Energy shortage

Coordinated handling of a potential disturbance in the Nordic power system

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Summary

In a situation with low levels of water in the Nordic hydro power reservoirs, together with nuclear plants out of operation and limitations in transmission lines there is a risk for (long term) energy shortage in the Nordic electricity system, especially if combined with cold weather. Such events will normally be handled through the function of the market. However, there is a risk that a situation may occur where the market runs out of options and the governments and authorities must have prepared measures to avoid severe consequences for the society.

These measures have not been coordinated or discussed across the borders. This report is a first attempt to describe and discuss the differences, to find weaknesses and to explore potential benefits of further coordination and/or information exchange between the Nordic countries.

There are primarily two countries that have prepared measures to handle an energy shortage – Norway and Sweden. This is also due to the fact that these two countries have the largest dependency on hydro power. Denmark and Finland have preparations for other types of disturbances. They will however in one way or another be affected by a Nordic energy shortage, since disturbances and extreme prices spread like ripples on the water in the interconnected system.

A governmental intervention will have a range of consequences, not least an economic burden on the society and on the end users that are targets of the interventions. This will contribute to the hesitance of the politicians making the decision. There is also a range of uncertainties as to when the society needs to intervene in order to avoid a disaster. But one fact remains – the government and authority that is first in implementing these measures will impose the economic burden on its own society, and the other countries may be spared without significant consequences. Hence a coordinated effort between Sweden and Norway is preferred for the common good.

A development of mutual principles in terms of applying countermeasures could be preferred. The amount of uncertainties to consider however are numerous. And reducing the national self-governance is not desirable. The Nordic countries can nevertheless develop close cooperation and information exchange to be applied concerning the energy situation and prepared measures. This can be done on several “layers” (political, authorities, TSOs).

Content

Background

In the case of a long term or major energy shortage, serious consequences for major parts of the Nordic power system can be expected. There are national regulation and described roles/responsibilities concerning such a situation in some countries (primarily SE and NO). However, any coordination or dialogue at Nordic level on planning or handling of an energy shortage has yet not occurred.

In the NordBER Action plan for 2013-2015[1] it is therefore stated that the Nordic countries shall develop the understanding of the risk for, and handling of, an energy shortage in every country. An evaluation shall also be made to see whether situations may occur where national perspectives and solutions would result in unwanted negative consequences.

Method

The work has basically been explorative and analytic. The original plan was that the working group (WG) would compile the national systems and tools and analyse the material. After this, the plan was to hold a Nordic workshop about the results. Because of the complexity of the issues, the WG decided to change the plan. A scenario[1] in three steps was developed, and a Nordic workshop/exercise was organised, with participants from TSOs and authorities from all four involved countries[2]. The subsequent analysis was then based on the material from both the national inventories and the exercise, and the conclusions were mainly made in lively and constructive WG-meetings.

The procedure of the work is described in the figure below.

Figure 1. Progression of the working group

[1] See Appendix 2 – the scenario
[2] See Appendix 3 – notes from the exercise

The working group

A working group with participants from the Nordic countries within the common synchronous power grid has undertaken the task. The group is led by **Daniel Lundqvist**, Energimyndigheten. The participants in the working group are
Lars Andreas Eriksson, NVE;
Lars Gjedsted Sørensen (until January 2015)/**Peter Frost Andreasen**, (after January 2015) Energinet.dk;
Matti Jauhiainen (until June 2014)/**Petri Nieminen** (from March 2014), Försörjningsberedskapscentralen (NESA) and
Uffe Strandkjær (until January 2015), Energistyrelsen.

The working group have had 9 meetings, of which 3 were held on phone/web:

12 Nov 2013	Stockholm	Start-up meeting WG
12 March 2014	Telephone/web	WG
12th June 2014	Copenhagen	WG
9th Sept 2014	Stockholm	WG
7th Oct 2014	Telephone	WG
15th Oct 2014	Oslo	Table Top exercise with a wide range of participants
17th Oct 2014	Telephone	WG
27th Nov 2014	Helsinki	WG
26th Feb 2015	Copenhagen	WG
26 Aug 2015	Stockholm	WG
10 Sep 2015	Reykjavik	NordBER meeting

Table 1. Meetings within the scope of the working group

Energy shortage

The Nordic countries are interconnected on the mutual electricity market. In theory the prices in the market areas will reflect the current power and energy balance within the area, as well the perspectives of future import from, or export to, other market areas. Considering energy scarcity high prices reflect an expected shortage today, or in the future. In a hydro power influenced system the prices typically culminates in the spring. The producers will typically act to maximize their profit from the stored water by producing at high prices and storing at low prices. If a cold and dry winter is expected the best strategy for a single producer is to store more water to capitalize from the high prices later on. If many producers make the same assumption the resulting collective urge to save water drive the prices up earlier in the season and makes it less profitable to save water for production later on. This will in turn counteract the notion to save water, until equilibrium is found. This equilibrium (or market price) is constantly updated as more information on the future is obtained, for example with updated weather and snow reports, or the occurrence of outages.

In a situation with low levels of water in the Nordic hydro power reservoirs, together with nuclear plants out of operation and limitations in transmission lines there is a risk for (long term) energy shortage in the Nordic electricity system, especially if combined with cold weather. During such a situation the prices can be expected to be extremely high, and all available production capacity in the Nordic system may be vital. The hydro power plants will also produce at maximum, potentially resulting in extremely low water levels – so low that the power plants gradually will run “dry” and stop producing power. If this would happen, the Nordic power balance will be at risk, and the TSOs might be forced to start load shedding. This might last for a long time – weeks or even months, depending on the time for the spring flood.

When all possibilities within the function of the market are exhausted, it can be necessary for governments and authorities to resort to intervene with measures to prevent such a development - an energy shortage. Such a situation has low probability. However, it has happened in the seventies, and it has been very near during several winters the last couple of decades. The measures to handle energy scarcity are designed to either save resources or allocate them in such a way that the consequences of the shortage are minimized.

The working group is aware of the ongoing development of a new European power market design, network codes and other internal market issues. This may or may not affect the future framework for handling of an energy shortage.

There have been changes in recent years that both reduce and increase the risk for energy shortage.

Reduced risk	***Increased risk***
The capacity and number of interconnectors within and between countries have increased.	Several coal- and oilfired condensing power plants have been shut down and even been demolished in Finland, Denmark and Sweden.
New production capacity – not least wind power – have been built at large scale.	Changes to established production patterns as baseload plants are phased out in the Nordic countries and Germany and replaced with intermittent energy sources.
Nuclear plants in Sweden have been upgraded	Capacity markets in surrounding countries

to higher capacity.	(such as Russia) are limiting the possibilities to import power.
A new nuclear power plant is under construction in Finland	The oldest nuclear plants in Sweden and Finland will eventually be phased out
	Increasing dependency on electricity in the society

Table 2. Changes affecting risk of energy shortages

Hydropower is largely the backbone of both energy supply, power supply and capacity for regulation and balancing in the Nordic system. The large share of hydropower in Norway and Sweden however also brings the risk of energy shortage since the "refuelling" of these production sites is out of man's control. The inflow to the reservoirs in Norway and Sweden vary between years. These variations are to some extent "coordinated" by the nature – a "dry year" sometimes brings low levels in both countries, as illustrated in figure 2 below.

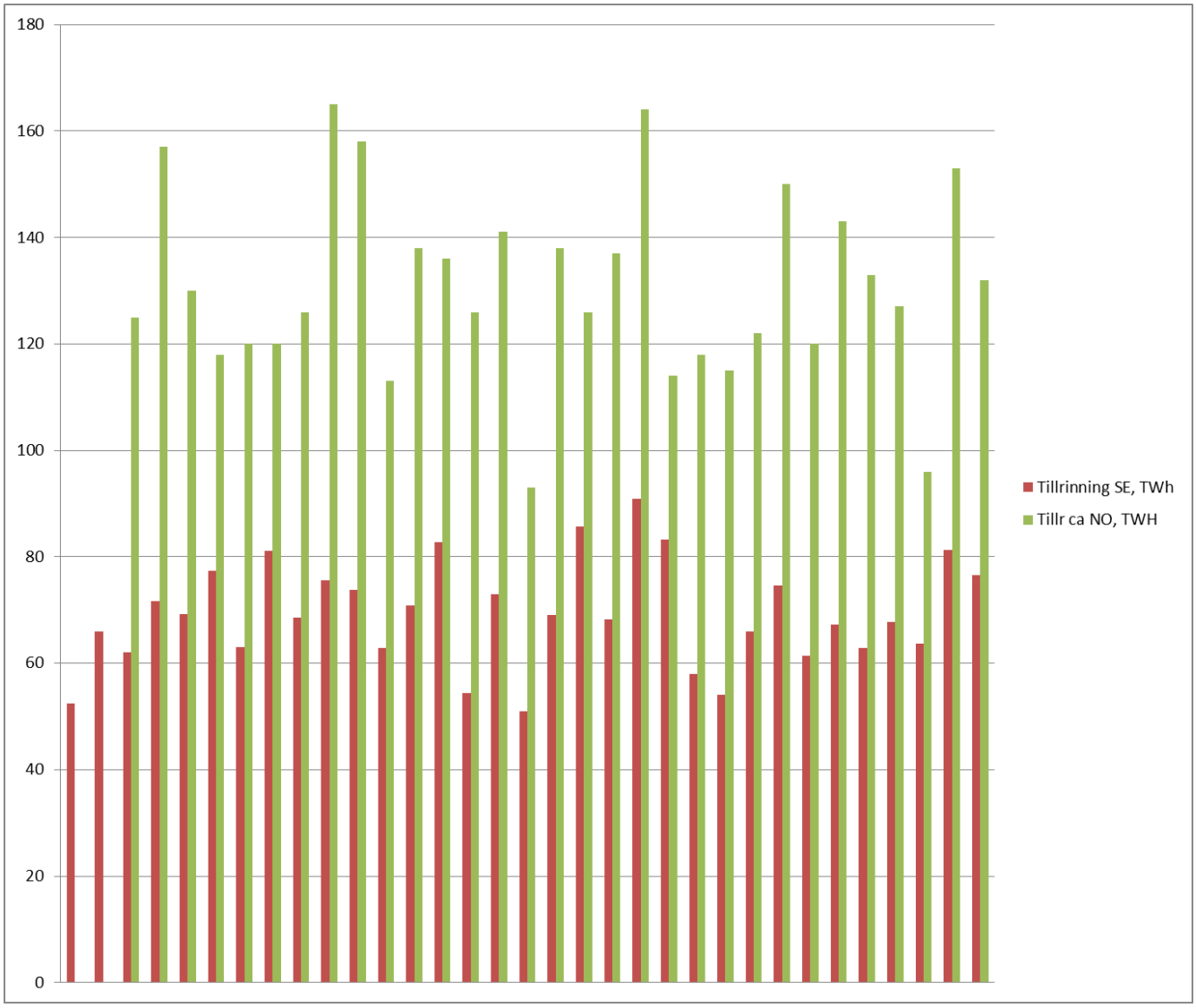


Figure 2. Comparison of yearly inflow to the hydro power reservoirs in Sweden and Norway (1978-2012)

