_{net}
P_{net} = sum (MW) of net power generation capacity for power plants and maximum power for grid energy storage systems beyond the connection point, chapter 2.2.4
- if the power generating unit's power is max. 1 MW, its P_{net} = 0
- if the power generating unit's combined power P_{net} is higher than 450 MW, it will not increase the reactive power window, i.e. max. (0.1 x P_{net} / 0.9) = 50.0 MVAr

2.2.4 Reactive power window for energy storage connections

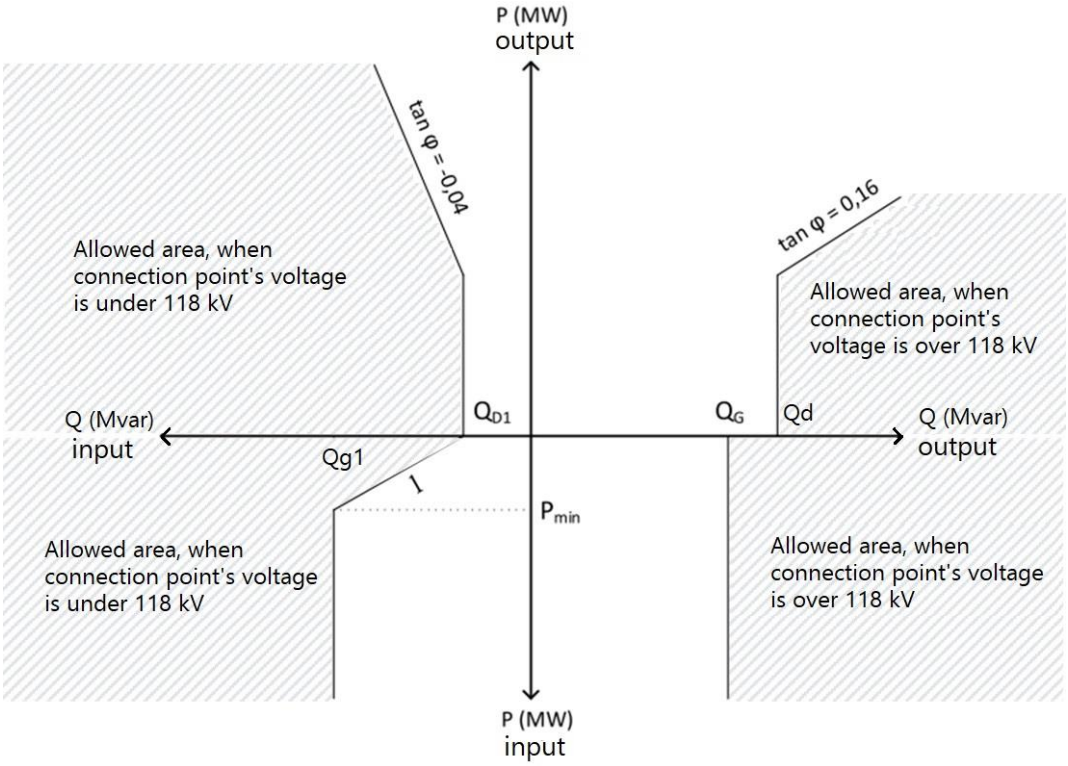

Figure 2. The reactive power window specifies the volume of reactive power that can be delivered to and received from the main grid through individual connection points without separate compensation. Additionally, for converter-connected grid energy storage systems connected directly to the main grid, output of reactive power is not invoiced when the voltage at the connection point exceeds 118 kV. Similarly, input of reactive power is not charged when the voltage at the connection point is less than 118 kV.

— For energy storages connected directly to the main grid, the connection point's output of reactive power from the main grid is not invoiced when the voltage at the connection point exceeds 118 kV. Similarly, the input of reactive power into the main grid is not charged when the voltage at the connection point is less than 118 kV.

— During the rest of the time when consuming active power the connection point's output of reactive power from the main grid is at most equal to the Q_D value specified in chapter 2.2.1 or 16% of the active power output from the main grid, and the input of reactive power into the main grid is at most equal to the Q_{D1} value specified in chapter 2.2.1 or 4% of the active power output from the main grid.

