Reliability Standards and System Operating Practices

in Nordel

Report from Nordel ad hoc group

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Table of Contents

1. Introduction

Over the last years there have been a number of meetings of the European Electricity Regulatory Forum in Florence. At the eighth meeting on 21–22 February 2002 the following was stated under item IV. Security and reliability standards:

> *A comprehensive set of common security and reliability standards to be observed by TSOs and network users should be presented and further developed and put in the public domain in order to ensure the efficient and secure functioning of the interconnected system and appropriate quality of electricity supply. UCTE, together with Nordel and other network associations were invited, in close collaboration with the Commission, the CEER, ETSO and other relevant stakeholders, to present and further develop such standards, and to present them for discussion by 1st September 2002.*

On 4 June 2002 there was a meeting in Brussels at EU DG TREN where the status of the work on the above topics was discussed. In the minutes from this meeting it is stated:

> *Technical rules contain several areas which are less relevant to the market. However, there is a strong interaction between the technical rules and the market rules.* ***It is this interaction between the technical rules and the market rules which needs to be discussed in the Florence process.***

At its meeting on 13 June 2002, Nordel's Board decided that Nordel should prepare a report on Nordel's security and reliability standards. This report is the result of that work.

2. The Nordic Electricity Market

2.1 History

The liberalisation of the electricity markets in the Nordic countries started in the beginning of the 1990´s. The public authorities in the countries initiated the process, and comprehensive reports and discussions with the industry resulted in new legislation paving the way for the deregulation.

The deregulation process started in Norway with a new Energy Act that came into force on 1 January 1991. This opened up for competition in generation and sale of electricity and generally wherever possible in the electricity business.

The networks, as natural monopolies, were separated from competitive activities. All networks were opened up for a general third party access, regardless of the connection point. This meant free access on equal terms for everyone to transmit power through all Norwegian transmission and distribution networks. Network monopolies were regulated by the authorities. All customers were made eligible from day one.

In Finland a new Electricity Market Act came into force on 1 June 1995. This opened up for competition in power generation, sale and foreign trade. From November 1995 the grids were opened for all customers whose purchase exceeded 500 kW. From January 1997 all customers were eligible. Full opening of the Finnish electricity market took place in September 1998 when load type curves were introduced for smaller customers.

In Sweden new regulations for the electricity market came into force on 1 January 1996, following amendments to the Electricity Act and introduction of a new law concerning trade in electricity. Competition was introduced in generation and sale and all networks were opened up. All electricity consumers were given the opportunity to choose their supplier freely, provided that power consumption was measured by the hour. This requirement was abolished by 1 November 1999 when instead load type curves were introduced for smaller customers.

1998 was the first year of competition in the Danish electricity market. The liberalisation was based on the new Electricity Supply Act that had been passed by the Danish Parliament in the summer of 1996 and had been notified by the EU Commission at the end of 1997. The main implication of the Act was that large customers and distribution companies consuming or selling more than 100 GWh per year now had open access to all grids. Several amendments to the Electricity Supply Act have followed in the last years. The entry level was reduced to 10 GWh on 1 April 2000 and to 1 GWh on 1 January 2001. Full opening of the Danish electricity market including all small customers will take place on 1 January 2003.

An important part of the development of the common Nordic electricity market is the development of the power exchange Nord Pool. The basis for Nord Pool was laid at the end of 1992 when a power exchange in Norway was established as a subsidiary of the Norwegian transmission system operator (TSO) Statnett. When Sweden opened the electricity market in 1996, Nord Pool was established on 1 January 1996 as the first international power exchange in the world. It was then jointly owned by the two TSOs in Norway and Sweden, Statnett and Svenska Kraftnät.

From 1998 also Finland joined Nord Pool and the common Nordic electricity market. The Western part of Denmark was included in the market area on 1 July 1999 and the Eastern part of Denmark was included on 1 October 2000.