Prepared measures in four Nordic countries

The Nordic countries have developed different sets of measures in order to cope with the potential or evident energy shortage[3]. The common denominator at these national measures is that interference to the electricity market and implementation of rationing are the very last options.

Norway

The long term Norwegian energy security is normally obtained by the mechanisms of the Nordic electricity market. Should the situation occur that the market mechanisms fail to deliver an acceptable distribution of the available energy resources measures to handle such situations have been developed. The exception from normal market conditions are referred to as "rationing", which is a state that can be activated by the Ministry of Petroleum and Energy while the rationing authority (NVE) have the legal warrants to develop and implement the necessary measures. NVE is also responsibly of assessing the risk of a future rationing and detect the need for extraordinary measures. In addition to the regulation on rationing the responsibility to develop and implement measures to handle (a) strained situations and (b) highly strained situations have been assigned to the TSO. The measures designated to handle the former are mainly directed towards the balance of the power system. Inevitable these measures are also to a varying degree effective on the energy balance. The later measures are however specifically intended to reduce the probability for rationing. These measures can only be activated during a highly strained energy situation as defined by the NVE. The measures are normally denoted "SAKS-measures", from the Norwegian abbreviation of a "highly strained power situation". The available measures are applied in the order described below:

1. The measures of the TSO to handle a strained situation.
2. SAKS-measures.
    a. Energy options in consumption
    b. Two gas fired turbines, each with the capacity of 150 MW.
3. Rationing.
    a. Forced reduction of consumption by:
        i. quota rationing
        ii. rolling black-outs (brown-outs)
    b. Re-establish import. Primarily applied within Norway.
    c. Reregulating concept. Designed for an extreme situation.

The main Norwegian rationing measure is the forced reduction of consumption, while two additional concepts of countermeasures have been developed by the NVE. The reregulating concept is intended for use if the market mechanisms, for some unforeseen reason, are not available, and is not of vital relevance in this context. The countermeasure aimed to "re-establish of import" does however require an explanation. There will be an interface between the surrounding unaffected market and a pseudo-market, which has been interfered by the countermeasures to the energy scarcity. Normally the price difference between two market areas reflect the margin-benefit of one additional energy unit, and should be allowed to route the import/export flows. In the interface between normal market conditions and a tampered pseudo-market that prerequisite is however no longer true. Hence, the need for tools to re-establish an

[3] For details on the countermeasuers, see Appendix 1.

energy flow that has been reduced by other countermeasures may arise. Such a measure has been developed for use if it is deemed necessary.

The plans of NVE to administer a rationing have recently been subject to revision. The details of the revised plans are currently being developed.

Denmark
Denmark has no specific regulations covering the handling of (electrical) energy shortage and Energinet.dk has no specific plans for handling such shortage.

In case of serious risk of such energy shortage in one or more of the other Nordic countries Energinet.dk will help with the aim to reduce the problem in the following ways:

1. Energinet.dk will consider to postpone planned outages of relevant part of network/grid (in order to allow more electrical energy flowing to the affected areas)
2. Energinet.dk will assist other Nordic TSO's in a dialogue with the German TSO's regarding possible activation of more energy production from the south (to reduce the Nordic energy deficit)

If a long term energy shortage in the Nordic system should result in a serious risk of power shortage Energinet.dk might be forced to act according to the plans for Critical power shortage ("Kritisk effektbrist") - e.g. ordering manual load shedding – provided that the operation reliability is endangered.

Finland
Energy shortage as such is not a critical issue regarding Finnish power system. Energy shortage at Nordic level will, however, lead to acute problems in Finland as well. The main issue being discussed in Finland is the diminishing of long term power production capacity (mainly coal condensing power), which may lead to severe power shortage if problems with base-power generation and/or cross-border interconnections would occur.

If the sufficiency of power has not been ensured, taking into account reasonably likely incidents, Fingrid as the transmission system operator (TSO) may have to disconnect significant amounts of electricity consumption from the grid during severe disruptions. It is difficult to find sufficiently large electricity loads that could be disconnected without significantly impacting the functioning of the society; furthermore, the precise targeting of which electricity loads would be disconnected is challenging.

The basic task of Fingrid as the transmission system operator is to maintain Finland's power system in such a state that the system is able to withstand the dimensioning unit (usually the largest power plant in operation) dropping off the grid. When grid stability is threatened, Fingrid can either start up its system reserves or limit the loads supplied to the users of electricity. Fingrid has just below 1,000 MW of its own system reserves, with around 300 MW more reserved from other electricity producers. In addition to these, the company has made agreements on around 300 MW of electrical loads in the industry that can be quickly disconnected (so-called industrial reserve). In total, the system reserves therefore match the power of Olkiluoto 3.

Sweden
A fundamental principle in the Swedish approach is that the market is expected to handle severe and strained situations. The idea is to create both short- and long-term incentives for the stakeholders to develop production and distribution capacities.

The government has appointed Energimyndigheten as the responsible authority to act in case of an energy shortage that the market after all has failed to prevent. In order to keep the guiding principle described above, the countermeasures must be prepared, transparent and predictable, and designed to disturb the market as little as possible. Thus the government will wait until it is obvious that the market mechanisms is insufficient or if the consequenses for the society are too severe to accept. Only at the point, and after Energimyndighetens recommendation, the government will decide to interfere with the market. In accordance with the government's decision, three tools will be at hand:

- Information campaign (targeting households)
- A governmental directive to all governmental authorities
- Rationing of all industrial companies.

None of these actions are fully prepared at this stage. Through extensive ongoing work the aim is to have them ready for use 2016.

Besides this, there is extensive legislation, routines and mechanisms in place to handle a power shortage. As the last resort, when all other measures are applied, Svenska kraftnät will order load shedding, which will be conducted in a well-defined order of priority (Styrel)

Prepared measures and their capability

In an effort to get an overview of the prepared measures for handling an energy shortage the working group have compiled these in table 3 below. It describes the approximate capability of each measure, and it also implies the time it takes from decision to use each measure until it actually has the planned effect.

Estimated effects of public measures to handle Energy shortage

National measure (public interference beyond market based)	Country	Estimated Effect (GWh/week)	Verified in practice? (Y/N)	Startup time (from decision to effect) (weeks)	Potential endurance (weeks)	Responsible	Dependency to other measure	Side effects	Other remarks
Create new elspot-area	NO	-	Y	4	Unlimited	Statnett	No	Reduction of competition. Price areas are supposed to reflect other parameteres, ex. Contingencies	Focuses the price incentive. Primarily suited to give long-term incentives to locate production and consumption.
Cancel planned outages	NO	10-100	Y	0	Unlimited	Statnett	No	In the long run - Stocking up of necessary outages	
Disconnecting boilers	NO	70	Y	0	Unlimited	Statnett	No		Disconnecting boilers with alternative energy sources
Increase import capacity	NO	+5-15 % import	Y	> 1	Unlimited	Statnett	No	Reduced system resiliance	Use of protection schemes and/or reserve components such as transformers og capacitor banks
Awareness campaigns	NO	5%	Y	2	10	Statnett/NVE	No		
Increase import w reduced operational reliability	NO	okt-50	Y	0	Unlimited	Statnett	No	Reduced system reliability	N-0 and N-1/2
Obtain detailed informaton	NO	-	Y	1	Unlimited	Statnett/NVE	No		
Provide detailed information	NO	-	Y	0	Unlimited	Statnett/NVE	Above	Disturbing the market.	Only after NVE approval. Expected to improve resource utilization
Energy options	NO	5-70	N	1	20	Statnett/NVE	SAKS-measure 1	Possible reduced price incentive for industries to reduce consumption during scarcities	Only after NVE approval and SAKS-decision. The larger impact for shorter periods.
Back-up power plants	NO	50	N	2	20	Statnett/NVE	SAKS-measure 2	Possible reduced price incentive for producers to store water for scarce situations	Only after NVE approval and SAKS-decision. Located in NO3, but can be moved in 2 months. Start-up time can be reduced to few hours
Disconnection of unneccessary consumption	NO	Symbolic	N	2	Unlimited	-	Rationing 1		Only after governmental decision
Rationing (50 % quote) of industry	NO	400	N	2	Unlimited	NVE	Rationing 2	Severe loss of welfare. Price drop. Undesired reduction in	Only after governmental decision
Rationing (70 % quote) of industry	NO	180	N	1	Unlimited	NVE	Rationing 3	Severe loss of welfare. Price drop. Undesired reduction in	Only after governmental decision
Rationing (30 % quote) of remaining consumption	NO	450	N	1	Unlimited	NVE/DSO	Rationing 4	Severe loss of welfare. Price drop. Undesired reduction in import. Social discontent	Only after governmental decision. Can also be performed as brown-outs
Rationing (50 % quote) of remaining consumption	NO	300	N	1	Unlimited	NVE/DSO	Rationing 5	Severe loss of welfare. Price drop. Undesired reduction in import. Social discontent	Only after governmental decision. Can also be performed as brown-outs
Rationing (70 % quote) of remaining consumption	NO	300	N	1	Unlimited	NVE/DSO	Rationing 6	Severe loss of welfare. Price drop. Undesired reduction in import. Social discontent	Only after governmental decision. Can also be performed as brown-outs
Re-establish import	NO	0 - 975	N	0	Unlimited	NVE	Applied at a suitable point R2-R6	Need to be coordinated with neighbouring countries.	Designed to counter lost import due to tampered consumption.
Administrative dispatch of production	NO	-	N	0	10	NVE	Last resort	Severe at all levels of society. The only worse option is a long period of blackouts	Designed to handle dispatch if the market function fails. Detailed solutions are to be found. Not yet approved as an official measure
Information campaign	SE	100	N	2	10	Energimyn-digheten	First measure		Only after governmental decision
Directive to all state-controlled authorities etc	SE	Symbolic	N	2	10	Government	Simuntanious with Info		
Rationing (quote) of industry	SE	0-600	N	4	12	Energimyn-digheten	Started after	Expected price drop, possible unwanted export	Only after governmental decision
Power reserve (all the way to brownouts)	SE		Reserve Y, Brownouts N	0	?	Svenska kraftnät	Indepen-dent		
	FI								
	FI								
	FI								
	DK								
	DK								

