Explanatory document for the amended Nordic LFC block methodology for ramping restrictions for active power output in accordance with Article 137(3) and (4) of the Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation

Explanatory document to the proposed methodology of 30 January 2023 (for public consultation)

Contents

1. Introduction

The Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation (hereinafter **"SO Regulation"**)[1] 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 the SO Regulation/Regulation (EU) 2019/943 is the safeguarding of operational security, frequency quality and the efficient use of the interconnected system and resources. In order to deliver these objectives, a number of steps are required.

One of these steps is to define the ramping restrictions for active power output for the Nordic LFC block. Pursuant to Article 119(1)(c) of the SO Regulation, all Transmission System Operators in the Nordic LFC block shall jointly develop common proposals for ramping restrictions for active power output in accordance with Article 137(3) and (4).

According to Article 6(3)(e)(i) of the SO Regulation the methodology for ramping restrictions for active power output in accordance with Article 137(3) and (4) shall be submitted for approval by the relevant national regulatory authorities (hereinafter "NRAs").

The methodology that is accompanied by this explanatory document amends the methodology that has been approved by the NRAs in February 2022. This methodology is from all TSOs of the Nordic LFC block (hereinafter **"TSOs"**).

This explanatory document contains an explanation of the amendments. It is structured as follows. The legal requirements for the Methodology are presented in Chapter 2. Chapter 3 describes the objective of ramping restrictions. Chapter 4 provides an overview of the existing situation. Chapter 5 describes the developments that trigger this amendment and chapter 6 explains the amendments. An outlook to future developments is described in Chapter 7. Chapter 8 describes the expected impact on the relevant objectives of the SO Regulation. Finally, Chapter 9 provides the timeline for implementation and Chapter 10 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 Methodology must take into account. These are cited below.

(1) Article 119(1)(c) and (2) of the SO Regulation constitutes the legal basis that the Methodology should take into account. Article 119 has the following content:

> *"1. By 12 months after entry into force of this Regulation, all TSOs of each LFC block shall jointly develop common proposals for:[…]*
>
> *(c) ramping restrictions for active power output in accordance with Article 137(3) and (4); […]*
>
> *2. All TSOs of each LFC block shall submit the methodologies and conditions listed in Article 6(3)(e) for approval by all the regulatory authorities of the concerned LFC block. Within 1 month after the approval of these methodologies and conditions, all TSOs of each LFC block shall conclude an LFC block operational agreement which shall enter into force within 3 months after the approval of the methodologies and conditions"*

[1] As amended by Commission Implementing Regulation (EU) 2021/280 of 22 February 2021, amending Regulations (EU) 2015/1222, (EU) 2016/1719, (EU) 2017/2195 and (EU) 2017/1485 in order to align them with Regulation (EU) 2019/943.

(2) Article 137(3) and (4) of the SO Regulation has the following content:

"3. All connecting TSOs of an HVDC interconnector shall have the right to determine in the LFC block operational agreement common restrictions for the active power output of that HVDC interconnector to limit its influence on the fulfilment of the FRCE target parameter of the connected LFC blocks by agreeing on ramping periods and/or maximum ramping rates for this HVDC interconnector. Those common restrictions shall not apply for imbalance netting, frequency coupling as well as cross-border activation of FRR and RR over HVDC interconnectors. All TSOs of a synchronous area shall coordinate these measures within the synchronous area.

4. All TSOs of an LFC block shall have the right to determine in the LFC block operational agreement the following measures to support the fulfilment of the FRCE target parameter of the LFC block and to alleviate deterministic frequency deviations, taking into account the technological restrictions of power generating modules and demand units:

(a) obligations on ramping periods and/or maximum ramping rates for power generating modules and/or demand units;

(b) obligations on individual ramping starting times for power generating modules and/or demand units within the LFC block; and

(c) coordination of the ramping between power generating modules, demand units and active power consumption within the LFC block."

(3) Article 6(3)(e)(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: […]
(e) methodologies and conditions included in the LFC block operational agreements in Article 119, concerning:
(i) ramping restrictions for active power output in accordance with Article 137(3) and (4);

2.2 Interpretation and scope of the Methodology

Article 137(3) of the SO Regulation provides the TSOs with the right to determine common restrictions for the active power output of that HVDC interconnector.

These restrictions may impact both operation of the HVDC interconnectors and market exchanges over these interconnectors as indicated in Figure 1. The red line shows the commercial flow of an HVDC interconnector resulting from the different power markets. The commercial flow has the same resolution as the power markets and is therefore constant during one Market Time Unit (MTU). Consequently, the commercial flow schedules are characterised by discrete *steps between MTUs*. The blue lines indicate the physical ramping pattern which is followed in operations. The line shows that at the beginning of the *ramping period*, the HVDC interconnector starts ramping to the value for the next MTU following a constant *ramping rate*.

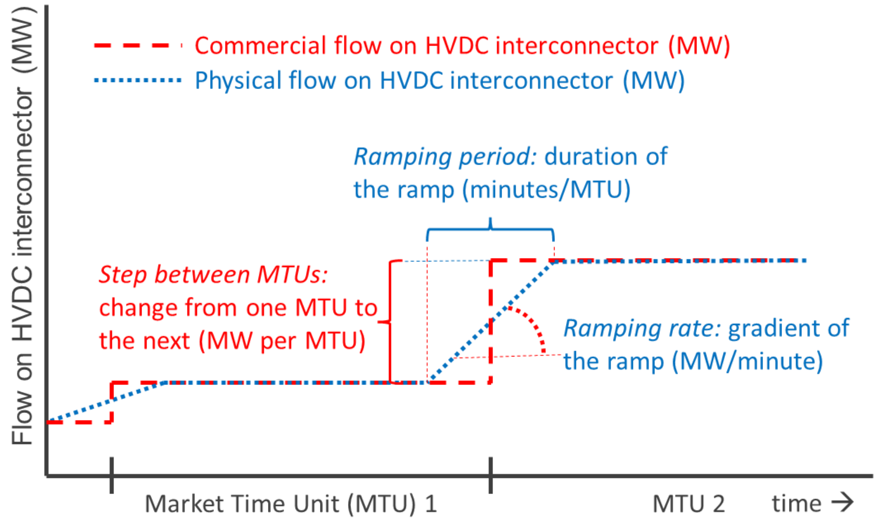


Figure 1: Relation between operational and market impact of ramping restrictions and terminology

Article 137(3) of the SO Regulation allow physical ramping restrictions specified by maximum *ramping period* and the maximum *ramping rate*. The amended methodology therefore specifies these parameters. However, it is noted that these restrictions can only be implemented in market systems by a maximum *step between MTUs* which is based on the multiplication of the maximum *ramping period* and the maximum *ramping rate*.

Since the Nordic synchronous area only consists of one LFC block, the HVDC interconnectors to other LFC blocks are always HVDC interconnectors to other synchronous areas. The restrictions for the active power output of HVDC interconnectors between synchronous areas as referred to in Article 137(1) and (2) of the SO Regulation shall therefore be the same as the restrictions for the active power output of the HVDC interconnectors that are proposed in this Methodology.

Article 137(4) of the SO Regulation provides the TSOs with the right to determine ramping restrictions for power generating modules and demand units. Article 137(4)(a) and (b) allow defining obligations for power generating modules and/or demand units while Article 137(4)(c) allows the TSOs to actively coordinate between generating modules, demand units and active power consumption within the LFC block.

3. Objective of ramping restrictions for active power output

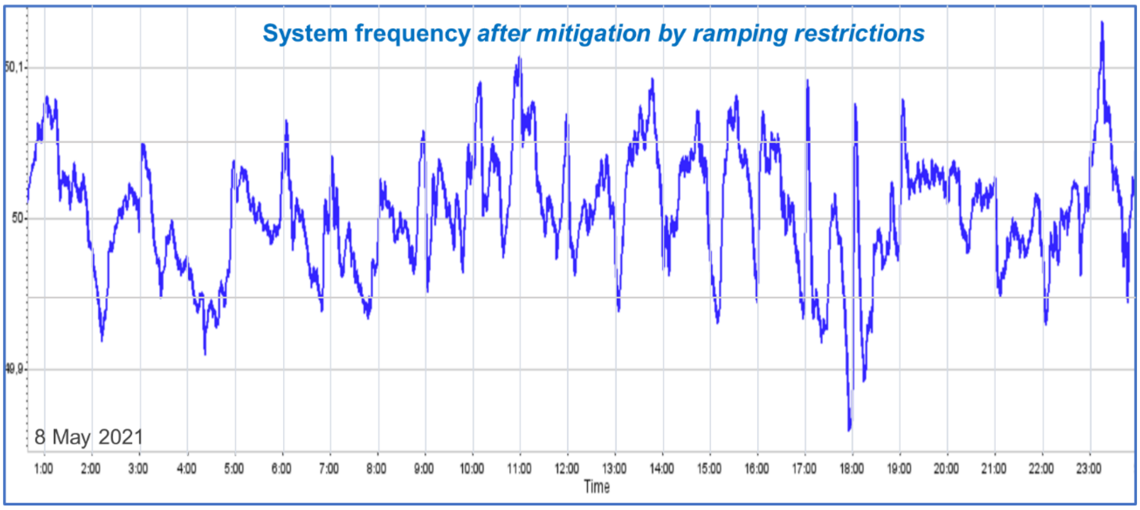


Figure 2: Example of system frequency in the Nordic synchronous area. The figure shows that even after taking a number of measures Deterministic Frequency Deviations (DFDs) around the hour shifts are clearly visible *(source Energinet)*

Figure 2 shows that the system frequency in the Nordic synchronous area is characterised by sharp peaks around the times that the market schedules change, which are currently hour shifts. These peaks are called deterministic frequency deviations (DFDs) and are caused by the momentary structural imbalances that result from differences in ramping between electricity demand, production and HVDC exchange to other synchronous areas.

In order to keep the DFDs manageable, the Nordic TSOs introduced a number of measures that reduce the structural imbalance. Most notably, ramping restrictions on HVDC cables and production reduce the mismatch between HVDC ramping, production ramping and consumption ramping. The remaining momentary imbalances are mitigated by activating automatic reserves (FCR, aFRR). Figure 2 shows that even with all these measures in place, the DFDs do not completely disappear. However, they are reduced sufficiently to meet the frequency quality targets in the SO Regulation, which is not more than 15,000 minutes per year outside the 49.9-50.1 Hz range. However, in most years, the aimed frequency quality of not more than 10,000 minutes per year is not met. Textbox 1 provides further details.

The main objective of ramping restrictions is *ensuring security of supply* in general and most specifically related to the Nordic frequency quality and the FRCE quality in both the Nordic LFC blocks and in each LFC area. Ramping restrictions especially reduce the size of steps in schedules and therefore limit the size of deterministic changes in both system balance and network loading. Hence, ramping restrictions contribute to mitigating the deterministic frequency deviations (DFDs) and consequently meeting the targets for frequency quality and FRCE quality. Maybe even more important, ramping restrictions may prevent for very large frequency deviations in the Nordic synchronous area and play an important role in safeguarding the network stability.

An important objective of this amendment is to *optimise market facilitation*. This means that the ramping restrictions shall promote an efficient use of HVDC interconnectors and therefore optimise the use of restrictions to the above-mentioned security of supply objectives. A previous assessment indicates that there might be possibilities to increase the efficiency of the ramping restrictions, by e.g. including combined ramping restrictions. Furthermore, the use of ramping restrictions shall be optimised with other mitigating measures like e.g. aFRR volumes, based on technical and socioeconomic efficiency.

In addition, ramping restrictions shall *limit the need for corrective measures* in real-time. I.e. in 'normal operation' the ramping restrictions shall prevent the FCR and aFRR activation for deterministic imbalances, counter trading/redispatch using FRR resources and 'five minutes production shifts'. In the ideal situation, corrective measures will only to be used in unexpected situations.

The amendment to the methodology shall implement the changes that are required when the *15 minutes MTU in the day-ahead and intraday market* is introduced. The amendment shall both cover *the enduring situation and the intermediate step* in which the 15 minutes MTU has only been implemented for the intraday market and not yet in the day-ahead market.

The methodology shall also be able to follow the many developments in the Nordic LFC block in the coming years, including (but not limited to) the connection to the connection to the Mari and Picasso platforms and the increasing share of renewable energy sources in electricity production.

The amended methodology shall be *dynamic and flexible* and able to optimise ramping restrictions on a regular basis without the need for amending the methodology again.

Textbox 1: Need for frequency quality – deterministic frequency quality.

If the system frequency in the Nordic synchronous area is outside the standard frequency range (49.9 to 50.1 Hz), the synchronous area faces an increased risk for load shedding or even blackouts. For this reason, the *'number of minutes outside the standard frequency range per year'* is one of the main indicators that is monitored by the Nordic TSOs. Article 127 of SO Regulation stipulates a target parameter of 15 000 minutes per year for this parameter and the Nordic TSOs aim as specified in their System Operation Agreement is 10 000 minutes per year[2]. Figure 3 shows the number of minutes outside the standard frequency range per year since 2011.

