Explanatory document for the Nordic synchronous area proposal for frequency quality defining parameters and the frequency quality target parameter in accordance with Article 127 of the Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation

1. Introduction

The Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation (hereinafter **"SO Regulation"**) sets out rules on relevant subjects that should be coordinated between Transmission System Operators, as well as between TSOs and Distribution System Operators and with significant grid users, where applicable. The goal of SO Regulation is to ensure provision of an efficient functioning of the interconnected transmission systems to support all market activities. In order to deliver these objectives, a number of steps are required.

One of these steps is to determine the frequency quality defining parameters and the frequency quality target parameter. Pursuant to Article 118(1)(c) of the SO Regulation, all Transmission System Operators in the Nordic Synchronous Area shall jointly develop common proposals for the frequency quality defining parameters and the frequency quality target parameter in accordance with Article 127 of the SO Regulation.

According to Article 6(3)(d)(i) of the SO Regulation the proposal for the frequency quality defining parameters and the frequency quality target parameter (hereafter referred to as "**Proposal**") shall be submitted for approval by the relevant national regulatory authorities (hereinafter "NRAs") no later than 14 September, 2018. The proposal is submitted for regulatory approval to all NRAs in the Nordic synchronous area. According to Article 6(6) of the SO Regulation the Proposal needs to be submitted to ACER as well, who may issue an opinion on the proposal if requested by the NRAs.

This document contains an explanation of the Proposal from all TSOs of the Nordic synchronous area (hereinafter **"TSOs"**).

It is structured as follows. The legal requirements for the Proposal are presented in Chapter 2. Chapter 3 starts with describing the objective of frequency quality. Chapter 4 provides an overview of the existing situation. The proposed frequency quality defining parameters and the frequency quality target parameter are described in Chapter 5. Chapter 6 describes the expected impact on the relevant objectives of the SO Regulation. Finally, Chapter 7 provides information about the implementation and Chapter 8 describes the public consultation.

2. Legal requirements and interpretation

2.1 Legal references and requirements

Several articles in the SO Regulation set out requirements which the Proposal must take into account. These are cited below.

(1) Article 118(1)(c) and (2) of the SOGL constitutes the legal basis that the Proposal should take into account. Article 118 has the following content:

> *"1. By 12 months after entry into force of this Regulation, all TSOs of each synchronous area shall jointly develop common proposals for:[…]*
>
> *(c) the frequency quality defining parameters and the frequency quality target parameters in accordance with Article 127; […]*
>
> *2. All TSOs of each synchronous area shall submit the methodologies and conditions listed in Article 6(3)(d) for approval by all the regulatory authorities of the concerned synchronous area. Within 1 month after the approval of these methodologies and conditions, all TSOs of each synchronous area shall conclude a synchronous area operational agreement which shall enter into force within 3 months after the approval of the methodologies and conditions."*

(2) Article 127 of the SOGL has the following content:

> *"Article 127: Frequency quality defining and target parameters*

1. The frequency quality defining parameters shall be:

(a) the nominal frequency for all synchronous areas;

(b) the standard frequency range for all synchronous areas;

(c) the maximum instantaneous frequency deviation for all synchronous areas;

(d) the maximum steady-state frequency deviation for all synchronous areas;

(e) the time to restore frequency for all synchronous areas;

(f) the time to recover frequency for the GB and IE/NI synchronous areas;

(g) the frequency restoration range for the GB, IE/NI and Nordic synchronous areas;

(h) the frequency recovery range for the GB and IE/NI synchronous areas; and

(i) the alert state trigger time for all synchronous areas.

2. The nominal frequency shall be 50 Hz for all synchronous areas.

3. The default values of the frequency quality defining parameters listed in paragraph 1 are set out in Table 1 of Annex III.

4. The frequency quality target parameter shall be the maximum number of minutes outside the standard frequency range per year per synchronous area and its default value per synchronous area are set out in Table 2 of Annex III.

5. The values of the frequency quality defining parameters in Table 1 of Annex III and of the frequency quality target parameter in Table 2 of Annex III shall apply unless all TSOs of a synchronous area propose different values pursuant to paragraphs 6, 7 and 8.

6. All TSOs of CE and Nordic synchronous areas shall have the right to propose in the synchronous area operational agreement values different from those set out in Tables 1 and 2 of Annex III regarding:

(a) the alert state trigger time;

(b) the maximum number of minutes outside the standard frequency range.

7. All TSOs of the GB and IE/NI synchronous areas shall have the right to propose in the synchronous area operational agreement values different from those set out in Tables 1 and 2 of Annex III regarding:

(a) time to restore frequency;

(b) the alert state trigger time; and

(c) the maximum number of minutes outside the standard frequency range.

8. The proposal for modification of the values pursuant to paragraph 6 and 7 shall be based on an assessment of the recorded values of the system frequency for a period of at least 1 year and the synchronous area development and it shall meet the following conditions:

(a) the proposed modification of the frequency quality defining parameters in Table 1 of Annex III or the frequency quality target parameter in Table 2 of Annex III takes into account:

(i) the system's size, based on the consumption and generation of the synchronous area and the inertia of the synchronous area;

(ii) the reference incident;

(iii) grid structure and/or network topology;

(iv) load and generation behaviour;

(v) the number and response of power generating modules with limited frequency sensitive mode — over frequency and limited frequency sensitive mode — under frequency as defined in Article 13(2) and Article 15(2)(c) of Regulation (EU) 2016/631;

(vi) the number and response of demand units operating with activated demand response system frequency control or demand response very fast active power control as defined in Articles 29 and 30 of Regulation (EU) 2016/1388; and

(vii) the technical capabilities of power generating modules and demand units;

(b) all TSOs of the synchronous area shall conduct a public consultation concerning the impact on stakeholders of the proposed modification of the frequency quality defining parameters in Table 1 of Annex III or the frequency quality target parameter in Table 2 of Annex III.