Table 3. Estimated effects of public measures to handle Energy shortage (electricity)

Surveillance of the energy balance:

Surveillance of the Norwegian and Nordic power market is a task performed by NVE, Energimyndigheten and others. The surveillance consists of tracking the development of indicators such as prices, production, consumption, reservoir levels, operating status of the

nuclear reactors and power exchange. The observations are summarized in weekly reports that are published in Norway and Sweden respectively. This consistent process results in a solid knowledge of the market function and the Nordic resource situation.

Weekly simulations are performed in Norway using a model called Samkjøringsmodellen (EMPS model) that utilizes a detailed model of the hydrological system in Norway and Sweden. The model yield prognoses of the reservoir levels until spring flood.

A similar model (Energibristmodell) is used by Energimyndigheten in Sweden, though applied in different frequency depending on the current season. In times with low reservoir levels the model is used weekly. The outcome of the model is an estimate of remaining levels by the time of the spring flood. (See example below.) In very constrained situations further analysis, cooperation and information exchange will take place.

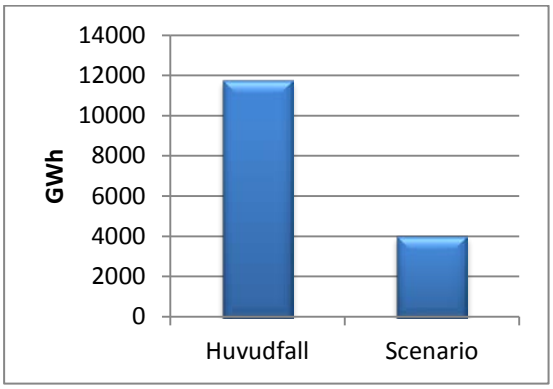


Figure 3. Estimate of remaining energy in the Swedish hydro reservoirs by the time of coming spring flood (example of estimation made in November - Energibristmodellen).

Considering Norway, in situations where the prognosis indicates that the reservoir levels during spring will be lower than usual, the snow reservoirs and the market for future power prices are considered by NVE. If the situation so require, the TSO is contacted in order to try to create a mutual understanding of the situation. This dialogue may result in an exchange of knowledge and comparison of results from the respective models.

The TSO may inform the public about its assessment of the energy situation. This is based on a set of model results that estimate the probability of rationing. If the probability of energy scarcity increase the dialogue between NVE and the TSO is intensified and meetings are held frequently.

Difficult to predict

An energy shortage is a gradual state, and there are generally no distinct thresholds where an administrative interference to the market suddenly is needed to avoid a disaster. Hence it is difficult to predict the points where any authority or government will act.

Is energy shortage a Swedish and Norwegian issue?

Over time interconnectors will act to spread energy scarcities, and high prices, to surrounding areas. None of the Nordic countries have maintained the administration to centrally control the allocation of supply and demand without the help of the market functions. In practice this means that any disturbances in the power system will affect the price in one area and from there spread like ripples on the water. The impact of the ripples on the surrounding areas is directly proportional to the strength of the interconnectors between the areas, meaning that strong connections yield equal prices.

By decentralizing our production decisions to the market and connecting to each other we have made each other dependent to the actions of our neighbors. This is especially true for Denmark and Finland who do not have large scale hydropower production, and are more dependent on electrical energy import. Strong interconnection of the Nordic countries is a fundamentally positive mechanism considering the probability of energy scarcity, as the market prices are stabilized and the overall probability of energy scarcities is reduced. This has been an important argument for the first intra-Nordic interconnectors. During a situation where the energy scarcity occurs in spite of the strong interconnections, they do however also spread the challenge.

Differences between the Nordic countries

There are large differences between the level of attention and the amount, and type, of measures the Nordic countries have prepared to handle an energy scarcity. These differences coincide with the dependence of hydro power storages in the countries. Norway represents the cautious outlier with wide warrants and an array of measures ranging from market invasive to market replacing. Denmark and Finland resides in the other end, and are only marginally concerned with electrical energy issues. The Finnish and Danish attention has been focused on power issues and the available measures are the ones prepared for that reason.

It should, however, be pointed out that the physical difference between power and energy is *time*, and the energy contribution from “power-measures” may be substantial. Both power measures and energy measures act as an increase in power over a given time, the main difference is basically the timing and durance of deployment and the consequences for the market and the end users. Energy measures are designed to act proactively and to be deployed before an actual power scarcity arises. The Finnish power system is to a large extent powered by CHP and nuclear power. The Danish power system is to a large extent powered by wind power supported by fossil power sources. The power system in both countries can run on different kinds of fuels that can be stored in sufficient amounts. Therefore it is natural that the concern for a scenario with energy scarcity is focused on power issues spilling in from Sweden or Norway.

Sweden and Norway have chosen a more precautious attitude towards energy shortage. The past few years there has been strong activity in Sweden to prepare measures to reduce consumption during an energy shortage. A number of measures have been evaluated and the ones considered most effective have been chosen for implementation. The main measure considering energy volume is forced reduction (rationing) of the industrial sector, representing up to 40 % of the electricity demand, but only 0,6 % of the number of customers.

Norway developed energy measures during the early 00`s, being highly influenced by the experiences with dry years in the late 90`s and early 00`s. Based on these experiences there were a strong political pressure to make sure that energy scarcities could be handled. Hence the regulation on rationing received few bounds to the available measures other than that they must be necessary and rational, and must be activated by the Ministry.

From the outside this may appear as a sign of mistrust to the power market, which is intended to solve energy shortages, but the contrary is more accurate. The wide array of measures is due to a strong trust in the market solution. The rationale is: If the need to set the normal market mechanisms aside should arise, the situation is likely to be something out of the extraordinary and unexpected. Therefore the measures cannot be limited to the ones most likely to be necessary, but should also strive to handle situations of different characters, including a complete market failure. The main Norwegian measure is forced limitations to consumers, which can be facilitated in an almost stepless manner.

Consequenses of lacking Nordic coordination

There is a mutual understanding between the participating Nordic bodies that a governing principle should be that neighboring countries ought to help each other to a reasonable extent. This is in line with the stated goals of the Nordic Council of ministers as well with those of NordBER. The working group strongly supports the development of the same kind of principles in handling of energy scarcities. This could be explicitly stated as a mutual obligation to help the other Nordic countries when they are handling an energy scarcity as long as the net Nordic gain is positive.

The TSOs are collaborating on a daily basis, and have routines for monitoring and dealing with the balance of the Nordic power system. But a potentially arising energy shortage is not an issue dealt with by them. Apart from the Norwegian TSO, none of them have tasks in that respect. The authorities and the governmental ministries do not have routines or policies in cross-border dialogue specifically about energy shortages. This is potentially a weak point in the Nordic cooperation.

Sweden and Norway have different sets of measures prepared to handle an energy shortage. They are different by their nature, by their expected impact on the scarcity, by the involved stake holders and by the time it takes from the decision to use them, until they actually start having an impact. It is also very difficult to decide when these measures are absolutely necessary, both for engineers/economists and for politicians. And if one of the countries decides to implement one or more measures, it can potentially save the whole Nordic system from ending up in power shortage and brown-outs. But it cannot be predicted who will act first, given no coordination.

These differences in prepared measures are relevant, due to differences in national systems, structure and pattern of energy useage etc. It is also relevant that the individual countries maintain the self-governance, considering issues as financial competitiveness, concern for the security/safety of the citizens etc.

All of these aspects underline one fact: The government and authority that is first with implementing these measures will impose the economic burden of avoiding the disaster on its own society, and the other country may be spared without significant consequences.

The analysis of this working group have also shown that there are stages in an energy shortage when several countries will potentially face *power* shortage, and will depend on and, possibly in vain, hope for imports from each other. This is a potential clash of national interests.

Conclusions

First of all: The Nordic power system is robust, both in terms of supply, distribution and market. The responsibilities for maintaining these functions are clear, and the mechanisms that are in place can handle a wide range of constrained situations. So the issues being discussed in this report will hopefully never be of practical use.

However, the risk of Nordic energy shortage must not be neglected. Local shortages may occur, due to several issues combined with bottlenecks or failures in the grid between price areas or between countries. Such situations will affect the price levels, but will be handled in Sweden or Norway respectively.