[2] See further explanation in the report Nordic Balancing Philosophy, by the Nordic TSOs dated 2021-11-10. The main reasons for applying the aimed frequency quality of 10 000 minutes/year are that the Nordic frequency quality varies a lot from year to year (see Figure 3) and that the Nordic TSOs want to avoid going over 15 000 minutes/year. The Nordic aim of 10 000 minutes/year provides a margin. The TSOs further note that in the first decade of this century, changing market rules and adding HVDC interconnectors caused a quickly deteriorating frequency quality. Since it is not possible to accurately predict how the many market changes in the coming years will impact the frequency quality, a margin is required. Experience showed that long leading times may apply to implementing/changing measures, especially when NRA approved methodologies need to be changed. For these reasons, the TSO apply the margin.

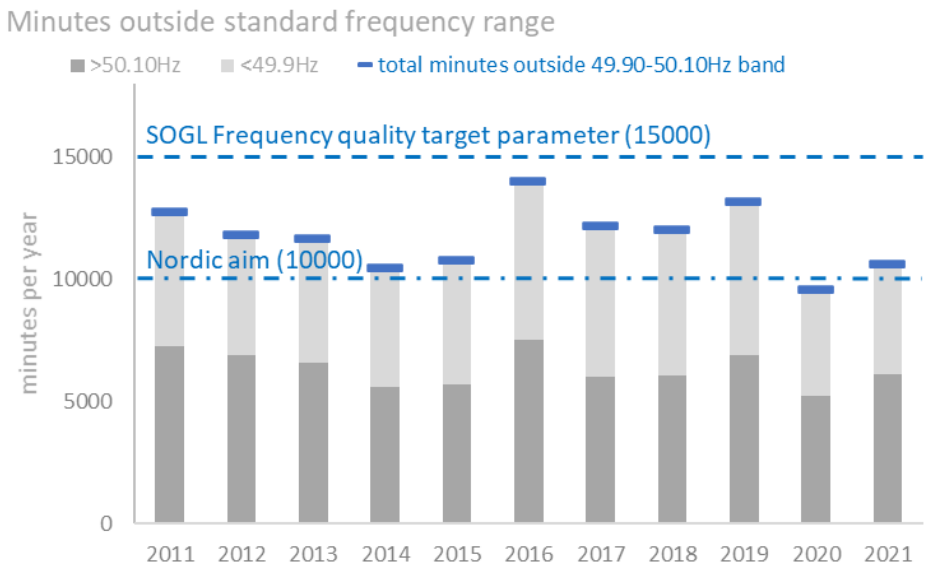


Figure 3: Number of minutes outside the standard frequency range per year in the Nordic synchronous area

A major cause of the excursions of the system frequency outside the standard frequency range are Deterministic Frequency Deviations (DFDs). DFDs are caused by the structural imbalances that result from differences in ramping between electricity demand, production and HVDC exchange to other synchronous areas. Per definition, DFDs appear around the times that the market schedules change, which are currently hour shift. This is illustrated in Figure 4 which shows that there are typically more frequency deviations in the beginning and end of the hour than in the rest of the hour.

Figure 4: Number of seconds per hour outside the standard frequency range for each minute of an average hour. (source: Fingrid frequency quality report 2020)

In order to keep the DFDs manageable, the Nordic TSOs introduced a number of measures that reduce the imbalances causing the DFDs or that mitigate these DFDs. Ramping restrictions contribute by limiting ramping of HVDC schedules and accordingly limit the mismatch of HVDC ramping with production and consumption that cause structural imbalances and DFDs. Furthermore, Nordic ramping restrictions for production units make sure that large production changes will be better spread-out over the hour. It is noted that even with these measures, DFDs do not disappear, as shown in Figure 2 and Figure 4. However they are reduced sufficiently to meet the frequency quality targets in the SO Regulation as shown in Figure 3.

4. The existing situation

Since 2007, the Nordic TSOs apply harmonised limits for ramping-up and ramping-down the power flows on the HVDC interconnectors between the Nordic and other synchronous areas. Similarly, the TSOs apply rules for ramping of production. The objective of these rules and restrictions is to protect the power system against too fast changes of the power balance and the power flows. This is required to stay within the security limits.

In short, the current ramping restrictions and rules are as follows[3]:

- *A maximum* ramping rate of 30 MW/min on each HVDC interconnector;
- A *maximum* step on each HVDC interconnector of 600 MW per hour;
- BRPs with production plans changing more than 200 MW at hour shift need to reschedule their plan with quarterly steps;
- TSOs are allowed to request advancing or delaying parts of planned production steps at the hour shift from 30 minutes before hour shift till 30 minutes after the hour shift;
- A combined restriction HVDC interconnectors connecting LFC area NO2 with Denmark-West (DK1), Germany and Netherlands[4].

In this chapter, the existing ramping restrictions for active power output are detailed. Section 4.1 describes the existing ramping restrictions for HVDC interconnectors and section 4.2 describes the existing ramping restrictions for production plans. Section 4.3 describes the existing possibilities for the TSOs to coordinate ramping between production plans. Ramping of consumption is currently not restricted nor coordinated. The TSOs have investigated the efficiency of the existing ramping restrictions based on figures and simulations of 2019 and updated these simulations in 2021. Section 4.4 provides a summary of the results.

[3] The description of the existing ramping restrictions is based on the amended methodology that has been approved by the Nordic NRAs in February 2022. The methodology is being implemented in accordance with Article 5 of that methodology and the full implementation is expected to be completed by Q1 2023. This description describes the full implementation and adds footnotes to the issues that are not yet completely implemented at the time of writing of this document. Please refer for the exact rules to the NRA approved methodology: *'Amended Nordic synchronous area methodology for ramping restrictions for active power output in accordance with Article 137(3) and (4) of the Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation'* and its explanatory document.

[4] This restriction has not yet been completely implemented. The Skagerrak HVDC interconnector will be added to the combined restriction on NordLink and NorNed as soon as the required update of the XBID system has been completed, which is expected by Q1 2023. Until then, a temporary combined restriction of 900 MW/hour from one hour to the next is applied for NordLink and NorNed and a temporary restriction of 450 MW/hour on each of the HVDC interconnectors Skagerrak and North Sea Link.

4.1 Existing restrictions for HVDC interconnectors

The existing ramping restrictions methodology[3] stipulates that the *maximum ramping rate* on each HVDC interconnector is 30 MW/min. In addition, the *maximum step* per hour on each HVDC interconnector is 600 MW. The TSOs apply different ramping periods on the HVDC interconnectors. A combined restriction applies to HVDC interconnectors connecting LFC area NO2 with Denmark-West (DK1), Germany and Netherlands[4].

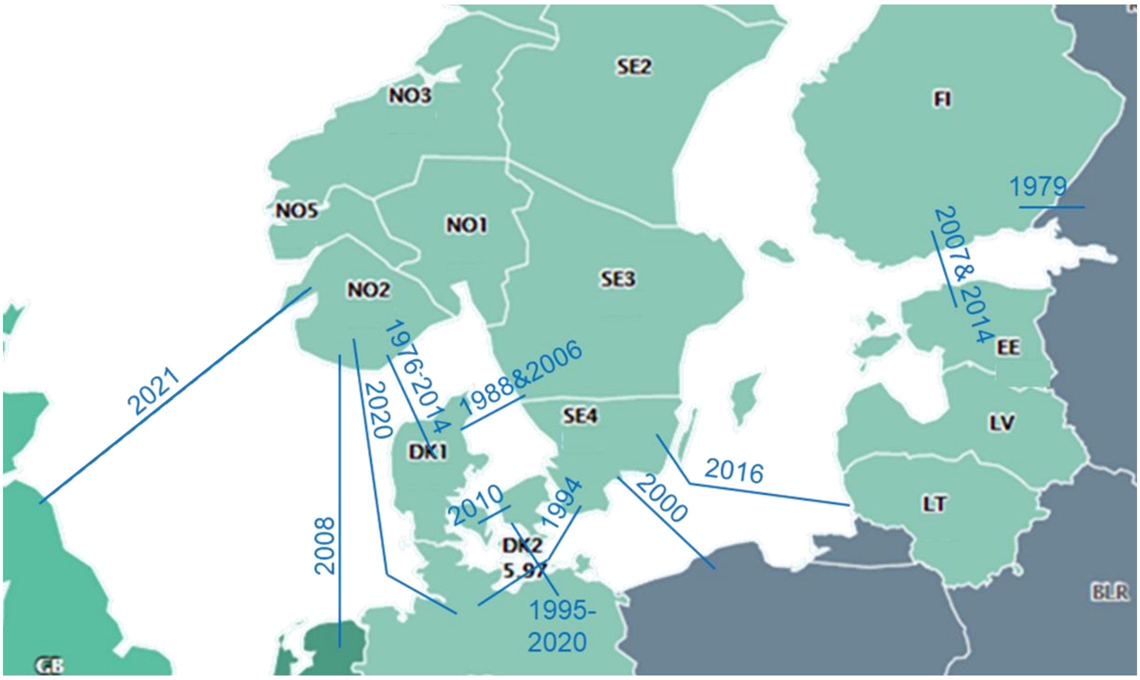


Figure 5: Interconnectors between Nordic and other synchronous areas with their year of implementation (note that some interconnectors consist of several cables implemented in different years)

Figure 5 shows that since the harmonised Nordic HVDC interconnectors started in 2007 the number of HVDC interconnectors increased from 7 to 12. Because the same ramping restrictions are applied on each new HVDC interconnector, the total potential ramp on all Nordic interconnectors and the maximum step from one MTU to the next increased from 2007 with more than 50%. While this has created more room for (ramping) market exchange between the Nordic and other synchronous areas, it also increased the challenge for the TSOs to manage the power imbalance and stay within the security limits for especially FRCE and frequency quality.

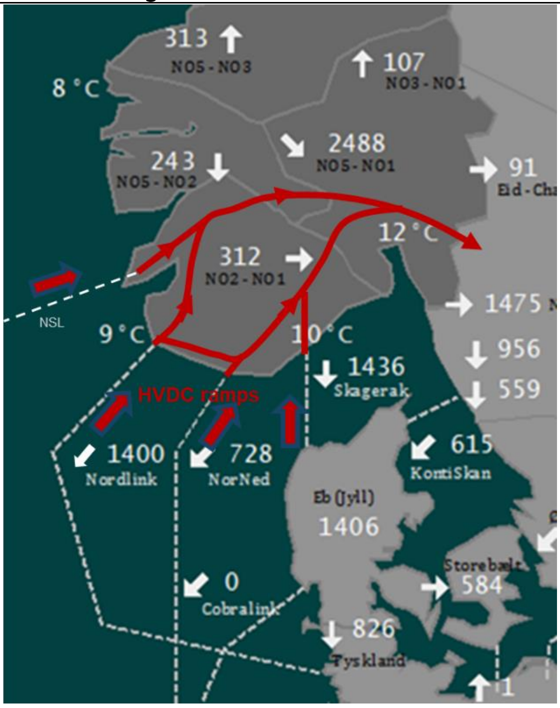
An assessment by the TSOs showed that these ramping restrictions are an efficient tool to prevent momentary imbalances that cause DFDs. They are far more efficient than alternative mitigation measures such as counter trade and contracting additional aFRR. This is further discussed in section 4.4.

The existing individual ramping restrictions do not only limit the ramping on the HVDC interconnectors, but also on the AC network. Consequently, if the ramping restrictions on HVDC interconnectors are relaxed or even removed, the ramping on AC lines may also increase. This does not only apply to AC lines close to HVDC interconnectors but may also affect the lines around connected customers (mainly generation, but maybe also large consumers) that follow the exchange schedules. This may become critical which is illustrated by the need for the current combined ramping restrictions for the HVDC interconnectors connected in NO2 (see Textbox 2).

Textbox 2: Increased ramping on HVDC interconnectors to NO2 affects AC grid

If the 'standard' individual maximum ramping rate of 30 MW/min would be applied to the four interconnectors that connect to NO2, the total flow change could be up to 120 MW/min. At the same time, the margins between grid capacity given to the market and the maximum flow (the TRM), is 50 to 150 MW, dependent on the bidding zone border. With four HVDC interconnectors, the flow in the grid may change so much and fast that it is impossible to prevent overloads in the grid. It is noted that there are many potential congestions between Norwegian HVDC terminal points and Sweden. Consequently, the speed and magnitude of flow changes from ramping needs to be restricted to safeguard system security.

The current ramping restrictions on NO2 limit the ramping to 90 MW/min and safeguard a secure starting position of the daily operation. In cases with unforeseen operational situations or situations not dimensioned for, the TSOs may require additional measures, including the remedial actions as listed in Article 22(1) of the SO Regulation. A large scale and regular use of counter trade between TSOs using mFRR, would require that mFRR volumes had to be secured and considered in the FRR dimensioning. This would tie up resources from use in the energy markets.



4.2 Existing ramping restrictions for production plans

The TSOs apply a ramping restriction on BRPs representing power generating modules in Finland, Norway and Sweden when their hourly production plan changes more than 200 MW at hour shift. In this case BRPs need to reschedule their plan with quarterly steps 15 minutes before hour shift, at hour shift and 15 minutes after hour shift in order to adjust the plans to better correspond to the consumption pattern. In Norway, the steps can be applied 30 minutes before the hour shift until 30 minutes after the hour shift. The detailed terms and conditions are specified on national level. This obligation is not relevant in Denmark East due to the physical characteristics for production.