The Finnish power exchange EL-EX was established in 1996 for hour based exchange with limited trading time. In 1999 Sweden joined EL-EX as an own area, and after two years development phase, a 24-hour market with one hour gate closure was working in these two countries. This is the Elbas market , which is now part of Nord Pool’s products in these two countries.

From 1 January 2002 the organisational structure of Nord Pool was changed so that the day-ahead physical Elspot trade was transferred to a separate company, Nord Pool Spot, while the financial trade continued in the mother company. From 1 July 2002 the ownership of Nord Pool Spot was widened so that now all the TSOs in the market area are owners of the company. Fingrid in Finland, Statnett in Norway, Svenska Kraftnät in Sweden and Nord Pool all have 20 % of the shares in Nord Pool Spot. The remaining 20 % is held 10 % by Elkraft System in Eastern Denmark and 10 % by Eltra in Western Denmark.

2.2 Basic features of the Nordic electricity market

On establishing the Nordic electricity market, the parliaments developed similar legislation in all countries. In each country a regulator was given an important role in implementing the market opening. In all Nordic countries a transmission system operator (TSO) solution was chosen. The ownership of the TSOs is different for each of the TSOs, ranging from state ownership via mixed private and state shareholders to cooperative consumer owned.

There are several fields of knowledge and experience that have contributed to the development of the Nordic electricity market. A market mechanism has been developed. Power and energy balances still have to be maintained. There has to be a balance between striving for competition and the stability in the system. The infrastructure must be in place to develop the market.

The opening of all networks to all market participants and the introduction of a point tariff system were important parts of the market opening.

There are several market places. Bilateral trade and the power exchange coexist to mutual benefit. Brokers operate separate market places. There are a large number of players in the retail market.

A number of service providers have developed, such as: Analysis service providers, information service providers, portfolio managers and balance responsible parties.

2.3 Key figures for the Nordic electricity market

The common Nordic electricity market comprises the four countries Denmark, Finland, Norway and Sweden. Iceland is also taking part in the Nordic co-operation such as in the Nordel organisation, but is not interconnected to the other countries. In table 1 key figures for the Nordic electricity system for 2001 are shown. The peak load for the interconnected system is slightly less than 70 000 MW, and the total consumption for the same area was 393 TWh.

The population of the common trade area is 24.0 million, with 5.4 in Denmark, 5.2 in Finland, 4.5 in Norway and 8.9 in Sweden.

TABLE I
KEY FIGURES FOR THE NORDIC ELECTRICITY SYSTEM FOR 2001

		Denmark	Finland	Iceland	Norway	Sweden	**Nordel**
Installed capacity	MW	12 480	16 827	1 427	27 893	31 721	**90 348**
Generation	GWh	36 009	71 645	8 028	121 872	157 803	**395 357**
Imports	GWh	8 603	12 790	.	10 753	11 167	**43 313**
Exports	GWh	9 180	2 831	.	7 161	18 458	**37 630**
Total consumption	GWh	35 432	81 604	8 028	125 464	150 512	**401 040**
Breakdown of electricity generation:							
Hydropower	%	0	19	82	99	50	**55**
Nuclear power	%	.	31	.	.	44	**23**
Other thermal power	%	88	52	0	1	6	**20**
Other renewable power	%	12	0	18	0	0	**2**

. No nuclear power production

0 Less than 0.5 %

The physical electricity spot (Elspot) trade on the power exchange Nord Pool was in 2001 111,2 TWh. The same year the financial trade (eltermin and eloption) on Nord Pool was 909,8 TWh. Finally clearing of bilateral contracts amounted to 1748 TWh. The elspot trade was 28,3 % (111,2/393) of the total consumption in the market area.

3. Nordel Reliability Standards

3.1 Introduction

The Nordic electricity system has a long tradition for co-operation and co-ordination in operation and planning. This was earlier based on Nordel recommendations, and is now based on a common Nordic system operation agreement between the Nordic TSOs. The agreement forms a part of a Nordic Operation Code.

