European Network of
Transmission System Operators
for Electricity

NORDIC GRID DISTURBANCE STATISTICS 2012

21.11.2013

REGIONAL GROUP NORDIC

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1 INTRODUCTION

This report is an overview of the Danish, Finnish, Icelandic, Norwegian and Swedish transmission grid disturbance statistics for the year 2012. Although Iceland does not belong to the ENTSO-E Regional Group Nordic, it is included in this report. In addition, the disturbance data of the whole Denmark is included in this report, although only the grid of eastern Denmark belongs to the synchronous Nordic grid. Transmission System Operators providing the statistical data are *Energinet.dk* in Denmark, *Fingrid Oyj* in Finland, *Landsnet* in Iceland, *Statnett SF* in Norway and *Svenska Kraftnät* in Sweden.

The report is made according to the Nordic Guidelines for Classification of Grid Disturbances [1] and includes the faults causing disturbances in the 100–400 kV grids. The guidelines for the Classification of Grid Disturbances [1] were prepared by Nordel[1] during the years 1999–2000 and have been used since 2000. Most charts include data for the ten-year period 2003–2012. In some cases where older data has been available, even longer periods have been used.

The statistics can be found at ENTSO-E website, www.entsoe.eu. The guidelines and disturbance statistics were in the “Scandinavian” language until 2005. In 2007, however, the guidelines were translated into English and the report of the statistical year 2006 was the first set of statistics written in English. The structure of these statistics is similar to the 2006 statistics.

Although this summary originates from the Nordic co-operation that has aimed to use the combined experience from the five countries regarding the design and operation of their respective power systems, other ENTSO-E countries are encouraged to participate in the statistics as well. The material in the statistics covers the main systems and associated network devices with the 100 kV voltage level as the minimum. Control equipment and installations for reactive compensation are also included in the statistics.

Despite common guidelines, there are slight differences in interpretations between different countries and companies. These differences may have a minor effect on the statistical material and are considered being of little significance. Nevertheless, users should – partly because of these differences, but also because of the different countries’ or transmission and power companies’ maintenance and general policies – use the appropriate published average values. Values concerning control equipment and unspecified faults or causes should be used with wider margins than other values.

Chapter 2 summarises the statistics, covering the consequences of disturbances in the form of energy not supplied (ENS) and covering the total number of disturbances in the Nordic power system. In addition, each Transmission System Operator has presented the most important issues of the year 2012.

[1] Nordel was the co-operation organization of the Nordic Transmission System Operators until 2009.

Chapter 3 discusses the disturbances and focuses on the analysis and allocation of the causes of disturbances. The division of disturbances during the year 2012 for each country is presented; for example, the consequences of the disturbances in the form of energy not supplied.

Chapter 4 presents tables and figures of energy not supplied for each country.

Chapter 5 discusses the faults in different components. A summary of all the faults is followed by the presentation of more detailed statistics.

Chapter 6 covers outages in the various power system units. This part of the statistics starts from the year 2000.

Chapter 7 presents a brief summary of HVDC statistics. The HVDC section was included first time in the report for the year 2010 and for this report, it has been developed further. In the following years, the report will have more detailed information on the availability of the HVDC links.

There are no common Nordic disturbance statistics for voltage levels lower than 100 kV. However, Appendix 8 presents the relevant contact persons for these statistics.

1.1 CONTACT PERSONS

Each country is represented by at least one contact person, responsible for his/her country's statistical information. The contact person can provide additional information concerning ENTSO-E Nordic disturbance statistics. The relevant contact information is given in Appendix 7.

1.2 GUIDELINES OF THE STATISTICS

The scope and definitions of ENTSO-E Nordic disturbance statistics are presented in more detail in the Nordic Guidelines for the Classification of Grid Disturbances [1].

1.3 VOLTAGE LEVELS IN THE ENTSO-E NORDIC NETWORK

Table 1.1 presents the voltage levels of the network in the Nordic countries. In the statistics, voltage levels are grouped according to the table.

