APPENDIX 2
Unofficial translation

Application Instruction for the Maintenance of Frequency Controlled Power Plant Reserves as of 1 January 2012

Contents

1 GENERAL

This Application Instruction presents the principles and general procedures related to the management and procurement of frequency controlled power plant reserves. This Application Instruction is an appendix to the Yearly- and Hourly Market Agreement for Frequency Controlled Normal Operation Reserve and Frequency Controlled Disturbance Reserve, signed between Fingrid and Reserve Holder.

The maintenance obligations concerning the frequency controlled reserves have been agreed through an operation agreement signed between the Nordic transmission system operators. In order to fulfil the reserve obligation, there can also be transactions between countries. Fingrid has a right to sell reserves, which have been sold to Fingrid by reserve holders, further to other transmission system operators.

Fingrid procures some of the relevant obligation from the annual market, from power plants located in Finland, on the basis of competitive bidding. In addition, Fingrid procures reserves from the direct current transmission links from Russia and Estonia as well as through daily purchases from the hourly market in Finland and the other Nordic countries.

2 REPORTING AND FOLLOW-UP OF RESERVE MAINTENANCE

Reserve Holder and Fingrid shall supply each other with information electronically.

Reserve Holder shall provide its own balance provider with information related to the maintenance of the frequency controlled reserves, balance management and balance settlement. Reserve Holder shall agree on this separately with its balance provider.

2.1 Reserve plans

Reserve Holder, which has signed an annual agreement, shall supply Fingrid with the hourly reserve plan concerning the reserve volumes in the next calendar day. The volume stated in the reserve plan can be at the most equal to the reserve volume agreed in the annual agreement. The plans shall be delivered to Fingrid in EDI messaging using DELFOR message format, by 18.30. The reserve plan shall reach Fingrid by the deadline. Plans arriving after the deadline are not accepted.

No reserve plan is delivered of transactions conducted in the hourly market.

2.2 Real-time data

Reserve Holder shall deliver, at its own expense, the following machinery-specific data to a point of delivery indicated by Fingrid:

- status information
- active power (MW)
- maximum power (MW)
- volume of frequency controlled normal operation reserve (MW)
- volume of frequency controlled disturbance reserve (MW)
- droop (%) if the machinery has more than one verified droop.

The maximum sending cycle of the data shall be three minutes. The data shall be delivered in accordance with the data exchange principles maintained by Fingrid and

published on its website. Fingrid monitors the maintenance and activation of the reserves on the basis of the real-time data.

2.3 History data

At Fingrid's request, Reserve Holder shall deliver the machine-specific active power data on Reserve Holder's power plant machinery contributing to the regulation in a numerical format at such accuracy that Reserve Holder can prove that its machinery activates in accordance with the Agreement for example in disturbance situations. Reserve Holder shall store the history data for at least four days.

2.4 Invoicing data

Reserve Holder shall deliver the following actual data on power plant machinery contributing to the maintenance of the reserves in the previous month. This data shall be delivered at Reserve Holder's own expense as hourly time series by the 10th day of each month.

- machinery-specific hourly average power
- machinery-specific hourly maximum power
- volume of frequency controlled normal operation reserve by virtue of the annual agreement and in the hourly market
- volume of frequency controlled disturbance reserve by virtue of the annual agreement and in the hourly market.

The data shall be delivered to Fingrid in electronic EDI messages using the MSCONS message format.

2.5 Fingrid's reporting to Reserve Holder

Fingrid shall report the following hourly data to Reserve Holder:

- actual transactions and prices in the hourly market
- volume and price of reserve electricity.

3 CALCULATION PRINCIPLES OF RESERVE CAPACITY

The machine-specific reserve volume of the frequency controlled normal operation reserve and disturbance reserve is calculated in accordance with the following principles:

1. When the machinery-specific average power is close to the minimum power P_{min}, the volume of the frequency controlled normal operation reserve P_f is calculated in so far as there is regulating reserve power available for the hour in question within the scope of minimum power; however, at the most the volume verified in regulation tests.

2. When the machinery-specific average power is higher than the frequency controlled normal operation reserve verified in the regulation tests but below the maximum power P_{max} so that the difference between the maximum power and the average power is higher than or equal to the sum P_h of the frequency controlled normal operation reserve and disturbance reserve, the proportion of the above reserves is calculated at the full volume.

3. When the machinery-specific average power is close to the maximum power, first the volume of the frequency controlled normal operation reserve and after it the volume of the frequency controlled disturbance reserve is calculated in so far as there is regulating reserve power left after the frequency controlled normal operation reserve has been deducted from the maximum power; however, at the most the volume of the frequency controlled disturbance reserve verified in the regulation tests.