4.3 Coordinate ramping of production plans

Based on the planning information and real-time information, each TSO assesses the impact of ramping around hour shifts from a national perspective. In addition, Svenska kraftnät and Statnett assess whether the changes in production plans in the Nordic area and the HVDC exchange around hour shift will impact the system frequency in a way that cannot be entirely handled by control centres in the minutes before and after hour shift. If so, there is a need to advance or delay parts of planned production steps at the hour shift. The power schedules may be changed from 30 minutes before hour shift till 30 minutes after the hour shift.

This coordination is mainly important during morning and evening hours and also around day shift. If the changes in the production plans are deemed to be too high, the TSOs make a coordinated plan on how to level out these changes by an agreement with BRPs that represent power generating modules to reschedule the production. In situations with congestions, there is also a need to decide in which order the rescheduling should take place. E.g. in case of close to congestion on Hasle from Norway to Sweden it may be wise to start with increased production in Sweden/Finland 15 minutes before hour shift and decreased production in

Norway in the first 15 minutes after the hour shift[5]. The volumes to be shifted after the hour shift might be reassessed closer to real time if something unplanned occurs that would interfere with the initial plan.

4.4 Assessment of the efficiency of ramping restrictions

Steps in electricity trade have increased over the last decades due to tighter market integration and an increasing number of interconnections between countries and synchronous areas. As a result of this, increasing steps in production make it more and more difficult to ensure the security of supply in the Nordic synchronous area in general and the Nordic system frequency quality in particular. To mitigate this, the Nordic TSOs developed a 'package of measures' which include – among other measures – ramping restrictions on both HVDC interconnectors and production plans (see Textbox 3). Both ramping restrictions aim for reducing the deterministic steps in minute-by-minute plans. While the ramping restrictions on HVDC interconnectors limit the size of the steps from one hour to the next, ramping restrictions for production aim for splitting-up the steps at the hour shift to smaller quarterly steps. Together, these ramping restrictions limit the minute-by-minute imbalances and help the TSOs to maintain the system frequency.

Textbox 3: Deterministic Frequency Deviations (DFDs), Structural imbalances and Ramping restrictions in perspective

Structural imbalances are not the only cause of frequency deviations. Figure 6 also shows stochastic imbalances and disturbances. Furthermore, ramping restrictions are not the only mitigation measure that reduce structural imbalances and limit DFDs. Also FCR and aFRR will contribute to this.

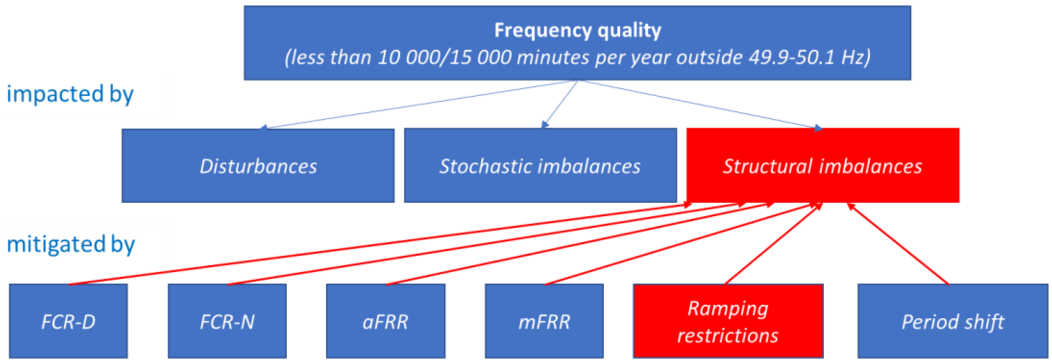


Figure 6: Frequency quality split out to causes and mitigation measures.

As a result of the complexity sketched-out in Figure 6 it is difficult accurately determine the impact of ramping restrictions. However, the assessment in 2020 (see section 4.4) shows that these ramping restrictions are an efficient tool to prevent structural imbalances that cause DFDs. They are far more efficient than the mitigation measures of counter trade and contracting more aFRR.

The TSOs assessed these ramping restrictions in 2020. The assessment covered the ramping arrangements described in sections 4.1 to 4.3 and assesses operational and market issues with a focus on the Nordic synchronous area in 2019. In 2022, part of the assessment has been updated. The most important findings are summarised below.

[5] In Norway and Sweden, it is sometimes possible to reschedule production steps within the hour if there are available production changes to reschedule.

Ramping restrictions for HVDC interconnectors

To evaluate the efficiency of the ramping restrictions on HVDC interconnectors (as described in in section 4.1), the Nordic TSOs assessed the socioeconomic cost of ramping restrictions and compared them with the cost of alternatives, while keeping the current frequency quality at today's level. For this, the TSOs performed market simulations, using the Euphemia algorithm: Both the situation with the existing ramping restrictions on HVDC interconnectors and the hypothetical situation without ramping restrictions have been simulated for four months in 2019 (January, March, June and October), using historical grid situations and historical bids. A similar simulation has been performed for two full month periods in 2021 (15 May– 15 June and October).

The simulation results for 2019 show that ramping restrictions on HVDC interconnectors are most effective when they are most needed: In the approx. 1% of the hours that without ramping restrictions the steps would have been the largest, ramping restrictions reduce the total step on all Nordic HVDC interconnectors to other synchronous areas by 570 to 2200 MWh/h (830 MWh/h on average) and prevent for situations with a step of more than 4300 MWh/h. The simulation results show that the steps on restricted HVDC interconnectors are either shifted to other hours or to other HVDC interconnectors. This results in only minor changes in average Nordic bidding zone prices. The impact of the restrictions on the socioeconomic welfare is limited to less than 1 million Euro per year.

The simulations for 15 May– 15 June 2021 show similar results as for 2019: the difference in socioeconomic welfare between ramping restrictions on individual HVDC interconnectors and 'no ramping restriction' was approx.. 28,000 Euro for the entire period. The results for October 2021 are somewhat different. The main difference is the *new* NordLink (NO2-DE) interconnector which is operated at its maximum ramping rate (600 MWh/h) for approx.. 60 hour shifts during that period. Only the figure for the Skagerrak HVDC interconnector is larger (approx.. 80 hours). The resulting European socioeconomic cost of ramping restrictions was approx.. 640,000 Euro, which is higher than in an average month in 2019 (less than 100,000 Euro)[6].

Ramping restrictions for production

The second type of ramping restrictions aim at minimising minute-by-minute imbalance by distributing hourly steps in production plans over different quarters (as described in section 4.2). The rules require that when the hourly production plan of a BRP changes more than 200 MWh/h at hour shift, the BRP is obliged to send in a quarterly production plan. BRPs ramping above 200 MWh/h usually have a larger number and mix of production units, which can be reoptimized across hours without deviating from the optimal setpoints of production units. In contrast, applying these rules to smaller steps than 200 MWh/h would also affect BRPs with less production units. If they cannot reoptimize across production units, this would result in a deviation from operating at optimal setpoints and, thus, a reduction in production efficiency. This would harm the level playing field and results in energy losses in the Nordic power system.

In practice, these rules mainly affect BRPs that operate hydro units with storage since these BRPs are able to quickly ramp at hour shift. This does not mean that the rules are not applicable to other types of production. However, due to their technical restrictions these other units implicitly follow the requirements (thermal units) or are hardly able to adjust (e.g. intermittent generation and run-of-river hydro generation). Consequently, the rules mainly impact Norway and Sweden, have limited impact in Finland (limited hydro with storage) and are not applied at all in Denmark (no hydro with storage).

The rules further allow the TSOs to adjust the production plans in order to minimise the minute-by-minute imbalance in the Nordic LFC block (as described in section 4.3). The TSOs mainly adjust the plans during morning ramp hours and the day shift. But also during the evening there is quite significant quarterly adjustment. During these hours the TSOs shift up to 480 MW on average weekdays. In total, the TSOs shifted

[6] The combined restriction for NO2 may change the situation from Q1 2023 onwards. Simulations for this scenario are pending because of the unavailability of the Euphemia simulation facility.

403 GWh in 2019, which is less than 0,1% of the total Nordic production in 2019. For these adjustments the TSOs paid a compensation payment of 2.8 million Euros to mainly Norwegian and Swedish BRPs.

Additional measures

The restrictions above reduce the Nordic imbalance around the hour shift. To further reduce the minute-by-minute imbalance, the Nordic TSOs procure 600 MW of FCR-N around the clock and 300 MW aFRR (upward and downward) for the hours with the largest ramps. This is however not sufficient to meet the aimed frequency quality of 10.000 minutes outside the standard frequency range but meets the target frequency quality parameter of 15.000 minutes outside the standard frequency range as specified in the SO Regulation.

Alternative measures to ramping restrictions

It can be argued that if more automatic reserves would be available, the ramping restrictions could be relaxed. However, this comes at a far larger cost: Contracting aFRR in order to slightly relax the ramping restrictions (from 600 MWh/h to 700 MWh/h) would in 2019 have cost 10 to 20 million Euros/year while the socioeconomic benefit in terms of avoided ramping restrictions would be less than 1 million Euro/year (resulting from the simulations described above). A reason for the big difference is that ramping restrictions only reduce socioeconomic welfare in hours that they are effective. Conversely, aFRR capacity needs to be procured for all the hours that large steps on interconnectors could be the result of the energy market clearing. It has to be further noted that – at least in the short term – this alternative is only a theoretical one since insufficient aFRR capability would be available to relax the potential ramping restrictions. Furthermore, it may be operationally challenging to operate with very large amounts of aFRR with current setup since these may also create additional flows and bottlenecks in the system. Additional aFRR is therefore not considered more efficient and effective than ramping restrictions.

Counter trading may also be considered as an alternative to mitigate ramping issues after the market results are known. The assessment shows that this alternative does not result in higher socioeconomic welfare than ramping restrictions while increasing the complexity in operations and the risk of market power abuse. Furthermore, an important challenge of the use of counter trade is that the prices in the spot market will not reflect the real value of power in the different bidding zones with detrimental consequences for use of hydro power storage as well as investments in consumer flexibility or generation capability. The TSOs therefore do not consider counter trading as a more efficient solution for ramping restrictions either.

Conclusion

To sum up, the TSOs consider ramping restrictions on HVDC interconnectors and production BRPs an efficient tool for mitigating large minute-by-minute imbalances at hour shifts, at least until the introduction of the new Nordic Balancing Model and the 15 minutes MTU. However, the assessment also provides some indication that ramping restrictions may be improved and better adapted to the increasing number of HVDC interconnectors.

5. Developments in the Nordic Power system that trigger this amendment

5.1 Main trigger: Introduction of a 15 minutes MTU

The existing ramping restrictions and rules that are discussed in chapter 4 apply to the current situation in which the Imbalance Settlement Period (ISP) and the Market Time Unit (MTU) in the Nordic synchronous are equal to a time period of 1 hour. In May 2023 the Imbalance Settlement Period (ISP) in the Nordic synchronous area will change from 1 hour to 15 minutes. Following this change, the Market Time Unit (MTU) of the Intraday market will also change from 1 hour to 15 minutes (planned for 2024), followed by the change of the MTU in the day-ahead market to 15 minutes (planned for 2025).

The changes of the MTU are the main trigger for the Nordic TSOs to review the strategy towards ramping restrictions[7].

The 15 minutes MTUs in the intraday and day-ahead results in market schedules that will change four times per hour instead of only once per hour. As illustrated in Figure 7, this will create a smoother ramp. It is therefore expected that the implementation of the 15 minutes MTU and ISP will reduce the mismatch between the ramping of demand, production and HVDC. Accordingly, the structural imbalances that cause deterministic frequency deviations will reduce.

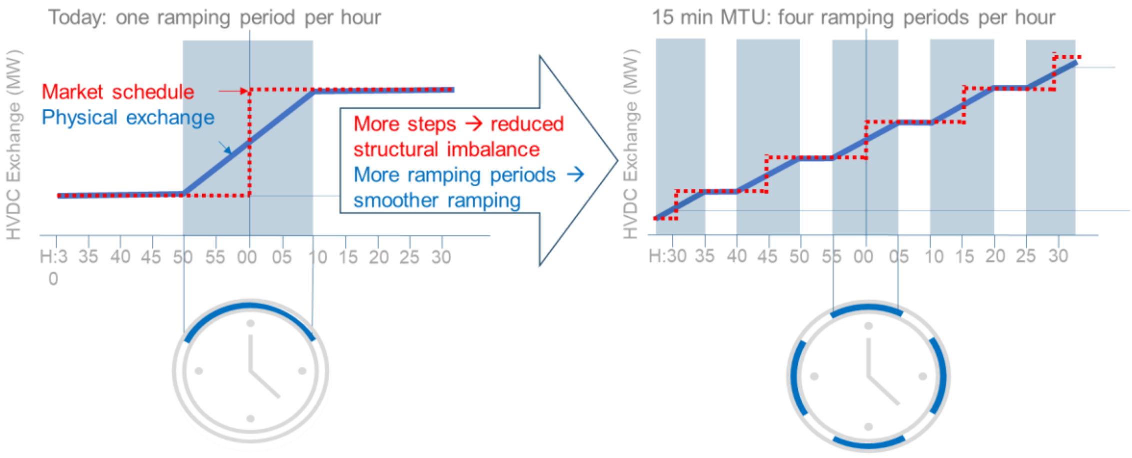


Figure 7: 15 min ISP/MTU results in four ramping periods instead of one which should result in a smoother ramp

The TSOs assume that BRPs feel sufficiently incentivised to split their hourly schedules into 15 minutes schedules. However, it is uncertain *how quickly* BRPs implement the 15 minutes schedule and this may be different for conventional generation, renewable generation, consumption, large or small parties etc. The main incentive for the BRPs to adapt may be the imbalance price which will be impacted by the change as well. If the imbalance prices are low BRPs may wait with implementing the 15 minutes schedules.