9. All TSOs shall endeavour to comply with the values for the frequency quality defining parameters or for the frequency quality target parameter. All TSOs shall verify the fulfilment of the frequency quality target parameter at least annually.''

(3) Table 1 and Table 2 of Annex III of the SOGL have the following content:

Frequency quality defining parameters referred to in Article 127:

Table 1

Frequency quality defining parameters of the synchronous areas

	CE	GB	IE/NI	Nordic
standard frequency range	± 50 mHz	± 200 mHz	± 200 mHz	± 100 mHz
maximum instantaneous frequency deviation	800 mHz	800 mHz	1 000 mHz	1 000 mHz
maximum steady-state frequency deviation	200 mHz	500 mHz	500 mHz	500 mHz
time to recover frequency	not used	1 minute	1 minute	not used
frequency recovery range	not used	± 500 mHz	± 500 mHz	not used
time to restore frequency	15 minutes	15 minutes	15 minutes	15 minutes
frequency restoration range	not used	± 200 mHz	± 200 mHz	± 100 mHz
alert state trigger time	5 minutes	10 minutes	10 minutes	5 minutes

Frequency quality target parameters referred to in Article 127:

Table 2

Frequency quality target parameters of the synchronous areas

	CE	GB	IE/NI	Nordic
maximum number of minutes outside the standard frequency range	15 000	15 000	15 000	15 000

(4) Article 6(3)(d)(i) of the SO Regulation states:

"The proposals for the following terms and conditions or methodologies shall be subject to approval by all regulatory authorities of the concerned region, on which a Member State may provide an opinion to the concerned regulatory authority: […]
(d) methodologies, conditions and values included in the synchronous area operational agreements in Article 118 concerning:
(i) the frequency quality defining parameters and the frequency quality target parameter in accordance with Article 127;

2.2 Interpretation and scope of the Proposal

This Proposal reflects the frequency quality defining parameters and the frequency quality target parameter in accordance with Article 127. The scope of this Proposal only includes these parameters. Although these parameters are related to security of supply, under different circumstances they may have different impact on the operational security of the Nordic synchronous area. I.e. although the frequency quality defining parameters apply for all hours of the year, the risk of a supply interruption due to the exhaustion of FCR will vary over the year, dependent on load, generation and generation mix, import and export. Furthermore, a frequency excursion outside the standard frequency range may have a differing impact on the risk of a supply interruption for different hours of the year. Article 131(2) of the SO Regulation requires that all TSOs of each synchronous area shall jointly develop common proposals for a methodology to assess the risk and the evolution of the risk of exhaustion of FCR of the synchronous area. This methodology will be described in a separate proposal and will address impact of different circumstances.

3. Objective of frequency quality

3.1 Main objective maintaining frequency quality

To maintain a good security of supply level, TSOs shall maintain the active power[1] balance between consumption and generation in the synchronous area. The system frequency is a direct indicator for the total active power balance in the whole synchronous area:

- If the active power generation exceeds the active power consumption, the system frequency will rise, and, vice versa,
- if the active power consumption exceeds the active power generation, the system frequency will fall

and will result in a deviation from the Nominal Frequency. The gradient (the speed) of the frequency deviation is determined by the amount of kinetic energy stored and released by the synchronously connected rotating masses (inertia) after a disturbance of the active power balance (there are also first attempts to obtain the same effect from non-synchronously connected generators via power electronics). The frequency deviation is in principle the same all over the synchronous area[2]. Therefore, the system frequency and frequency quality shall be considered a 'common good' that affects all system users.

Since for technical reasons the operational range of generators is limited to a certain system frequency range, frequency deviations outside of this range would trigger the according automatic protection mechanisms leading to a disconnection of the generators in the whole synchronous area, immediately followed by a complete blackout.

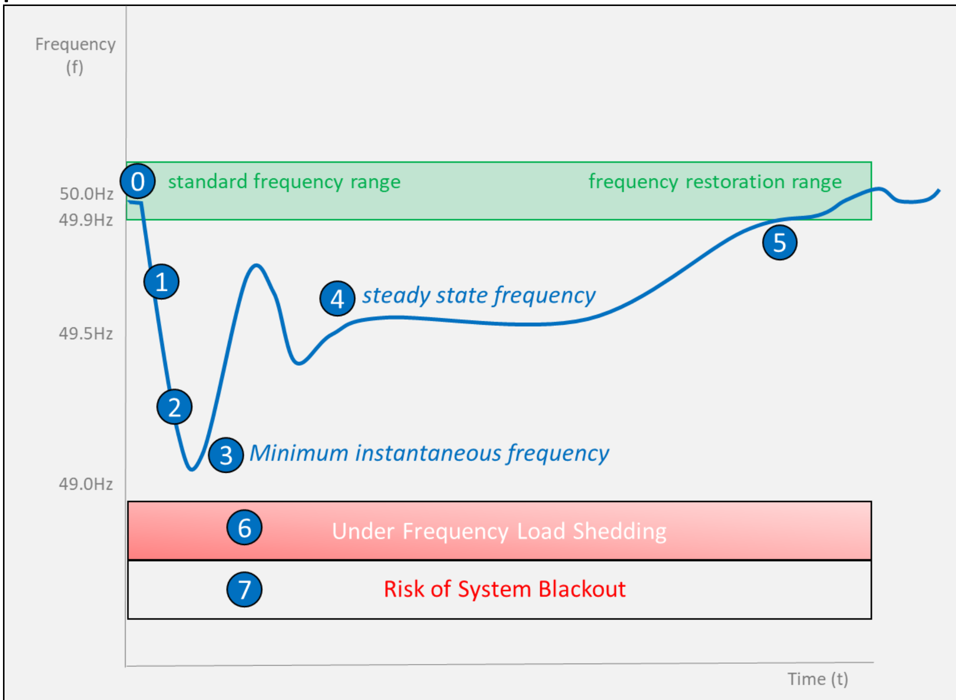
To avoid the complete blackout, TSOs maintain the *frequency quality* by:

[1] Active power is defined as the real component of the apparent power at fundamental frequency, expressed in watts or multiples thereof such as kilowatts ('kW') or megawatts ('MW').
[2] See Figure 3 for an exception of this principle.

1. Keeping the *frequency* at times without large disturbances close enough to 50Hz;
2. Arrange sufficient and accurate measures (reserves, inertia) to limit the instantaneous and stationary *frequency deviation* after an incident;
3. Arrange *emergency measures* such as automatic Under Frequency Load Shedding (UFLS) to limit the impact of large events that are not addressed sufficiently by the measures mentioned under 2.

Textbox 1 explains what happens in case of a large instantaneous imbalance in (a) negative or (b) positive direction.

Textbox 1a: **What happens after a large instantaneous imbalance in a negative direction, e.g. a trip of a large power plant?**



0 After the disturbance (e.g. a trip of a large generator), 1 the instantaneous imbalance results in a fall of the system frequency *(f)*, the slope of the system frequency fall *(df/dt)* is limited by the kinetic energy in the system (inertia). In case of less inertia, the slope of system frequency will be steeper, and vice versa;

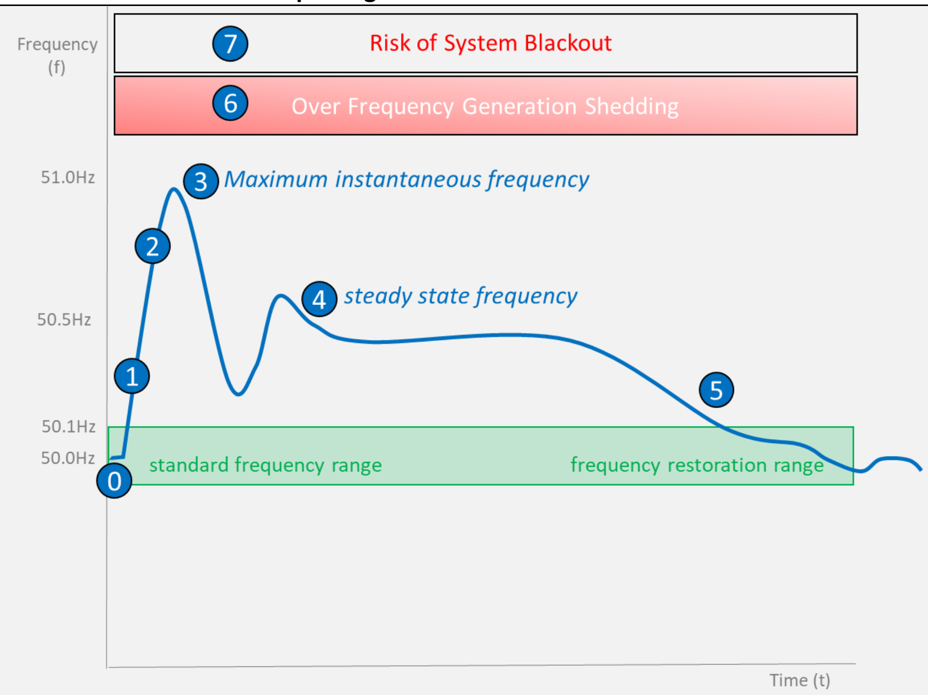
2 Frequency Containment Reserves (FCR) providers respond within seconds, 3 the FCR response stops the frequency decrease at the *minimum instantaneous frequency* and 4 restores the frequency to the *steady state frequency*;

5 The Frequency Restoration Reserves (FRR) replace the FCR response within minutes and brings the frequency back to the frequency restoration range;

6 If the FCR process is not able to keep the frequency above the frequency at which automatic Under Frequency Load Shedding (UFLS) is triggered, automatic UFLS will trip part of the load in stages at different frequency levels until the frequency has stopped to decrease;

7 If even automatic UFLS is not sufficient to stop the frequency from falling, generators may trip and a blackout may take place.

Textbox 2b: **What happens after an instantaneous imbalance in a positive direction, e.g. a trip of a very large industrial customer or an exporting HVDC interconnector?**



0 After the disturbance (e.g. a trip of an exporting HVDC interconnector), 1 the instantaneous imbalance results in a rise of the system frequency *(f)*, the slope of the system frequency rise *(df/dt)* is limited by the inertia in the system. In case of less inertia, the slope of system frequency will be steeper, and vice versa;

2 Frequency Containment Reserves (FCR) providers respond within seconds, 3 the FCR response stops the frequency increase at the *maximum instantaneous frequency* and 4 restores the frequency to the *steady state frequency*;

5 The Frequency Restoration Reserves (FRR) replace the FCR response within minutes and brings the frequency back to the frequency restoration range;

6 If the FCR process is not able to keep the frequency below a certain frequency, generation will be automatically reduced;

7 If even automatic reduction of generation is not sufficient to stop the frequency from rising, more generators may trip and a blackout may take place.