4. When the machinery-specific average power is almost at the maximum power, the volume of the frequency controlled normal operation reserve is calculated in so far as there is regulating machinery power available for the hour in question within the maximum power; however, at the most the volume of the frequency controlled normal operation reserve verified in the regulation tests.

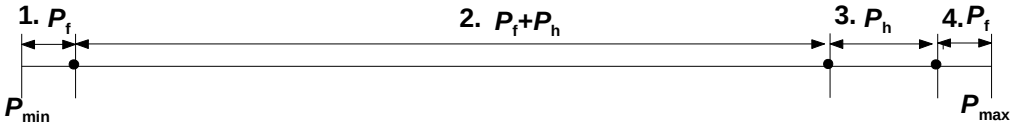

Figure 1. Calculation of frequency controlled normal operation reserve and disturbance reserve at different power ranges.

4 CALCULATION PRINCIPLES OF ENERGY FEE

Reserve electricity refers to the balance error caused by the frequency controlled normal operation reserve in the production balance, with the reserve electricity calculated in accordance with Equation 1.

∑R denotes the total volume of the frequency controlled normal operation reserve of all parties included in balance provider's balance multiplied by 10 (frequency response). A party's frequency controlled normal operation reserve is verified by means of measurements, and it is at the most equal to the total volume agreed in the annual agreement and in the hourly market.

Δt denotes the change in the time deviation in seconds during the hour in question. The correction coefficient (k=0.7) takes into account the effect of the dead band on the activated energy.

$$Reserve\ electricity = \frac{\Sigma R \times \Delta t \times 50Hz}{3600s} \times k \qquad (1)$$

The balance error caused by the frequency controlled normal operation reserve is calculated hourly and removed by means of a transaction from the production balance of Reserve Holder's balance provider in conjunction with the nation-wide balance settlement. The basis of compensation is the hourly regulating price as follows:

- In a situation with a frequency below the normal range, the calculatory energy caused by the frequency controlled normal operation reserve is reimbursed at the up-regulating price.
- In a situation with a frequency above the normal range, the calculatory energy caused by the frequency controlled normal operation reserve is charged at the down-regulating price.

5 VERIFICATION OF TECHNICAL REGULATION FEATURES OF POWER PLANT MACHINERY

Reserve Holder shall make sure that Reserve Holder's power plant machinery participating in the maintenance of the frequency controlled normal operation reserve and disturbance reserve fulfils the requirements imposed on its regulation features within the available capacity.

The fulfilment of the requirements shall be verified by means of regulation tests carried out at the power plant. These tests shall be carried out using regulation settings which conform to the normal run of the machinery in a normal operating situation. The regulation tests shall be conducted before the entry into force of the Agreement.

The regulation tests shall also be carried out whenever the power plant machinery is modified in a manner which influences its regulation capability. Such modifications include changes to the power plant machinery, such as power increases or changes influencing efficiency, renewal of control or hydraulics equipment, and changes to control parameters. If no modifications influencing regulation capability are performed on the power plant machinery, the regulation tests shall be repeated at least every ten years.

The regulation settings shall be verified by Reserve Holder after service and repairs and, if necessary, frequency response tests shall be carried out if there is reason to assume that the regulation capability of the power plant machinery has altered.

5.1 Quantities specified on the basis of regulation tests

5.1.1 Droop, regulation power and frequency controlled normal operation reserve

When the frequency of the power system decreases, turbine controllers increase the active power of generators in order to compensate for the power deficiency and to raise the frequency. Correspondingly, in overfrequency situations turbine controllers decrease the active power of generators in order to decrease the frequency. Droop s can be defined by means of step response tests when the frequency change Δf to be made and the consequently obtained power change ΔP are known. In this way, the droop is obtained from Equation 2 by using the above quantities, the nominal frequency f_n of the grid and the nominal power P_n (rating plate value) of the generator:

$$s = \frac{\frac{\Delta f}{f_n}}{\frac{\Delta P}{P_n}} \times 100\% \qquad (2)$$

The droop of power plant machinery verified in regulation tests must be below 6%. Power plant machinery can have several droops, which Reserve Holder can control in remote control wherever necessary. The capability of power plant machinery to participate in automatic frequency regulation is referred to as regulation power R. Its magnitude is determined by the features of the turbine and by the settings of the controllers related to it. The regulation power can be calculated by means of the frequency change and the consequently obtained power change using Equation 3.

$$R = \frac{\Delta P}{\Delta f} \qquad (3)$$

The frequency controlled normal operation reserve is that change in active power which is activated automatically within three minutes when there is a stepped frequency change of ±0.1 Hz. The frequency controlled normal operation reserve must remain activated even after three minutes if the frequency differs from the nominal frequency of 50 Hz.