FIGURE 1.1 THE NORDIC MAIN GRID [2]

TABLE 1.1 VOLTAGE LEVELS IN THE ENTSO-E NORDIC NETWORK

Nominal voltage level kV	Statis-tical voltage U (kV)	Denmark		Finland		Iceland		Norway		Sweden	
		U_N kV	P %	U_N kV	P %	U_N kV	P %	U_N kV	P %	U_N kV	P %
≥400	**400**	400	100	400	100	-	-	420	100	400	100
220–300	**220**	220	100	220	100	220	100	300	90	220	100
220–300	**220**	-	-	-	-	-	-	-	-	-	-
220–300	**220**	-	-	-	-	-	-	220	10	-	-
110–150	**132**	150	63	110	100	132	100	132	98	130	100
110–150	**132**	132	37	-	-	-	-	110	2	-	-

U – statistical (designated) voltage, U_N – nominal voltage
P – percentage of the grid at the respective nominal voltage level for each statistical voltage.

The following tables use the 132, 220 and 400 kV values to represent the nominal voltages, in accordance with Table 1.1.

1.4 SCOPE AND LIMITATIONS OF THE STATISTICS

Table 1.2 presents the coverage of the statistics in each country. The percentage of the grid is estimated according to the length of lines included in the statistics material.

TABLE 1.2 PERCENTAGE OF NATIONAL NETWORKS INCLUDED IN THE STATISTICS

Voltage level	Denmark	Finland	Iceland	Norway	Sweden[1)]
400 kV	100%	100%	-	100%	100%
220 kV	100%	100%	100%	100%	97%
132 kV	100%	96%	100%	100%	81%

[1)] Percentage for Sweden is reduced due to one regional grid did not deliver complete data.

The network statistics of each country, except Iceland, cover data from several grid owners, and the representation of their statistics is not fully consistent.

Finland: The data includes approximately 96% of Finnish 110 kV lines and approximately 90% of 110/20 kV transformers.

Iceland: The network statistics cover the whole 220 kV and 132 kV transmission grid. There is only one transmission company in Iceland.

Norway: A large part of the 132 kV network is resonant earthed but is combined with a solid earthed network in these statistics.

2 SUMMARY

In 2012, the energy not supplied (ENS) due to faults in the Nordic main grid was relatively low, except for Iceland. ENS totalled 6.69 GWh, which is clearly below the ten-year average. The annual average of ENS was 8 GWh in the ENTSO-E Nordic region during the period 2003–2012. The corresponding average value for each country is presented in brackets in the following paragraphs. The following paragraphs also present the number of disturbances for each country as well as the number of disturbances that caused energy not supplied in 2012. The corresponding annual averages are calculated for the period 2003–2012. In addition, the summaries present the most important issues in 2012 defined by each Transmission System Operator.

2.1 SUMMARY FOR DENMARK

For Denmark, the energy not supplied in 2012 was 18.03 MWh (ten-year average 817 MWh). The number of grid disturbances was 44 (ten-year average 64) and 8 of them caused ENS. On average, 5 disturbances per year caused ENS in 2003-2012. Two major grid disturbances caused approx. 85% of the year’s ENS.

On May 21st 2012 at 9.23 AM a maintenance was planned in the 400/150 kV substation Trige in mid-eastern part due to this maintenance, one of the 150 kV busbars in the TRI substation were taken out of service, and all load was moved to the other 150 kV busbar. By local maloperation an earthing switch was operated on the 150 kV busbar in service. The busbar protection made circuit breaker trip causing an outage of three 150/60 kV substations. By this outage approx. 95000 customers including northern part of the city Aarhus, the city Randers and the Djursland-region were interrupted in between 7 to 13 minutes. This fault resulted in 11.2 MWh ENS.

