

Reliability of supply in liberalised electricity markets: The Nordic electricity market

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Et selskap i NHH-miljøet

Security and reliability of supply



Source: EU DGTREN

Outline



Introduction

- ☞ EU Agenda
- ☞ Concepts: Security vs. Reliability
- ☞ Measuring Reliability



Status

- ☞ EU
- ☞ Nordic power market
 - ☞ Transmission networks



Regulation

- ☞ Need for harmonisation
- ☞ Options
- ☞ Performance /costs



Conclusions



EU Agenda

Three interrelated elements

- Security of Supply
 - Reliability
 - Prices
 - Geopolitical robustness
- Efficiency
 - Market: Workable competition
 - Net: Effective regulation
- Environment
 - Kyoto protocol
 - Ambient environment

Referanser

- *Green Paper : Towards a European strategy for the security of energy supply*
- ***Security of gas supplies in the framework of the energy internal market. Directive 2004/67/EC of the European Parliament and of the Council of 26 April 2004***
- *Study of Energy supply security and Geopolitics*
- **Directive 2003/54/EC of the European Parliament and of the Council of 26 June 2003**
- **Regulation (EEC) No 1228/2003 of the European Parliament and of the Council on Conditions for Access to the Network for Cross-Border Exchanges in Electricity, 26.6.2003**
- **Directive 2003/55/EC of the European Parliament and of the Council Concerning common Rules for the Internal Market in Natural Gas and Repealing Directive 98/30/EC, 26.6.2003**
- **Proposal for a Regulation on conditions for access to the gas transmission networks, COM(2003) 741, 10.12.2003**

Security and reliability of supply: Multiplicity of definitions

DESCRIPTIVE (QWWW, Quality supplies, What ever, Whenever and Where ever)



NORDEL

☞ (Rekommendation om fastställande av definitioner, NORDEL, June 2000)

- ☞ Energy security
- ☞ Power security
- ☞ Security of supply



CEER

- ☞ Security
- ☞ Quality- Commercial quality /Continuity of supply
(“Second benchmarking report on quality of electric supply”, Working group on quality of electric supply, CEER, AEEG Milan September 2003.)



System robustness (Krafrapport 2004, Statnett, Jan 2005)

ANALYTICAL (QSCP (QWWW, Quality supplies, at Sustainable, Competitive Prices)

- ☞ Adequacy
- ☞ Reliability of supply
 - ☞ (Oren, S. “Capacity Payments and Supply Adequacy in Competitive Electricity Markets.” Proceedings from the symposium of specialists in electric operational and expansion planning, Curitiba, Brazil. May 21-26, 2000)
 - ☞ (Joskow, P. and J. Tirole “Reliability and competitive electricity markets.”)
- ☞ System vulnerability (Sårbarhetsutvalget, 2000/ Vulnerability of the Nordic Power System, Report TR A5962, SINTEF)

Security of Supply : A Conceptual framework

	Availability: Normal conditions	Availability: Contingencies
Capacity	<i>Production, Storage Network</i>	<i>Production, Network</i>
Primary Energy	<i>Water, gas, coal</i>	
Demand Flexibility	<i>Inter-fuel /temporal</i>	<i>Inter-fuel /temporal</i>
	Energy security	Reliability
	System robustness / vulnerability	
Consequences	Price spikes/ price and non-price planned interruptions	System collapse / non price unplanned interruptions

Source: Singh (2004) "Forsyningssikkerhet i et markedsbasert kraftsystem." Seminar Statnett, 28.04.2004.

Security of Supply : The Traditional Approach

- 👍 Electricity supply requires two inputs: Capacity, primary energy
- 👍 Security of supply for a given time period is determined by demand and supply of electricity
- 👍 Supply of electricity is constrained by capacity and primary energy
- 👍 Pricing and Investment rules- Deterministic case
 - ☞ Ref: Turvey, R. (1971) *Economic Analysis and Public Enterprises*, London: George Allen and Unwin.
 - ☞ **Pricing rule:**
 - ☞ Price should equal marginal cost and a mark-up if necessary to restrict demand to capacity or primary energy stock
 - ☞ **Investment rule:**
 - ☞ The present value of the dual (shadow) values of different kinds of capacity should equal their marginal cost
- 👍 Security of supply is a non-issue
 - ☞ Caveat: The only issue is the socially acceptable level of demand we chose to satisfy

Security of Supply : Traditional Approach contd.