Nordel is now an organisation for co-operation between the Nordic TSOs. The primary objective for Nordel is to facilitate an efficient and harmonised Nordic electricity market. There are three main activity areas for Nordel: System planning, market development and system operation.

3.2 The System Operation Agreement (An Operation Code)

3.2.1 Objectives

The objective of the system operation agreement is to make use of the advantages of an interconnected operation of the Nordic power system. The TSOs shall thus jointly maintain the coherent operation of the Nordic power system with a satisfactory level of security and quality.

The TSOs shall jointly maintain a supply quality that is appropriate with respect to the joint system operation, e.g. frequency, time variation, system oscillations, etc.

The TSOs shall jointly operate the interconnected Nordic power system in a manner which promotes power trading in the Nordic electricity market and the efficient utilisation of existing resources, as well as trading in a potentially wider international market. The system operation agreement specifies the detailed commitments that the TSOs shall undertake to fulfil their responsibilities in the operational collaboration. The common operating activities and principles will be discussed in the following paragraphs.

3.2.2 Reliability criteria

The reliability criteria are based on the n-1 criterion.

This implies that:

- Single faults in a subsystem shall not result in serious operational disturbances in adjacent subsystems.
- There shall be an adequate disturbance reserve and transmission capacity to enable the Nordic power system to cope with clear design contingencies.

- The loss of a bus bar in a subsystem must not lead to serious operational disturbances in other subsystems.
- Following a disturbance on the n-1 level, the system shall within 15 minutes resume operation within normal limits of transmission capacity and frequency deviation.
- System protection schemes are accepted as part of n-1 criterion, and are used to a variable degree in the various countries.
- Temporary n-0 principle is to a variable degree accepted regionally by each TSO under special operating conditions and when important lines are out for maintenance.

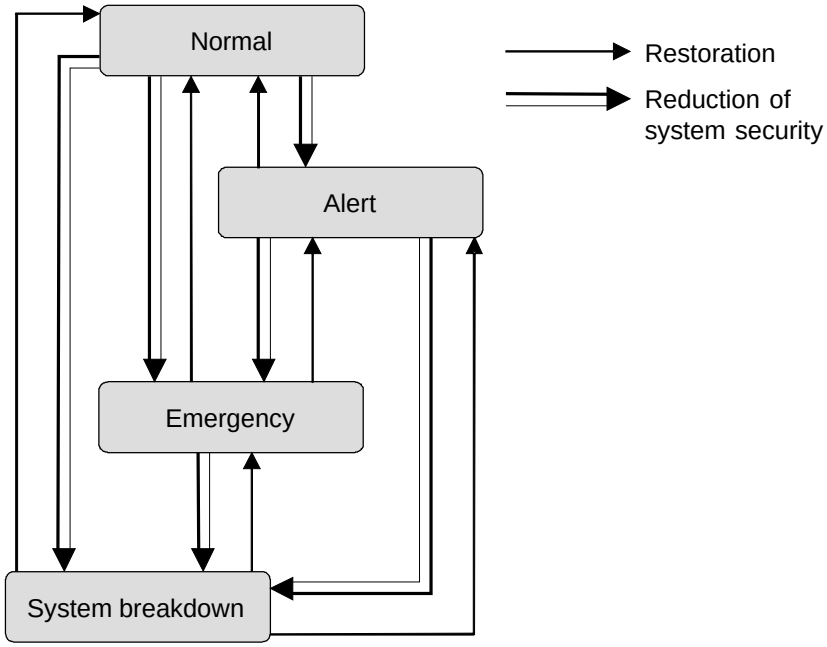

Figure 1 System state model

3.2.3 Reserves

Operations are based on a number of different reserves, such as

- Frequency control reserve (100 % activated at 49,9 Hz)
- Instantaneous disturbance reserve (50% activated at 5 sec. and 100% at 30 sec.)
- Fast active reserve (15 min.)
- Slow active reserve (4-8 hours)
- Reactive reserve

The Nordic TSOs have different principles of maintaining slow active reserve. Due to the limited size of the system compared with for instance the UCTE, the instantaneous disturbance reserve has to be activated faster than in the UCTE system, that is, 50 % must be active within 5 sec.