5.1.2 Frequency controlled disturbance reserve

The frequency controlled disturbance reserve P_h is that part of the active power reserve which begins to activate automatically when frequency decreases below 49.9 Hz and which must be activated when frequency decreases to 49.5 Hz. The frequency controlled disturbance reserve of the power plant machinery is the smaller of the following active powers: that which is activated at a stepped frequency deviation of -0.5 Hz in 30 seconds or that which is activated in five seconds multiplied by two.

The power regulation of some power plant machineries shifts over to disturbance operation parameters automatically when frequency decreases below 49.9 Hz. In this case, the turbine controller parameters shift automatically from normal operation values to disturbance operation values. For this reason, the measurement of the frequency controlled disturbance reserve at such power plants shall be carried out using the parameters for disturbance operation.

5.1.3 Dead band in frequency regulation

The dead band of the power plant machinery is the lowest frequency change to which the machinery responds so that the activated active power can be measured.

5.2 Measurement principle

The regulation test measurements shall be carried out by means of step response tests. The step response test shall be carried out by supplying a permanent frequency deviation to the frequency measuring branch of the turbine controller. The measurement of the frequency of the grid shall be interrupted for the duration of the test, and instead of it, a signal corresponding to the step change shall be supplied to the frequency measuring branch.

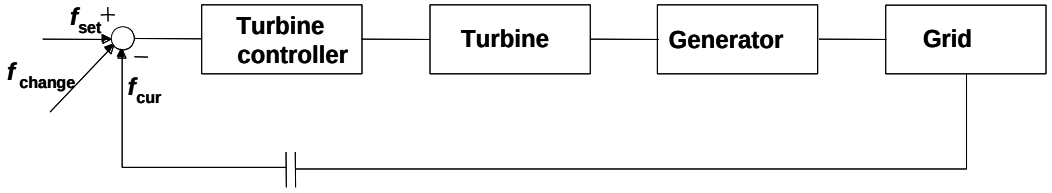

Figure 2. Supplying the step change to the frequency measuring branch.

If the test cannot be performed by supplying the frequency deviation to the frequency measuring branch, the step response test can be carried out by simulating the change in the frequency of the grid or by changing the set value of frequency.

In a test carried out by changing the set value of frequency, the frequency changes have the opposite effect as compared to frequency changes which are supplied to the frequency measuring branch. In other words, a change of 50.0 - 50.5 Hz in the set value corresponds to a change of 50.0 - 49.5 Hz in the frequency of the grid. If the test is carried out by changing the set value, both the set value and the measurement value of the frequency of the grid shall be the same as accurately as possible in the initial situation.

The power change achieved as a result of the step change shall be recorded and the results shall be registered.

Before the beginning of the test, the settings of the turbine controller shall be recorded, and the parameter list concerning the regulation features of the power plant machinery shall be drawn up. Other factors potentially influencing the results of the test, such as falling height of hydropower and external temperature, shall also be recorded.

If, due to the features or structure of the power plant machinery or control equipment, the test or a part of it cannot be performed as described above, Fingrid and Reserve Holder can agree on another procedure to verify the regulation capability of the power plant machinery. Reserve Holder shall submit an alternative procedure to Fingrid for evaluation one week before the measurement. Reserve Holder shall be responsible for the potential additional costs required by an alternative measurement procedure.

5.2.1 Measurement of frequency controlled normal operation reserve

The frequency controlled normal operation reserve and regulation power shall be verified by using a step response test on the regulating power plant machinery. In the test, deviations +0.1 Hz and -0.1 Hz shall be supplied to the measuring branch for frequency regulation, and the corresponding power changes shall be recorded in three minutes separately with each frequency deviation.

If the frequency deviation cannot be supplied to the measuring branch, the step response test shall be carried out by changing the guideline value for frequency with deviations +0.1 Hz and -0.1 Hz.

5.2.2 Measurement of frequency controlled disturbance reserve

The frequency controlled disturbance reserve shall be verified by means of a step response test, by supplying, instead of the grid frequency, a signal which corresponds to a frequency deviation of -0.5 Hz to the turbine controller. The power change caused by the frequency change shall be registered for one minute. The measurement result shall be recorded at 5 and 30 seconds. The disturbance reserve shall remain activated even after 30 seconds.

If the test is carried out by changing the guideline value for frequency, a guideline value deviation of +0.5 Hz shall be supplied in the measurement of the frequency controlled disturbance reserve.

5.2.3 Measurement of dead band and dead time in frequency regulation

The dead band of frequency regulation shall be measured in all power plant machinery participating in reserve maintenance.