- ☞ Both demand and availability of capacity and primary energy is subject to uncertainty
- ☞ Responsive pricing that always restrains demand to available capacity or primary energy stock is not always practicable
- ☞ Total avoidance of interruptions and variations in quality of supply is not possible or commercially viable
- ☞ The objective is to maximise
 - ☞ Expected consumer benefit from supply --expected primary energy cost –capital cost – Penalty (Expected consumer loss from energy not supplied)
- ☞ Ex-ante Pricing and Investment rules when all demand is subject to rationing and constant cost of energy not supplied
 - ☞ Ref: Turvey, R. and D. Andersen (1977) *Electricity Economics*, Baltimore: The John Hopkins University Press.
 - ☞ **Pricing rule:**
 - ☞ Price should equal probability-weighted average of the marginal cost of meeting demand and the marginal social cost of failing to meet demand.
 - ☞ **Investment rule:**
 - ☞ The marginal cost of capacity equals its expected marginal benefit
- ☞ Security of supply is at an optimal level
 - ☞ Caveat: Penalty function reflects the true cost of failing to meet demand

Security of Supply in liberalised electricity markets

👉 Qs. Can deregulated markets achieve optimal security of supply? In other words, can markets prices satisfy the pricing and investments rules of the central planner?

👉 Energy Security: YES

👉 Caveats

- 👉 Real time prices reflects the social cost of generation
- 👉 Suppliers face real time prices
- 👉 All available capacity is made use of during rationing periods
- 👉 Suppliers can demand any level of rationing
- 👉 Only price insensitive consumers are rationed

👉 See: Joskow, P. and J. Tirole (2004) *Reliability and competitive electricity markets*

👉 Reliability: NO

- 👉 At the present level of technology reliability is not a private good.
- 👉 Supply side is a natural monopoly

Security of supply in liberalised electricity markets: Some problems

Energy Security

Market design

- Incomplete set of markets
- Implicit / explicit price caps

Market structure

- Market power
- Ineffective competition regulation

Non - market mechanisms

- System protocols
- Legal constraints
- Tax regimes

Reliability

Regulation

- Incomplete network regulation
- System protocols
- Legal constraints

Market design

- Ancillary service markets
- Balancing markets
- Congestion management

Measuring Reliability of supply: Some indices



Quantity Indices

☞ **System average interruption frequency index**

SAIFI= Total number of customer Interruptions / Total number of customers served

☞ **System average interruption duration index**

*SAIDI= Sum (Interruptions * Customers affected) / Total number of customers served*

☞ **Customer average interruption duration index**

*CAIDI= Sum (Interruption durations * Customers affected) / Total number of customer interruptions*

