SUPPLY OF REACTIVE POWER AND MAINTENANCE OF REACTIVE POWER RESERVES

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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 generators.

In so far as the measures presented in this application instruction concern a power plant 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 plant 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.

The Customer has the right to obtain the measurement data necessary for the 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 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 operator, 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.

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.

The connection point's reactive power output limit Q_D

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 beyond the connection points, article 2.2.4
- if the power plant's power is max. 1 MW, its P_{net} = 0
- if the power plants' 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.

The connection point's reactive power input limit Q_{D1}

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.

Reactive power output limit Q_G and input limit Q_{G1} are not applied for connection points that fulfill the following criteria.

— There are power plants connected to the connection point with no longer than 15 km power line.

— The power plants actively participate in the voltage control of the main grid.

— The annual consumed energy is no more than 1/4 of the produced annual energy.

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 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.

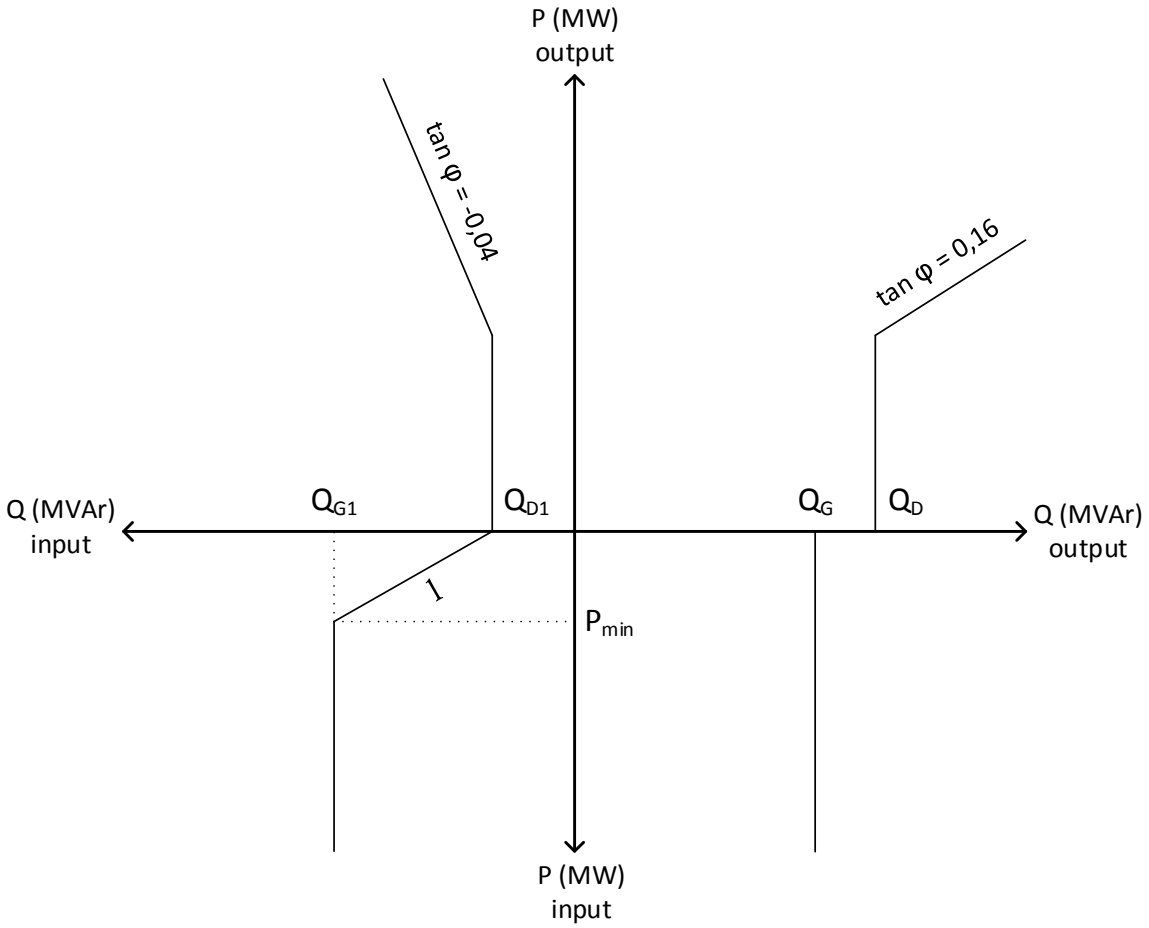

Figure 1. The reactive power window specifies the volume of reactive power that can be delivered to and received from the main grid through individual connection points without separate compensation.