The main objective of *maintaining frequency quality* is to limit the risk of supply interruptions caused by imbalances to acceptable levels. Following this main objective, the frequency quality determining parameters set the limits for frequency deviations for which the power system shall be capable to handle the so-called reference incidents[3] without any interruptions of supply, i.e. without applying the emergency measures such as automatic UFLS. This means that after an occurrence of the reference incident while the system frequency

[3] According to SO Regulation, article 3(2)(58) 'reference incident' means the maximum positive or negative power deviation occurring instantaneously between generation and demand in a synchronous area, considered in the FCR dimensioning. The Nordic proposal for 'the dimensioning rules for FCR' (in line with SO Regulation, article 118(1)(a)) further details the definition of reference incident for the Nordic situation.

is within the standard frequency range, the system frequency shall not reach the levels at which automatic UFLS will start to be applied.

3.2 Other objectives maintaining frequency quality

The requirements in the European Generator Connection Code and the Demand Connection Code[4] describe that if the frequency is in between 49.0 and 51.0Hz, demand and generation shall be capable of remaining connected to the network and operating for unlimited time. If the frequency is outside this range, but inside 47.5-51.5Hz, demand and generation shall be capable of remaining connected to the network and operating for at least 30 minutes.

European Standard EN 50160 specifies the Voltage characteristics that shall be supplied by electricity distribution networks. In fact, this standard defines the minimum quality that end users may expect at their connection. With respect to system frequency, EN 50160 requires that - under normal operating conditions - the system frequency shall be within 49.5-50.5Hz for 95% of time[5]. Currently, the Nordic frequency quality is far better than required by this standard since excursions outside this frequency band are very rare and usually very short[6].

Network equipment of TSOs and DSOs shall be able to operate safely and securely within the frequency range in which the power system is operated. Typically, power transformers may be vulnerable to a combination of high voltage and low frequency. In this situation, (over)flux may create intolerable heating of the core. Transformer design needs to take this into account.

4. The existing situation

4.1 Nominal Frequency and Standard Frequency range

The existing Nordic System Operation Agreement (SOA) describes the current requirements. Section 1.1 of appendix 3 of the SOA states that the highest permissible variation in the frequency during normal state is within the 49.90 to 50.10Hz band and that the goal of the Nordic TSOs is to maintain 50.00 Hz. The number of minutes with frequency outside 49.90 to 50.10Hz band shall be kept at a minimum.

4.2 Maximum steady-state frequency deviation

The main reason for keeping the frequency within the 49.90 to 50.10Hz band is that frequencies outside this band are reserved for disturbances. I.e. below 49.90Hz, Frequency Controlled Disturbance Reserves (FCR-D) will be activated. FCR-D will be fully activated and stabilises on a steady state frequency of 49.50Hz. FCR-D is dimensioned in such a way that it is sufficient to ensure that the biggest single incident in the system[7] will not result in instantaneous frequencies that may trigger automatic Under Frequency Load Shedding (UFLS), which is the last barrier to prevent for frequencies that may trigger power plant outages and consequently a blackout. Furthermore, the frequency shall stabilise on a steady state value of not lower than 49.50Hz.

4.3 Maximum instantaneous frequency deviation

It shall be noted that apart from FCR-D also other system parameters (inertia, response of load to frequency, contribution of load trips etc.) affect the instantaneous frequency deviation after the reference incident. These parameters change continuously and accordingly affect the instantaneous frequency deviation after the reference incident. The SOA specifies that the first stage of automatic UFLS will be triggered at 48.80Hz.

[4] Article 12 of Commission Regulation (EU) 2016/1388 of 17 August 2016.

[5] To be more precise: based on 10s measurement intervals monitored over 1 week.

[6] According to Fingrid's F-Report (report Frequency quality analysis for year 2015, Fingrid, 16.8.2016) between 2008 and 2015 on average 1 event per year with a duration of not more than 10.8s.

[7] 'Dimensioning fault' according to the existing Nordic System Operation Agreement and the 'reference incident' in accordance with the terminology applied in the SO Regulation.

Even at unfavourable conditions such as low inertia levels, this should be below the minimum instantaneous frequency after the reference incident that took place at 49.90Hz.

4.4 Time to restore frequency and frequency restoration range

The Frequency Restoration Process restores FCR-D by activating Frequency Restoration Reserves (FRR). Currently, the TSOs apply mainly manual FRR (mFRR) and the full activation time of this mFRR has been set to 15 minutes. One of two main reasons for having a time limit of 15 minutes is that it is a good time span for starting up hydro power units and gas turbines. The second reason for it is that it takes approximately 15 minutes for an overloaded power line to start sagging dangerously[8], which means that manual mFRR activation shall have mitigated the overloadings after imbalances within 15 minutes. In line with this, the current SOA states that after an N-1-fault the system shall be brought to a state where it can withstand any N-1-fault within 15 minutes, i.e. where the activated FCR-D is completely restored/replaced by FRR which shall be the case if the frequency is above 49.90Hz. Based on the above and in the terminology of the SO Regulation: the restoration range is 49.90 – 50.10Hz and the time to restore the frequency to this range is 15 minutes.

