ANALYSIS & REVIEW OF REQUIREMENTS FOR AUTOMATIC RESERVES IN THE NORDIC SYNCHRONOUS SYSTEM

Intermediate Technical Report

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1. Scope of the project: Stop the weakening trend and improve frequency quality!

The current requirements for Automatic Reserves (i.e. primary control or Frequency Containment Reserves) in the Nordic synchronous system have not been changed for tens of years:

- Frequency Controlled Normal Reserves (FNR), with the objective to keep frequency between 49.9 and 50.1 Hz (± 100 mHz);
- Frequency Controlled Disturbance Reserves (FDR) with the objective to stabilise frequency after a (large) disturbance. These reserves are activated if the frequency goes below 49.9 Hz.

ENTSO-E applies for both FNR and FDR the new term Frequency Containment Reserves (FCR). The term FCR is used in this report for newly proposed automatic frequency containment reserve products. We refer to FNR and FDR for the existing products.

However, in this period the Nordic power system, the generation mix in the Nordic electricity market and the market integration with other synchronous systems have changed significantly.

Starting ten years ago, the frequency quality has been continuously decreasing, which is shown by the increasing numbers of minutes that the frequency is outside the ±100 mHz band that is specified in the Nordic Grid Code.

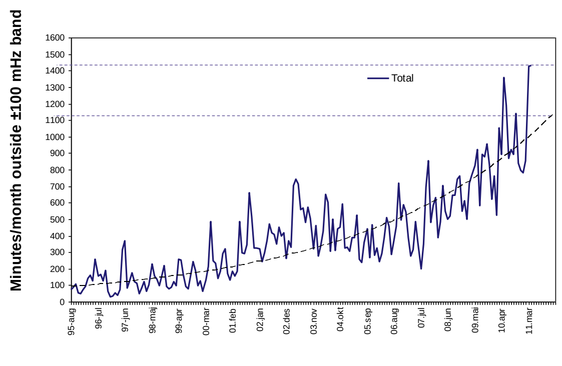

Figure 1: Number of minutes/month that the frequency was outside the ±100 mHz band

New (HVDC) interconnections, market developments and the increasing amounts of intermittent generation (mainly wind) should be expected to lead to a further deterioration in the frequency quality.

ENTSO-E Regional Group Nordic (RGN) resp. the Nordic TSOs set up a project to analyse and review the Nordic requirement for automatic reserves. The scope of the project is to analyse and propose technical requirements for automatic reserves and determine the volumes of these reserves.

A project team of technical experts from the Nordic TSOs, assisted by E-Bridge Consulting analysed the decreasing frequency quality, reviewed the existing automatic reserves, studied possibilities to improve the requirements for automatic reserves and drafted recommendations for an improved set of automatic reserves.

This report is a major input for a following market workstream of this project which has started in August 2011. The objective of the market workstream is to analyse the required market set-up and funding for the newly proposed products.

The project team developed a new simulation model that was specially designed for studying automatic reserves in the Nordic system.

2. Revising requirements for automatic reserves within normal operation band (± 100 mHz)

According to the Nordic Grid Code the automatically activated 'Frequency Controlled Normal Reserves' (FNR) shall keep the frequency within the normal operation band between 49.9 and 50.1 Hz (± 100 mHz). Simulation results show that the Nordic Grid Code requirements for FNR (600 MW available in 2-3 minutes) are not sufficient for keeping the frequency within the normal frequency band. The simulations also show that even with more capacity, the specified reserves are too slow for frequency containment.

The analysis of the current situation based on simulations and available measurements shows that the implemented automatic reserves in the Nordic system are faster than required by the Nordic Grid Code. Also the activated capacity is usually higher than the required 600 MW (850 MW). Still figure 1 shows that the automatic reserves are not able to keep the frequency within the normal frequency band.

It would be possible to keep the frequency within the normal band by increasing the speed of FNR and adding FNR capacity.

In addition to changing the requirements with respect to FNR, use of automatic Load Frequency Control has been considered. In contrast to the decentralised FCR controllers preventing the frequency from decreasing or increasing further, the LFC is a central controller that is designed for bringing the frequency back to 50 Hz. The LFC provides Frequency Restoration Reserves (FRR).The simulation results show that automatic Load Frequency Control (LFC) keep the frequency closer to 50 Hz than Frequency Containment Reserves (FCR).

It is not possible to keep the frequency within the normal band by using only automatic LFC. Therefore the project team recommends applying both FCR and FRR.

The project team studied different combinations of FCR and FRR with different characteristics and proposes the following requirements for these automatic reserves:

FCR within the normal frequency band (± 100 mHz):

- The optimal system time constant is between 30 s and 60 s, a faster system time constant reduces the need for capacity for FCR;
- These reserves shall be controlled by governors with a considerable proportional gain (K_p).

Frequency Restoration Reserves (FRR):

- Total response time for the full delivery of the response shall be between 120 s and 210 s, a faster response time reduces the need for capacity for FRR;
- The FRR shall be provided by automatic Load Frequency Control (LFC), which is a central controller that is designed for bringing the frequency back to 50 Hz.

3. Revising requirements for automatic reserves for disturbance reserves

The currently implemented Frequency Controlled Disturbance Reserves (FDR) may be too slow.

