Evaluation of the ramping restriction in the energy market

Nordic Operations Development group (NOD)

20 December 2010

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1 Summary

The Nordic TSOs have agreed on some actions which they consider necessary to maintain an acceptable frequency quality and system security. One of these actions is the so called ramping restrictions for how quickly exchange over HVDC-connections can vary, and the incorporation of these restrictions in the day-ahead spot market.

This report concludes that a restriction in the energy market is the best tool which is available today for handling of ramping on HVDC-connections. This may change in the future. Evaluated alternatives to the current solution are:

- **Counter trade.** This report shows that counter trade does not theoretically lead to higher socio-economic gain compared to ramping restrictions. Furthermore, the integration of markets after the spot market and the TSO arrangements between the continental and Nordic side of the HVDC connections are not sufficiently developed to guarantee that counter trade can be performed.
- **More automatic reserves.** The solution is available and will make it possible to reduce the current restriction, but the costs for this seems to be much higher than the current “market costs” associated with the restriction in the energy market. However, in contrast to counter trade, additional automatic reserves may improve system flexibility and generation efficiency.
- **Better TSO control of changes in physical production.** Implementation of new rules, procedures and systems like quarterly (i.e. 15 minute) production plans and development of control systems, will make it possible to reduce the restrictions in the future but those actions are currently not considered to be sufficient to handle ramping without additional “help” from one of the other alternatives.

The method for restriction in the energy spot market could be made more optimal. An optimisation procedure could be introduced in the spot algorithms to improve the socioeconomic efficiency. This possibility should be evaluated further.

There are also some long term possibilities which will be elaborated further like new or changed ramping rules on production and exchange, better coordination between synchronous systems and quarterly (15 minute) settlement.

2 Introduction

Changes in trade have increased over the last years due to tighter market integration and more connections between the countries. As a consequence, the balancing control has become increasingly difficult. Frequent large changes in production and flow in fully loaded corridors in the grid make it more difficult to control the frequency. The security of the power system is threatened in the synchronous Nordic system. Local voltage problems also occur frequently.

As a consequence the Nordic transmission system operators (TSOs) in 2007 decided to harmonize the so-called ramping rules for commercial trade between the Nordic and the Continental European synchronous systems. The objective was to limit the planned changes in load flow between the Nordic synchronous system and continental Europe to what could be handled with current infrastructure and arrangements for system operation. A ramping restriction in planned flow of a maximum 600 MW difference from one hour to the next is applied separately on all HVDC connections between the two systems. The HVDC connections in question are NorNed (Netherland-Norway), Skagerrak (Denmark-Norway), KontiSkan (Denmark-Sweden), Kontek (Denmark-Germany), Baltic Cable (Germany-Sweden) and Swepol Link (Poland-Sweden), numbering 6. From August 2010 Storebælt (Zeeland-Jutland) was commissioned with the same restriction.

The market was informed about the common Nordic ramping rules in Exchange information No. 53/2007 'Extended use of ramping on HVDC links'. In practice the ramping restriction was implemented first in the Elspot market. Then in May 2009 the restriction was implemented also for the Elbas market, Exchange information No. 53/2009 'Ramping rules in the Elbas market'.

The ramping rules are elements in a 'package' of instruments/means that the Nordic TSOs consider necessary to maintain an acceptable system security. Some of those are already implemented, and others will be implemented in the coming couple of years. Examples are:

- A gate closure for binding production plans to the TSOs,
- Quarterly (15 minute) resolution for production plans,
- Minute based plans on some large production units in ramping hours to give needed production support for the frequency,
- Introduction of Load Frequency Control (LFC) also in the Nordic synchronous area.

3 Ramping rules

To avoid imbalances in the Nordic synchronous system, the changes in flow on the HVDC-cables must be followed by corresponding changes in production. With current arrangements for system operation and production control (many manual procedures), it is crucial that the flow on the cables don't change too quickly. Consequently a restriction for flow gradient is set to max 30 MW/min per connection. With six relevant connections today, this means a total gradient for the synchronous system of 180 MW/min. To try to illustrate the implication for the Nordic synchronous system, frequency violations of the defined limits (+/- 0.1 Hz deviation from 50 Hz) will occur after less than four minutes given a constant set-point for production, a constant consumption and the current requirement for frequency controlled reserves (FNR) of 600 MW. The violations of the frequency limits lead to reduced system security.