4.5 Maximum Number of Minutes outside the standard frequency range

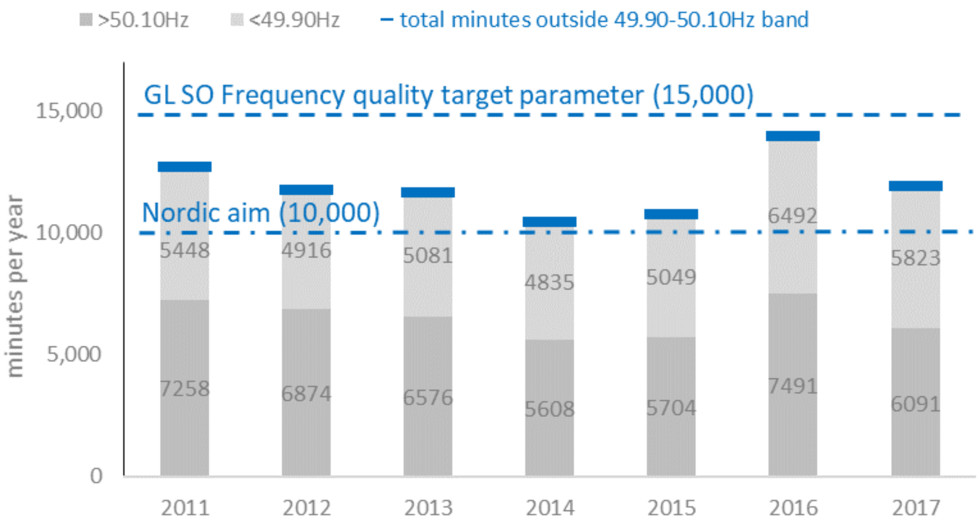


Figure 1: Number of minutes outside the standard frequency range per year[9].

If the reference incident takes place at times that the frequency levels are below 49.90Hz, there is a risk that automatic UFLS takes place. For many years, the Nordic TSO apply the Minutes outside the standard frequency range per year as a proxy for this risk. The Nordic synchronous area faced an increasing number of minutes outside the standard frequency range in the first decade of this century. In order to stop this trend, the TSOs applied several measures and Figure 1 shows that the number of minutes outside the standard frequency was in the years 2011-2017 between 10,000 and 15,000.

The Nordic TSOs agreed that the aim for frequency deviations outside standard frequency range is not more than 10,000 min/year. This aim is considered when specifying the measures to keep frequency within the

[8] Rule of thumb. Depends on loading before over loading occurs, and is also depending on chosen construction criteria of single lines.

[9] The numbers are determined using the definition explained in Textbox 3 which is in accordance with the SO Regulation. The TSOs applied another definition before which means that the values from before 2011 are not completely comparable with the values in this figure.

standard frequency range. However, it should not be seen as an absolute ‘maximum’ for the number of minutes outside the standard frequency range, as mentioned in article 127 of the SO Regulation.

Textbox 3: Counting minutes/time outside the standard frequency range

SO Regulation article 131(a)(iv) requires that “*The frequency quality evaluation criteria shall comprise [..] for the instantaneous frequency data [..] the total time in which the absolute value of the instantaneous frequency deviation was larger than the standard frequency deviation[..]”*. Since SO Regulation article 3(2)(156) defines standard frequency deviation as *“the absolute value of the frequency deviation that limits the standard frequency range”*, this is in fact the time that the frequency is not within the *standard frequency range.* SO Regulation article 3(2)(131) defines “*instantaneous frequency data*’ as *“a set of data measurements of the overall system frequency for the synchronous area with a measurement period equal to or shorter than one second used for system frequency quality evaluation purposes;*

It may therefore be understood that the minutes outside the standard frequency range shall be determined by observing all frequency samples which should have a measurement period equal to or shorter than one second. If the value is outside the standard frequency range, $\frac{\text{measurement period in s}}{60s}$ shall be added to the number of minutes outside the standard frequency range.

5. Proposal for frequency quality defining parameters and the frequency quality target parameter

The frequency quality defining parameters represent the values which are used for the design of control processes and reserve dimensioning. Furthermore, they are aligned with emergency procedures and operation ranges for generators. The operation of synchronous area has been designed in such a way to guarantee that after a disturbance of the active power balance frequency deviations are kept within a certain range.

For the Nordic synchronous area this implies that large imbalances do not lead to frequency deviations that would trigger automatic under-frequency load-shedding (UFLS). The largest imbalance which by design shall not cause a violation of admissible system frequency ranges is named the reference incident (it also serves as input to the dimensioning of FCR). The reference incident for the Nordic synchronous area is defined in the methodology for dimensioning FCR[10].

The frequency quality defining parameters define the acceptable ranges for system frequency before and after an occurrence of the reference incident (Figure 2). It is important to notice that the parameters do not only include ranges but also the time durations (time to restore frequency) in which the respective ranges should be reached.