CAIDI= SAIDI / SAIFI



Value Indices

☞ *Customer damage functions*

☞ *Individual, Composite- Sectoral, Tariff group etc.*

Measuring Reliability of supply: Methodology



Quantity indices

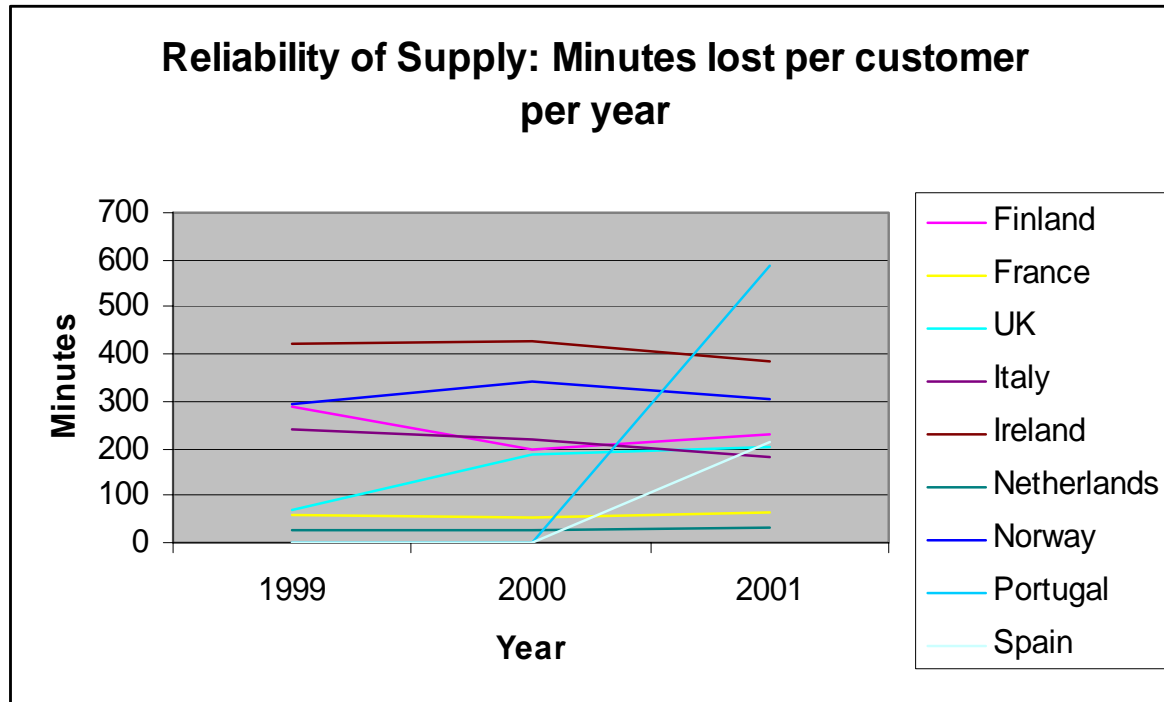
- ☞ Census methods



Value Indices

- ☞ Stated preference methods/ contingent valuation of interruptions
 - ☞ Direct costs, Willingness to pay/ accept
- ☞ Revealed preference methods
 - ☞ Averting behaviour methods
- ☞ Normalisation
- ☞ Estimation of energy not supplied
- ☞ Estimation of damage functions
 - ☞ Non normal data problems

Reliability of Supply: Status



Source: ("Second benchmarking report on quality of electric supply", Working group on quality of electric supply, CEER, AEEG Milan September 2003.)

Reliability of Supply: Comparison Problems

Variation in measurement practices

Variation in measurement practices			
<i>Countries</i>	<i>Duration</i>	<i>Voltage</i>	<i>Coverage</i>
Finland	> 3 mins	MV	80-90% MV
France	> 3 mins	MV,LV	Mainland
UK	> 3 mins	HV,MV,LV	GB only
Italy	> 3 mins	HV,MV,LV	99.9 % of customers
Ireland	> 3 mins	MV,LV	
Netherlands	All	HV,MV,LV	
Norway	> 3 mins	HV,MV	
Portugal	> 3 mins	MV,LV	99.5% Country
Spain	> 3 mins		