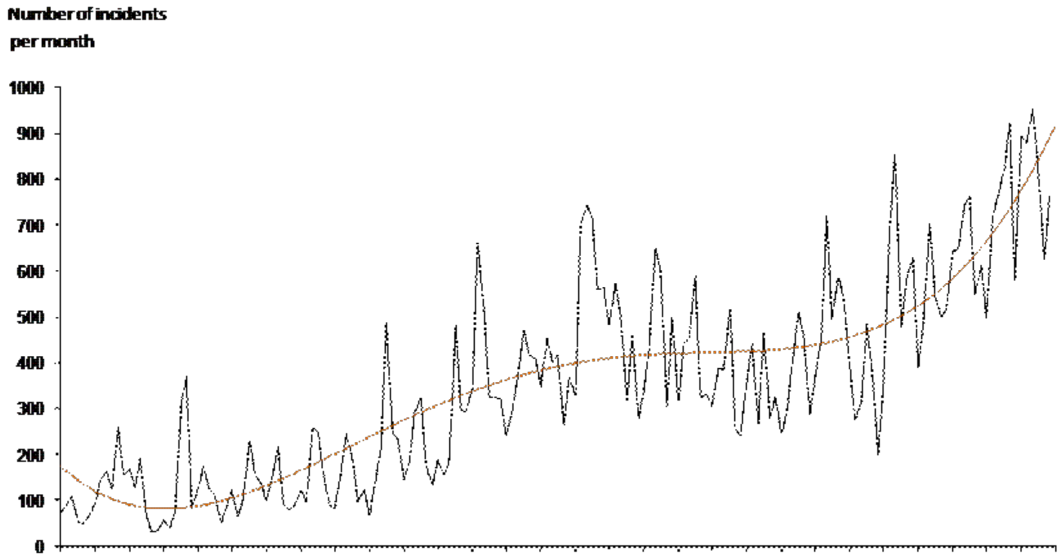


Fig.1 Development of the frequency quality the last 12 years (nr. of violations of limits pr. month)

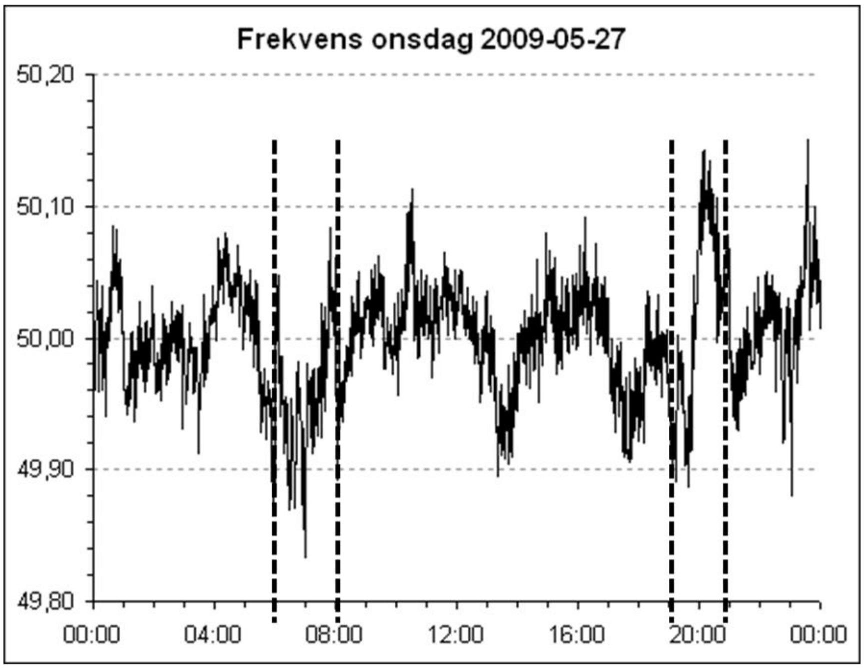


Fig 2: Typical frequency trend for the Nordic synchronous system showing concentration of violations of frequency limits in "ramping hours".