[10] Nordic synchronous area proposal for the dimensioning rules for FCR in accordance with Article 153 of the Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation

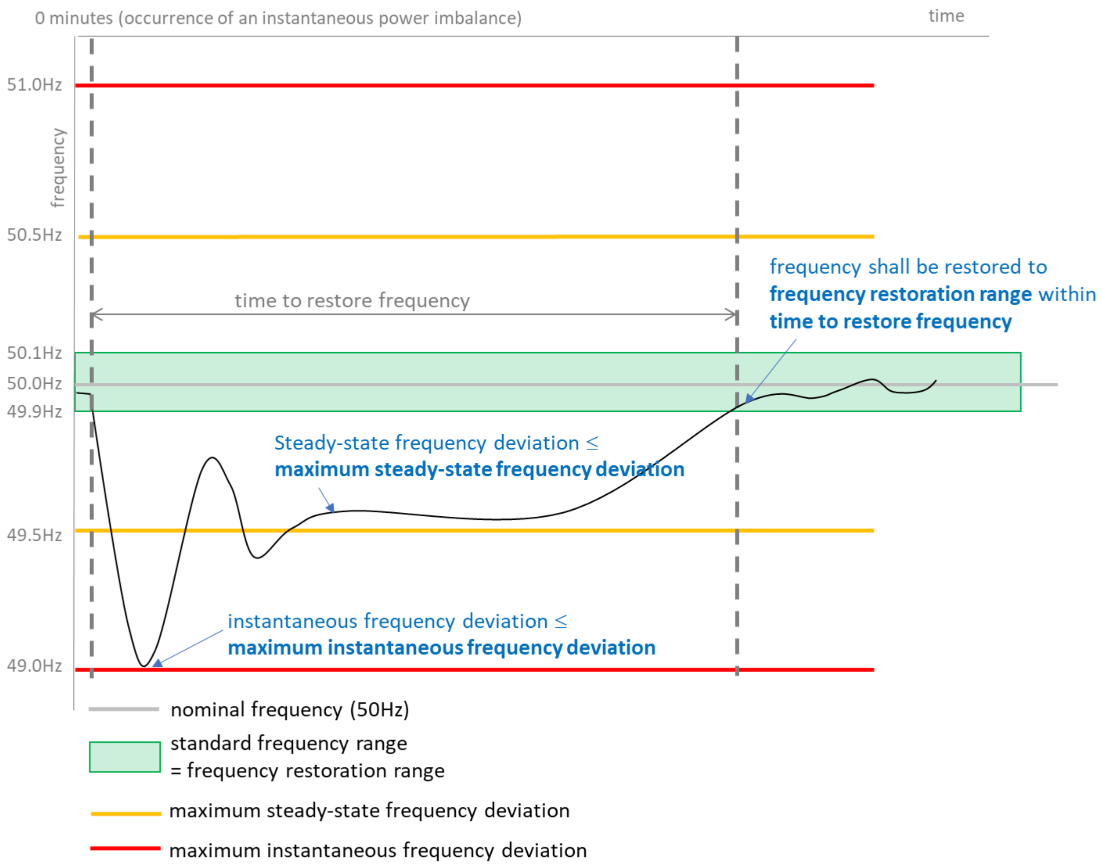


Figure 2: Frequency Quality Defining Parameters

The proposals set out below shall be considered as a continuation of the philosophy that has been applied in the years before this methodology came/comes into force (see section 4).

5.1 Nominal Frequency, Standard Frequency range and Maximum Number of Minutes outside the standard frequency range

The standard frequency range is defined by Article 3(2)(155) of the SO Regulation as the "*defined symmetrical interval around the nominal frequency within which the system frequency of a synchronous area is supposed to be operated.*" Article 127(2) and (3) of the SO Regulation define that the nominal frequency shall be 50Hz and that the default value for the standard frequency range is ± 100mHz, which is the same as the "*highest permissible variation in the frequency during normal state*"[11] in the current Nordic System Operation Agreement (SOA).

The Nordic Frequency Containment Process (FCP) is divided in a 'normal' and 'disturbance' process[12] and applies different types of Frequency Containment Reserves (FCR) for these processes. The intention is that the FCR for normal operation (FCR-N) is used for normal continuous imbalances and that FCR-D is used for incidental disturbances. The activation of the two is linked to the definition of the standard frequency range, i.e. if the frequency is inside the ± 100mHz range, only FCR-N is activated, at ± 100mHz FCR-N reaches its maximum activation and if the frequency is outside the ± 100mHz range also FCR-D responds.

The frequency quality target parameter defined by Article 127(4) the SO Regulation allows the frequency to be outside the standard frequency range for 15,000 minutes per year, which is 2.9% of the time. This number

[11] Nordic System Operation Agreement (SOA) of 20 September 2017, appendix 3, section 1.1 Quality standards

[12] There are differences in how FCR respond in the Nordic countries, mostly due to differences in technology used in the power plants (hydro, thermal).

of 15,000 minutes is the default parameter for frequency quality target parameter for all four synchronous areas that are addressed by the SO Regulation. The current aim of the Nordic TSO is 10,000 minutes per year. The aim of 10,000 minutes per year should be seen in the perspective of stopping the trend of increasing numbers of minutes outside the band of the first decade of the century (see section 4). When specifying measures to improve the frequency quality, the Nordic TSOs therefore apply 10,000 minutes per year.

5.2 Maximum instantaneous frequency deviation

The default value for *maximum instantaneous frequency deviation* is defined by the SO Regulation as 1000mHz and therefore allows an instantaneous frequency of up to 51.0Hz and down to 49.0Hz. For under frequency, this leaves 200mHz to the first trigger frequency of the automatic UFLS relays at 48.8Hz. This 200mHz buffer seems reasonable, and includes a margin for geographic variations in frequency and inaccuracies in models and measurements[13]. Figure 3 shows an example of the geographic variations in frequency after an instantaneous imbalance. The TSOs therefore propose applying the default value that is specified in table 1 of Annex 3 of the SO Regulation: 1000mHz.