But if (and when) a major pan-Nordic energy shortage occurs, the scenarios are:

- It is handled separately in Sweden *or* Norway, which would be the case if it happened today. This would most likely fulfill the objective. But it would be very expensive for the society in the country that "pulls the trigger". The other countries will be somewhat spared from disaster, since measures taken in one country may solve the whole situation.
- It is handled simultaneously in *both* countries, but not coordinated. Then there is a potential risk that too forceful restrictions will be imposed on the system, causing unnecessary damage and costs to the societies. Due to strong physical and market connections between the countries, poorly coordinated measures may have large and unforeseen consequences.
- It is handled *in coordination* between Sweden and Norway. Simultaneous and coordinated rationing in two countries gives milder shares for all. "Shared burden is a lesser burden".

One important aspect, regardless scenario, is that every measure takes time from decision to effect. Even with synchronous decisions of forceful measures it will take 1-4 weeks before substantial improvements will start taking place. During that time an energy shortage will be allowed to develop. The working group would like to stress the importance of *proactive coordinated actions and awareness of the time aspects to the decision makers*.

The government and authority that is first implementing countermeasures will impose the economic burden of avoiding the disaster on its own society, and the other countries may be spared. This may impose additional hesitation in the decision making. This underlines the need of good *coordination of countermeasures and mutual trust* as a remedy also to this potentially unfortunate mechanism.

However, the self-governance of the individual countries must be protected. A common legislation would not be desirable or feasible due to the differences in structure, crisis management systems etc.

The large differences in terms of prepared measures between the countries may cause challenges where a pan-Nordic energy scarcity arises. One country is ready to deploy strong and invasive countermeasures with a potentially severe influence on the other countries. It could be argued that an early intervention will undermine the general trust to the market. It could, however, also be argued that the countries not being able to intervene in due time evades their responsibility. Undoubtedly the optimal solution is *development of mutual principles* on when to intervene and how. Establishment of such principles will face the handling of massive uncertainties and

success appears unlikely. The political freedom of action must also remain. The second best option consists of several parts:

(1) Close cooperation during the operative phase of an energy scarcity

(2) Cooperation on identifying and analyzing the energy situation

(3) Knowledge of each other's available measures

(4) Mutual trust by continuous dialogue at multiple layers (political, authorities, TSO)

Besides the price reflections described in this report, at an extreme energy shortage situation, a country might consider limiting or stopping the cross-border trade in order to secure its' own area. This would be a severe interference to the Nordic power system, and would accordingly affect the neighboring nations. It could also violate the EU directives on the common market and security of supply[4]. The general conception within the energy branch in the Nordic countries and in this working group is that locking the borders is not an option to consider[5]. There are however national plans to re-establish power flow that has been reduced by other rationing measures. This must be taken into account in the coming development of Nordic cooperation.

Nationally the possibilities of *regulations on production planning in hydropower* have been, and will continue to be, discussed. It is beneficial to achieve a Nordic perspective on those analyses and facilitate a good information exchange on the matter.

Measures to consider

Keeping in mind the mutual obligation to help the other Nordic countries when they are handling an energy scarcity, the measures to consider could be:

- Enhanced coordination of the deployment of national measures before and during an energy shortage. The first step towards that is establishing routines for initiating appropriate dialogue at the different layers of responsible actors (political, authorities, TSO).
- Forums (for example NordBER) for information sharing and cooperation before a strained situation.
- A Nordic situational picture during an energy shortage. At least routines for sharing energy forecasts and analysing methods on a regular basis should be established.

NVE and Energimyndigheten will continue their cooperation and information exchange in line with the conclusions in this report and in line with already established plans.

[4] See Article 42, Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC,

[5] See also "Joint Declaration for Regional Cooperation on Security of Electricity Supply in the Framework of the Internal Energy Market", signed by Sweden, Norway, Denmark and nine other European states in June 2015.

Appendix 1 – National survey of measures to handle an energy shortage

Background

In the case of a long term or major energy shortage, serious consequences for major parts of the Nordic power system can be expected. There are national regulation and described roles/responsibilities concerning such a situation in some countries (primarily SE and NO). But any coordination or dialogue at Nordic level on planning for or handling of an energy shortage has yet not occurred.

In the NordBER Action plan for 2013-2015[6] it is therefore stated that the Nordic countries shall develop the understanding of the risk for, and handling of, an energy shortage in every country. An evaluation shall also be made to see if there can be situations where national perspectives and solutions might bring unwanted negative consequences.

The first step made by the working group on this topic was to make a survey and national workshops/meetings:

En skriftlig sammanställning av respektive lands regelverk, ansvar och roller görs nationellt. Därefter genomförs nationellt minst en workshop eller motsvarande för att öka förståelsen och kunskapen om risken för elenergibrist, diskutera och utveckla principer för hantering av energibrist, samt förankra dessa principer hos samtliga berörda aktörer.

This paper is a brief description of these regulations, responsibilities and roles.

The legislation and principles for handling a situation with (long term) energy shortage is currently subject to changes in both Sweden, Norway and Finland. This document is therefore partly based on a proposed future set of responsibilities, roles and rules.

National legislation, roles, responsibilities

Norway

Introduction

Norway is more than other countries dependent on hydro power to cover its electricity demand. In 2013 about 129 TWh of electrical energy was consumed. During a year with normal precipitation the inflow to the hydro power plants makes it possible to produce about 130 TWh. The natural variations are, however, considerable and every tenth year the energy inflow can be expected to be lower than 99 TWh. In addition electricity cover a very large share of the energy used to cover basic domestic needs, like heating. In spite of having a lot of installed capacity the country is vulnerable to seasons with extremely low precipitation. The Nordic power market is considered to supply sufficient mechanisms to ensure an acceptable security of supply for the majority of realistic scenarios.

In 2001 the present regulation on rationing was passed. Rationing is the Norwegian administrative response to an energy scarcity that is severe enough to call for extraordinary measures in the electricity market. NVE is the rationing authority and is as such given the responsibility to detect, plan for and administer a rationing whenever such a situation would

[6] NordBER rullande handlingsplan 2013-2015, Bilaga 6, *Att utveckla en samnordisk förståelse av risk för och hantering av energibrist*

occur. However, the authority to activate the warrants of the regulation lies within the Ministry of Oil and Energy. It is a prerequisite that the power market has failed to supply sufficient energy security before the regulation can be activated. High prices are in this context considered a remedy and are not to be considered a reason to declare a state of rationing.

Since 2006 the TSO have had prepared measures to reduce the probability that a rationing becomes necessary. These measures are normally referred to as the "SAKS-measures", derived from a Norwegian phrase describing a very tight energy situation. Today the measures consist of energy options in consumption and two mobile gas fired turbines. A frequently discussed issue concerning the SAKS-measures is the effect the expected shaving of peak prices may have on the hydro power producers incentives to store water for the dry scenarios. One effect may be that the existence of countermeasures in it self increase the probability that they become necessary. The TSO is responsible to continuously consider the need for additional SAKS-measures. Activation of the measures must be approved by NVE.

The regulation on rationing represents the start of the modern age of rationing in Norway. During the first couple of years it was assumed that energy scarcity best was handled by opposing forced reductions on the consumption whereas the price in the rationed area was set administratively at a sufficiently high level to ensure maximum import from surrounding areas. In due time focus was turned to the market implications of a price disconnected from the market mechanisms and energy situation within the rationed area. The most severe consequence was expected to be suboptimal utilization of the scarce resource. As a result thereof, the plans were revised during 2013 and 2014. This revision did not only come up with an improved set of plans, but it also identified additional challenges that need to be addressed. Hence the Norwegian plans will be subject to continuous improvement during the next couple of years.

The norwegian measures

The backbone of the rationing plan is three types of measures to handle energy scarcity. All of them represent an intrusion on the power market and the principles of the free market. This follows from the fact that rationing is designed to apply to the situations where the power market, for whatever reason, does not supply sufficient energy security. Today there exists no centralized entity with the sufficient resources to plan for the entire production in Norway, or a significant part of the same. Hence we have become dependent on the market mechanisms that utilize the dispersed resources during normal circumstances. The dilemma is inevitable when planning for rationing.

Forced reduction of consumption

The fundamental measure to handle energy scarcity is to force consumers to reduce their consumption. This is a powerful tool forcing severe disadvantages upon single entities in order to spare other consumers from negative consequences. The measure can be utilized using one of two methods. Firstly, and preferably, quota rationing, which means that each consumer is assigned a specified amount of energy that can be bought from the market during a specified time period. The quota should ideally be adjusted in relation to the need of each consumer, considering both the desired amount and the consequences opposed by the limitation. In practice the consumers are divided into groups with similar characteristics. Consumption exceeding the quota will result in a deterring economic sanction, i.e. a fee. The second option is to perform brown outs, which means physically disconnecting consumers from the grid, hence preventing them from covering their full demand. Brownouts are expected to impose severe consequences on consumers and societies where applied.

Planning to perform forced reductions in the lower voltage levels have been delegated to the DSOs. The local system operators have been deemed the ones best suited to minimize the consequences at the detailed level. To simplify the planning, a degree of predictability have been introduced by relating the levels of reduction to 30, 50 and 70 % of the consumption during the same period the previous year. Interruption costs for rationing show that the consequences can be expected to be lower when opposing reductions on consumption directly connected to the higher voltage levels. These consumers typically use about 30 % of the electric energy in the Norwegian areas. In addition the consequences when applying forced reductions to the lower voltage levels are harder to predict, and may include hazard to life and health of the population.

The mentioned reasoning have led up to an escalation scheme for forced reductions on consumption:

1. Quota rationing in the higher voltage levels
2. Quota rationing in the lower voltage levels
3. Brownouts in the lower voltage levels

Although the plan appear sequentially, there have been developed tools to minimize the interruption costs independent of the escalation scheme. Disconnecting of consumption on special tariffs (unprioritized) will occur no later than simultaneously with the first introduction of quota rationing.