If the power plant machinery is such that the dead band for its turbine controller can be set as a parameter, the functioning of regulation shall be tested outside the set dead band so that the turbine controller is supplied a step change which is slightly greater than the dead band, and the consequently activated active power shall be measured for three minutes from the step change.

If the power plant machinery is such that the dead band for frequency regulation cannot be set, the measurement shall be carried out by supplying a stepped frequency change to the turbine controller, and the consequently activated active power shall be measured. The activated active power shall be measured for three minutes from the step change. The first frequency change to be used is ±10 mHz, after which the

measurement shall be carried out, if necessary, at four other points at steps of ±10 mHz up to a frequency deviation of ±50 mHz.

The measurement shall be carried out using the same power levels as in the measurements of the frequency controlled normal operation reserve and disturbance reserve in accordance with Figure 2. The dead band of the power plant machinery is the lowest frequency change to which the machinery responds so that the activated active power can be measured. The measurement shall be carried out both with and without clearance. If different values are obtained for the dead band with different power levels, the average of the dead bands measured shall be applied to the Agreement.

If the power plant consists of at least two power plant machineries which are similar in terms of their power, structure and the features of the turbine controller, the dead band can be measured in one of these machineries if so agreed upon between Fingrid and Reserve Holder separately, and the result obtained shall be applied to all power plant machineries at the same magnitude.

5.2.4 Other issues to be considered in the measurements

The power values before and after the frequency change shall be recorded. A power range at which the reserves can still be activated shall be specified in the test, using the typical controller settings of each power plant machinery. This means that the tests shall be performed at the following power levels:

- at minimum power $P_{min,ajo}$, from which the power of the power plant machinery can still be decreased by the frequency controlled normal operation reserve P_f
- at a power which is approx. 50 per cent of the nominal power P_n of the power plant machinery, with both the frequency controlled normal operation reserve P_f and frequency controlled disturbance reserve P_h to be specified at this power
- at power $P_{max,ajo}$ specified close to the maximum power P_{max} of the power plant machinery, after which a power equal to the sum of the frequency controlled normal operation reserve and frequency controlled disturbance reserve can still be activated upwards in the power plant machinery.

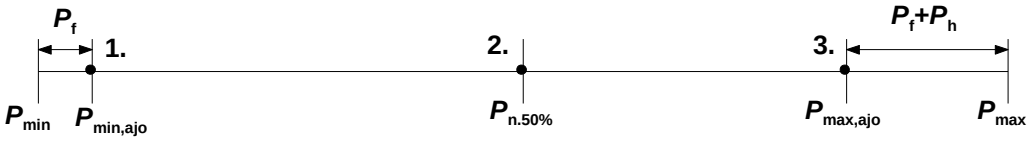

Figure 3. Measuring points 1, 2 and 3 used in the test.

The frequency controlled normal operation reserve and disturbance reserve is the smallest of the measurement results obtained at the power levels shown in Figure 2.

It shall be remembered in the measurement of the frequency controlled disturbance reserve that the frequency controlled normal operation reserve shall also activate within three minutes from the stepped frequency change.

The power change caused by the step response shall be measured for five minutes, because the measured power change shall be permanent. The measurement results shall be registered, and curves shall be drawn of each measurement, indicating the power change after the frequency change.

Based on the measurement of the frequency controlled normal operation reserve, droop shall be calculated at each power level using Equation 2, and regulation power shall be calculated using Equation 3.

5.2.5 Accuracy requirements concerning measuring and registration equipment

Various sources cause inaccuracy in the measurement results. These include the inaccuracy of frequency setting, instrument transformers, power sensor, and A/D card. The total error in the measurement shall be below 10 per cent.

The setting accuracy of the frequency setting shall be specified before the measurements.

The sampling interval of the registration equipment shall be at least 0.2 seconds so that the frequency controlled normal operation reserve and disturbance reserve as well as other parameters relating to the regulation features can be defined at sufficient accuracy.

5.3 Performing and documenting the regulation test

Reserve Holder shall be responsible for performing the measurements and for drawing up the measurement records in accordance with this test specification. If Reserve Holder does not present reliable test results, Fingrid does not have to accept the power plant machinery in question for reserve maintenance. If necessary, the regulation tests can be commissioned to be performed by a jointly agreed expert. Fingrid has the right to send its representative to the regulation test. Fingrid is only responsible for its own personnel costs.

Fingrid shall be informed of the measurements at least two weeks before the measurement date so that Fingrid can send its own specialist to the test. In this conjunction, Reserve Holder shall inform Fingrid of the measurement date and location and present the measurement programme. If this is not done, Fingrid has the right not to accept the measurement results.

After the test, Reserve Holder shall deliver to Fingrid the measurement record of the regulation test.