From our analysis, the project team concludes that:

- The required time constant for disturbance FCR (<49.9 Hz or > 50.1 Hz) depends on Frequency Bias Factor and inertia in the system;
- A system time constant of 30 s will keep the minimum frequency above 49.2 Hz and the steady state frequency above 49.5 Hz if a dimensioning fault will take place at a worst case frequency of 49.9 Hz. Preconditions are that the inertia is at least 2,700 MWs/Hz (currently 5,000 – 10,000 MWs/Hz), the frequency bias factor is at least 6,500 MW/Hz and the proportional gain (K_p) is considerable. *(Disturbances usually start at a higher frequency and are usually not as big as the dimensioning fault. Currently the minimum frequency usually stays above 49.5 Hz and the steady state frequency above 49.8 Hz. Since the consequences of applying the above-mentioned values of 49.2 Hz for minimum and 49.5 Hz for steady state frequency may be very large and cannot completely be overseen, the project team suggests further and more detailed studies on these limits before implementing)*

In the future the inertia in the system may be reduced because the energy that is now supplied by conventional generators may be imported or delivered by intermittent generation (wind turbines). At the moment the inertia is not too low, but the project team suggests start working on measures that guarantee a minimum level of inertia.

4. Methods for determining the volumes of automatic reserves

The report proposes a methodology for determining the optimal volumes of FCR for the ± 100 mHz band and FRR. This methodology has the required frequency quality and historical frequency measurements as inputs. By performing a large number of simulations, the methodology determines a set of acceptable combinations for FCR and FRR (more than one) for the required frequency quality.

There is flexibility in selecting the optimal combination of FCR and FRR depending on the expected costs for FCR and FRR respectively.

The target frequency quality that is used in this project for the determination of the volumes is an average frequency of 50 Hz with a standard deviation of 33 mHz. Assuming a normal distribution, this equals 1420 minutes/year outside the ± 100 mHz band. This target frequency quality is recommended as a long term goal and may be achieved by intermediate goals.

This quality level is similar to the quality level before the quality level started to decrease about 10 years ago (see Figure 1, standard deviation of approx. 32 mHz). Furthermore, a 1983 paper referred to a standard deviation of about 0.03 Hz, which equals 450 minutes/year outside the ± 100 mHz band. Unfortunately, the existing Nordic Grid Code does not include a minimum standard for 'minutes outside the ± 100 mHz band'. However, a target of 1420 minutes/year is similar to comparable targets in other European, American and Australian power systems.

5.'60 s oscillation' issue

In the Nordic system a slow oscillation in the grid frequency exists with periods of 40 to 90 seconds. These oscillations are likely caused by suboptimal governor settings. Consequently, when changing the governor setting for obtaining other system time constants, the '60 s oscillations' may change. It can therefore only be guaranteed that the new requirements to the FCR for the ± 100 mHz band will not increase the '60 s oscillations', after FCR providers prove that the response of each generator to all frequencies is damped.

Because of the time constants of the proposed LFC and system response times of the FRR providers, 60 s oscillations will not be influenced by LFC.

Since understanding and reducing the '60 s oscillations' is a prerequisite for implementing the newly proposed FCR, and it may take some time to reduce the '60 s oscillations', the project team proposes starting activities for solving the '60 s oscillation issue' as soon as possible. On a high level, these activities include:

- Better understand the background of the '60 s oscillation issues' by studying and reviewing existing material, involving experts and start detailed measurements at individual (larger) generating units/power stations;
- Detailed modelling and simulations of individual plants with Aristo and/or Simulink (start with the larger plants);
- Find the sources and reasons, background.

If the reason for 60 s oscillation are in the governor settings it is necessary to define new governor settings for the plants and revise the governors (start with the larger plants). The new settings need to be studied, simulated and tested before implementation.

All this work requires good coordination between Nordic TSOs and a common methodology to study the issues and implement improvements. The project team suggests starting with a pilot project in which the methodology will be defined and tested on a limited selection of the largest generators that provide FCR.

6. Recommendations

The project team recommends applying in the future the following automatic reserve products:

- Frequency Containment Reserves (FCR) for normal operation to keep frequency between 49.9 and 50.1 Hz (± 100 mHz) which are faster than current FNR;
- In addition to the FCR for normal operation, apply Frequency Restoration Reserves (FRR) by implementing an automatic Load Frequency Control (LFC);
- Frequency Containment Reserves (FCR) for disturbances for both upwards and downwards regulation with slower system time constants than the Frequency Controlled Disturbance Reserves (FDR) that is specified in the current Nordic Grid Code.

The project team has developed a methodology for determining the volumes of automatic reserves.

In order to make a final recommendation on the product combination and the necessary volumes the associated costs need to be taken into account.

The technical recommendations are the starting point for the market workstream of the Automatic Reserves project. The objective of the market workstream is to analyse and recommend the required funding and market set-up for Frequency Containment Reserves (FCR) and Frequency Restoration Reserves (FRR) (e.g. LFC). Together with the technical work stream, the combination of reserves for normal operating conditions and disturbance situations shall be optimised with recommendations for initial volumes. The requirements for reserve volumes may have to be increased later if wanted effect on the frequency quality is not experienced. If other measures improve the frequency quality significantly the minimum required volume could be decreased.

There will also be a need for implementation groups for both FCR and FRR, and some details will have to be determined in those groups. Especially implementation of new requirements for FCR is expected to take 2-3 years before it is finished.

7. Further issues and outlook for implementation plan

Automatic reserves do not mitigate the causes of the imbalances. Hence, automatic reserves only correct the remaining imbalances and prevent the frequency from deviating too much from 50 Hz. Since reducing the imbalance will limit the amounts of FCR and FRR that are required for keeping the frequency in the ±100 mHz band, the project team recommends limiting the imbalances by solving the imbalance at their source.

The project team supports the already proposed measures to mitigate causes of the imbalances:

- Correlated ramping speed for production and HVDC interconnectors;
- Introduction of quarterly schedules, 5 minute schedules or even 1 minute schedules;
- Introduction of quarterly energy markets;
- Improving forecasts / forecasting tools;
- Improving operational information-systems;
- Use of HVDC-interconnectors to other synchronous systems (exchanging imbalances).

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