Re-establish import

Forced reduction of consumption is designed to improve the energy balance in the affected area and reduce the risk of emptying the magazines before the spring flood. The market prices are supposed to reflect the value of stored water considering, amongst other things, the energy situation. Hence the reduction in consumption can be expected to yield lower prices in the affected area. This may induce three effects affecting the outcome of the first rationing measure.

Producers acting in the power market have no obligation to avoid energy scarcity and have economic incentives to produce when the revenues from producing today are higher than the expected future revenue. This is however to an unknown extent counteracted by other drivers, such as social responsibility. An expected price reduction will affect the future revenue, making producers less prone to save water.

The price signal gives a continuous incentive to consumers to adjust their power usage in accordance with the added value from the use, or reduction, of another energy unit. If the price reduces, some consumers may find it beneficial to increase their consumption. Hence, a price reduction due to forced reductions to the energy usage by some consumers may be counteracted by others increasing their usage. Little is known about to what extent there may be a solidarity effect diminishing this phenomena during extraordinary events, but scientists have been suggesting a similar effect for households.

Finally the price signal has an important role considering the flow of energy between different areas. The power market is designed to optimize the flow from areas with abundant energy and low prices to areas with energy shortage and high prices. By administratively reducing the consumption in one area the price signal given by the new, and artificially reduced, price will no longer give an appropriate power flow when compared to the energy situation in surrounding areas. The result may be reduced import or, in the extreme case, even export from the area that originally was deemed to suffer from the worst energy balance.

To counter these effects a measure have been designed that apply existing mechanisms to control the power flow to a rationed area. During normal operation the TSO can set constraints to the power flow to and from price areas on the Nordic power market with reference to system security. There have been cases where the maximum export capacity is set to negative values. Allocating negative export capacities will ensure that the market algorithm always comes up with import to the affected area. The designed measure utilizes the very same mechanism and the TSO is given the task to, on behalf of the authorities, set the trading capacity in such a manner that the lost energy import to the rationed due to the reduced consumption is minimized. The setting of trading capacities is intended to mimic the import that the affected area would have received, where it not for the strong constraints already opposed on the consumers. The TSO will be given the flexibility to consider other operational constraints on an hourly basis.

The measure may cause some issues concerning the relationship to other states where import is set into a low-price area. Therefore a mutual understanding must be achieved before the measure is applied to border-crossing connections. The measure is directly linked to the state of "rationing", which is to be considered a legal state of emergency. NVE is expecting an understanding for the desire to re-establish the power flow between countries if it has been reduced by other countermeasures.

Reregulating concept

The last measure is designed for scenarios where the market mechanisms, still utilized while using the other rationing measures, does not supply a rational distribution of the remaining energy resources and the other measures are unsufficient. A fundamentally different apparatus for production planning and allocation of energy has therefore been designed.

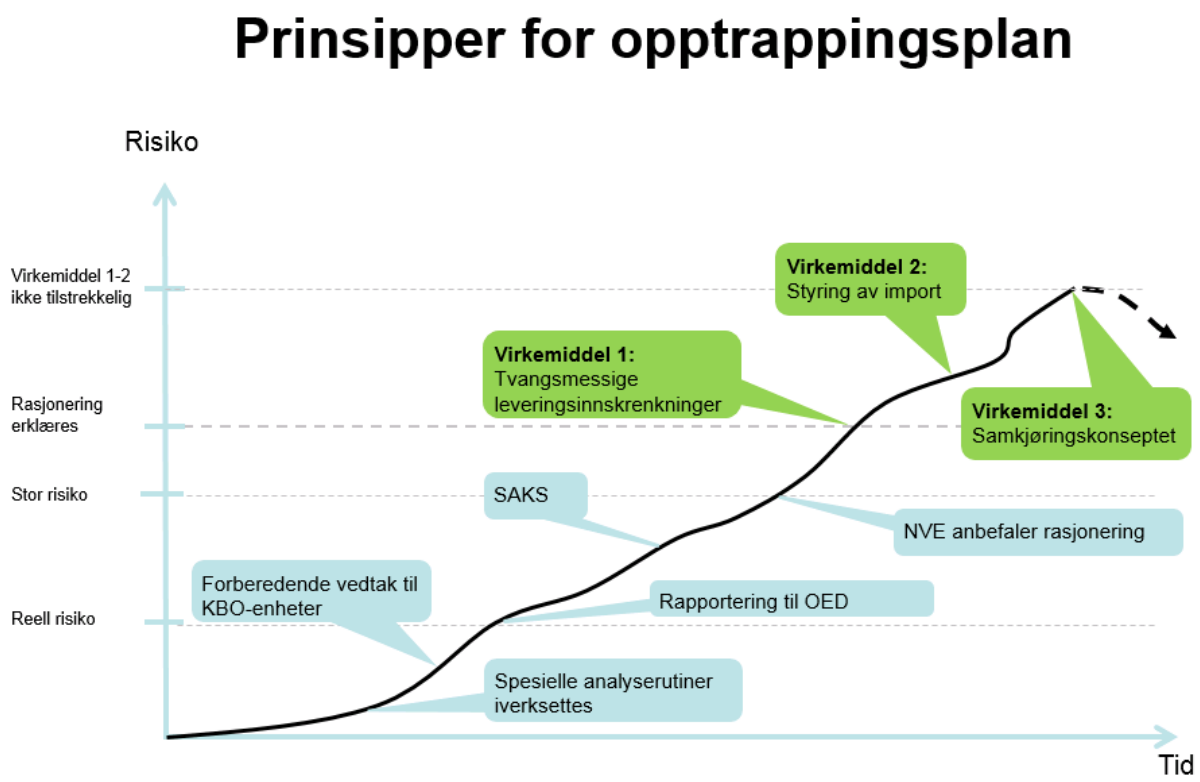
All the main market place participants and grid operators are also members of a preparedness organization called "KBO". Being a member in KBO makes them subject to rules in the regulation of preparedness in the electricity sector. Hence they can be given specified tasks and responsibilities by the authorities during rationing. In addition the KBO-members can be delegated the necessary authority to perform these tasks. The situation where the reregulating concept is necessary is assumed to be grave enough to make most entities willing to cooperate and contribute for the greater good, but to ensure this NVE will be use the KBO-hierarchy and warrants to apply a social responsibility as well as principles for the actions of these entities. It is considered to be of the outmost priority that the competence and resources that is dispersed among the market participants is utilized at the time of greatest need. The reregulating concept can be considered to consist of the following parts:

- Forced reductions on consumption
- Active use of the hierarchical structure of KBO to maximize operational decisiveness
- Establishment of a platform of cooperation between grid operators, producers and other relevant market participants
    - Principles governing the actions of entities
    - Authority to perform the rational actions
    - Clear chain of command and access to guidance by the rationing authorities

It should be noted that the reregulating concept need further development before being operational. At this point most attention has been turned on the measures that are most likely to

be put into use. Hence the modus operandi is that the timing and use of the other measures specifically should strive to reduce the probability that the concept becomes necessary.

Graphical overview of the most important step during an escalating energy scarcity



Denmark

Introduction

Denmark has no specific regulations covering the handling of (electrical) energy shortage and Energinet.dk has no specific plans for handling such shortage.

In case of serious risk of such energy shortage in one or more of the other Nordic countries Energinet.dk will help with the aim to reduce the problem in the following ways:

Energinet.dk will consider to postpone planned outages of relevant part of network/grid (in order to allow more electrical energy flowing to the affected areas)

Energinet.dk will assist other Nordic TSO's in a dialogue with the German TSO's regarding possible activation of more energy production from the south (to reduce the Nordic energy deficit)

If a long term energy shortage in the Nordic system should result in a serious risk of power shortage Energinet.dk might be forced to act according to the plans for Critical power shortage ("Kritisk effektbrist") - e.g. ordering manual load shedding – provided that the operation reliability is endangered.

The way to handle *power shortage* is described below:

The Danish planning is based on the following definitions:

- A risk of power shortage defines the state when a forecast shows that a subsystem can no longer maintain the demand for a manual active reserve, which can be activated within 15 minutes.

- Power shortage occurs during the hour of operation when a subsystem is no longer capable of maintaining the demand for a manual active reserve which can be activated within 15 minutes.

- Critical power shortage occurs when consumption has to be reduced/disconnected without commercial agreements about this.

Risk of power shortage and power shortage

In case of a risk of power shortage, the relevant TSO shall inform the other TSOs as soon as possible. If necessary, the market shall also be informed. 600 MW of the most expensive manual active reserve in the regulation list is earmarked. During bottlenecks in Elspot, 600 MW of electricity with the highest Elspot price in the area(s) is earmarked. Any other local measures by the respective TSO are carried out in accordance with the TSOs' own instructions.

In case of a subsystem no longer being capable of meeting the requirement for manual active reserve and there are not sufficient available market-based bids in the neighboring systems, then a power shortage exists. The other TSOs and the market shall be informed as quickly as possible.

If additional upward regulation is needed, market-based bids in the regulation list are used. Regulation takes place in accordance with normal regulation principles. Bids that are trapped behind bottlenecks or are unavailable for other reasons are skipped and marked as unavailable in NOIS. Prearranged trading between players is fixed and cannot be changed. If necessary, intra-day trading in Elbas can be limited. Any other local measures by the respective TSO are carried out in accordance with the TSOs' own instructions.

Preparations for critical power shortage

When all market-based bids have been activated, it is checked that the earmarked reserve of 600 MW is in the regulation list. If bottlenecks have emerged in system operation, it may be necessary to redistribute the earmarked reserve.

If a power shortage occurs suddenly (without time for preparation) in the hour of operation, 600 MW have to be earmarked at the latest when all the market-based bids are activated.