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 article 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 article 2.2.1 or 4% of the active power output from the main grid.

— In active power production, the reactive power output from the main grid is at most equal to the Q_G value specified in article 2.2.2 and the input of reactive power into the main grid is at most equal to the Q_{G1} value specified in article 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} = the connection point's reactive power input limit in active power consumption
P = mean active power produced into the main grid (MW)
Q_{G1} = the connection point's reactive power input limit in active power production
P_{min} = the lowest active power level that the power plants beyond the connection point can produce without a time limit
- $P_{min} = -0.1 \times P_{net}$
- P_{net} = sum (MW) of net power generation capacity for power plants beyond the connection point
    - if the power plant's power rating is max. 1 MW, its $P_{net} = 0$
    - if the power plants' power P_{net} is higher than 450 MW, it will not increase the reactive power window, i.e. max. $(0.1 \times P_{net} / 0.9) = 50.0$ MVAr

2.2.4 Reporting of the net power generation capacity of a power plant

The Customer must report the net power generation capacity of its power plant or of a power plant connected to the Customer's electricity network that exceeds the net power generation capacity of 1 MW pursuant to Commission Regulation (EU) 543/2013.

Net power generation capacity refers to the upper limit of production potential, meaning the highest net power rating that a power plant can produce within at least one hour in a normal operational situation. The net production of power plants shall be determined by deducting from the gross production the power plants' own hourly-metered consumption energy as defined in Decree 309 by the Finnish Ministry of Trade and Industry, issued on 11 April 2003, or in any revised decree. At Fingrid's request, the Customer shall deliver the measurement and calculation criteria for the internal consumption energy used in the determination of net production. In setting the net power generation capacity, the machinery and equipment of the power plant is also taken into account: for instance, boilers and the joint production process with industrial plants.

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 ($\cos \varphi = 0.9$) in Fingrid's Specifications for the Operational Performance of Power Plants.

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 plant is commissioned or an existing power plant 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.

2.4 Railway traction substations

The operator of a railway traction substation shall agree with Fingrid on the reactive power limits and usage for the substation connected to Fingrid's electricity network, and in connections with other networks, with the operator of the network in question.

If railway traction substations are connected to the Customer's electricity network, their filter capacitators increase the Customer's Q_{D1} and Q_{G1} limits; however to no more than 4 MVAr for each substation.

3 ABATEMENTS IN THE USE OF REACTIVE POWER

3.1 Reactive power of power plants

For power plants 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 plant 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 plant with the values.

In order for the reactive power reserves of generators to support the system's voltage during power plants' 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.

3.2 Reactive power in consumption

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 two (2) weeks is considered to be a reasonable repair period for a single event. The same policy can also be applied to a power plant used for compensation in a fault situation.

If a more than 10 MW power plant beyond the Customer's connection point is not used to compensate local reactive power, the effect of the power plant's reactive power can, upon separate agreement, be deducted from the connection point's reactive power measurement. In addition, the effect of a power plant'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 plants 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.

4 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 article 3 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, excesses 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.

In the extraordinary and short-term special situations of power plants 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 plant 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.

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.

If there is a longer-term need in the main grid for the reactive power produced or consumed by the Customer in order to support voltage control, and it is, on the whole, techno-economically sensible, the supply of reactive power shall be agreed on separately.

5 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.

6 REACTIVE POWER PRICING

Reactive power is invoiced according to the amount in excess of the reactive power window limit. The reactive power fee is defined as mean hourly power according to the highest amount of excess for each month. The reactive energy fee is determined according to the reactive energy in excess of the reactive power window for the month in question, multiplied by the valid unit price. The invoicing takes into account the principles for determining fees in this application instruction.

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

Figure 2 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.