Conversely, the TSOs know how the change to 15 minute schedules on the HVDC interconnectors between the Nordic synchronous area (SA) and the Continental Europe (CE) SA will impact the minute to minute schedules.

The implementation of the 15 minute schedules on the HVDC interconnectors towards Great Britain and Russia will not change, at least not at the same moment as the interconnectors to CE and Baltic: The HVDC interconnector towards Russia (Vyborg) will keep their hourly schedule. The HVDC interconnector towards Great Britain will initially keep using a 60 minute schedule while a transition to 30 minutes schedule might take place in the future. It may therefore be expected that the steps in power exchange between the Nordic and other synchronous areas will be larger between the 4th and the 1st ISP than the steps between the other ISP shifts within the hour. Since these changes need to be followed by production (or, less likely consumption), it may also be expected that the production changes will be larger at hour shifts.

While the implementation of the 15 minutes MTU will eventually result in a more or less equal distribution of the ramping of consumption, generation and exchanges over HVDC interconnectors, it is very uncertain

[7] In addition, the Nordic NRAs required the TSOs to *'submit a new proposal before the implementation of 15 min ISP'* in their decision of July 2019 to approve on the *'Amended Nordic synchronous area proposal for ramping restrictions for active power output in accordance with Article 137(3) and (4) of the Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation'*.

how many years this transition will take. The transition time depends on factors like implementation date of 15 minutes MTU in the day-ahead market, response time of BRPs to the change incentivised by the (uncertain) imbalance prices and the implementation of 15 or 30 minutes schedules in the HVDC interconnectors towards Great Britain and (unlikely) Russia.

5.2 Other developments in the Nordic power sector

Although the main trigger for this amendment to the ramping restrictions methodology is the change to a 15 minutes MTU in the day-ahead and intraday market, the amendment takes into account other developments in the Nordic power sector. Table 1 provides a non-exhaustive list of the main developments and their expected impact. The amended methodology or other measures shall cater for the expected impact.

Table 1: Overview of relevant developments that may impact the need for ramping restrictions.

Change	Expected impact	Planned implementation[8]
Implementation of automated mFRR EAM for Nordic TSOs and DK1	Considering the size of DK1 compared to the Nordics synchronous area, the Nordic TSOs do not expect major mFRR steps on the schedules of the HVDC interconnectors between the Nordic synchronous area and DK1.	2023, Q4
Exchange of mFRR with other synchronous areas via Mari platform / Exchange of aFRR with other synchronous areas via Picasso platform	Ramping of mFRR exchange will add to the ramping resulting from day-ahead and intraday markets. Since large scale FRR exchange over HVDC is almost entirely new for the Nordics, the dynamics and volumes are difficult to assess. It is noted though that Nordic FRR is often rather inexpensive and largely available. In case of a large disturbance in CE, this could well result in a large and sudden Nordic mFRR export to CE.	2024, Q4
ACE balancing on LFC area level	The introduction of balancing per LFC area will distribute the responsibility for local reserves and own imbalances to each TSO which should improve the FRCE quality of both the LFC area and LFC block.	2023, Q4
Increased share of intermittent generation	An increased share of renewable intermittent generation will impact balancing, FRCE and frequency quality and potential need for ramping restrictions, but uncertain up to what extent. Renewables could also start providing balancing energy.	continuously
New HVDC interconnectors and energy islands	New HVDC interconnectors and energy islands will impact balancing and potential need for ramping restrictions, but it is uncertain up to what extent	continuously
New CACM regulation	New CACM regulation will require frequent evaluation of allocation constraints, including ramping restrictions. Updates may be required. Allocation constraints shall be aligned with ramping restrictions.	2023-2024?
Implementation of flow-based market coupling	Should not have impact.	
Exchange of FCR and FFR over HVDC interconnectors	To be investigated when considering implementation of FCR/FFR exchange	

[8] Source: https://nordicbalancingmodel.net/roadmap-and-projects/

5.3 HVDC interconnector capability

5.3.1 Changing exchange and operation of HVDC interconnectors

In the coming years, the exchange on the HVDC interconnectors will change with respect to products to be exchanged and with respect to the dynamics of the products. Firstly, the introduction of a 15 minute MTU in the day-ahead market and intraday market will increase the number of *flow changes* from one to *four*, each with a *shorter ramping period* (likely 10 minutes, see section 6.4.2). In addition, it is expected that after connecting to Mari and Picasso, *large amounts of balancing energy* may be exchanged over the HVDC interconnectors. The connection to Mari may also introduce the exchange of direct activated mFRR which can be activated at every moment. Picasso will cause a continuous ramping. Because the balancing markets seem more volatile and because activation in Picasso and Mari relies heavily on automation, *increasing fluctuations* of the flow are expected. This may also lead to a more likely *Operation close to zero be more likely* and that *zero crossings may happen more often*.

5.3.2 HVDC ramping capabilities

At the moment, the TSOs connect 17 HVDC interconnector systems (single cables plus their converter stations) to other synchronous areas. In general, the HVDC interconnector systems have been constructed for steady operation. This typically means ramping in one direction during the morning hours and ramping back in the evening hours. Consequently, the number of zero crossings would be limited (less than 1000 per year) and also the operation around zero can be reasonably avoided.

The 17 HVDC systems can be grouped in two categories. There are twelve HVDC interconnector systems applying Line Commutated Converter (LCC) technology[9] and five applying Voltage Source Converter (VSC) technology[10]. While both technologies are different on a number of aspects, this section focuses on the characteristics of both technologies that impact their ramping capabilities in relation to the changes described in section 5.3.1.

The owners and operators of the HVDC interconnector systems have expressed concerns about the future operation of their systems. These include (but may not be limited to):

- *Flow direction changes:* For LCC systems, a change in the flow direction requires a polarity change on the cable. Operationally this requires ramping down the flow. At the same time, the voltage quality needs to be managed by changing tap positions at transformers, switching filters and capacitor banks. Furthermore, a flow change of LCC systems requires a deionisation period of 2 minutes at which there is no ramping possible. An increased number of flow direction changes will result in more stress on the cable and more frequent operation of tap changers, switchgear and capacitor banks. This will cause an increased risk of faults, the need for more maintenace and reduced lifetime of the HVDC cable system. A limit for flow direction changes cannot be specified generically but depend on the characteristics of each HVDC interconnector.
- *Operating within dead bands:* Because of stability issues, LCC systems' control systems avoid ramping if the market result is within a dead band.
- *Large and frequent fluctuations:* A change in the absolute power flow results in an increasing or decreasing temperature of the cable. In mass impregnated HVDC cables (applied in most LCC and several VSC interconnector systems) this may cause cavity formation in the impregnating mass of the insulation system and partial discharges in these cavities cause ageing of the cable insulation, i.e. reducing its lifetime. HVDC cable owners are most worried about frequent changes of more than 20% of the nominal capacity[11], especially in downward direction. If these fluctuations happen more

[9] Baltic Cable, EstLink 2, Great Belt, Kontek 1, Kontiskan 1, Kontiskan 2, NorNed, Skagerrak 1, Skagerrak 2, Skagerrak 3, Swepol, Vyborg Link.

[10] EstLink 1, Nordbalt, NordLink, North Sea Link, Skagerrak 4.

[11] For some HVDC cables this is even less.

often, this aging process is speeding-up which reduces the lifetime even more quickly. In addition, fluctuation on HVDC interconnectors results in more frequent operation of tap changers, switchgear and capacitor banks, which also causes increased aging and requires more maintenance. A limit for unacceptable large and frequent fluctuations cannot be specified generically but depend on the characteristics of each HVDC interconnector.

5.3.3 Challenges for HVDC systems

As discussed, in section 5.3.1 the TSOs expect that the operation of HVDC interconnectors will be different from today. Since there are limitations to the HVDC capabilities of especially LCC systems (see 5.3.2), the TSOs expect challenges with accommodating future flows over HVDC interconnectors.

6. Amendments to the methodology

This chapter 6, firstly addresses the high-level approach in section 6.1 and the main principles and assumption in section 6.2. After that, sections 6.3 to 6.9 describe the proposed amendments to respectively the definitions in Article 2, the ramping restrictions to HVDC interconnectors in Article 3 to 7, the ramping rules for production and consumption in Article 8 and the implementation schedule in Article 9 of the methodology. Finally, section 6.10 elaborates on the impact of the methodology.

6.1 High-level approach

The trigger for amending the ramping restrictions methodology is the change to a 15 minutes MTU. Furthermore, the Nordic TSOs aim for a methodology that is sufficiently flexible and does not require amendments in the next 5 to 10 years. Considering the many changes and developments in the Nordic power system in this period (see chapter 5), the amended methodology therefore needs to be flexible, which means that the parametrisation of the ramping restriction needs to be continuously optimised to the actual situation[12].

The flexibility is realised by adding a TSOs’ task to annually review the effectiveness of the ramping restrictions and optimise the ramping restriction parameters to the actual situation. This is in line with the general philosophy in EU regulation (EU network codes and Clean Energy Package) that the need for restrictions to the market should be continuously evaluated[13].

6.2 Main principles, assumptions and constraints

As discussed in section 3, the main objective of the ramping restrictions methodology is to maximise socioeconomic surplus while at the same time meeting FRCE and frequency quality targets. As ramping restrictions aim for mitigating DFDs, the focus shall be to mitigate the structural imbalances that cause DFDs.

Below a number of principles, assumptions and constraints are described that have been applied in the amended methodology.

EU regulations principles applied

The principles of the EU regulations are implemented. For example, there will be no undue discrimination between HVDC interconnectors, which means that HVDC interconnectors will be treated as equally as

[12] The TSOs considered the continuation of the existing practice in which the ramping restrictions are exactly quantified for each interconnector in the ramping restriction methodology. The TSOs rejected this alternative because the duration of the update cycle is likely over one year which is considered far too long to stay in synch with the developments.

[13] More concretely, see e.g. requirements in CACM (art. 26 and 29) and SOGL.

reasonably possible. Considering the expected increase in ramping possibilities, this would mean that no interconnector should be worse-off than today.

Starting point are existing rules

The Nordic power system can only handle a certain change between two MTUs. For the existing situation, the ramping restrictions efficiently restrict the ramping (See section 4.4). In combination with other measures these result in reasonable frequency quality. The future rules are therefore based on the current rules. Ongoing and future changes in production structure and other "system changes" are however considered.

Additional complexity in balance with benefits

Considering the already existing complexity of the power system and market, the TSOs take into account that the additional complexity that may come with new rules will be reasonably in balance with the benefits of these rules. In addition, considering the scarcity of specialists in general and IT staff in particular, the expected effort required for implementation also needs to be reasonable.

Practical IT constraints

New ramping restrictions need to be implemented in the IT systems of TSOs and NEMOs. The TSOs studied different sets of ramping restrictions and their IT implementation constraints. Especially the XBID system has several constraints that may need to be mitigated depending on proposed ramping restrictions. These include (but are note limited to):

- *Implementing the possibility to differentiate restrictions for different MTU shifts:* required for optimising between HVDC interconnectors that apply different MTUs (see section 6.4.4).
- *Line-set functionality:* required for Nordic combined ramping restrictions (not proposed, see section 6.4.5).
- *Implementing the possibility to differentiate restrictions for the intraday and day-ahead market:* may be required for optimally implementing ramping restrictions in the period between implementation of the 15 minutes MTU in the intraday market and the day-ahead (see chapter 9).

Capability of individual HVDC interconnectors

The capability of HVDC interconnectors shall be considered individually. This allows less flexible HVDC interconnectors to be operated within their technical limits while more flexible HVDC interconnectors are not limited by generic restrictions.

The updates may have impact on the performance of the market systems which needs to be confirmed.

6.3 Amendments to Article 2: definitions

6.3.1 Article 2(2)

For clarification reasons and without the intention to change the meaning, the definition of the HVDC interconnector has been changed from *'a HVDC interconnector means one or more HVDC cables between a bidding zone in the Nordic LFC block and a bidding zone in another LFC block'* to *'a HVDC interconnector means all HVDC cables between a LFC area in the Nordic LFC block and a LFC area in another LFC block'.*

6.4 Amendments to Article 3: Ramping restriction for the active power output of HVDC interconnectors

6.4.1 Introduction

Since 2007 all HVDC interconnectors are subject to a maximum individual ramping rate. The objective of that ramping rate is supporting the frequency quality or –in more formal terminology – limit the influence of HVDC interconnector schedules on the fulfilment of the FRCE target parameter of the connected LFC blocks and frequency quality target parameters of the synchronous area. Currently, the Nordic TSOs are in the process of changing their balancing philosophy[14] which includes the addition of balancing per LFC area. For this reason, *'LFC areas'* has been added to the introductory sentence.