3.2.4 Bottlenecks

The TSOs shall be bilaterally responsible for transmission on the respective links between the subsystems not exceeding set transmission limits. If a limit is exceeded due to an outage, normal conditions shall be reestablished within 15 minutes.

The TSOs shall bilaterally coordinate terms, conditions and management routines in order to be able, when required, to reduce flows in order not to violate transfer limits. The separate terms and conditions that are applicable to each respective link, are set forth in the Operation Code.

The TSOs shall be obliged to manage all transmission problems, within their own subsystems. Furthermore, the TSOs shall be responsible for implementing the necessary control on their side of the links and for costs thus arising, unless otherwise agreed between the TSOs concerned.

3.2.5 Managing operational disturbances

In case of operational disturbances, normal operation shall be resumed without undue delay. The TSOs shall assist one another in minimising the consequences of disturbances.

For disturbances within its own subsystem, the affected TSO will be responsible, at its own expense, for remedial actions. Whenever it is appropriate to carry out remedial actions in another subsystem, the affected TSO shall be responsible for the resulting cost.
In the event of disturbances on a link between the subsystems, the TSOs concerned shall, at their own expense, be responsible for the necessary measures on their own side of the link, unless otherwise agreed.

For activation of the joint instantaneous active disturbance reserve, compensation shall normally be rendered via the settlement of balance power.

The TSOs shall promptly inform one another of operational security risks or disturbances that arise.

3.2.6 Balance management

The Elspot market is used in each subsystem by the various actors for planning their balance a day-ahead on an hourly basis.

In addition, the hour-ahead Elbas market is used in Sweden and Finland for balancing on an hourly basis. Final balancing of actor's balance for each operational hour is done by using balancing power. This balance is settled afterwards.

The TSOs shall collaborate with the aim of minimising the costs of balance regulation by utilising, to the greatest extent possible, one another’s control resources when this is technically and financially appropriate.

The basis for the balance management of the synchronous system is frequency control. Control is distributed in accordance with the requirement for regulation capability and a joint

Nordic merit order list. The entire Nordic power system shall constitute a single market for regulating power. In the event of bottlenecks between the control areas, the regulating power market will be divided.

The TSOs shall inform of control problems within the hour of operation and especially on the hour. Major changes of exchange plans are managed currently via agreements on appropriate control measures.

The balance regulation of each subsystem within the interconnected Nordic synchronous power system shall be carried out in accordance with the principles set forth in the Operation Code. Statnett and Svenska Kraftnät have the main responsibility to keep the frequency in the synchronous system.

Eltra looks after the balance regulation of the Western Danish area within its responsibility to the UCTE system and in accordance with an agreement with E.ON Netz. Consequently, Eltra has agreements with two balance areas; the UCTE system and the synchronous Nordic system.

3.2.7 Information exchange

The Operation Code specifies the information that shall be exchanged between the TSOs for system operation requirements. Such information shall, within the framework of the legislation in force in each respective country, be deemed to be classified.

An agreement between the TSOs and Nord Pool defines essential information which must be given by the system operators to the market at the same time and in an equal and fast way (in practice on the internet).

3.2.8 System protection

System protection schemes have been developed to increase the capacities in the grid without heavy investments in new transmission capacities, and still keeping the n-1 criterion. The purpose of using system protection schemes is to increase ATC (Available Transmission Capacity) in the system. New schemes have been introduced according to operational needs. Network protection requires a reliability of the supporting control systems on the level of primary protection.

In addition to system protection schemes, the transmission capacities have also been increased without new transmission lines, by extensive introduction of temperature upgrading and installation of shunt as well as series capacitor banks.