At the same time preparations must be made for manual load shedding. The parties agree on the subsystem in which the potential load shedding must take place in accordance with the following principles

- *Power shortage without bottlenecks between bidding areas:*

  If there are no bottlenecks between bidding areas, the planning of load shedding shall take place in that subsystem which has the largest negative balance. Manual active reserve that is not activated and that is not trapped behind local bottlenecks shall be included in the balance. If two subsystems have an equally large deficit, the load shedding shall be divided between these subsystems.

- *Power shortage with bottlenecks between bidding areas:*

  If there are bottlenecks between bidding areas, the planning of load shedding shall take place in that part of the Nordic synchronous system that relieves the bottlenecks. In the

calculation of the balance, only the balances in those bidding areas within each subsystem which relieve the bottlenecks shall be examined, not the balance of the entire subsystem. The calculation of the balance of a bidding area shall also include imports to/exports from other bidding areas in the synchronous system. Manual active reserve that is not activated and that is not trapped behind local bottlenecks shall be included in the balance. The balance of the subsystems shall not be recalculated after load shedding has been implemented. Load shedding shall continue in the same subsystem until the frequency is stable at over 50.00 Hz. If there is anything that changes the operational situation, for example a fault in the power system, it may be necessary to re-calculate the balance of the subsystems.

Critical power shortage

When only the earmarked bids are left at 50.00 Hz but the frequency drops, the following takes place:

1. Activation of the earmarked reserve (600 MW)
2. Manual load shedding is ordered
3. Whereupon load shedding takes place and the frequency rises, and upward regulation of hydropower is deactivated

The deactivation of upward-regulated hydropower is done to restore the requirement of 600 MW of manual active reserve in the synchronous system. This helps to maintain the requirement for frequency controlled normal operation reserve.

Attention shall be paid to the practical procedures, and load shedding in steps of 200-300 MW at a time is considered as a suitable level. Load shedding and the deactivation of upward-regulated hydropower shall take place in steps until the requirement of 600 MW of manual active reserve in the synchronous system is met and the frequency is stable at 50.00 Hz. In the deactivation of hydropower, attention shall be paid to the location of a bid in relation to the bottlenecks, and to the size of the bid. A bid with a small volume can be skipped to simplify the procedures. If the frequency fell again under 50.00 Hz, hydropower bids which were deactivated shall be activated and load shedding shall be ordered. When the frequency rises, hydropower shall be deactivated again until the requirement of 600 MW of manual active reserve in the synchronous system is met.

The TSO that carries out load shedding shall inform the market and the other TSOs of critical power shortage.

Finland

1. Background

Energy shortage as such is not a critical issue regarding Finnish power system. Energy shortage at Nordic level will, however, lead to acute problems in Finland, as well. Main issue discussed in Finland is the diminishing of long-term power production capacity (mainly coal condensate), which may lead to severe power shortage if there becomes any problems with base-power generation and/or cross-border interconnections.

If the sufficiency of power has not been ensured, taking into account reasonably likely incidents, Fingrid as the transmission system operator (TSO) may have to disconnect significant amounts of electricity consumption from the grid during severe disruptions. It is difficult to find sufficiently large electricity loads that could be disconnected without significantly impacting the functioning of the society; furthermore, the precise targeting of which electricity loads would be disconnected is challenging.

The basic task of Fingrid as the transmission system operator is to maintain Finland's power system in such a state that the system is able to withstand the dimensioning unit (usually the largest power plant in operation) dropping off the grid. When grid stability is threatened, Fingrid can either start up its system reserves or limit the loads supplied to the users of electricity. Fingrid has just under 1,000 MW of its own system reserves, with around 300 MW more reserved from other electricity producers. In addition to these, the company has made agreements on around 300 MW of electrical loads in the industry that can be quickly disconnected (so-called industrial reserve). In total, the system reserves therefore match the power of Olkiluoto 3.

Fingrid may only begin taking measures related to maintaining of the power grid stability, if:

- There is simply not enough power available commercially, or
- The internal stability of the grid is threatened (exceptional load situation) and there are voltage problems in the grid, or
- The frequency quality is exceptionally poor

The starting point is that the impact of Fingrid's operations on market pricing should be as small as possible. In other words, Fingrid would not be allowed to start up its system reserves if there is power/production that suits the purpose commercially available – regardless of its price.

It should be noted, however, that Fingrid's duties do not include responsibility for the sufficiency of electricity production capacity located in Finland – nor should it. Fingrid is responsible for maintaining grid stability, and can momentarily utilise its system reserves in order to fulfil its duties. It is Fingrid's duty, however, to disconnect the reserves from production immediately when a corresponding amount of commercial production has been started up. The disconnected reserves allow Fingrid to ensure that the grid will once again withstand a dimensioning unit dropping off the grid.

2. Legislation, responsibilities and roles

The responsibility to maintain sufficient electricity (power levels and energy) lies on the market actors. The market has the necessary tools and mechanisms for this. The government and it’s authorities supervise the market, but will not interfere through limitations/regulation of production, transmission or end use.

Act on Preparedness (1552/2011, Beredskapslag) defines the actions for several areas of the society, including power, at a case of emergency. If an emergency situation takes place (separate definitions), respective Decree on Preparedness, and its consequencies related to power, will be issued the Ministry of employment and the economy (TEM, energy department). This Decree is under renewing process.

At the same time in 2014 National Emergency Supply Agency (NESA) and Power pool of National Emergency Supply Organization (NESO, public-private partnership) are renewing their

directions for operation during crisis situations. The Decree on Preparedness gives certain obligations and duties to power pool should an emergency situation appear.

The TSO, Fingrid Oyj, has a three step approach in case power shortage becomes apparent:

1. Strained power balance in the Finnish power system

   Balance providers are requested to check the production and consumption plans and to submit additional up-regulation bids. Grid owners are requested to prepare for a worsening situation.

2. Power shortage in the Finnish power system

   Fingrid has started its power reserves.

   Fingrid requests the balance providers to submit additional up-regulation bids. Grid owners are requested to prepare for a worsening situation.

3. Serious power shortage in the Finnish power system

   Fingrid will start to disconnect load to control the national power balance.

   Grid companies have prepared rationing plans for 10 % steps (10 %, 20 %, 30 %,…).

   If the situation escalates very rapidly, the TSO will start immediate rationing, which will inevitably cause uncontrolled und unwanted consequences.

Fingrid's role and duties with regard to ensuring the moment-to-moment stability of the power grid are very clear. The role and duties of the National Emergency Supply Agency are also very clear relating to traditional long-term preparation related to states of emergency, and energy supply security. Between these perspectives with different scopes of time, however, there remains a grey area where a sudden power shortage may lead, as Fingrid must start up its system reserves or disconnect consumers from the grid while maintaining grid stability. Return from the grey area to normalcy should take place with the help of slow-starting electricity production operating on market terms, allowing Fingrid to disconnect its system reserves from the grid for maintaining of moment-to-moment grid stability.

Sweden

Energimyndigheten is currently developing a new system with new legislation for rationing. Hence the processes, roles and legislation etc described below are not yet in place.

1. **Legislation, responsibilities and roles – energy shortage**

The responsibility to maintain sufficient electricity (power levels and energy) lies on the market actors. The market has the necessary tools and mechanisms for this. The government and it’s authorities supervises the market, based on national and European legislation, but will not interfere through limitations/regulation of production, transmission or end use. A fundamental principle in the Swedish approach is that the market is expected to handle severe and strained situations. The idea is to create both short- and long-term incentives for the stakeholders to develop production and distribution capacities.

The government has appointed Energimyndigheten as the responsible authority to act in case of an energy shortage that the market after all has failed to prevent. In order to keep the guiding principle described above, the countermeasures must be prepared, transparent and predictable, and designed to disturb the market as little as possible. Thus the government will wait until it is obvious that the market mechanisms is insufficient or if the consequenses for the society are too severe to accept. Only at the point, and after Energimyndighetens recommendation, the government will decide to interfere with the market. In accordance with the government's decision, three tools will be at hand:

- Information campaign (targeting households)
- A governmental directive to all governmental authorities
- Rationing of all industrial companies.

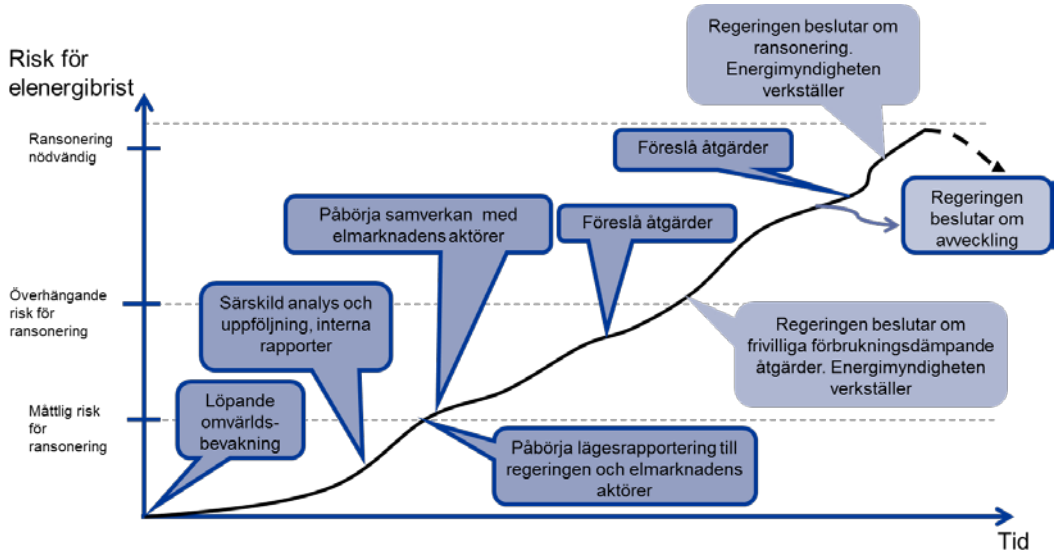
None of these actions are fully prepared at this stage. Through ongoing work the aim is to be ready for the first two points before next winter season and for rationing before the season 2015-16.