6.4.2 Ramping period (Article 3(1)(a) and 3(2)(b) and 3(6)(a))

The existing ramping restrictions methodology does not explicitly state a ramping period. However, considering the maximum gradient for change in flow of 30 MW/min and the maximum change to the trading plans of 600 MW per MTU (or hour), the ramping period should be at least 20 minutes. Considering the change from a 1 hour to a 15 minutes MTU in the IEM, Articles 3(1)(a) and 3(2)(b) now explicitly specify this ramping period at 10 minutes per MTU for the HVDC interconnectors that apply a 15 minutes MTU. The ramping period of 10 minutes aligns with the common practice in continental Europe[15] and the ramping period of the mFRR standard product. Table 2 provides a comparison between the impact of a 10 minute ramping period and the alternative of continuous ramping.

Figure 7 visualises this change and shows that the total ramping time in one hour doubles from 20 minutes to 40 minutes.

Table 2: Impact of ramping periods on 10 minutes ramping period and continuous ramping

	10 minutes ramping period	**continuous ramping**
Ramping period start	5 minutes before MTU start	7.5 minutes before MTU start
Ramping period stop	5 minutes after MTU start	7.5 minutes after MTU start
Ramping period	10 minutes	15 minutes
Consumption	May cause momentary imbalances with continuous consumption ramping	Aligns with continuous consumption ramping
Hydro production	May cause momentary imbalances with step-wise (hydro) production ramping	May cause momentary imbalances with step-wise (hydro) production ramping
Thermal production	May cause momentary imbalances with continuous thermal production ramping	Aligns with continuous thermal production ramping

It is noted that the MTU for the HVDC interconnectors that do not participate in the IEM (such as NSL) does not change at the moment but may change in future. In addition, some HVDC interconnectors that participate in IEM may not (directly) change to a 15 minutes MTU either. For these HVDC interconnector, Article 3(6)(a) now explicitly specifies that the total duration of the ramping periods per hour shall not exceed 20 minutes.

[14] See https://nordicbalancingmodel.net

[15] See section B-4 of Policy 1 of the Synchronous Area Framework Agreement (SAFA) for Regional Group Continental Europe.

6.4.3 Maximum ramping rate (Article 3(1)(b) and 3(3)(b))

Currently, the TSOs apply maximum ramping rates of 30 MW/min on all HVDC interconnectors[16]. In addition, a combined restriction on LFC area level is applied. These maximum ramping rates result in reasonable frequency quality in combination with other measures such as FCR and FRR. This means that the existing maximum ramping rates prevent for the situation that structural imbalances are so big that FCR and FRR cannot mitigate them sufficiently to meet the FRCE target parameters and the frequency quality target parameter: Figure 3 shows that the frequency quality generally meets the frequency quality targets but not yet the aimed frequency quality which are both specified in the NRA approved methodology on frequency quality[17] .

The TSOs conclude that the existing maximum ramping rate in conjunction with other measures are dimensioned in such a way that they just meet the targets and therefore do not excessively restrict the market. The existing maximum ramping rates could therefore be considered as appropriate and an appropriate starting point for the situation after the implementation of the 15 minutes MTU. However, considering the conclusion in chapter 5 that future developments will have unclear impact on the deterministic frequency deviations, it is only a starting point. The TSOs propose continuously evaluating and if necessary updating the maximum ramping rate. This is discussed in section 6.5.

For these reasons the TSOs propose 30 MW/min as the starting point for ramping restrictions on individual HVDC interconnectors.

6.4.4 Combined ramping restriction per bidding zone/LFC area (Article 3(2))

As discussed in section 6.3, the Nordic TSOs do not propose implementing combined ramping restrictions for the Nordic LFC block. However, similar to the total LFC block, ramping in LFC areas/bidding zone also results in structural imbalances for the LFC area. This especially impacts LFC areas with many and large HVDC interconnector, such as LFC areas NO2 and SE4. It is noted that HVDC interconnectors to NO2 are historically ramping more often than other Nordic HVDC interconnectors.

As explained in Textbox 2, the structural imbalance within an LFC area impacts the momentary flows between the Nordic LFC areas significantly. The reason is that these structural imbalances are fast and therefore mitigated by FCR reserves that are homogenously activated all over the Nordic synchronous area. E.g. FCR in the entire Nordic region will respond to a structural imbalance in NO2 of SE4. This would result in flows towards the LFC areas with the structural imbalance. For the flows caused by the activation of FCR, a Transmission Reliability Margin (TRM) /Reliability Margin is applied. In the Nordics these are typically 50 – 150 MW, which is rather small compared to the TRMs in continental Europe but are designed to make as much as possible capacity available to the day-ahead and intraday markets. Consequently, the TSOs need to make sure that these TRMs are not exceeded, which means that structural imbalances shall be avoided for. For this reason, the Nordic TSOs require combined restrictions for individual or groups of LFC areas.

At this moment, this situation is most critical for LFC area NO2, which is connected to four interconnectors of which three have a capacity of more than 1000 MW. If the initial maximum ramping rate of 30 MW/min would be applied to the four interconnectors that connect to NO2, the total flow change could be up to 120 MW/min. At the same time, the margins between grid capacity given to the market and the maximum flow (the TRM), is 50 to 150 MW, dependent on the bidding zone border. With four HVDC interconnectors, the flow in the grid may change so much and fast that it is impossible to prevent overloads in the grid. It is noted

[16] Please note that most HVDC interconnectors are physically able to ramp far more than 30 MW/min. The reason for the ramping restrictions of 30 MW/min is the impact of ramping on structural imbalances and deterministic frequency deviations, i.e. physical ramping limits are typically not the restrictive reason for the proposed ramping limits.

[17] *"Nordic synchronous area proposal for the 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"* of 10 September 2018, approved by the Nordic NRAs in March 2019.

that there are many potential congestions between Norwegian HVDC terminal points and Sweden. Consequently, the speed and magnitude of flow changes from ramping needs to be restricted to safeguard system security.

The current ramping restrictions on NO2 limit the ramping to 90 MW/min, consisting of an individual limit of 30 MW/min for the HVDC interconnector with Great Britain and a combined limit of 60 MW/min for the HVDC interconnectors towards the Netherlands, Germany and Western Denmark (DK1). These restrictions safeguard a secure starting position of the daily operation. In cases with unforeseen operational situations or situations not dimensioned for, the TSOs may require additional measures, including the remedial actions as listed in Article 22(1) of the SO Regulation. A large scale and regular use of counter trade between TSOs using mFRR, would require that mFRR volumes have to be secured and considered in the FRR dimensioning. This would tie up resources from use in the energy markets.

It is foreseen that after the introduction of a 15 minutes in the Nordics, the MTU on the HVDC interconnector between NO2 and Great Britain (NSL) will still be one hour or may be changed to 30 minutes. Hence, NSL will not ramp between the first and the second MTU of the hour and also not between the third and the fourth MTU (and maybe also not between the second and the third MTU). At these MTU shifts, the full 90 MW/min could in principle be allocated to the HVDC interconnectors towards the Netherlands, Germany and Western Denmark (DK1). However, as discussed in section 6.2, the current IT systems do not support different ramping restrictions per MTU shift. If this will be change in future, Article 3(2)(c) allows for implementing the wider limits for these HVDC interconnectors at the MTU shifts that NSL does not ramp.

For this reason, the TSOs propose maintaining the existing combined restriction for NO2.

6.4.5 Combined Nordic ramping restriction (not included in proposed Methodology)

Since 2007, the Nordic TSOs applied individual ramping restrictions on each of the HVDC interconnectors to other LFC blocks[18]. These ramping restrictions limited the sum of the schedule changes on all HVDC interconnectors to less than 3000 MW in more than 99.9% of the hours in 2020 and 2021 and 99.7% in 2019 (see section 4.4).

In response to public consultations on previous versions of this ramping restriction methodology, several stakeholders suggested the implementation of a combined ramping restriction for all Nordic interconnectors instead of ramping restrictions on individual HVDC interconnectors. This would allow a better optimisation of the use of the interconnectors while the FRCE target parameter of the LFC block could still be met.

In practice, a combined Nordic ramping restriction can only be implemented for the HVDC interconnectors that take part in the same market. In the Nordic case, the combined restriction may therefore be applied to the HVDC interconnectors that connect the Nordic LFC block with other LFC blocks that participate in the internal energy market (IEM) (see Figure 8). The HVDC interconnectors with Great Britain and Russia still require individual restrictions.

The TSOs have investigated combined restrictions while also taking into account the changes related to the implementation of the 15 minutes MTU. In this new situation each 15 minutes MTU has a ramping period of 10 minutes which means that the total ramping time per hour will be 40 minutes, hence twice as long as today's ramping time of 20 minutes per hour. While keeping the maximum ramping rates on 30 MW/min, this effectively doubles the steps in market exchange on each interconnector per hour from 600 MW to 1200 MW.

The TSOs' simulation results show that this change significantly increases the European Socio Economic Welfare (SEW). However, the TSOs also find that further increasing the maximum ramping rate above 30 MW/min (i.e. allowing a change in flow on an interconnector per hour of more than 1200 MW), does not

[18] To be complete: A combined restrictions has been applied for the HVDC interconnectors from Norway and Sweden to Western Denmark and is currently applied for HVDC interconnectors from Norway to the Netherlands and Germany.

increase the European SEW significantly. Hence, the TSOs' conclusion is that introducing a combined Nordic restriction for being able to remove the maximum ramping rates on individual HVDC interconnectors does not have significant benefits. In addition, the implementation of combined Nordic ramping restrictions requires significant upgrades in day-ahead, intraday and balancing market systems.

Additionally, the implementation of a combined restrictions in day-ahead, intraday and balancing platforms is quite complex and costly. *For these reasons, a combined Nordic restriction is not proposed in this amended methodology. Appendix 1 provides more detail on this issue.*

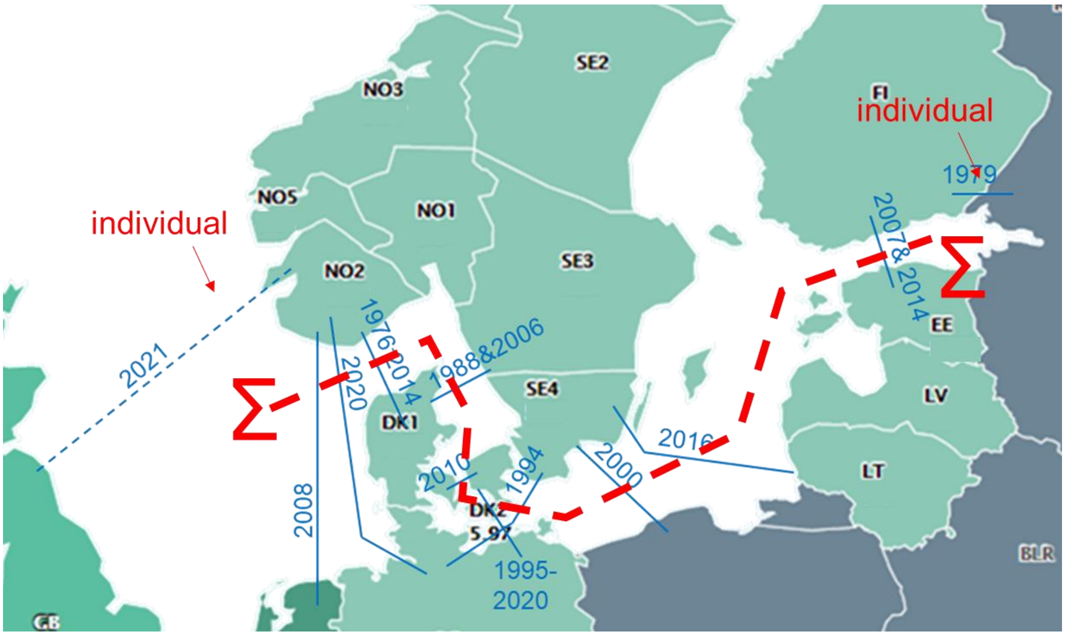


Figure 8: Proposal for a combined ramping restriction for the Nordic LFC block

6.5 Evaluation and update of ramping restrictions on HVDC interconnectors (Article 4)

Chapter 5 discusses several developments in the Nordic power system that will be implemented during the coming years and impact the frequency quality in general and deterministic frequency deviations in particular. Some developments – such as the implementation of the 15 minutes MTU – will likely reduce deterministic frequency deviations while others – such as Mari – will increase them. Also the increasing renewable generation will likely have an impact. Since there are many uncertainties, it is not possible to predict the optimal maximum ramping rates for the coming years. Furthermore, since many changes will come gradually, there may not be one set of ramping rules that will be optimal for the coming years.

The alternative of taking all uncertainties into account in the definition of new ramping restrictions would result in very conservative assumptions and strict ramping restrictions. In order to define more efficient rules that ensure sufficient security of supply, the Nordic TSOs propose an annual evaluation and update of the ramping restrictions, which shall be based on measured frequency quality in general and the share of deterministic frequency deviations in particular. Accordingly, the most efficient balance between security of supply and market restrictions could be achieved.