System protection schemes in the AC system are based on generator tripping, network splitting or selective load shedding initiated automatically by severe line outages.

In DC facilities, system protection consists of emergency power settings at the converter stations. The activation criteria can be the locally measured frequency and voltages or via telecommunication based on the supplied signal. Upon activation, any ongoing normal control is interrupted. Activation over and above agreed limits and regulation back to plan may only take place following the counter-party’s approval.

3.2.9 Managing transmission constraints between subsystems

3.2.9.1 Background

Transmission capacity shall be put at the disposal of the players on the electricity market at equal terms and in accordance with the general rules applicable to transmission between the subsystems.

System operators may need, for reasons of operational reliability or the status of affairs in their own or adjacent networks, to limit the transmission capacity of the links between the subsystems.

For the transmission capacity of the border links between Elspot areas, the same prioritisation rules are to be applied by all system operators in the subsystems. This prioritisation is shown in table 2 below.

Priority		Sweden	Finland	Norway	Eastern Denmark	Western Denmark
1	Elspot	X	X	X	X	X
2	Elbas	X	X			
3	Hourly trading	X	X		X	
4	Short-term power trade	X	X	X	X	X
5	Balancing power (Regulating power)	X	X	X	X	X

Table 2 Prioritisation rules for transmission capacity

Elspot is the basic physical trading product for the day-ahead trade at Nord Pool Spot.

Elbas is traded for the period after Elspot is closed until one hour before operation. It is used for balancing purposes, and can be traded 24 hours a day. It can only be traded in Finland and Sweden.

Hourly trading is bilateral hourly trade that can take place the last hour before operation if there is available capacity in the transmission system. The TSOs have to be notified before the hour of trade.

Short-term power trade is trade of power between the TSOs.

Balancing power is the difference between all trade and measured transmissions between the TSOs. The amount of balancing power is also affected by the activated bids in the regulating power market.

Elspot, Elbas and hourly trading are trade between players in the electricity market. Short-term power trade and balancing power are trade of power between the TSOs.

3.2.9.2 Handling of transmission constraints during the planning phase, prior to completed trading on Elspot

1. Elspot is the basic physical trade product and is in addition used to balance transmission constraints between the subsystems during the planning phase by market splitting. The involved TSOs reach agreement on a day-to-day basis regarding the trading capacity for exchanges between the subsystems.

2. In the event of limited duration of the reduced transmission capacity between the subsystems, the system operators may agree to use counter trade.

3. In the event of transmission constraints within an elspot area, it will be the respective system operator's responsibility to manage the limitation by using constrained redispatch or by limiting the trading capacity to neighbouring elspot areas.

3.2.9.3 Handling of transmission constraints during the operational phase, following completed trading on Elspot

1. During the operational phase, reduced transmission capacity as a consequence of disturbances, is managed between the subsystems using counter trading. There is no limitation to the players' planned power trading on Elspot. Constrained redispatch takes place during the remainder of the current period when trade on Elspot has been settled.

   For Elbas trading, the trading capacity is reduced, but prearranged trading will be subject to counter trading for the remainder of the current Elspot period.

   For hourly trading, counter trading is only carried out during the remainder of the hour when the disturbance occurred, as well as the subsequent hour between Sweden and Finland and the subsequent two hours between Sweden and Eastern Denmark.

2. In the event of a disturbance in one subsystem, the TSO in that control area will bear the full technical, financial and operational responsibility for eliminating the effects of the incident.

3. In the event of a disturbance on the border links themselves, the system operators on both sides of the link will bear the technical, financial and operational responsibility for eliminating the effects of the incident on their own subsystems.

3.2.9.4 Reduction of the trading capacity during planned outages

Major changes of the transmission capacity due to outages on a link between two elspot areas may lead to major changes in power flows from one hour to another. These major changes can be difficult to manage from a control point of view. Thus, restrictions are placed on changes of MWh/h from one hour to the next. This change may be a maximum of 600 MWh/h.