As in Norway, high prices are in this context considered a remedy and are not to be considered a reason to declare a state of rationing.

In September 2014 Energimyndigheten delivered suggestions to the government containing new and changed legislation, to be decided by the parliament (law), the government (förordning) and our agency (föreskrift):

1. A new regulation (förordning) under Ransoneringslagen (1978:268) for rationing electricity.
2. Alterations in Ellagen (1997:857) together with a change in one regulation under this law – the so called Mätförordningen (1999:716).

Through this Sweden will have a simple, but robust system ready to handle rationing of electricity – robust enough to work at almost any degree of preparedness. The system will require a minimum of resources from both state and grid companies «normal» years. During a rationing all grid companies will be obliged to send information about all industrial users to Energimyndigheten, while Energimyndigheten will handle most of the other tasks necessary. A close dialogue with the TSO Svenska Kraftnät and other organisations will naturally be crucial during such a situation.



Figur xx. Energimyndighetens principiella agerande vid elenergibrist

2. Legislation etc – power shortage

The event of a power shortage is not described in this report. There are however of course mechanisms, tools and legislation to handle such a situation in Sweden. Since a few years, there is also legislation, routines etc in place to handle load shedding in a well-defined order of priority. This has been developed under the supervision of Energimyndigheten with extensive work made by municipalities, regional county councils, grid companies etc. This system is called Styrel.

Svenska kraftnät can, as a last resort, order load shedding (“manuell förbrukningsfrånkoppling – MFK”). Before Styrel, the grid companies had no legal grounds to make priorities as to which lines and end users to disconnect and which to keep on line. With Styrel, the end users with importance for the society have been given priority in an 8 graded scale.

Appendix 2 – The scenario used in the TableTop exercise in October 2014

Scenario – Nordic Energy Shortage

In preparation for Table top exercise on Energy Shortage in Oslo 15 October 2014

Introduction

The scenario described in this paper gives a foundation for the discussions during the exercise. We will work through the stages of the scenario together there and then.

Scenario

Starting point

It is the 21th of February. It is unusually, but not extremely, cold for the season. During the autumn and winter the power demand has been high. The hydro reservoir storage level in the Nordic countries has been low for several months due to a sunny summer and an autumn with low precipitation. During the last weeks the storage levels in Sweden and Norway have fallen even further and are now almost at the all-time low level for this time of the year. In Finland the reservoir level is slightly better but far from satisfactory. The snow level is unusually low. Only a small amount of precipitation is expected for the next two weeks.

All nuclear plants in Sweden and Finland are in operation except for Oskarshamn 2 where a large project is ongoing. Since a couple of years, the flow of electricity between Russia and Finland is low due to changes in the Russian power market design.

The transmission capabilities within and between the Nordic countries are at nominal levels. The link between Norway and the Netherlands is unavailable due to maintenance work. The link is estimated to be operational by 1st of May.

A maintenance work at the converter station in Finnböle is planned to start by 15th of March, which means that there will be no transmission capacity in the Fenno-Skan 2 from Sweden to Finland the following 35 days.

The nuclear power plants Olkiluoto 1 and Forsmark 1 are scheduled for maintenance including refueling from 1st of April. The other nuclear plants are scheduled for maintenance from mid-May or later.

Low wind power production and technical problems in Germany is limiting the transmission capacity from Germany to Denmark and Sweden. The capacity is reduced to 30% of installed capacity. This situation is expected to remain for at least six weeks.

Events

In the last week there have been several short stops in a couple of the Swedish nuclear power plants. Today an earlier unknown technical problem is discovered in one of the plants (Ringhals 2). The plant is stopped with uncertain timing of a restart. One day later the Radiation Safety

Authority in Sweden decides that the all Swedish nuclear power plants with the same technical solution must be stopped as a precaution. Within two weeks six Swedish plants have gradually been taken out of operation for this reason (Oskarshamn 1 och 3; Ringhals 2, 3 and 4; Forsmark 3). In Finland the Radiation and Nuclear Safety Authority decides to stop Loviisa 1 and Olkiluoto 2 for investigation due to the Swedish problems. These plants are gradually taken out of service within two weeks. The Swedish and Finnish plants are expected to be out of service for at least two months.

After a week, on the 28th of February, a strange problem occurs in the IT-system used for control and supervision of the link between Finland and Estonia. The problem may coincide with the major cyber-attack that has been ongoing for two days which has hit several important Estonian establishments. The problem forces the Estonian TSO to shut down the links to Finland for an unknown period of time.

On March 10, a fire at a substation north of Karlshamn makes it impossible to import electricity from Poland to Sweden. The fire also disconnects two of the three oil-fired power blocks in Karlshamn from the transmission grid. One oil-fired block is connected to the distribution grid and may be used in production. However, this particular plant is, until March 16, part of the Swedish power reserve. Furthermore this block has operational restrictions due to environmental reasons. The fire damaged substation is expected to be in operation within two weeks.

Appendix 3 – Notes from the TableTop exercise in October 2014

Minutes of meeting: Table Top Exercise/Workshop on Energy Shortage, October 15 2014

Time: October 15 2014, 08.30-11.30

Place: Statnett, Oslo/Norway

Participants:

Finland
Petri Nieminen, NESA
Timo Ristikankare, Fingrid
Jyrki Uusitalo, Fingrid

Norway
Lars Andreas Eriksson, NVE (notes on white board and map)
Vegard Willumsen, NVE
Helge Ulsberg, NVE
Ann-Kristin Larsen, NVE
Lars Martin Teigset, Statnett
Ole-Bengt Eliasen, Statnett

Denmark
Uffe Strandkjær, Energistyrelsen
Lars Gjedsted Sørensen, Energinet.dk

Sweden
Daniel Lundqvist, Energimyndigheten (chair)
Mikael Toll, Energimyndigheten
Åsa Åhlén Hagman, Energimyndigheten (secretary of meeting)
Kajsa Helmbring (consultant and moderator) Energimyndigheten/Combitech

1. Background

In June 2014 relevant NordBER- participants were invited by the Working Group on Energy Shortage witihin NordBER, to participate in this simplified, workshoplike Table top Exercise handling the event of a major (long term) energy shortage in the Nordic power system.

The objective for the Working Group is that the Nordic countries have knowledge about how the different countries' actions during a situation of energy shortage will affect the Nordic situation. Thereby it will be possible for the countries respectively to strive for minimising the negative consequences of the different approaches.

The objective of this exercise is to increase the awareness about:

- The risk of a Nordic long term energy shortage (electricity)
- Differences in national procedures, roles and regulations during an energy shortage
- Potential needs for development or clarification of national principles, responsibilities and plans
- Mutual interdependence and need for cooperation/dialogue on Nordic level

The results will at this stage be an important input to an ongoing analysis within the NordBER working group on Energy shortage, which will be finalised in 2015.

2. Introduction to the Table top exercise/Workshop on Energy Shortage

Daniel Lundqvist welcomes the participants on behalf of the Working Group. He describes the purpose and the objects of today's Table top-exercise/Workshop with the help of some Power Points (see attachement).

Presentation of the participants around the table including short description of function/role (also in the case of a power energy shortage).

English is used in this workshop to facilitate mutual understanding as much as possible. Also "the Chatham Rules" will be applied:

"In a meeting held under the Chatham House Rule, anyone who comes to the meeting is free to use information from the discussion, but is not allowed to reveal who made any comment. It is designed to increase openness of discussion."

3. Starting point

Kajsa presents the starting point on the basis of the scenario in this exercise (also she stresses that it's not important that we reach to event number 3 in the scenario).

It is the 21th of February. It is unusually, but not extremely, cold for the season. During the autumn and winter the power demand has been high. The hydro reservoir storage level in the Nordic countries has been low for several months due to a sunny summer and an autumn with low precipitation. During the last weeks the storage levels in Sweden and Norway have fallen even further and are now almost at the all-time low level for this time of the year. In Finland the

reservoir level is slightly better but far from satisfactory. The snow level is unusually low. Only a small amount of precipitation is expected for the next two weeks.

All nuclear plants in Sweden and Finland are in operation except for Oskarshamn 2 where a large project is ongoing. Since a couple of years, the flow of electricity between Russia and Finland is low due to changes in the Russian power market design.

The transmission capabilities within and between the Nordic countries are at nominal levels. The link between Norway and the Netherlands is unavailable due to ***maintenance work****. The link is estimated to be operational by 1th of May.*

A maintenance work at the converter station in Finnböle is planned to start by 15th of March, which means that there will be no transmission capacity in the Fenno-Skan 2 from Sweden to Finland the following 35 days.

The nuclear power plants Olkiluoto 1 and Forsmark 1 are scheduled for maintenance including refueling from 1st of April. The other nuclear plants are scheduled for maintenance from mid-May or later.

Low wind power production and technical problems in Germany is ***limiting the transmission capacity from Germany to Denmark and Sweden****. The capacity is reduced to 30% of installed capacity. This situation is expected to remain for at least six weeks.*

Kajsa asks the participants "Does the scenario feel realistic?"

Remarks:

<u>Finland</u>

- "Business as usual" (Finland)

<u>Norway</u>

- This wouldn't be so serious, but we would be on our toes.
- In this kind of situation we would use a model to simulate the risks for an energy shortage and increase our monitoring (there are special routines for that).
- We would ask the hydro power companies to state the amount of water in the reservoirs in this situation (= the hydro reservoir storage level).
- We would ask for and also give information to the actors on the market/in the el spot areas.
- Monitoring of the prices: how would the market react? (An El Spot Area is bigger than this smaller area). There is historical knowledge about how such a situation has been handled. But Norway is a long country so it might be some consideration about consequences for the grid and transmission capacities in the longer run.
- Also some information would be given to the public. We would prepare an information campaign already in this early situation, with "light version messages" (advise to turn of the lamps and so on/how to save energy/getting the consumption down). The Ministry would be informed about the reasons for this situation, but the main strategy would still be to let the market handle this.