In the Continental synchronous system, there is a requirement that planned changes of flows on interconnectors between countries shall be performed within 5 minutes before and 5 minutes after the hour shift. Based on this restriction and the restriction in the previous paragraph (max. 30 MW/min), the maximum possible change in flow from one hour to the next hour on the six relevant connections would be 6x30x10 = 1800 MW while the potential difference in the market is 8000 MW. This is the background for the current restriction in the energy market (chapter 2) also considering practiced flow-changes on the connections and the problems the TSOs experience in the system operation with those.

4 Socioeconomic costs of ramping restrictions

4.1 Approach

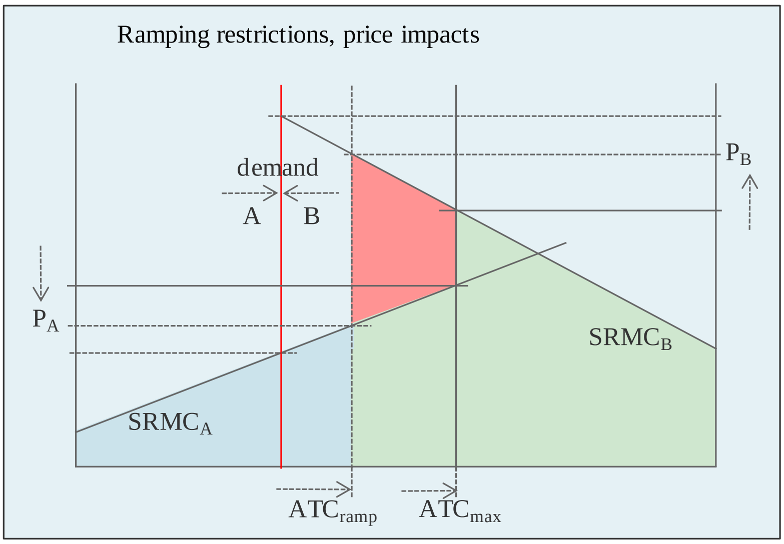
The exchange between two areas is dependant on the fluctuations in the market prices in the two areas. The variation in the exchange secures a more optimal use of the resources in the two areas together. When a restriction for the exchange like the ramping restriction is introduced, this will reduce the market efficiency and the value of the interconnection. When system security is not considered, the socioeconomic costs consists of changes in congestion rent with and without the restriction and changes in consumer and producer surplus. Based on the assumption that the price effects are minor, an often used simplified method to monitor the impact from varying capacity on interconnectors is to look at variations in the congestion rent from the interconnector. Impact on market prices is another indicator which also can justify if the simplified method is acceptable. In this report it is assumed that the reduction in congestion rent is a good approximation of the socioeconomic costs for the ramping restriction.

The methods used to handle ramping on HVDC-connections should be chosen based on a full socioeconomic evaluation. A potential reduction of the ramping restriction will reduce the socioeconomic costs related to the market, but will on the other hand trigger off some other socioeconomic costs related to system security and the goal must be to find the optimal mix of different means.

4.2 Socioeconomic consequences of ramping restrictions

To illustrate the socioeconomic consequences of ramping restrictions, a figure has been included. The figure below shows a snapshot of the use of an interconnector between markets A and B:

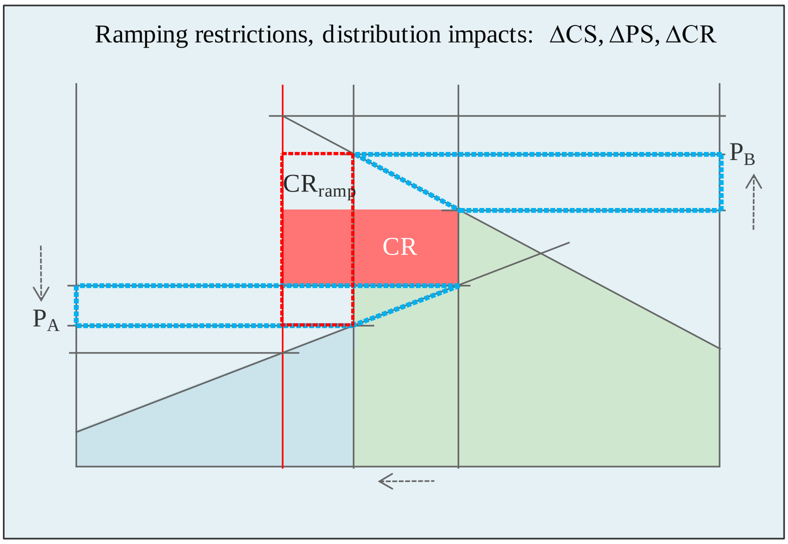
- The horizontal axis represents the total demand of the two markets, with markets A and B on separate sides of the red vertical line. For simplicity, the demand is assumed to be completely inelastic.
- The short-run marginal cost (SRMC) for production is shown in the two markets by two increasing lines, market A from the left and market B from the right.
- The prices in autarchy, ie a situation where no trade is possible, shown with two horizontal lines intersecting the red, vertical line. The price in area A is shown by the lowest horizontal line on the left side of the figure and the price in area B is shown by the upper horizontal line on the right side of the figure.
- The transmission capacity between markets A and B is represented by one vertical line for the maximum capacity from A to B (shown by the arrow denominated ATC_{MAX}), and one for the reduced/restricted capacity due to ramping (shown by the arrow denominated ATC_{ramp}). The corresponging prices are shown by horizontal lines. Increasing transmission capacity causesprices to converge, thus the price difference is greatest at autarchy and smallest when the interconnection is used at maximum, unrestricted capacity. The arrows denominated



P_A and P_B indicate the price movements due to ramping restrictions in the energy market. We can hence see that the price difference is larger when the transmission capacity is restricted than without the restriction.

The red trapezoid shows the “efficiency loss” caused by the ramping constraint in comparison with the ideal, unrestricted case: The constraint causes increased production in market B at high cost, and reduced production in market A at lower cost. The area of the trapezoid represents the corresponding increase of generation cost.
The efficiency loss of using ramping constraints should be compared to the costs of handling ramping by other means. It is however important to note that it is not possible to get rid the costs altogether.

For the distributional impacts of the ramping constraints, see the next diagram. The change in consumer surplus is shown in grey for each market. The change is positive in market A where the market price goes down, and negative in market B where there is a price increase. The change in producer surplus is shown as a blue polygon in each market. Market A has negative change due to reduced price AND volume, whereas the opposite occurs in market B. The filled red rectangle shows the congestion rent (CR) at full use of the transmission capacity, whereas the unfilled red rectangle shows the CR in the case of ramping restriction. In principle, the change of CR may be positive or negative The net cost is equal to the area shown in the figure above. .



historical data are not necessarily representative for a longer period, nor for prediction of the future.

5.1 Impact to bottleneck hours

Ramping restrictions increase the number of bottleneck hours. The HVDC connections would have been congested for many hours even without ramping restrictions, and the analyses shows that the used ramping restriction has a limited impact on the total congested time. By raising the ramping restriction up to 800 MW, the increase in number of bottleneck hours would be about halved.

1.11.2007 – 29.9.2008	Kontek	Skagerrak	Kontiskan
600 MW	2,8 %	3,2 %	3,7 %
800 MW	1,1 %	1,5 %	1,4 %
Congested time - no ramping	34,6 %	76,5 %	46,8 %

1.1.2009 – 31.5.2009	Kontek	Skagerrak	Kontiskan
600 MW	7,4 %	12,8 %	12,3 %
800 MW	3,2 %	6,9 %	6,0 %
Congested time - no ramping	45,5 %	35,2 %	19, 7 %

Table 1. Increase in number of bottleneck hours with different ramping restrictions compared to the case with no ramping restrictions

5.2 Impact to area prices

The analyses show that impact of 600 MW ramping restriction to the average area prices during the whole analysis period is non-significant, some euro cents per MWh or even smaller.