As illustrated by Figure 6, the challenge in the above is that frequency quality is more complex than sketched above. Most importantly, the frequency quality is not only determined by structural imbalances (causing deterministic frequency deviations), but also by stochastic frequency deviations and disturbances. It is difficult to categorise the cause of the frequency excursion in practice. Another issue is that next to ramping restrictions other measures – such as FCR and FRR – are used to mitigate (deterministic) frequency deviations. Also here it is difficult to distinguish the impact.

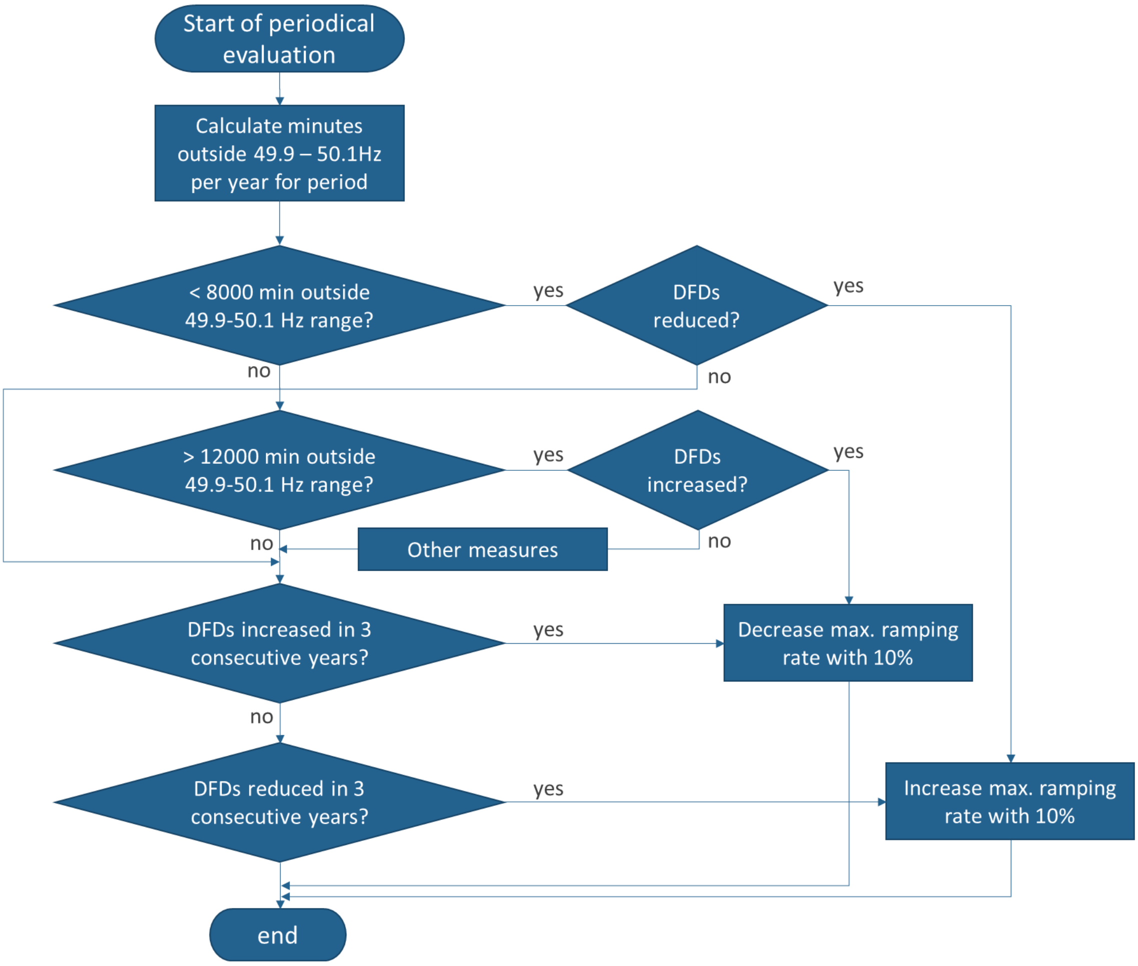


Figure 9: Proposed update procedure for ramping restrictions (Note that the values of 8 000 and 12 000 are based on the existing aimed Nordic frequency quality defined as 'less than 10 000 minutes outside the 49.9 – 50.1 Hz range' in the NRA approved methodology on frequency quality[22])

For that reason, the TSOs suggest a two-step approach which is shown in Figure 9. In the first step the TSOs evaluate the frequency quality target parameter which is a well-established parameter in the Nordics. If this frequency quality target parameter is outside a certain range, the TSOs will assess if the excursion is resulting from a change in deterministic frequency deviations[19]. If this is the case, the TSOs may adapt the ramping restrictions with exactly 10%[20] (rounded to the nearest whole number[21]). Alternatively other measures may be considered to improve the FRCE quality and frequency quality of the LFC block.

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[19] Parameters that are currently applied for evaluating deterministic frequency deviations are based on a one-hour MTU. When changing to the 15 minutes MTU, these parameters need to be adapted to the new situation. The Nordic TSOs suggest applying common European definitions instead of developing specific Nordic definitions. These European parameters still need to be defined.

[20] 10% is chosen as a pragmatic figure balancing the wish for stability in framework conditions for balancing as frequency quality is varying a lot between years and the wish to react to development trends within reasonable time.

[21] For example, 33 MW/minute could become 36 MW/minute.

The TSOs defined that a change of ramping restrictions will only be considered if the number of minutes outside the standard frequency range is more than 20% below or above the aimed frequency quality. This aimed Nordic frequency quality is currently defined as 'less than 10 000 minutes outside the 49.9 – 50.1 Hz range' in the NRA approved methodology on frequency quality[22] .

For the case that the assessment shows a significant decrease/increase of deterministic frequency deviations *in three consecutive years* the TSOs added the possibility to similarly adapt the ramping restrictions, even if the number of minutes outside the standard frequency range is in the range of 80-120% of the aimed Nordic frequency quality.

A similar evaluation will be performed for the combined maximum ramping rate for NO2. The reference for the evaluation will be the FRCE limit of the NO2 LFC area as to be included in appendix 1 of the LFCR Annex of the Nordic System Operation Agreement.

The proposed update procedure will ensure that the maximum ramping rates will follow the developments in the Nordic system. This will safeguard that the ramping restrictions will be both efficient and effective in meeting the FRCE and frequency quality targets. The update procedure is applied to the maximum ramping rate on individual HVDC interconnectors. A similar update procedure is applied to combined restrictions.

The annual review and update of the maximum ramping rates will be done in a transparent way by making the assessment results and the updated maximum ramping rates available to the stakeholders and NRAs.

6.6 Restrictions to operation of individual HVDC interconnectors (Article 5)

The existing HVDC interconnectors have been constructed for stable operation which means that they typically follow day-night patterns and change from import to export in the morning and back to import in the evening. This operation results in less than 1000 direction changes per year.

Considering the developments in the Nordic power system (see chapter 5), the TSOs expect that the operation of HVDC interconnectors will be different from today. Firstly, there will be more flow changes than today because changes to day-ahead and intraday schedules may happen every 15 minutes instead of every hour. Secondly, there will be more exchange in balancing energy when the Nordic balancing markets connects to Mari and Picasso. This will cause more fluctuation caused by 15 minutes schedules day-ahead, intraday and scheduled mFRR exchange. In addition, more fluctuation is expected by incidental exchanges for direct mFRR activation and continuous changes (every 4 seconds) for aFRR exchange. The TSOs also expect larger volatility than today because of more automated activation. More fluctuations may consequently result in more direction changes.

In order to limit the restrictions to the market, the TSOs do not propose a generic restriction covering the technical issues related to the operations of HVDC cables. Instead, the TSOs propose that operational limits will be applied only to the HVDC interconnectors that are subject to the concerns above. For this reason, the TSOs propose that for ramping on HVDC interconnector cable resulting from day-ahead, intraday and FRR exchange additional ramping restrictions may be defined in case of technical or operational limitations of the HVDC cable, including converter stations, filters, circuit breakers, capacitors etc.

The TSOs suggest implementing restrictions to the maximum number of zero crossings and dead bands for continuous operation in the Capacity Calculation Methodology (CCM) in accordance with Article 37 in the EB Regulation.

[22] *"Nordic synchronous area proposal for the 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"* of 10 September 2018, approved by the Nordic NRAs in March 2019.

Paragraph 2 describes the process that needs to be followed by the TSOs to implement the additional restrictions as referred to in paragraph 1. This paragraph aims for safeguarding a diligent and transparent evaluation and decision process.

6.7 Increasing maximum ramping rate for HVDC interconnectors subject to a combined restriction (Article 6)

Note: This Article 6 includes the same rules as Article 3(3)-(5) in the previous version of this methodology. For clarity reasons, the three paragraphs have been moved to the new Article 6.

Since the combined restriction of Article 3(2) limits the total step of HVDC Interconnectors connecting NO2 to other LFC areas participating in the IEM, it is a possibility to enlarge the maximum ramping rate specified in Article 3(1) on these HVDC interconnectors, without increasing the total step for the Nordic LFC block and bidding zone NO2. This would allow the market algorithm to better optimise the allocation of the flows to these HVDC interconnectors. Article 6 opens for this. However, some conditions need to be fulfilled, including the technical feasibiliy of the HVDC interconnector (Article 6(1)(a)). Furthermore, increasing the enlarged ramping restrictions must not result in network issues on both ends of the HVDC interconnector (Article 6(1)(b)+(c)).

The maximum individual ramping restrictions will in practice not be larger than the combined maximum ramping restrictions in accordance with Article 3(2).

Article 6(2) and 6(3) describe the processes of implementing and removing an increased maximum ramping rate.

6.8 Coordination with cable partners (Article 7)

The HVDC interconnectors considered in this methodology each connect to two different synchronous areas, LFC blocks and LFC areas. Each synchronous area has its own frequency and the TSOs of each synchronous area are concerned with maintaining the frequency quality of their own synchronous area. Similarly, the TSOs are maintaining the FRCE target parameters of their LFC block and LFC area(s). Consequently, the TSOs of synchronous areas, LFC blocks and LFC areas implement measures to maintain the frequency quality and FRCE quality, including ramping restrictions.

With respect to this methodology, the Nordic TSOs propose ramping restrictions with the objective to meeting the FRCE target parameters for their LFC block as referred to in Article 128 of the SO Regulation. TSOs of other LFC blocks and synchronous areas may define their ramping restrictions independently, depending on their evaluations of the frequency and FRCE quality in their synchronous area and LFC block. In case the maximum ramping rates are set differently on each side of an HVDC interconnector or a combination of HVDC interconnectors, the lowest value will prevail. This may result in a need to deviate from the resulting ramping rate according to the rules in this methodology.

6.9 Ramping rules for power generating modules and demand units (Article 8)

6.9.1 Hourly ramping rules for production become obsolete (Article 8(1), 8(2) and 8(3))

Article 4 (now numbered Article 8) of the existing Nordic ramping restrictions methodology includes rules that make sure that hourly changes in production are re-distributed over the four quarters. By doing this, the structural imbalances at the hour shift are reduced. After the implementation of the 15 minutes MTU in both the day-ahead market and the intraday market, Articles 8(2) and 8(3) do not have a meaning anymore and shall be considered obsolete.

For the time between the implementation of the 15 minutes MTU in the intraday market and 15 minutes MTU in the day-ahead market, this is not completely obvious. If most power is traded in the intraday market, the rule will not be used anymore and effectively becomes obsolete. However, if most trade will still be in the day-ahead market, the rule will still be used and important to keep. For these reasons, the article shall be considered valid until the 15 minutes MTU has also been implemented in the day-ahead market. The new Article 8(1) is arranging this.

6.9.2 Hourly ramping rules for production become obsolete (Article 8(4) and 8(5))

Currently, Statnett's and Svenska kraftnät's operators are allowed to activate mFRR *at every moment* in such a way that the production ramp follows the demand and HVDC exchange as good as possible and structural imbalances are prevented for. This is a manual process that makes use of the operators' experience and the possibility to start activations every minute.

In the automated operation of the mFRR EAM, operation of scheduled mFRR will be fully automatic and scheduled activations can only be made once per quarter, which will create structural imbalances around the 15 min MTU shifts. For this reason, additional measures may be required. The newly proposed Article 8(4) therefore suggests that each TSO should consider ramping rules *"in order to minimise the activation of reserves, the FRCE of the LFC block and LFC area and the corresponding (deterministic) frequency deviation of the synchronous area. These could be reflected, for example, by financial incentives or operational requirements provided by TSO to balancing service providers, balance responsible parties that represent power generating modules and/or demand units."*.

In order to be unambiguous about the optimal ramping by BRPs, Article 8(5) explains that *"ideally, the BRP's ramp starts between 7.5 and 5 minutes before the start of an MTU and linearly ramps to the schedule for the next MTU which shall be reached between 5 and 7.5 minutes after the start of that MTU"*. A similar rule for mFRR response by BSPs is proposed to be included in the next version of the Nordic System Operation Agreement.