- Some interaction would occur between NVE, Statnett and the Energy Ministry.
- We would check the plans for maintenance – are there any work that is possible to postpone in this situation?
- "The bigger and the smaller players-focus" – there are different point of views and different number of bidding areas/el spot areas in different countries. If there's a restrained situation somewhere, is it possible to create a new (high price) area also considering of the bottle necks in the power system? The TSO:s have the mandate to decide that within 2-4 weeks? But one reason to split areas would be to send a long term message long term need for energy.

Denmark

- The wind power import from Germany and our own production would go down simultaneously.
- Probably an increasing amount of media interest on the rising prices, politicians maybe would say something about the question "is the electrical market really functioning?"

Sweden

- We would not yet be at the point of an actual information campaign, but we would work more actively with advising the public (to turn down the heat/turn of the lamps and other cost saving measures for the consumers). But rather more as a part of the agencys' normal work though and not as part of an actual information campaign. Our main strategy and message would be that "the market should continue to handle this/we rely on the market to function and we should not interfere with. We trust the market to handle this situation themselves".
- The Ministries in Sweden and Norway would exchange information and also Energimyndigheten and NVE (informal contacts among other things). And hopefully decide/coordinate what message would be given to the public and the media

NordBER role?

- NordBER probably wouldn't have any role at this point, but the TSO:s would interact as usual.

Kajsa: one conclusion is that an action in one country could have consequences in other countries (for example actions in Norway would be something that Sweden would have to relate to).

4. Event 1

In the last week there have been several short stops in a couple of the Swedish nuclear power plants. Today an earlier unknown technical problem is discovered in one of the plants (Ringhals 2). The plant is stopped with uncertain timing of a restart. One day later the Radiation Safety Authority in Sweden decides that the all Swedish nuclear power plants with the same technical solution must be stopped as a precaution. Within two weeks six Swedish plants have gradually

been taken out of operation for this reason (Oskarshamn 1 och 3; Ringhals 2, 3 and 4; Forsmark 3). In Finland the Radiation and Nuclear Safety Authority decides to stop Loviisa 1 and Olkiluoto 2 for investigation due to the Swedish problems. These plants are gradually taken out of service within two weeks. The Swedish and Finnish plants are expected to be out of service for at least two months.

Kajsa asks the participants to comment Event 1 around the table - what reactions can be expected?

Finland

- Now the situation is getting worse.
- Half of the nuclear power is gone. It's serious but it's not critical yet. But the market would react.
- The power reserve could be activated through the El Spot Market if needed. Need of import from Russia. Russian import could become economically feasible at these prices, which are predicted to be fairly high.

Norway

- We would be more worried and increase the monitoring.
- Probably we would already import a lot from Sweden, but we might see some reduction in this because of the situation.
- If it's possible to postpone maintenance work, we would contact Svenska kraftnät about that.
- "Flexible consumers": reduced tariffs can be used in different areas. So if the prices rise this could be of interest. But we don't exactly know who are connected in real time now (that information could be up to one week old).
- Other things we could to do more locally is to increase the import to some areas and check out the reserve components. And import more to an area by reducing operational security (violate the N-1 criteria to some extent).
- We would be quite near to use the power reserve (that is some big factories can reduce their consumption/shut down some percentage. Has to do with the need of energy during certain times during the day, peak high reserve.).
- The rationing probability is rising and is something that would be discussed. The media pressure would be high to activate that. But it would be important to hold our heads cold…

Denmark

- We are more than worried now!
- Risk for power shortage. If the market hasn't already made the producers produce more, we would prepare for the use the mothballed ("det som ligger i malpåse").
- Inform the Ministry and Management.

- It would be some media discussion in general, but that's hard to know...

Sweden

- A very constrained situation.
- Svenska kraftnät has estimated that the transmission capacity from the bidding areas SE2 and SE 3 would be quite reduced and that the market price could rise to 1000 EUR/ MWh. According to Svenska kraftnät there's a need of import from Norway (about 800 MW from bidding area NO1). Statnett comments that it depends on how the energy flows are going and who has capacity to import/export now.
- Energimyndigheten would act. Now there's a risk for an actual energy shortage which may require fast political decisions. We would advise the political level to prepare for an information campaign and maybe even more (rationing). The high prices would of course affect the electricity flow directions.

Kajsa: What coordination between the countries would take place?

- This is a Nordic problem!
- The "Security of Supply Group" is mentioned. There is some experience since earlier events. But you need to find the right agency with the right mandate in different countries in this kind of situation. And a "Blame game" could take place. The market situation makes it difficult to predict the strategies of the hydro power owners. The prices are very high, with expectancies of potential even higher prices (or lower). They might maximise their production, in case of dropping prices/value of the water – hence helping the momentary power situation but potentially worsening it in coming weeks due to a energy shortage because of "dry" storages. So there's a risk for back fire...
- Sweden: to reduce consumption by X % would be the aim of an information campaign. The next step is rationing. It would be a lot of media attention and political debate/outbursts. A load shedding situation would affect the import/export-possibilities. The political decision would come late, we are aware of that. The Nordic different Ministries would probably be talking to each other.
- More energy is taken from the water reservoirs/hydro power instead of the nuclear plants. We are moving "towards the edge" a bit faster now, but the authorities/political levels would probably not act so much but rather "wait and see how the market handles the situation". But we need to look at the whole situation and decide "should we continue to rely on the market or make use of the mechanisms at hand and interfere with the market?"
- Some hoarding ("hamstring") could occur and the prices might go down.
- The main uncertainty is when the government level would approve of going into the rationing phase and how the market would calculate the risk for "destroying the market mechanisms".

5. Event 2

After a week, on the 28th of February, a strange problem occurs in the IT-system used for control and supervision of the link between Finland and Estonia. The problem may coincide with the major cyber-attack that has been ongoing for two days which has hit several important Estonian establishments. The problem forces the Estonian TSO to shut down the links to Finland for an unknown period of time.

Kajsa asks the participants to comment Event 2 around the table - what reactions can be expected?

Finland

- We could still keep up our own balance but nothing could be exported to Sweden any longer. It has become profitable to import from Russia but could be other (political) considerations. So we are still not so affected by these events.
- There are price differences between the different countries/bidding areas.

Denmark

- The cyber attack is a real "game changer"!
- We would be in close dialogue with the Ministry of Defence (would we expect attacks in other countries outside of Estonia or is this an isolated attack in Estonia?) We would be worried. It would be important to uphold the security in the system.

Norway

- To set different prices in different areas would be an example of uncoordinated plans.
- Even if an authority has the power to set the price in a certain situation, they probably wouldn't use that tool. It's hard to steer the market – the market will always react!
- Rationing is a very precise mechanism that could be unwise to use. And also affect the more long term relations between different countries.

Some general concluding comments

- We probably couldn't handle this situation perfectly, but we would cooperate and do our best. But it's hard to set some kind of common rules of solidarity, even if this could help.(apart from the "systemdriftavtal" that is already in place)
- Most of our countries are part of the EU and "locking borders" is not an option.
- What level of preparedness would be available in each country?
- We don't have formal agreements about giving "brotherly help" to each other. And when the situation gets very bad, that tends to get in the background. But this ongoing work (= today's workshop, the working group about energy shortage within NordBER and so on) is hopefully enhancing the possibilities to cooperate and help each other.

- We would probably first look the situation in our own countries and try to "save our own population". But what events/actions in one country would trigger negative consequenses and so on in another Nordic country?
- A "Blinking Game" might occur (= where the first one who blinks loses, so everyone will wait and see…).
- It's is mentioned that there's a need of a set on rules in an energy shortage situation – but how would that be possible?
- What kind of demands can be made on the producers such as the hydro power companies? Are there any incentives for them to "economize with the resources" despite high prices? (= some kind of production regulations).
- Can there be other scenarios that the Working Group on Energy Shortage in NordBER should analyse? Coordination is needed.

6. Summing up

Kajsa initiates a concluding discussion about comments on the scenario, the method, did we learn something (new) today? And what should the Working Group "AG Elenergibrist" continue to work with?

Comments

- Yes I think we learned a lot and that we have different systems. And that we should work more on this in order to try to reduce the consequences.
- The scenario would have needed more details about the situation in Germany and other countries outside of the Nordic ones.
- Could national workshops give some other complementing inputs? (Energimyndigheten/Sweden mentions their big exercise on Energy Shortage in 2010 with a lot of participating actors).
- It would have been fruitful with a more detailed analysis as a ground for further actions.
- Useful information that came up today in our discussions.
- Very useful exercise and we have all learned a lot from each other.
- This gives a good piece of information to the Working Group.

Daniel describes what will happen next: the result from today will be summed up into a report. And hopefully everyone can bring their experiences from this workshop back home as a basis for thoughts about needs for further action. Also he invites the participants to send some input to working group: what should we look more into?

Finally Daniel and the Working Group receives thanks from the participants for a very useful and well organized workshop.

From the white board ("Who does what and when?")

	Starting point	Event 1	Event 2	Event 3
Energinet	Rising awareness	Cancel revisions		
Energistyrelsen	Rising awareness	Inform the ministry.		
NESA	Rising awareness			
Fingrid	Rising awareness. Track status.			
NVE	Rising awareness. Savings campaign. Consumption reducing. Detailed information to/from the market.			
Statnett	Rising awareness. Measures: Increase information to/from NVE.			
Energimyndigheten	Rising awareness. Exchange information to/from NVE (planned).			
Svenska kraftnät	Rising awareness			