Measurement and registration errors

Measure do not correct for variation in weather conditions

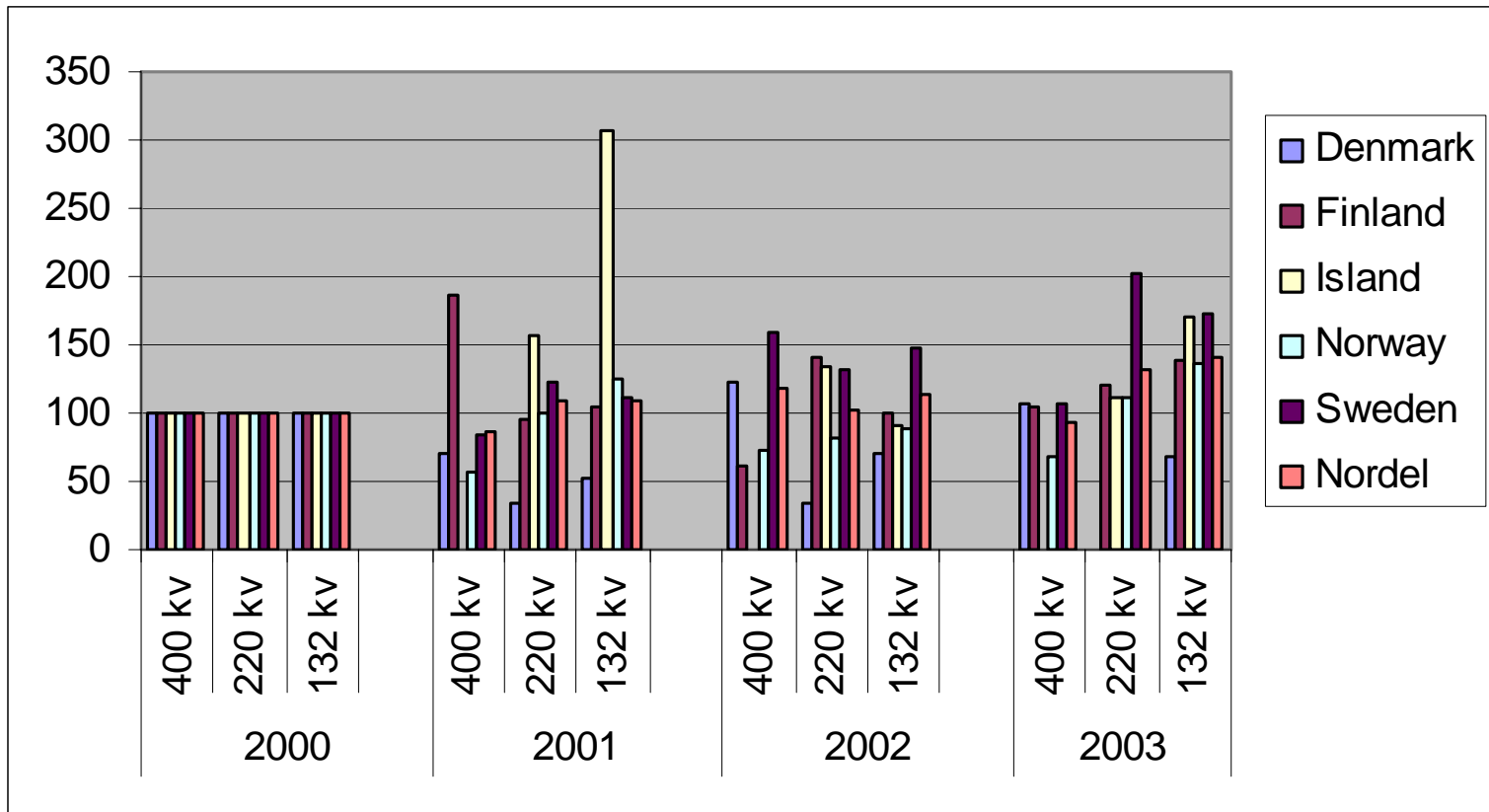
Reliability of Supply in Nordel: A Regional Picture



Nordel Fault Statistics: Some definitions

- ☞ **Fault:** *An event that involves a failure in functioning of a system component due to cause that may be internal or external to the system.*
- ☞ **Operational Disturbance:** *An event such as an automatic or a planned / unplanned manual disconnection of a system component due to a fault.*
- ☞ **Delivery point:** *The last system component that is covered by the statistic and from which energy is transported further for onward transmission to final user.*
- ☞ **Supply interruption:** *An event that involves an interruption in onward transmission of energy from a specified delivery point.*
- ☞ **Energy not supplied:** *Estimated quantity of energy that would have been delivered in the absence of a supply interruption.*

Index: Operational disturbances/00 km Nordel transmission network (2000=100)



Index: Operational disturbances/00 km Nordel transmission network (2000=100)