On August 27th 2012 at 9:58 AM the 150 kV line TRI-ÅSP (one of two 150 kV lines for the Djursland-region, same region which was interrupted on May 21st 2012) was out for maintenance. Due to a spontaneous trip the second 150 kV line (MES-TRI) was disconnected. By this, grid disturbance lead to an outage of two 150/60 kV substations and approx. 60000 customers in the Djursland-region was interrupted. The interruption lasted approx. 2 minutes. The same fault repeated itself another two times within a two-hour period resulting in a total of three short interruptions lasting in total less than 5 minutes and resulting in total of 3.8 MWh ENS. The cause of the faults was found to be a defect voltage transformer which gave misleading voltage signals to the protection relay. This fault lead to the spontaneous circuit breaker trips.

2.2 SUMMARY FOR FINLAND

For Finland, the energy not supplied in 2012 was only 158 MWh (ten-year average 298 MWh). The number of grid disturbances was 445 (ten-year average 360) and 62 of them caused ENS. On average, 67 disturbances per year caused ENS in 2003–2012.

In 2012, 64 % of ENS was caused by overhead lines faults and 35 % by substation faults. The biggest reasons were Operation and maintenance 44 % and Technical equipment 36 %. Most of the disturbances were caused by 'other environmental causes' and occurred during the summer months.

More effort is put to clarify the causes for primary faults in Finland. In the year 2010, 46% was unknown, in 2011 only 22% and in 2012 the part of unknown was 30 %. Almost all of the unknown disturbances occurred in 110 kV lines. 45% of ENS was caused by only five disturbances. The highest amount of ENS (16 MWh) in a single disturbance was caused by 'operations and maintenance' in 110 kV overhead line.

2.3 SUMMARY FOR ICELAND

For Iceland, the energy not supplied in 2012 was 3462 MWh (ten-year average 1072 MWh). The total number of disturbances was 40 (ten-year average 33) and 30 of them caused ENS. On average, 22 disturbances per year caused ENS in 2003–2012.

The year 2012 saw an unusually high rate of grid disturbances. The weather played a central role in most cases, as three severe storms struck the country during the year, each causing substantial damage to the grid as well as supply interruptions.

The year’s largest disturbances occurred in early January, February, September, November and late December. All of these were weather-related and caused extensive outages throughout the country. All of the disturbances were among the largest in Landsnet’s history.

The biggest disturbance hit in January when storm hit the country and caused a number of failures in the grid. This triggered considerable transmission disturbances throughout the country, particularly in west Iceland where there was salt-contaminated ice build-up on electrical equipment. A four-hour outage at the Brennimelur substation led to substantial curtailment for power-intensive consumers at Grundartangi. Considerable flashovers also occurred in south and west Iceland. 75% of ENS was caused by this storm only.

2.4 SUMMARY FOR NORWAY

In Norway, the energy not supplied in 2012 was 1165 MWh (ten-year average 2664 MWh). The number of grid disturbances was 160 (ten-year average 286) and 51 of them caused ENS. On average, 89 disturbances per year caused ENS in 2003-2012.

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2012 was Norway's all-time low if one considers number of disturbances, number of faults and the amount of ENS.

2.5 SUMMARY FOR SWEDEN

In Sweden, the energy not supplied in 2012 was 1889 MWh (ten-year average 3017 MWh). The total number of disturbances was 439 (ten-year average 545) and 111 of those caused ENS. On average, 135 disturbances per year caused ENS in 2003–2012. Lightning caused 10 % of ENS and 48 % of ENS was caused by failure in technical equipments.

One single disturbance on a 130 kV cable connection tripped two substations which were due to maintenance fed from one direction only. Total ENS during 11 hours was 559 MWh.

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3 DISTURBANCES

This chapter includes an overview of disturbances in the Nordic countries. It also presents the connection between disturbances, energy not supplied, fault causes, and division during the year 2012, together with the development of the number of disturbances over the ten-year period 2003–2012. It is important to note the difference between a disturbance and a fault. A disturbance may consist of a single fault, but it can also contain many faults, typically consisting of an initial fault followed by some secondary faults.