	DK1	NO1	SE	DK2
1-9/2008	0,094 €	0,007 €	0,009 €	0,001 €
1-5/2009	0,190 €	0,015 €	0,003 €	0,001 €

Table 2. Impact of 600 MW ramping restriction to the average area prices during the analysis periods

Looking at those specific hours when ramping restrictions has influenced to flows, the impact to area prices has been about 0,1 - 0,2 €/MWh. In DK1(Jutland) the impact has been more significant, over 1 €/MWh.

	DK1	NO1	SE	DK2
1-9/2008	1,16 €	0,10 €	0,14 €	0,21 €
1-5/2009	1,09 €	0,14 €	0,15 €	0,24 €

Table 3. Impact of 600 MW ramping restriction to area prices during those hours when ramping has had influence to hourly prices.

5.3 Impact to congestion income

The socioeconomic loss due to ramping restrictions in the energy market is understood as the difference of efficiency in the restricted case and the ideal, unrestricted case. Assuming small price impacts of ramping restrictions, the estimation of this difference amounts to calculating the reduction of congestion rent for all hours of ramping restrictions in the studied period, for the HVDC links considered for all ramping hours.

1.11.2007- 29.9.2008	Kontek	Skagerrak	Kontiskan	Total
Increase of congestion rent - ramping 600 MW	308 k€	586 k€	389 k€	1283 k€
Share of total congestion income	1,1 %	0,6 %	1,2 %	0,8%

1.1.2009 – 31.5.2009	Kontek	Skagerrak	Kontiskan	Total
Increase of congestion rent - ramping 600 MW	291 k€	692 k€	534 k€	1 517 k€
Share of total congestion income	2,7 %	9,8 %	24,7 %	8,2%

Table 4. Impact of 600 MW ramping restriction to congestion rent and the share of total congestion income

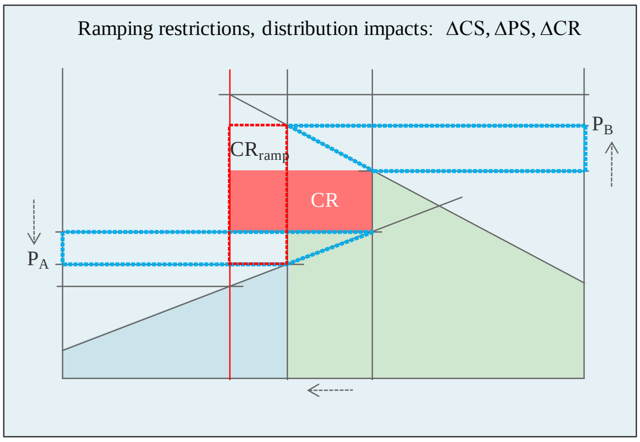
Taking into account the length of the analysis periods and the other interconnectors between the Nordic and the continental system, which are not a part of the Elspot market, a rough estimate can be that the increase of the total congestion rent due to the ramping restriction is about 2-4 M€/year.

5.4 Distributional impacts of ramping restrictions in Denmark West

The distributional impacts of ramping restrictions are the transfer of welfare between consumers, producers and the owners of the TSO links. The relative proportions of consumer surplus, producer surplus and congestion rent are examined below in a simplified manner, focussing on:

- The impact of ramping restrictions on consumer surplus in Denmark West. Only the price movement is taken into account, i.e. assuming inelastic demand (refer again to the market diagram, at right).

- The impact on total congestion rent on both HVDC links, considering the volume restriction only, and no price impact (assuming the slopes of marginal cost curves to be low and the CR reduction to be proportional to the reduction of transmission capacity).