3.3 The different markets

The processes for the physical day-ahead Elspot trade, the hour-ahead Elbas trade and the real-time balancing market are described.

The basic philosophy for the Nordic day-ahead market is:

- The power exchange Nord Pool is the common market place for physical Elspot trading in Denmark, Finland, Norway and Sweden
- The transmission network is the physical market place – the market place has a number of participants with equal access to the transmission system based on point tariffs
- The Nordic market place is one integrated market
- The TSO to decide the available transfer capacity (ATC)
- The available transfer capacity (ATC) is given 100 per cent to the market (Nord Pool)
- Bottlenecks between elspot areas are handled by market splitting
- The Nordic system is operated by five system operators and their aim is to act as one single system operator as far as possible
- In the afternoon before the operating day, production schedules for each hour are planned and the system is basically to be in balance as a result of the Elspot trade.
- Elbas trade and balancing activities starts in the evening before the operating day

3.3.1 Elspot Market and daily routines

The following figure shows activities to be completed during the day before the 24-hour period of operation:

08:00 - 09:30	Capacity usage based on the “use-it-or-lose-it” principle on the Danish-German borders
10:00 - 10:30	TSOs inform Nord Pool Spot about ATC between potential price areas within the Nord Pool market area
12:00	Deadline for bids and offers to Nord Pool Spot
13:00 - 14:00	Nord Pool Spot clears the market
14:00 - 19:00	Generators make final production plans
15:00 - 19:00	Production plans are submitted to the TSOs
16:00 - 19:00	Final production schedules are determined by the TSOs
16:00 - 19:30	Bids to the regulating power market (may be changed up to half an hour before the operational hour)
20:00 - 24:00	Load forecasts performed by TSOs

Table 3 Daily routines

3.3.2 Elbas Market

The Elbas Market is a physical market for power trading in hourly contracts for delivery today and the next day. It enables trading in Finland and Sweden for those hours where Elspot trade has been accepted, covering individual hours up to one hour before delivery.

After the Elspot market is cleared, ATC between Finland and Sweden is informed for next day and the market participants can start giving their bids.

3.3.3 Balancing Market

Nordel Operations Committee has developed a new order for the balance regulation cooperation within the Nordic countries. The goal has been to create a common regulating power market for all countries. The control cooperation will work in a way so that control come about in that part of the system that has the lowest cost for control and the players in the different parts of the system will meet as harmonised rules and prices as possible.

First, the new order will be implemented in the synchronised system. Second, Jutland (Western Denmark) that belongs to another control area will also be a part of the cooperation.

Main principles:

Each TSO receives regulating power bids within his system area and enters the bids to NOIS (Nordic Operational Information System), which is a web-based information system for exchange of operational information between TSOs. In NOIS a merit order list of all regulating power bids are put together and form a “staircase” visible to all TSOs.

Balance regulation of the synchronised system is frequency-controlled and control are in general activated in order of price of operation from the common list of the regulating power bids. At the end of each hour, the common regulating power price is determined in accordance with the marginal price for the operation. This price applies as reference price and is included in the calculation of the settlement prices for all the sub areas when the balance/imbalance is settled. Still, different models for balance settlement are used in the sub areas (one or two-price model, marginal price or middle price).

For situations with network congestion on the interconnections and within Norway the regulating power market is correspondingly divided into different price areas and bids for regulating power that are locked in are excluded from the “staircase”. Under these circumstances different regulating power prices occur for different sub areas.

The regulating TSO that performs the control action is to be paid for his costs. The price for balancing power between the various sub areas is determined at the common regulating power price, or middle price if these are different.

Statnett and Svenska Kraftnät share the main responsibility for the frequency control, in a similar way as today, and take initiatives to control actions within the synchronised system. Jutland will be managed in a similar way as today with planned supportive power exchange and will in that sense participate on the regulating power market. Eltra contributes frequency control within the UCTE-system and consequently operates balance control within the Eltra area.