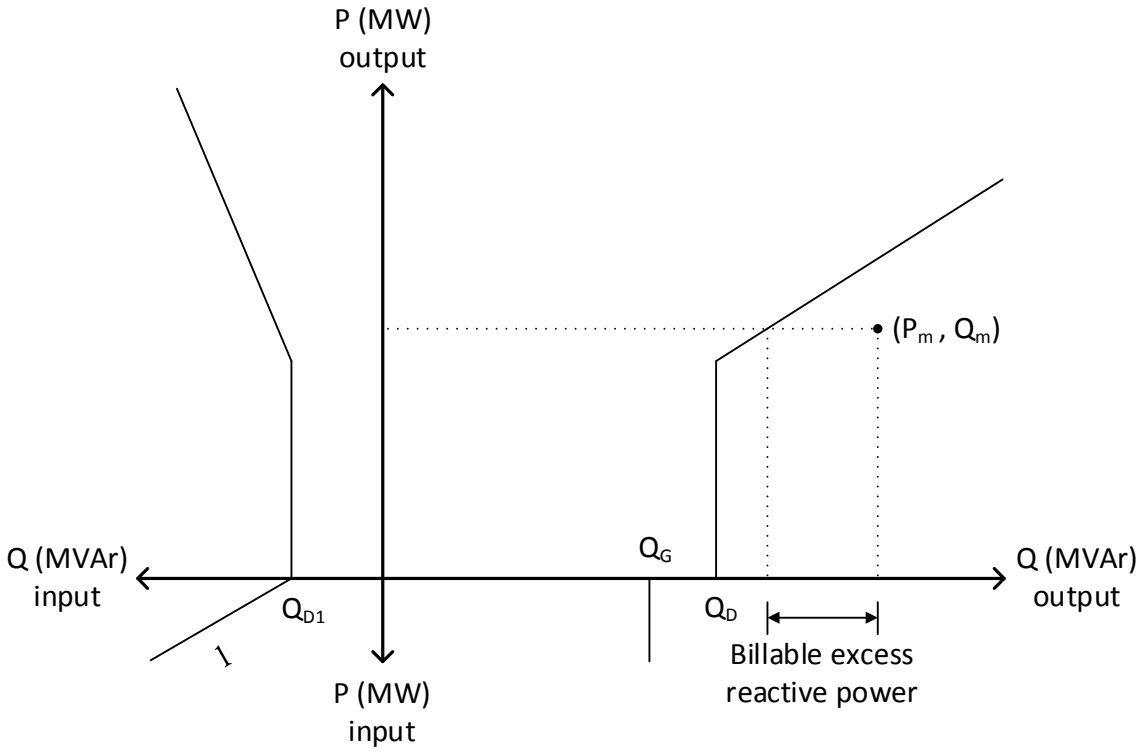

Figure 2. Determining reactive power invoicing. P_m refers to the hourly active power measured and Q_m to the hourly reactive power measured.

7 REACTIVE POWER RESERVES

The operational and structural demands set for reactive power reserves are defined in detail in the Specifications for the Operational Performance of Power Plants.

7.1 Method of control for generators

Generators with a power rating of over 10 MW must normally use constant voltage control, set according to instructions given by Fingrid. With constant voltage control, the reactive power reserves of generators appropriately support the electricity network's voltage during power plants' 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 generators, the solution and the control features shall be agreed upon separately with Fingrid.

7.2 Reserve requirements imposed on generators

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

The reactive-power-generating capacity and intake capacity of the generator shall be calculated at the nominal power and rated voltage of the generator. If $\cos \varphi < 0.9$ (ind.) φ applies for the generator, the reactive-power-generating capacity shall be calculated on the basis of $\cos \varphi < 0.9$.

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

Generators over 10 MW 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 plants and in the grid, and, if agreed upon separately, for short periods of time also during repairs and maintenance at power plants and in the grid.
Generators over 10 MW are obligated to follow the setpoint value for voltage or reactive power potentially given by Fingrid.

Fingrid can request, for example in main grid outage situations, the delivery of reactive energy in deviation of the normal operating procedure. Fingrid pays for the delivery of its requested reactive energy in accordance with the reactive power pricing.

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. The measurement and status information and their method of delivery shall be agreed upon separately.

8 MEASUREMENTS OF REACTIVE POWER

The appendices to the Main Grid Contract specify the measuring points for reactive power. Power plants connected to the Customer's grid must provide Fingrid with a reactive power measurement or series of measurements for over 50 MW power plants and for those power plants agreed on separately in article 3.2 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.