— During the rest of the time when producing active power the reactive power output from the main grid is at most equal to the Q_G value specified in chapter 0and the input of reactive power into the main grid is at most equal to the Q_{G1} value specified in chapter 0however less than the limit value, which is calculated using the formula:

$$l = Q_{D1} + P \times \frac{Q_{G1} - Q_{D1}}{P_{min}}$$

Q_{D1} = reactive power input limit when consuming active power
P = average power produced into the grid (MW)
Q_{G1} = reactive power input limit when producing active power
P_{min} = −0,1 x P_{net}
P_{net} = sum (MW) of maximum powers for grid energy storage systems beyond the connection point, chapter 2.2.4
- if the power generating unit's power is max. 1 MW, its P_{net} = 0
- if the power generating unit's combined power P_{net} is higher than 450 MW, it will not increase the reactive power window, i.e. max. (0.1 x P_{net} / 0.9) = 50.0 MVAr

2.2.5 Reporting of the net power generation capacity of a power plant and the maximum power of an energy storage

The net power generation capacity of a power plant shall be reported as instructed in Fingrid's Main Grid Service Terms and Conditions. In addition, the customer must notify Fingrid of the maximum power of its converter-connected grid energy storage systems or converter-connected grid energy storage systems connected to its network if its maximum power exceeds 1 MW and the electrical storage system operates with a constant voltage control.

In establishing the reactive power window, this same reported net active power value is used by converting the active power into nominal power using the coefficient (cos φ = 0.9).

2.3 Adjustment of the supply limits for reactive power

The supply limits on connection points for the next year are verified on the basis of measurement data every year by the end of November. The supply limits and the type of the connection point (production, consumption) shall be determined on the basis of the measurement readings of active power during a period of time between 1 October in the preceding year and 30 September in the current year.

If significant changes take place in the electricity usage or if a new power generating unit is commissioned or an existing power generating unit is decommissioned beyond the Customer's connection point during the adjustment period, the impact of the changes shall be assessed, and the information contained in the Main Grid Contract shall be revised immediately after the change has taken place to correspond to the new situation. The revised values shall come into force from the beginning of the calendar month following the date of review.

3 MONITORING OF REACTIVE POWER USE AND DETERMINATION OF FEES

The use of reactive power at the Customer's connection points is monitored separately for each connection point. In exceeding the reactive power limits, the operator of the connection point is invoiced for the excess use of the connection point's reactive power.

The abatements presented in chapter 5 are taken into account in the invoicing of reactive power. In addition, the invoicing does not take into account the fifty (50) largest, by absolute value, exceedings of the reactive power window within one month. The exceeding of the reactive power window shall not be invoiced if the excess is caused by a fault or disturbance in the main grid.

In longer-term or repeated instances of exceeding the reactive power supply limits, the aim is to determine, together with the Customer, the reason for the excess and to take the necessary measures to control the reactive power.

When the customer is planning to install a new reactor of more than 0.5 MVAr in the grid, the Customer must notify Fingrid accordingly. Notifications are primarily made through Fingrid's extranet services. This planning data is utilised at Fingrid for planning the reactive power compensation of the 400 kV network.

Fingrid can agree on the supply of reactive power into the main grid with the Customer, for example, in connection with outages in the main grid. Compensation according to the reactive power pricing shall be paid for the delivery of the requested reactive power.

4 REACTIVE POWER PRICING

Reactive power is invoiced based on the exceedings of the limits of reactive power window. The reactive power fee is determined by the average hourly power of the maximum invoiceable exceeding in each month. The reactive energy fee is determined by the total exceedance energy of the reactive power window in each month. The invoicing takes into account the principles for determining fees, instructed in chapter 3.

The unit prices of reactive power are presented in the service pricing appendix attached to the Main Grid Contract.

Figure 3 presents the principle of the reactive power window of the connection point, and the fees to be paid for exceeding the use of reactive power.