The proposed Articles 8(4) and 8(5) provide guidelines that could incentivise BRPs and BSPs to better follow the momentary power system needs on a minute-by-minute basis. They could be used by individual TSOs for implementing measures in e.g. their national Terms and Conditions.

In Norway and Sweden a new mFRR product called 'period shift' will be introduced to mitigate to reduce the structural imbalance. This product will provide the possibility to activate mFRR for 5 or 10 minutes periods and consequently assist with smoothening the power production ramp. This should reduce structural imbalances significantly.

6.10 Impact of the methodology

To assess the impact of the proposed ramping restrictions on HVDC interconnectors, the TSOs have performed market simulations. The simulations have been performed using the Euphemia algorithm and historical grid situations and bids of two periods in 2021: 15 May – 15 June and 1-31 October. Textbox 4 provides further background on the simulations.

Figure 10 and Figure 11 show that an increase of the ramping time per hour from one time 20 minutes to four times 10 minutes will provide a significant increase of European Socioeconomic Welfare (SEW). The figure further shows that removing all ramping restrictions would only give a limited increase of the SEW. Considering this, the TSOs conclude that the remaining restrictions result in a situation that hardly reduces the European SEW. The TSOs consider that this conclusion will hold for the new prices after the 2022 energy crises.

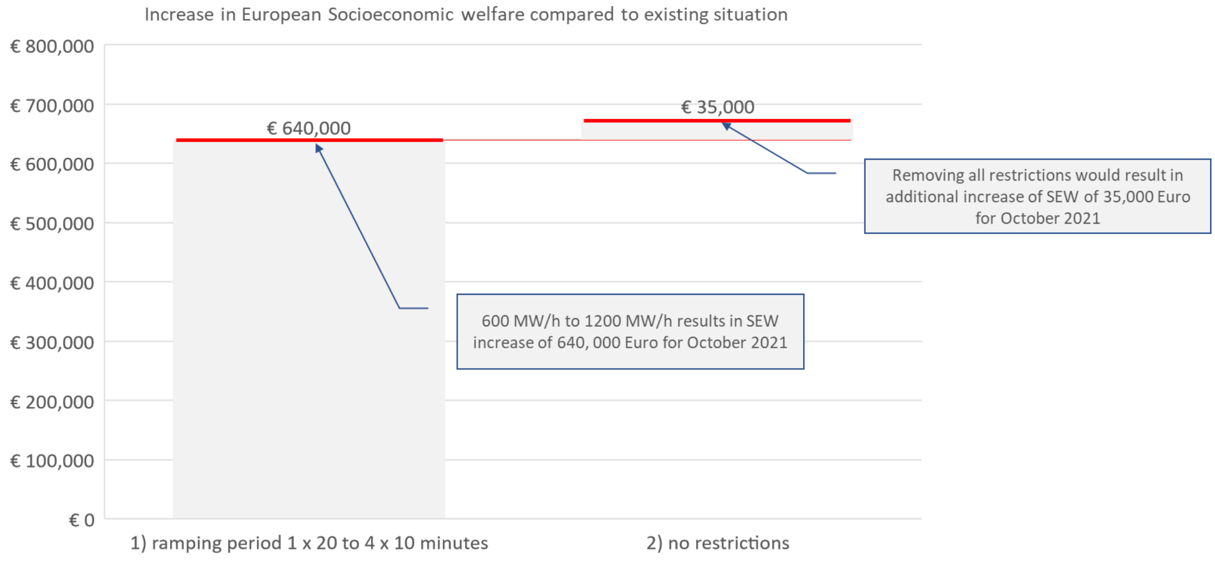

Figure 10: Impact of proposal on European socioeconomic welfare for one month, compared to the existing situation (Note that figures are based on simulations with market data for October 2021 and that the simulations do not consider the NO2 combined restriction)

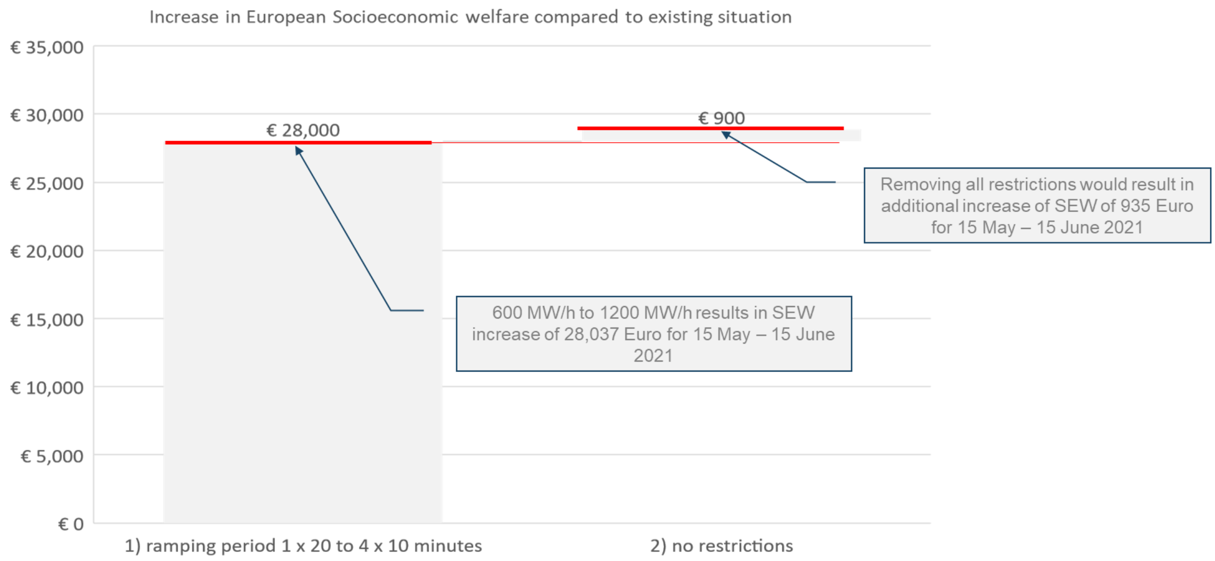

Figure 11: Impact of proposal on European socioeconomic welfare for one month, compared to the existing situation (Note that figures are based on simulations with market data for 15 May-15 June 2021 and that the simulations do not consider the NO2 combined restriction).

Textbox 4: Background information of market simulations

The quantitative figures presented in this chapter are the result of market simulations of the day-ahead market covering two months in 2021. The simulations have been performed on an hourly basis applying the Euphemia algorithm which is the algorithm used by TSOs and power exchanges for European market simulations[23].

For this analysis, the following had to be assumed:

- The assessment is based on day-ahead markets only;
- The comparison is done with the 2021 grid situation, restrictions and actual bids. This implicitly assumes that the new interconnectors and the new ramping restrictions do not change bidding behaviour in day-ahead market. In addition, differences between hydrological years will not be addressed;
- The simulations cover the European electricity market area.

Note on the accuracy of simulation results:
The objective of the Euphemia algorithms is to find the market outcome for which the socioeconomic European welfare is maximized. Since this algorithm needs to find an optimal combination of very many parameters which do not have a linear relationship, it is in practice impossible to calculate and compare results of all different possible combinations. Mathematically this is called a 'non-linear optimization problem'. The mathematical techniques applied by the simulation facility to solve this problem do not always find the optimum solution, but most likely finds a solution that is very close to the highest socioeconomic European welfare.

If several runs with the simulation facility are performed for identical situations, experience shows that there may be a spread in the results for European socioeconomic welfare of 250 kEUR for extreme days, which is high, but negligible compared to the total European electricity market. However, in this report the impact of ramping restrictions is analysed by reviewing the difference between simulation results. If the difference in socioeconomic welfare between these scenarios for a particular day is in the order of 250 kEuro, it is in the same order of magnitude as the inaccuracy in the results. Hence, it should be noted that the difference in socioeconomic welfare cannot be exactly quantified for these relatively small numbers.

The assessment for 2019 as described in section 4.4 is based on a comparison of 3000 hours in 2019. For these hours the simulation results of the existing situation have been compared with the historical market data as published by Nordpoolspot[24]. The comparison shows a correlation (R2) of 99,5% for both the interconnector flows and the bidding zone prices.

7. Outlook

During the coming years, the Nordic power system faces many changes. The TSOs consider that the proposed amendment in general includes the measures required to manage ramping in the changing Nordic power system in a secure, effective and efficient manner. This includes an annual evaluation and revision process that allows continuous optimising the maximum ramping rates in order to meeting their objectives in an efficient way. Furthermore, the proposed amendment provides guidelines that could be used by individual TSOs for implementing rules in their national Terms and Conditions that could incentivise BRPs and BSPs to better follow the momentary power system needs on a minute-by-minute basis.

[23] See http://www.nemo-committee.eu/assets/files/190410_Euphemia%20Public%20Description %20version %20NEMO%20Committee.pdf

[24] https://www.nordpoolgroup.com/historical-market-data/

8. Expected impact of the Methodology on the relevant objectives of the SO Regulation

The Methodology 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 Methodology 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.

The Methodology contributes to these objectives by specifying ramping restrictions for HVDC interconnectors and production plans (until these become obsolete after implementation of the MTU of 15 minutes). The methodology also defines a desired ramping for BRPs which may be used by individual TSOs in their terms and conditions. These ramping rules are required to maintain the operational security by reducing the risk for automatic Low Frequency Demand Disconnection (LFDD) and for system blackouts due to under or over frequency. Furthermore, the ramping restrictions are required to maintain the frequency quality level of the synchronous areas involved.

9. Timescale for the implementation

The main trigger for this amended methodology is the implementation of the 15 minutes MTU in the intraday market and day-ahead market. Consequently, the implementation of the ramping restrictions on HVDC interconnectors shall start when the first market implements the 15 minutes MTU.

The 15 minutes MTU in the intraday market is planned to be implemented *before* the 15 minutes MTU in the day-ahead market. This means that there may be a time period that the MTU in the intraday market will already be 15 minutes while the MTU in the day-ahead market is still 60 minutes. Consequently, there will be four ramping periods in the intraday market and only one for the day-ahead market.

For this interim time period, full implementation of the methodology would mean that the change of the ramping periods from 1 x 20 minutes to 4 x 10 minutes would reduce the maximum hourly market change for the day-ahead market from 600 to 300 MW (10 min * 30 MW/min). The TSOs consider this too restrictive, not only for the market but also for the market algorithms to solve. For this reason, the TSOs propose that it should be allowed to temporarily increase the ramping period for individual interconnectors from 10 to up to 15 minutes.

At this moment it is not yet clear how the day-ahead and intraday markets will be implemented for the HVDC interconnectors. However, the TSOs aim for maximising the market facilitation within the limits of what technically and operationally would be feasible. Within the proposed Article 9(2) this optimisation would be possible.

The TSOs consider it important though that the ramping period aligns with the ramping period of the mFRR standard product when they connect to the Mari platform for exchanging mFRR[25]. Consequently, the ramping period of up to 15 minutes will only be allowed until the Nordic TSOs have connected to Mari.

[25] Mari European platform for the exchange of mFRR in accordance with Article 20 of Commission Regulation (EU) 2017/2195

10.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 February to 1 March 2023 .

11. Appendix 1: Evaluation of combined ramping restrictions

11.1 Introduction

Until now, the Nordic TSOs applied individual ramping restrictions on each of the HVDC interconnectors to other LFC blocks[26]. These ramping restrictions limited the sum of the schedule changes on all HVDC interconnectors to less than 3000 MW in more than 99.9% of the hours in 2020 and 2021 and 99.7% in 2019 (see section 4.4).

In response to public consultations on previous versions of this ramping restriction methodology, several stakeholders suggested the implementation of a combined ramping restriction for all Nordic interconnectors instead of ramping restrictions on individual HVDC interconnectors. This would allow a better optimisation of the use of the interconnectors while the FRCE target parameter of the LFC block could still be met.

The TSOs have investigated combined restrictions while also taking into account the changes related to the implementation of the 15 minutes MTU. This appendix describes the results of this investigation.

11.2 Implementation of combined Nordic ramping restrictions

In practice, a combined Nordic ramping restriction can only be implemented for the HVDC interconnectors that take part in the same market. In the Nordic case, the combined restriction may therefore be applied to the HVDC interconnectors that connect the Nordic LFC block with other LFC blocks that participate in the internal energy market (IEM) (see Figure 12). The HVDC interconnectors with Great Britain and Russia still require individual restrictions (see section 11.3.2). Since the market processes that determine the HVDC interconnector schedules take place simultaneously, it is not possible to re- allocate the unused ramping from one to the other.