Definition of a grid disturbance:

Outages, forced or unintended disconnection or failed reconnection as a result of faults in the power grid [1, 3].

3.1 ANNUAL NUMBER OF DISTURBANCES DURING THE PERIOD 2003–2012

The number of disturbances during the year 2012 in the Nordic main grid was 1128, which is below the ten-year average of 1287. The number of grid disturbances cannot directly be used for comparative purposes between countries because of the large differences between external conditions in the transmission networks of the Nordic countries.

Table 3.1 presents the sum of disturbances during the year 2012 and the annual average for the period 2003-2012 for the complete 100–400 kV grid in each respective country. Figure 3.1 shows the development of the number of disturbances in each respective country during the period 2003–2012.

TABLE 3.1 NUMBER OF GRID DISTURBANCES IN 2012 AND THE ANNUAL AVERAGE FOR THE PERIOD 2003–2012

	Denmark		Finland		Iceland		Norway		Sweden		Nordic	
Time period	2012	2003–2012	2012	2003–2012	2012	2003–2012	2012	2003–2012	2012	2003–2012	2012	2003–2012
Number of disturbances	44	64	445	360	40	33	160	286	439	545	1128	1287

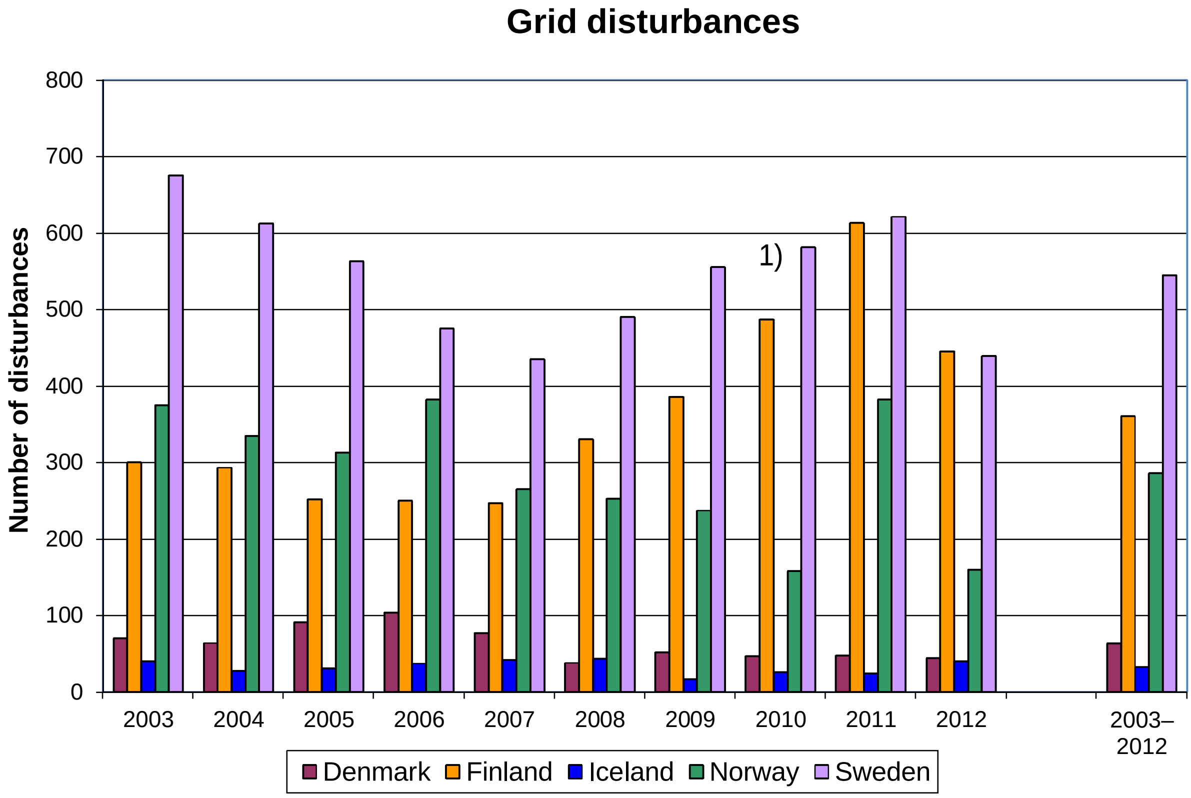

FIGURE 3.1 NUMBER OF GRID DISTURBANCES IN EACH NORDIC COUNTRY DURING THE PERIOD 2003–2012.