Consumer surplus in Denmark West:
Assuming the demand to be inelastic, there is no volume impact on the consumer surplus. The distributional impact of price movements due to ramping restrictions is small, according to the the figures in paragraph 5.2 . The average price increase over the two periods studied would be approximately 0,13 €/MWh. For a typical Danish household with a yearly consumption of 4000 kWh, the increased cost would be approximately 0,5 € yearly. For all the west Danish consumption in total, the cost of ramping restrictions would be approximately 2,6 mill € yearly. For a simple estimate of the distributional impact in DK1,the average price change is used.

6 Short term alternatives to current handling of ramping

To use market restrictions to solve physical problems is questioned as proper means. Currently this principle is practiced in all European countries where physical capacities on interconnectors are limiting the allowed trade between countries or areas. The ramping restriction has many similarities with this, but there are also differences.

Some other short term alternatives are:

- Counter trade
  - In The Day-ahead market
  - In The Intra-day market
  - In the Balancing market
  - Through bilateral agreements with suitable players
- More automatic reserves to handle imbalances
- Better TSO control of changes in physical production

6.1 Counter trade

All sorts of counter trade will involve TSOs as intermediaries between players on both sides of the HVDC-cables. Currently the integration of markets after the spot market and the TSO arrangements between the continental and Nordic side of the HVDC connections are not sufficiently developed to guarantee that counter trade can be performed. Among other things, cost sharing mechanisms between the Nordic and Continental European synchronous systems will have to be developed. Currently there are no practical and transparent procedures for counter trade available for the TSOs.

The number of market participant in the energy market is larger than in any practical "counter trade market". Credibility, liquidity, transparency and risk of manipulation are important factors for efficient electricity markets. There has been a lot of investigations about the effects of large scale counter trade and there are different views about this issue. Further analyses will have to be performed.

Counter trade as an alternative to spot market ramping restrictions is further discussed in chapter 7 .

6.1.1 Counter trade in the Day-ahead market

This involves EMCC, EEX, APX and Nord Pool Spot since trading has to be between the Nordic and the Continental European synchronous systems. Counter trade in Elspot was evaluated by Nordel some years ago as a method to reduce price differences in the Nordic market area. The method was not recommended in general because it brought about confusing price signals for all markets including the balancing market. Use of Elspot market for counter trade has also not been recommended in accordance with Nordic price area division studies.

6.1.2 Counter trade in the Intra-day market

Currently the Intra-day market has too little liquidity to guarantee that counter trade with needed volumes can be executed. There are also varying opinions if the TSOs should be allowed to be so direct market players with predictable direction for the volumes. This might raise the risk for unwanted arbitrage between the market segments. No solution is currently developed for this.

6.1.3 Counter trade in the Balancing market

Balancing market is a tool for balancing the system in the operating phase and is currently not regarded as a feasible tool for the counter trade in the planning phase. The time between gate closure for the market and the operating hour is very short and such a solution would use the limited resources which are needed for balancing.

6.2 More automatic reserves to handle imbalances

The challenge with ramping on HVDC-connections is handled to-day by restrictions in the energy markets (Day-ahead, Intra-day, bilateral trade) but also using automatic reserves. It is possible to change the composition of these tools. The restrictions in the energy markets can be reduced by using more automatic reserves. The right mixture of the tools can then be evaluated in an economic sense by comparing socioeconomic costs involved.

More automatic reserves is mainly needed in the Nordic synchronous system. This is because the flow on the HVDC-cables in the morning tends to change in the direction of additional demand in the Nordic system while the opposite is the case on the continent. This will be reversed in the evening with the same result on needs for reserves. If the physical ramping is conducted too quickly, also the Continental European synchronous systems will need to correct the balance using automatic reserves but with smaller volumes. Since the needed reserve requirements are not symmetric, it is not obvious that the Nordic system should bear all costs involved for the needed extra reserves in the Nordic area.

To increase the volume of automatic reserves, will lead to two types of socioeconomic costs:

- Production capacity must be kept outside of the energy market. For production with storage capacity and limited "fuel", this cost will be a function of the differences between peak and bottom prices in the market.
- The efficiency in the production will be reduced as more generators must be spinning and the set-points for production will be different from the optimal ones.

The automatically activated reserves can further serve two purposes.