	Denmark	Finland	Island	Norway	Sweden	Nordel
1991-2000						
400 kv	112	-		70	-	-
220 kv	50	-	-	108	-	-
132 kv	766	-	-	117	-	-
2000						
400 kv	100	100	100	100	100	100
220 kv	100	100	100	100	100	100
132 kv	100	100	100	100	100	100
2001						
400 kv	61	174		42	80	77
220 kv	29	90	128	74	116	89
132 kv	45	97	250	91	105	97
2002						
400 kv	106	56		54	150	105
220 kv	29	131	109	59	123	85
132 kv	62	94	74	65	139	103
2003						
400 kv	100	98		51	94	80
220 kv	0	111	82	83	178	106
132 kv	64	129	126	102	152	121

Regulatory frameworks in Nordel

Structure and regulation of service reliability of electricity Networks in the Nordic Market				
	Denmark	Finland	Norway	Sweden
Regulation: Service Reliability				
<i>Nature</i>	Voluntary		Ex-ante	Voluntary
<i>Reliability target variable</i>	None		Energy not supplied for interruptions > 3 minutes	None
<i>Benchmarking</i>	None		Historic values plus OLS extrapolation (for distn. net)	
<i>Economic Incentive</i>		Consumer compensation for interruptions exceeding 12 hours	Penalty / reward for deviation from reference	Voluntary compensation by networks
<i>Data reporting</i>	Voluntary	Obligatory	Obligatory	Obligatory
<i>Data registration</i>	Automatic (ELFAS)	Manual/Automatic (NIS/SCADA)	Automatic (FASIT)	Manual/Automatic (NIS/SCADA)
<i>Data values</i>		SAIFI, SAIDI	Energy not supplied	SAIDI, SAIFI, Planned/unplanned
<i>Reporting point</i>	Transformer	Transformer- Primary side	Transformer- Secondary side	End user
<i>Data availability</i>	Restricted	Public domain	Public domain	Public domain

Cross border externalities and need for harmonisation

Italy

On September 28, 2003, the main cause for the blackouts was a tree touching a 380kv **transmission line near the Swiss town of Brunnen**, that in turn led to a domino effect triggering grid failure across Italy.

Scandinavia: Eastern Denmark and Southern Sweden

On September 23, 2003, Eastern Denmark and Southern Sweden suffered an extensive power failure, resulting in a total blackout within these regions. The main origin of failure was a double bus-bar fault at a **sub-station in Southern Sweden**, which caused an outage of four transmission lines and two units of a nuclear power station. Prior to these faults, an apparently unrelated unit outage had occurred 5 minutes earlier, at another nuclear power station which undoubtedly compounded the effects of the following disturbances.

North America: New York-Cleveland-Toronto

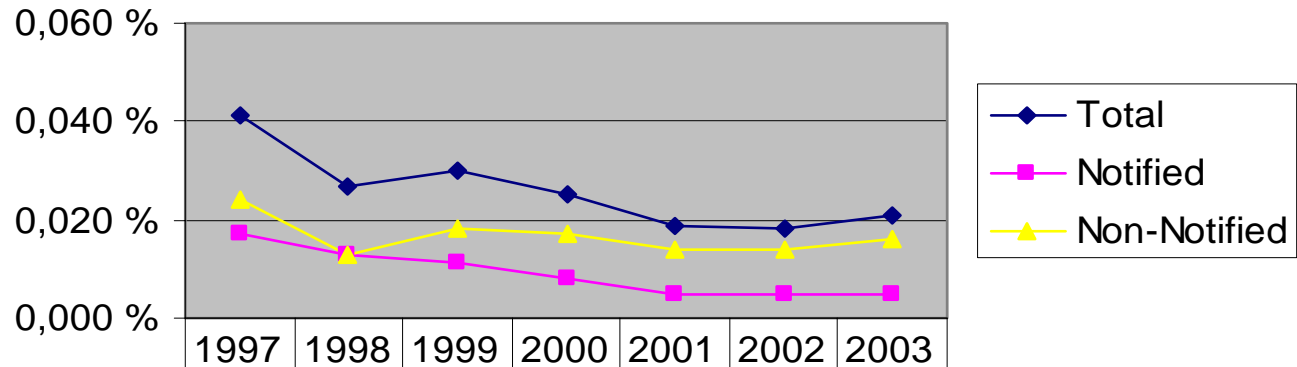
On August 14, 2003, significant portions of the north-eastern United States and Canada were plunged into darkness. The main origin for the blackout was a sudden failure of several transmission **lines in Ohio**, controlled by a private grid operator. Unable to take remedial action in good time, the local difficulty cascaded into a regional problem with cross-border implications in Canada; as one part of the grid after another automatically shut down to prevent the permanent damage that might result from a huge and unexpected power-surge.