The model is in force from 1 September 2002.

3.4 Interaction between technical rules and the market

The key to interaction between market and system operation is the criteria that are established when the trading capacities are determined.

A typical course of events may be as follows:

- Expected utilisation of the interconnectors between Nordel and the neighbouring areas
- Forecasts for load, wind production and other production plans
- Maintenance plans for production and transmission assets
- Review of limiting thermal values based on the n-1 criterion
- Review of limiting dynamic values based on forced outage of the largest unit or dimensioning fault
- Review of voltage stability
- The calculations are done for certain points of time for the coming 24-hour period
- Permissible exchange capacities are thereby determined.

Thus, the system operator is to ensure the technical security of supply. In practice, this means that the operational planning of the system operator must ensure that:

- It is possible to transport reserves through the system in case of forced outages or other events that require fast activation of production to avoid system collapse. The reserves in question are instantaneous reserves that are activated automatically within seconds.
- The balance can be restored in the individual areas after major forced outages in order to avoid thermal overload or instability. The individual areas must have reserve capacity at their disposal. Activation of this capacity may take place automatically or manually according to instructions or otherwise.
- Temporary overloading of single components can be contained within their short time ratings.

The transport capacity made available to the market players must be as large as possible, while also considering system reliability aspects.

4. Nordic Relations to Neighbouring Countries

4.1 The border between Finland and Russia

The interconnector between RAO UES of Russia and Fingrid is a back-to-back HVDC interconnector that is only able to supply towards Finland.

The interconnector is utilised for long-term contracts and there is a possibility of channel subscribtions. In addition to that Fingrid has an agreement for utilising 100 MW for reserves and system purposes.

From the beginning of 2003 a new 400 kV AC line shall be taken into operation. One Russian power plant shall be connected radially for export to the Finnish power system via that interconnector.

4.2 The border towards Poland

On the border between Nordel and Centrel (Sweden to Poland) there is an HVDC interconnector where part of the transport capacity is at the disposal of a single player.

4.3 The border towards Germany

A number of interconnectors between the Nordic area and Germany are subject to old contracts. To a certain extent, the use-it-or-lose-it principle applies.

On the border between Svenska Kraftnät and E.ON Netz there is an HVDC interconnection that exclusively is at the disposal of the owners of the interconnector which are generating companies.

On the border between Eltra and E.ON Netz (AC) and between Elkraft System and Vattenfall Europe Transmission (VET) (HVDC) an auction principle is used enabling purchase of capacities for bilateral cross-border trade. This trade may take place on an annual, monthly or daily basis.

4.4 General observation

It is important to develop a more harmonised interface to all neighbours to get a more integrated market.

5. Perspectives

Nordel has just prepared a Nordic Grid Master Plan illustrating possible expansion by new interconnectors. The report encourages to bilateral negotiations for expansion of the Nordic system.

An essential challenge is that even though overall profitability for expansion of a certain interconnector can be shown, it is seldom that the two TSOs that are to implement the project get a sufficient contribution margin to make the project profitable to the company.
Nordel is discussing how to solve this problem.

6. Conclusions

The Nordic system has the following characteristics:

- Coordinated system analyses are made for expansion by new interconnectors
- Agreement has been reached on a common Nordic Operation Code for system operation
- The target of system operation is to ensure that the spot market has the largest possible transport capacity at its disposal with due regard to maintaining the necessary system reliability
- The limits of the existing transmission system is increasingly extended by using system protection schemes as well as rehabilitation of the grid, thermal upgrading of lines and extensive reactive compensation

- An attempt is still being made to make the interconnectors at the border line between the Nordic and the neighbouring countries available to all players by replacing old contracts giving priority to some market players
- Today, the interconnection between the Nordic market and the market in the UCTE takes place on the basis of bilateral agreements. A more dynamic interaction between the markets is foreseen and will be developed further.

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