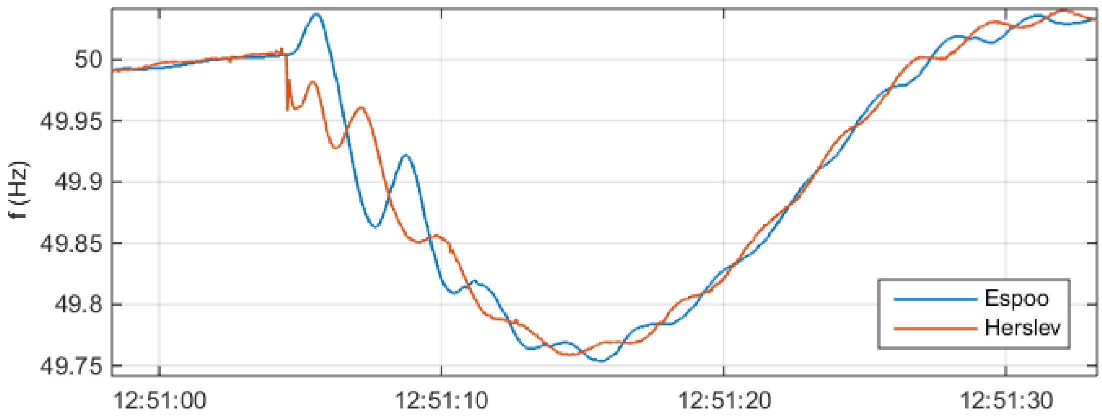


Figure 3: Frequency in Espoo (Southern Finland) and Herslev (Denmark) after a loss of 580MW

5.3 Maximum steady-state frequency deviation

The SO Regulation defines *steady state frequency deviation*[14] as the *"absolute value of frequency deviation after occurrence of an imbalance, once the system frequency has been stabilised*. Since the Frequency Containment Process (FCP) has the objective to stabilise the frequency[15], the steady state is implicitly defined as the situation after a disturbance in which the FCP has been completed and the Frequency Restoration Process (FRP) has to start. It shall be noted though that these periods may overlap, and that other imbalances may further impact the frequency. It is emphasized that the FCR response differs between the Nordic countries.

For the Nordic system, the *maximum steady-state frequency deviation* does not have a direct link to the UFLS risk. Hence, the *maximum steady-state frequency deviation* implicitly indicates the frequency range at which

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[13] A UCPTE document from 1997 splits the 200mHz margin used in Continental Europe into four parts: 1) Possible stationary frequency deviation before the disturbance (50mHz), 2) insensitivities of the turbine governor (20mHz); 3) larger dynamic frequency deviation at the geographic location of the disturbance which is not taken into account by the simulation model (50mHz); and 4) other simulation model inaccuracies, approx. 10% (80mHz). The margin for a possible stationary frequency deviation before the disturbance (50mHz) is not applicable to the Nordic synchronous area since it is already assumed that the disturbance starts at 49.9Hz.

[14] SO Regulation, article 3(2)(157)

[15] SO Regulation, article 142

FCR shall be activated. The *Maximum steady-state frequency deviation* therefore directly links to the definition of FCR-D, which requires an increasing activation from 0% to 100% if the frequency reduces from 49.9 to 49.5Hz. For this reason, it is logical to keep the maximum steady-state frequency deviation to default value that is specified in table 1 of Annex 3 of the SO Regulation: 500mHz.

5.4 Time to restore frequency and frequency restoration range

’Time to restore frequency’ is defined as the maximum expected time after the occurrence of a reference incident in which the System Frequency is restored inside a tolerance range which is named ’frequency restoration range’. Once the frequency is restored after a disturbance, the synchronous area should be able to handle the reference incident again without emergency measures such as automatic UFLS. Since this will only be feasible within the standard frequency range (49.90-50.10Hz), the ’frequency restoration range’ is defined the same as the standard frequency range: 49.90-50.10Hz.

It shall be noted that during the ’Time to restore frequency’ after a disturbance, a reference incident may result in emergency measures such as automatic UFLS. Consequently, the time to restore frequency shall be kept as short as possible. However, in order to restore the frequency, the Frequency Restoration Process (FRP) has to be completed. Especially if manual Frequency Restoration Reserves are involved that require starting up hydro power units or gas turbines, this may take up to 15 minutes.

For this reason, the default value of 15 minutes for time to restore frequency that is defined by the SO Regulation is reasonable and is proposed by the TSOs.

The impact of a ‘time to restore frequency’ of 15 minutes is that a) the power system may not be able to cater for a reference incident within 15 minutes after another incident; b) the specified duration of the full deployment of FCR must be at least 15 minutes and c) If the power system is operated in such a way that an instantaneous imbalance may lead to overloading a power line, it shall be possible to overload these lines for at least 15 minutes.

5.5 Alert state trigger time

Article 18 of the SO Regulation defines the system states, which are defined as the operational state of the transmission system in relation to the operational security limits which can be normal state, alert state, emergency state, blackout state and restoration state. This section 5.5 concentrates on the Alert state in relation to frequency and more specifically on the value for the Alert State Trigger Time. Since the definition of Alert State Trigger Time in the SO Regulation does not seem to be unambiguous, section 5.5.1 starts with a proposed interpretation of ‘alert state trigger time’ and ‘steady state frequency’.