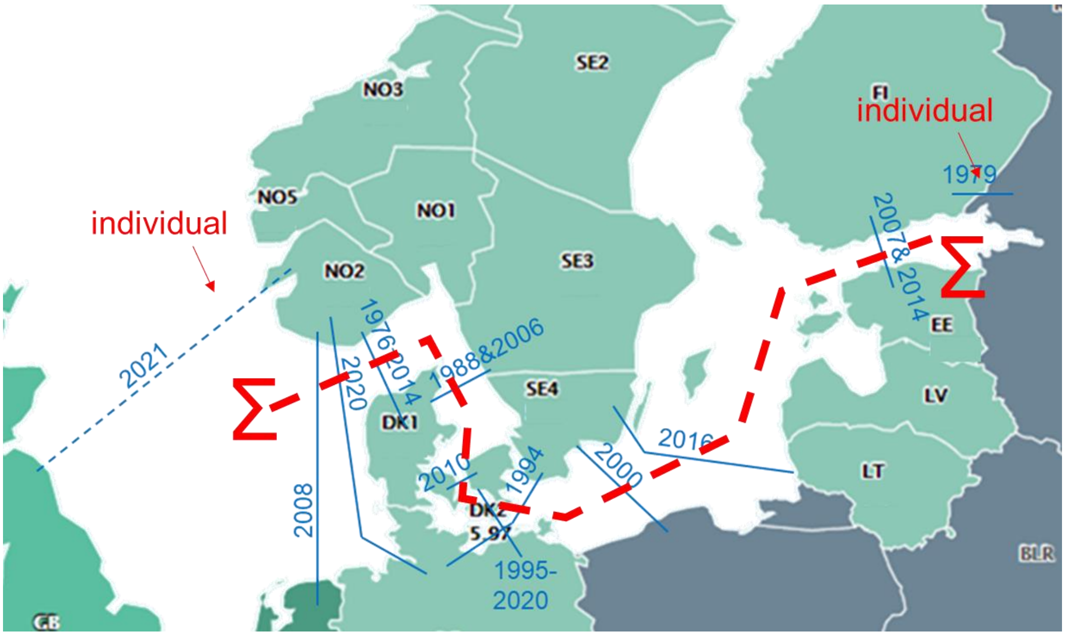

Figure 12: Proposal for a combined ramping restriction for the Nordic LFC block

[26] To be complete: A combined restrictions has been applied for the HVDC interconnectors from Norway and Sweden to Western Denmark and is currently applied for HVDC interconnectors from Norway to the Netherlands and Germany.

11.3 Dimensioning of combined Nordic ramping restrictions

11.3.1 *Required ramping restriction for all interconnectors*

The existing ramping restrictions per HVDC interconnector are defined as a maximum ramping rate of 30 MW/min for a ramping period of 20 minutes. Although in theory this would allow a total step on all interconnectors of 6000 MWh on an hour shift[27], in practice this does not happen. In fact, total steps larger than 3000 MWh/hour even hardly happen. In 2021, in more than 99.9% of hour steps in 2020 and 2021 were smaller than 3000 MWh/hour (see section 4.4). In 2019 this figure was 99.7%.

Consequently, a combined ramping restrictions of 3000 MWh/hour (or 150 MW/min for 20 minutes) would potentially only affect the market in approx. ten hours per year. However, if at the same time the maximum ramping rates on individual HVDC interconnectors are increased, this would allow faster ramping than today on HVDC individual interconnectors which would result in a better distribution of the ramping on HVDC interconnectors.

The Nordic TSOs therefore conclude that – for the current situation - a combined Nordic maximum ramping rate of 3000 MWh/hour with a larger maximum ramping rate on individual HVDC interconnectors would in practice result in an increase of the exchange possibilities between the Nordic LFC block and other LFC blocks, while not jeopardising the system security in the Nordic LFC block. Considering the current ramping periods this would mean a combined Nordic maximum ramping rate of 150 MW/min (3000MW/20 minutes/hour) for the current ramping period of 20 minutes should be acceptable. With the introduction of the 15 minutes MTU, the TSOs consider that this ramping rate of 150 MW/min should still be feasible, but that the ramping time may increase.

11.3.2 *Distribution between IEM, GB and Russian Interconnectors*

The combined ramping restrictions can only be implemented for the HVDC interconnectors that connect the Nordic LFC areas with LFC areas participating in the Internal Energy Market (IEM). At this moment (2022) this means that the HVDC interconnectors to Russia and Great Britain cannot be incorporated and require individual ramping restrictions[28]. These ramping restrictions shall – as far as reasonably possible – create a level playing field for the trade between the Nordics and all connected countries. For the individual ramping restrictions for the HVDC interconnectors to Russia and Great Britain, two boundary conditions are determined:

- Calculated per hour, the allowed change shall be not more than the allowed change as a result of the individual HVDC interconnectors (see section 6.4.3) with the lowest allowance which is [30 MW/min] * 40 min = 1200 MW;
- Calculated per hour, the allowed change shall be not less than the allowed change as a result of the combined HVDC interconnectors divided by the number of interconnectors. For example, Assuming a combined ramping restriction of on average 150 MW/min and a ramping period of 10 minutes per 15 minutes MTU, the total allowed change per hour would be 6000 MW, which is 567 MW per interconnector.

In practice it is very difficult to change the ramping restriction to Russia which is restricted to 600 MW/hour. This amount falls in between the boundary conditions above. Since the Russian and GB interconnectors should be treated in the same way, the TSOs propose for both interconnectors a maximum average ramping rate of 30 MW/min for a duration of ramping periods per hour of 20 minutes. The reason to restrict the hourly

[27] 12 interconnectors * 20 minutes ramping period/hour * 30 MW/min = 7200 MWh/hour per hour shift, reduced by the combined ramping restriction on NO2 that reduces the hourly step with 600 MWh/hour.

[28] A further practical consideration is that the MTUs on the interconnectors to Russia and Great Britain will stay on hourly basis. The MTU towards GB may change to 15 minutes.

duration of ramping periods and not to the ramping period itself is to be prepared for a change to more MTUs and consequently ramping periods per hour.

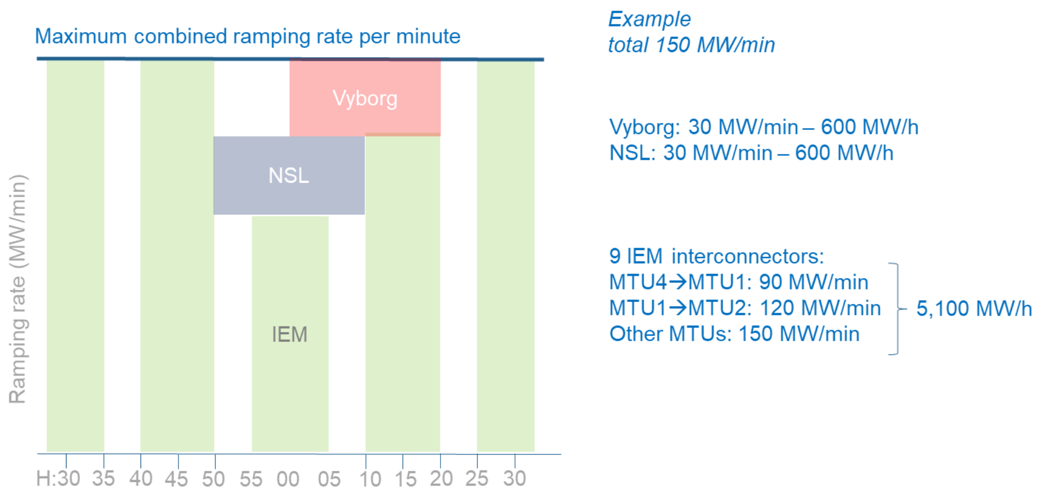

Figure 13: Distribution of combined Nordic maximum ramping rate between HVDC interconnectors that connect to IEM and NSL and Vyborg

Figure 13 shows how this could be implemented in practice. The figure shows that the maximum ramping rate of 150 MW/min is completely used for each MTU shift. This results in the same ramping rate for Vyborg as today. The ramping rate for NSL will increase to the same level as Vyborg. For the other 9 HVDC interconnectors the maximum ramping rate may result in ramping of 5100 MW/hour which is far more than the 3000 MW/hour that is only exceeded in approximately 10 hour shifts per year. Moreover, if the TSOs on both sites of the cable allow more ramping than 30 MW/min on the individual HVDC interconnectors, the market will be further optimised if faster ramping than today on HVDC individual interconnectors is allowed.

11.4 Combined ramping restriction per bidding zone/LFC area

The combined Nordic ramping restriction that is discussed above, requires that the *sum* of ramping on all HVDC interconnectors shall be below the maximum combined ramping rate. This means that there is a possibility of netting of the ramping which could result in extreme ramping for bidding zones/LFC areas. Figure 14 shows an extreme example for the situation that no individual ramping restrictions are applied anymore. In this example it is assumed that the maximum combined ramping rate is 125 MW/min. Since the NO1 to SE3 interconnector (Hasle) is fully used and there is still a price difference between NO125 and SE34, power may find its way via Western Denmark and Germany. Since ramping between NO2 towards DK1/DE is in the opposite direction of the ramping between DK2/SE3/SE4 and DK1/DE, the ramping may be netted.

If there would not be other ramping restrictions, the ramping is only restricted capacity and the setpoint of each individual HVDC interconnectors. Consequently, ramping per LFC area could become far higher – in this example 525 MW/min than the maximum combined Nordic ramping rate of 125 MW/min.

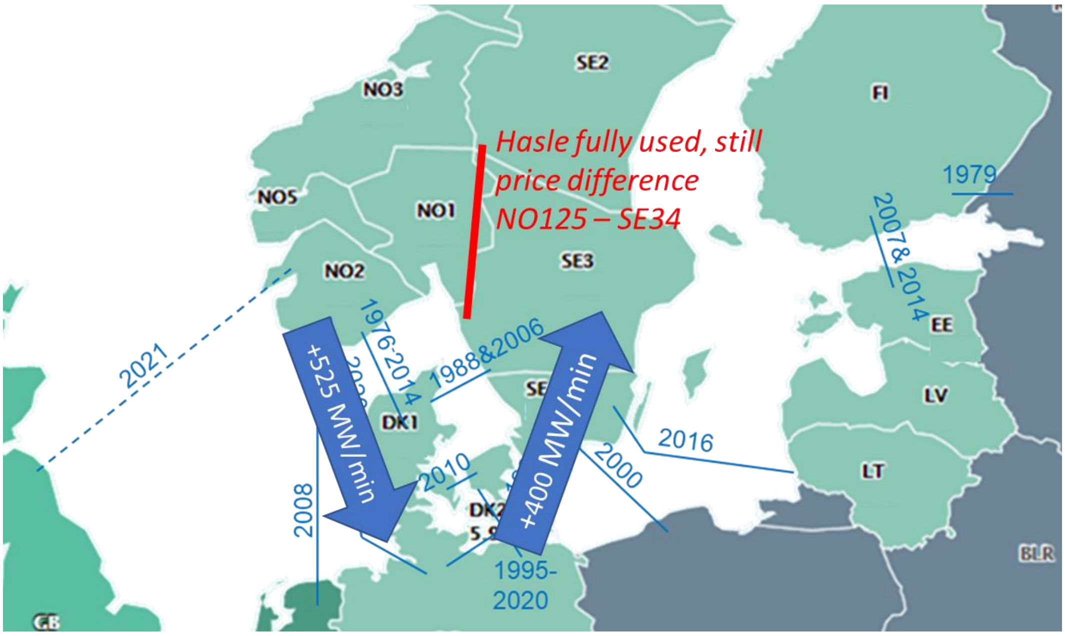

Figure 14: Example of potential result if only a combined maximum Nordic ramping rate is applied (in this example of 125 MW/min.

Similar to the total LFC block, ramping in LFC areas/bidding zone also needs to be followed by BRPs and BSPs. The combined ramping for each LFC area/bidding zone shall not be larger than the maximum combined ramping rate of the Nordic LFC block. For that reason, the TSOs conclude that introducing together with a maximum combined Nordic ramping rate, a maximum combined ramping rate for all LFC areas needs to be implemented.

11.5 The practical implementation

The practical implementation of a combined Nordic ramping restriction requires an update of the XBID system. Implementing the combined restriction requires the so-called 'line-set' functionality which is not yet scheduled to be implemented in XBID. Until this implementation is completed, the combined ramping restriction cannot be implemented. In addition, it needs to be confirmed that combined restrictions can be implemented in the balancing platforms. For this, the *'profile limits'* functionality in the balancing market platforms could be used. However, this functionality is in principle designed for incidental used while continuous use may be unacceptable. This requires texting.

11.6 Impact on socioeconomic welfare

In this new situation each 15 minutes MTU has a ramping period of 10 minutes which means that the total ramping time per hour will be 40 minutes, hence twice as long as today's ramping time of 20 minutes per hour. While keeping the maximum ramping rates on 30 MW/min, this effectively doubles the steps in market exchange on each interconnector per hour from 600 MW to 1200 MW. TSOs' simulation (see Figure 10 and Figure 11) show that this change significantly increases the European Socio Economic Welfare (SEW). However, the TSOs also find that further increasing the maximum ramping rate above 30 MW/min (i.e. allowing a change in flow on an interconnector per hour of more than 1200 MW), does not increase the European SEW significantly. Hence, the TSOs' conclusion is that introducing a combined Nordic restriction for being able to remove the maximum ramping rates on individual HVDC interconnectors does not have significant benefits. In addition, the implementation of combined Nordic ramping restrictions requires significant upgrades in day-ahead, intraday and balancing market systems.

11.7 Conclusion

The Nordic TSOs conclude that the benefits of combined restrictions are limited and that the implementation of a combined restrictions in day-ahead, intraday and balancing platforms is quite complex and costly. *For these reasons, a combined Nordic restriction is not proposed in this amended methodology.*