- Reserves can be used to balance minute by minute some minutes before real time based on plans and prognoses. Accurate production according to plans and good consumption prognoses is essential for this.
- Reserves can be used to handle the inevitable imbalance in real time.

The actual costs for reserves are difficult to calculate. An indication can be to multiply the average unit costs for primary reserves in the Nordic countries with expected increase in needed reserve-volumes to allow for a reduced ramping restriction in the energy markets. Based on an estimated unit cost of 6 €/MW for automatic reserves and that a reduction of the ramping restriction by 200 MW on 5 cables (Skagerrak and KontiSkan has a joint restriction of 600 MWh/h) will require 500 MW (the ramping is done with 50% before hour shift and 50% after hour shift) more reserves in 8 hours a day, the reserve cost for increased ramping will be 8.8 mill € pr. year which is 2-4 times as much as the calculated reduction in "market costs" if the ramping restriction was raised from 600 MWh/h to 800 MWh/h.

6.3 Better TSO control of changes in physical production

The frequent large changes in production and flow in fully loaded corridors in the grid make it difficult to control the balance and frequency of the Nordic synchronous system. For the same reasons local voltage problems also occur frequently.

Currently only hourly production plans are required in most Nordic countries. The change of production levels at hour shifts are to a large extent conducted manually. Requirements for quarterly (i.e. 15-minute) plans are now being developed to improve the match between production, consumption and exchange in the planning phase.

This alternative will, together with other actions under implementation, help on the challenge to control system security in ramping hours, but will not be able to solve the challenge alone.

7 A closer look at the counter trade alternative

7.1 Estimated TSO costs of counter trade

If the there were no ramping restrictions in the spot market, the TSOs would need to counter trade to reduce the flow on the interconnectors afterwards. The TSOs would sell power on the exporting side and buy power on the importing side.

The revenues and costs for counter trade as an alternative to spot market ramping restrictions were calculated for the study period based on the data set from 2008-2009, covering the Skagerrak and Kontiskan links. The aggregated results are shown in the table below. The hourly volumes of counter trade are defined by the differences between maximum and ramped flow in the ramping hours selected from the data set. The hourly prices are taken from historic spot data, and from the tertiary reserves markets of NO1, SE and DK1. When only one price is available for tertiary reserves, the spot price has been used instead when applicable. No price impact is considered, neither in the spot nor in the balancing markets. It should be notated that these costs are conservative, potentially significantly, since no price impact is considered. Including price impact, both the congestion rent and the rent from power sales would decrease, whereas the costs for power purchase would increase.

Counter trade, Skagerrak totals (MEUR)			
ΔCR	BP sale	BP purchase	Net CT cost
2.2	30.3	-34.5	-2.1
Counter trade, Kontiskan totals (MEUR)			
ΔCR	BP sale	BP purchase	Net CT cost
2.1	22.2	-27.2	-2.9

8 Long term alternatives to current handling of ramping

8.1 New rules with longer time frames for changes of exchange and productions

The basic reasons for the present ramping restrictions are that the changes of physical flows in the grid as a result of the changes of the market schedules take place too rapidly thus making it difficult to control the balance and frequency of the Nordic synchronous system and the local voltages. The Continental European synchronous system faces similar challenges especially around the hour shifts.

A solution might be to restrict the rate of change of physical productions and exchanges in the power systems. This would imply that the changes take place more slowly and would also result in a better approximation between the productions and the consumptions since the first mentioned to-day tend to change mostly around the hour shifts while the last mentioned change continuously during the hours. The restrictions must be formulated in a way where internal restrictions in the synchronous system is correlated with the external restrictions on the border towards other synchronous systems and where considerations to both system security and market efficiency is taken.

The Continental European synchronous system considers a restriction of at least 10 minutes (5 minutes before and 5 minutes after each hour shift) for the duration of each planned change of production. For the Nordic synchronous system, and maybe also for the continental system, a restriction of 30 minutes (15 minutes before and 15 minutes after each hour shift) for the duration of change of production with large volumes would probably be more appropriate and in line with a future transition to a more quarterly based regime.