5.5.1 Definitions and proposed interpretation

Steady State frequency

According to article 18 of the SO Regulation, the alert state is triggered if the *steady state frequency* is outside a specified band for a certain time. SO Regulation art. 3(2)(157) define steady state frequency deviation as the absolute value of frequency deviation after occurrence of an imbalance, once the system frequency has been stabilised. Hence, article 18 seems to assume that the steady state frequency is continuously changing. Conversely, article 3(2)(157) suggests that for each disturbance, there is only one value of steady state frequency. It is therefore concluded that the definition in article 3(2)(157) cannot be applied to article 18.

As an alternative, the Nordic TSOs apply the *rolling average of the previous 60s period* as a proxy for the *steady state frequency* that triggers the alert state in accordance to article 18 of the SO Regulation. The main argument for choosing a 60s average is to cancel out the effect of the frequency oscillations in the Nordic system.

Alert State trigger time

The ‘alert state trigger time’ is defined as *‘the time before alert state becomes active’ (SO Regulation art. 3(98))*. Since the *‘time before’* does have a starting point, the TSOs define the starting point as the time of the disturbance: *Alert state trigger time means the time that has elapsed after the disturbance and during which the average system frequency deviation calculated over the previous 60s continuously exceeded 50% of the maximum steady state frequency deviation (250mHz).*

5.5.2 Impact of 'Alert State' and 'Alert State Trigger Time'

The definition of 'Alert State' and setting the 'Alert State Trigger Time' will have impact on the following requirements in the SO Regulation:

- When entering in Alert State, the synchronous area monitor will need to inform the other TSOs that the system is in Alert State (SO Regulation art. 152(3));
- When in Alert State, the 'common rules' (SO Regulation art. 152(6)) and 'operational procedures' (SO Regulation art. 152(10)) for the alert state will become active. These rules and procedures shall be defined by the TSOs in other methodologies;
- When in Alert State, the TSOs have the right to require changes in the active power production or consumption of power generating modules or demand units in order to reduce or to remove the violation of the requirements concerning active power reserve (SO Regulation art. 152(11));
- SO Regulation art. 156(9-10) defines the minimum activation period to be ensured by FCR providers: 'As of triggering the Alert State and during the alert state, each FCR provider shall ensure that its FCR providing units or groups with limited energy reservoirs are able to fully activate FCR continuously for a time period to be defined.' 'This period shall not be greater than 30 or smaller than 15 minutes.' Alert State Trigger Time determines after what time this functionality requirement for FCR becomes active. Note that this functionality requirement is only valid for Alert State.

5.5.3 Alert State Trigger Time

The default value for alert state trigger time is defined by the SO Regulation to 5 minutes. However, according to the SO Regulation, the TSOs shall have the right to propose alternative values in the synchronous area operational agreement[16]. The TSOs will not use this right.

5.6 Summary

Table 1 provides an overview of the proposed parameters of the Frequency Quality Defining Parameters. These are in accordance with the SO Regulation.

Table 1: **Frequency quality defining parameters for the Nordic synchronous area.**

Frequency quality defining parameters	
nominal frequency	50 Hz
standard frequency range	±100 mHz
maximum instantaneous frequency deviation	1000 mHz
maximum Steady-state frequency deviation	500 mHz
time to restore frequency	15 minutes
frequency restoration range	±100 mHz
alert state trigger time	5 minutes

[16] SO Regulation, article 127(6)

The aim for frequency deviations outside the standard frequency range is not more than 10,000 min/year. However, Table 2 shows the frequency quality target parameter, which is considered as the absolute maximum of minutes outside the standard frequency range.

Table 2: **Frequency quality target parameter for the Nordic synchronous area.**

Frequency quality target parameter	
maximum number of minutes outside the standard frequency range	15,000

6. Expected impact of the Proposal on the relevant objectives of the SO Regulation

The Proposal generally contributes to and does not in any way hamper the achievement of the objectives of Article 4 of the SO Regulation. In particular, the Proposal serves the objectives to:

- Article 4(1)(c) determining common load-frequency control processes and control structures;
- Article 4(1)(d) ensuring the conditions for maintaining operational security throughout the Union;
- Article 4(1)(e) ensuring the conditions for maintaining a frequency quality level of all synchronous areas throughout the Union; and
- Article 4(1)(h) contributing to the efficient operation and development of the electricity transmission system and electricity sector in the Union.

The Proposal contributes to these objectives by specifying the values for the frequency quality defining parameters and for the value of the frequency quality target parameter that the TSOs shall endeavour to comply with. The proposed values for the frequency quality defining parameters and for the value of the frequency quality target parameter intend to set efficient limits to the system frequency in different circumstances with the main objective to balance the operational security (risk for supply interruptions) and efficient operation of the electricity system (cost of load-frequency control measures to comply with the values). Furthermore, compliance with the proposed values ensures compliance with relevant international standards for user appliances.

7. Timescale for the implementation

The Proposal is based on the limits that are currently applied in the Nordic synchronous area. The Nordic synchronous area generally complies with the proposed frequency quality defining parameters and the frequency quality target parameter. Therefore, the TSOs shall implement the Proposal not later than when Nordic synchronous area operational agreement enters into force in accordance with Article 118 of the SO Regulation.

8. Public consultation

Article 11 of the SO Regulation states that: *"TSOs responsible for submitting proposals for terms and conditions or methodologies or their amendments in accordance with this Regulation shall consult stakeholders, including the relevant authorities of each Member State, on the draft proposals for terms and conditions or methodologies listed in Article 6(2) and (3). The consultation shall last for a period of not less than one month."*

This proposal will be consulted in the period 1 June to 1 July 2018.