Index: Energy not supplied in Nordel (1991-2000=100)

	Denmark	Finland	Norway	Sweden	Nordel
<i>INDEX</i>					
1991-2000	100	100	100	100	100
2000	1	34	82	82	70
2001	48	84	77	177	101
2002	1263	21	79	120	97
2003	7276	24	69	450	264

Norway Energy not supplied

Norway- Energy not supplied as a percentage of supplied energy



◆ Total	0,041	0,027	0,030	0,025	0,019	0,018	0,021
■ Notified	0,017	0,013	0,011	0,008	0,005	0,005	0,005
▲ Non-Notified	0,024	0,013	0,018	0,017	0,014	0,014	0,016

Regulation Costs

Institutions and resource use in regulation of electricity Networks in the Nordic Market					
	Denmark	Finland	Norway	Sweden	Nordic Market
Regulatory Costs	Energitilsynet	Energimarknadsverket EMV	Norges vassdrags- og energidirektoratet NVE	Statens energimyndighet	
Labour inputs (Years)	20	16	50	30	116
Labour inputs/ utility	0,26	0,17	0,32	0,15	0,22
Network (1-110 kv) km /labour input	3384	9308	2101	7223	4641
Throughput / labour input (Gwh)	1746	3798	2509	5017	3204
Consumers 000/labour input	152	185	52	174	119
Energy not delivered Mwh /labour input	3	16	79	162	79

Cross border harmonisation: Some options

Cross border regulation of reliability of supply: Datum

Technical and administrative competence intensive regulatory problem

Severe informational asymmetry

Absence of supra national authority

Options

Formal judicial framework

Prone to both institutional and informational deficiencies

Prone to inflexible and costly targets

Costly in implementation

Voluntary cross-border agreements and domestic incentive regulation

Nordel System Operation Agreement – A model

“Systemdriftsavtale” 2004: Nordel system operation agreement: A model

Motivation

- ☞ History

- ☞ Credible Political threat
 - ☞ Nordic Council of Ministers commitment to cross border integration
 - ☞ Increasing demands by competitive segment for efficient regional transmission
 - ☞ Horizontal separation: ISO/TSO

- ☞ Good Economics
 - ☞ Incentive regulation at home and cross border economies of scale and scope
 - ☞ Regulatory pressure to reduce costs
 - ☞ High compliance costs associated with eventual formal regulatory inflexible targets

Conclusions

- ☞ The three main elements of the EU agenda are not independent of each other. Security/ Reliability, Economic Efficiency and Environmental Sustainability objectives are interrelated. There is a need to have goals that are compatible.
- ☞ Multiplicity of definitions and concepts needs to be narrowed down
- ☞ Multiplicity of metrics needs to be sorted out. Quantity indices give very little information about the welfare changes resulting from variation in reliability of supply. There is a need to have EU wide comparable valuations of reliability of supply.
- ☞ Current EU wide comparisons based on quantity indices is of limited use and can hardly be used as a basis for harmonisation.
- ☞ In a regulatory scenario involving economic incentives, regulation of reliability of supply calls for development of value measures for reliability of supply.
- ☞ Regional comparisons indicate positive experience with detailed value based regulation of reliability of supply.
- ☞ Can Detailed regulation be recommended? Too early to say so and besides detailed regulation is not costless.
- ☞ More regulation is not a legitimate goal in itself. There is a need to have a cost-benefit approach to choice of the regulatory structure and model.
- ☞ Cross border harmonisation of reliability is judicially difficult, technically complicated and resource intensive.
- ☞ Domestic regulation combined with voluntary cross-border agreements between system operators is an interesting option. Nordel operation agreement is an interesting model.