An agreement between the Nordic synchronous system and the Continental European synchronous systems of a restriction of 30 minutes (15 minutes before and 15 minutes after each hour shift) for the duration of change of exchange would probably solve a large part of the challenge with ramping on HVDC-connections.

A restriction on duration of change of physical productions with large volumes will mostly influence hydro power plants and other fast regulating units whereas the thermal power plants by nature have limited regulating gradients. Producers operating several fast regulating power plants may be able to approach the restriction by starting/stopping the plants at different moments within the required 30 minutes period.

This restriction will introduce imbalances of the physical productions/exchanges compared to the market schedules. In the imbalance settlement these can be taken care of by introducing this as a specific element. Furthermore these imbalances as regards the physical energy ought to level out from hour to hour.

8.2 Quarterly settlement in the Nordic area

With quarterly settlement in the Nordic area, the physical imbalances between production and consumption/exchange will be reduced. Consequently the needed volumes of and costs for reserves can be reduced. However, some other costs will be introduced for new meters, new or developed IT-systems and more comprehensive settlement procedures. The TSOs will try to evaluate these costs for this reason and for other more general reasons (market integration and harmonization).

The alternative will help on the challenge to control system security in ramping hours, but will not be able to solve the challenge completely.

8.3 Coordinated balancing of different synchronous areas

In the future it might also be developed a balancing mechanism where the Nordic and continental system are balanced as one physical area i.e. that the frequency control is coordinated between the two synchronous systems. High frequency in one area and low frequency in the other area is automatically levelled out by changing the flow on the HVDC-connections from scheduled values. When both systems have high or low frequency, agreed rules may determine if the flow is going to be changed or not, i.e. if one area is going to have priority given the observed deviation from target frequency. This will require a very well developed system for information exchange between the European TSOs or maybe even a centralised balancing organization for Europe. The management of heavy loaded corridors in the grid will be a challenge which must be solved, new control systems for the HVDC-regulation will have to be implemented and agreements for system operation and about how to settle economical consequences on reservation and activation of reserves between several TSOs will have to be developed. When all this is in place, the ramping problem will probably to a large extent be solved.

9 Possible development for the ramping restriction in the energy market

The current ramping restriction may be changed in the future if other alternative means are proven to be more socioeconomic efficient. A transformation of the restriction from a uniform restriction on all connections to an individual restriction based on some defined criteria (size of connection or other) is possible. An optimal solution from a market perspective could be to introduce an optimization algorithm in the exchange systems for day ahead trade which could allocate a sum-restriction to the connections with largest price differences. In this scenario some second level restrictions for subareas would probably also have to be introduced. These alternatives will have to be studied further.

10 Assembly diagram

Solution	Socioeconomic costs	Feasibility	Time frame	Basis	Comments
Ramping restriction		In operation	Present	Market	
Counter trade	No socioeconomic gain	Currently not feasible	Long-term	Market	Requires negotiations with foreign partners
More automatic reserves	Seems to be significantly higher than the ramping restriction	Feasible	Short-term	Physical operation	
Better control of changes in physical productions (quarterly production plans)		Feasible	Medium-term	Physical operation	Requires new regulations and developed operations planning systems
Longer time frames for physical changes		Feasible	Long-term	Physical operation	Requires new regulations and developed control systems
Quarterly settlement		Feasible	Long-term	Market	Requires new meters, developed IT-systems and more comprehensive settlement procedures

11 Further process

To follow up of possible developments, impact analyses of the ramping restriction will continue as well as further evaluation of alternative rules for ramping.

After implementation of LFC and quarterly production plans, the current restriction will be reconsidered based on experiences.

A discussion will be initiated within ENTSO-E if a slower ramping speed on HVDC-connections can be accepted.

Investments in technical development of control systems must be decided to make it possible with a better matching of production, consumption and exchange. The systems must be prepared for short time resolutions (quarters, minutes), ability to update plans and bids in short term markets quickly and communication which is quick and reliable.

Introduction of quarterly settlement in the Nordic area will be evaluated.