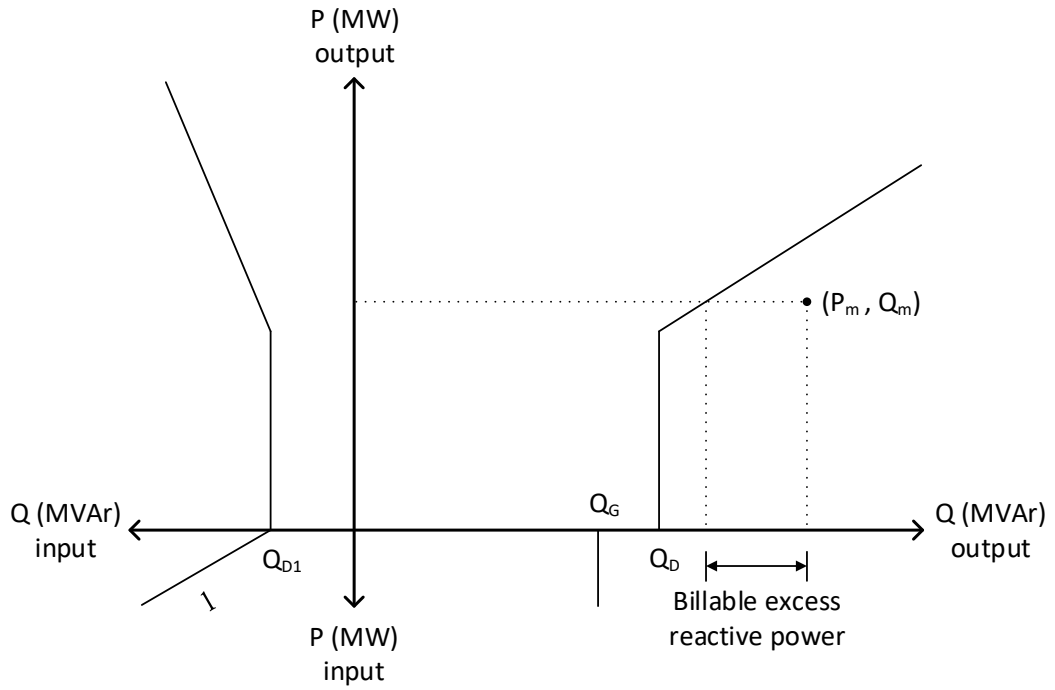

Figure *3.* Determining reactive power invoicing.
P_m refers to the hourly active power measured and Q_m to the hourly reactive power measured.

5 ABATEMENTS IN THE INVOICING OF REACTIVE POWER

Fingrid may grant abatements to the customer's reactive power invoicing when the conditions set out in this chapter are met. Exceptional situations must primarily be reported in Fingrid's extranet services.

5.1 Reactive power of power generating units

For power generating units that are directly connected to the main grid, Fingrid gives a voltage setpoint area and static reactive power setpoint value for constant voltage control. The aim is that, in a normal usage situation, no reactive power is transmitted via the Customer’s connection point. For a power generating unit connected to the Customer’s network, Fingrid and the Customer will settle the necessary voltage control values, and the Customer will provide the operator of the power generating unit with the values.

In order for the reactive power reserves of power generating units to support the system’s voltage during power generating unit’s and the network’s disturbances as intended, the Customer will not be charged reactive power fees for reactive power exceeding the reactive power window during disturbances.

5.2 Other abatements in invoicing

In repairs following a fault in a compensating unit of at least 0.5 MVAr connected directly or indirectly to the Customer’s electricity network or in repairs following a fault in a radial network feeding such compensating unit, the nominal reactive power value of the missing compensating unit shall be taken into account, at the Customer’s suggestion, in the output or input of reactive power at the connection point in question for the reasonable duration of the repair. No more than one (1) month is considered to be a reasonable

repair period for a single event. The same policy can also be applied to a power generating unit used for compensation in a fault situation.

If a larger than 10 MW power generating unit beyond the Customer's connection point is not used for compensating local reactive power, the effect of the power generating unit's reactive power can, upon separate agreement, be deducted from the connection point's reactive power measurement. In addition, the effect of a power generating unit's active power on the connection point can be eliminated from the active power measurement for reactive power and from the definition of the reactive power limits. In such cases, for power generating units connected to the Customer's network, the Customer must provide Fingrid with the hourly measurement data of reactive power in a manner such as that contained in the recommendations for information exchange in electricity trade.

In the extraordinary and short-term special situations of power generating units or the electricity network and upon separate agreement, more reactive power than what has been specified in the main grid contract can be delivered or received temporarily without fees being charged for exceeding the reactive power window, if there are weighty reasons for this and the operating situation of the grid or of a power generating unit allows this and if this does not cause significant disturbance or costs in the main grid. The condition for being exempt from paying the reactive power fee is that Fingrid has been given advance notice about the extraordinary situation, and that the disturbance or fault has been reported to Fingrid without delay. The notifications shall be made primarily through Fingrid's extranet service.

During the commissioning of a new main grid connection, no reactive power fees are invoiced for the connection point. When the connection and the equipment connected to beyond the connection point are fully commissioned, the reactive power invoicing normally takes effect according to the application instruction. The reactive power abatement specified for the commissioning of the equipment may last up to 12 months, but it will always end at the time when the commissioning tests are completed.

6 NETTING

If the Customer has several connection points at the same busbar at the switchyard, the energy volume forming the basis for reactive power monitoring and the reactive power limits shall be the net sum of hourly reactive power and reactive energy volumes at these connection points.

If hourly reactive power and reactive energy volumes of different customers' connection points that are connected to the same busbar at the switchyard are netted, this must be agreed on separately. The condition for netting is that a separate netting agreement be drawn up between the customers and Fingrid on the netting method in accordance with Fingrid's agreement model. The netting agreement states which measurements shall be netted and names one responsible Customer who will receive the credited amount. The aforementioned responsible customer shall distribute the amount among the netting agreement parties. This distribution principle shall be applied from the beginning of the month following the signing of the netting agreement.

Netting is not applied in fault, maintenance and modification situations on the main grid that affect the busbar in question and where electricity is transmitted by means other than the busbar in question.

7 REACTIVE POWER RESERVES

The operational and structural demands set for reactive power reserves are defined in detail in the Grid Code Specifications for Power Generating Facilities (VJV2018) and in Grid Code Specifications for Grid Energy Storage Systems (SJV2019).

7.1 Method of voltage control for power generating units

Power generating units with a power rating of over 10 MW or their connection point's rated voltage is over 110 kV must normally use constant voltage control, set according to instructions given by Fingrid. With constant voltage control, the reactive power reserves of power generating units appropriately support the electricity network's voltage during power generating unit's and the network's disturbances. If the Customer or a third party connected to the Customer's network wishes to use another control method in the units, the solution and the control features shall be agreed upon separately with Fingrid.

7.2 Reserve requirements imposed on power generating units

The reactive-power-generating capacity and intake capacity of a power generating unit connected to the main grid with a rated voltage of 400 kV shall, while the power generating unit is connected to the grid, be reserved as reactive power reserve in full, with the exception of the reactive power consumed by the unit's transformer and by the unit's own consumption. With other power generating units over 10 MW or connected to a grid with rated voltage of over 110 kV, half of the reactive-power-generating capacity and intake capacity of the power generating unit, measured at the connection point, shall be reserved as reactive power reserve while the unit is connected to the grid.

The reactive-power-generating capacity and intake capacity shall be calculated at the connection point of the power generating unit with rated power $\cos \varphi = 0{,}95$ and with the normal operating voltage of the connection point.

7.3 Maintenance of activated reserve

The voltage change resulting from a disturbance automatically activates the reactive power reserve. When the voltage returns to normal, the reactive power returns to its normal control value. In prolonged disturbances, for example as a consequence of a severe fault, the reactive power reserve can be activated for a longer period, in which case the reactive power reserve activated by the change in voltage must not be switched off without the approval of Fingrid's Main Grid Control Centre before the voltage returns to the normal range. Fingrid's Main Grid Control Centre can provide guidance, if needed.

7.4 Voltage support in fault, disturbance and maintenance situations

Power generating units with a power rating of over 10 MW or their connection point's rated voltage is over 110 kV are obliged, while they are connected to the grid, to support the system voltage by means of the reactive power reserves during faults and disturbances at power generating units and in the grid, and, if agreed upon separately, for short periods of time also during repairs and maintenance at power generating units and in the grid.

Power generating units with a power rating of over 10 MW or their connection point's rated voltage is over 110 kV are obligated to follow the setpoint value for voltage or reactive power potentially given by Fingrid.

Fingrid may, for example, request the supply of reactive power (outside of normal operating requirements) in the event of interruptions in the grid. Fingrid pays compensation according to the pricing of the reactive power for the supply of reactive power it requests. The compensation shall be calculated for exceedings of the reactive power limits calculated for the connection point (Chapters 2.2.1 and 2.2.2), taking into account the abatements defined in Chapter 3. Fifty (50), by absolute value, of the largest exceedings of the reactive power window within one month are not taken into account.

7.5 Monitoring of reserve maintenance

Fingrid shall be responsible for monitoring the maintenance of reactive power reserves. For monitoring purposes, the Customer shall deliver to Fingrid the necessary measurement and status information on the generators. The measurements used in the monitoring of reactive power reserves are operation control measurements. Measurement and status data and the methods of transmission are discussed in more detail in the application instruction *Real-time information exchange*.

8 MEASUREMENTS OF REACTIVE POWER

The appendices to the Main Grid Contract specify the measuring points for reactive power. Power generating units connected to the Customer’s grid must provide Fingrid with a reactive power measurement or series of measurements for over 50 MW power generating units and for those power generating units agreed on separately in chapter 5 that are not used for local reactive power compensation.

The measurement instruments and their installation shall be subject to the applicable public recommendations for information exchange in electricity trade that are generally applied to measurements in electricity trade.

9 REACTIVE POWER OF DIRECT CURRENT CONNECTIONS

When a high-voltage direct current (HVDC) connection or equivalent is connected to the main grid, Fingrid and the party connecting to the main grid shall agree on the supply of reactive power and on the reactive power reserves individually in each case.