1) The increased number of lightning faults affects the number of grid disturbances in Finland and Sweden.

3.2 DISTURBANCES DIVIDED ACCORDING TO MONTH

Figure 3.2 presents the percentage distribution of grid disturbances according to month in different countries in the year 2012. In addition, Figure 3.3 shows the ten-year average distribution of disturbances during the period 2003–2012.

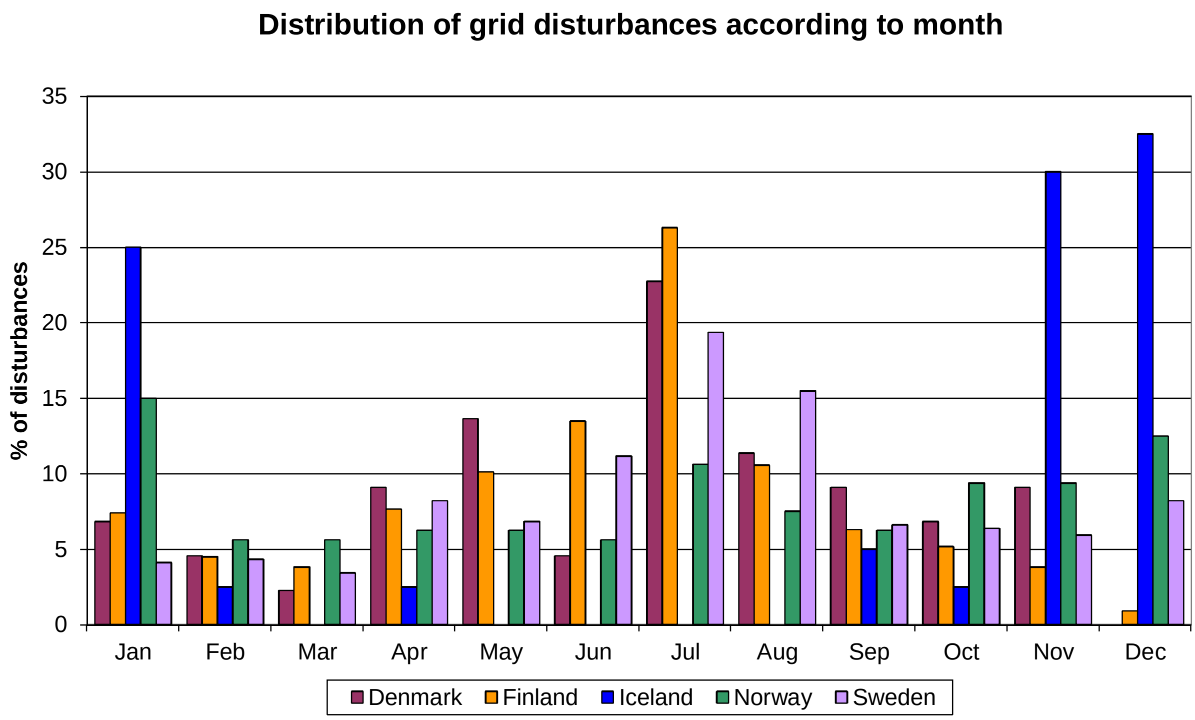

FIGURE 3.2 PERCENTAGE DISTRIBUTION OF GRID DISTURBANCES ACCORDING TO MONTH IN EACH COUNTRY IN 2012.

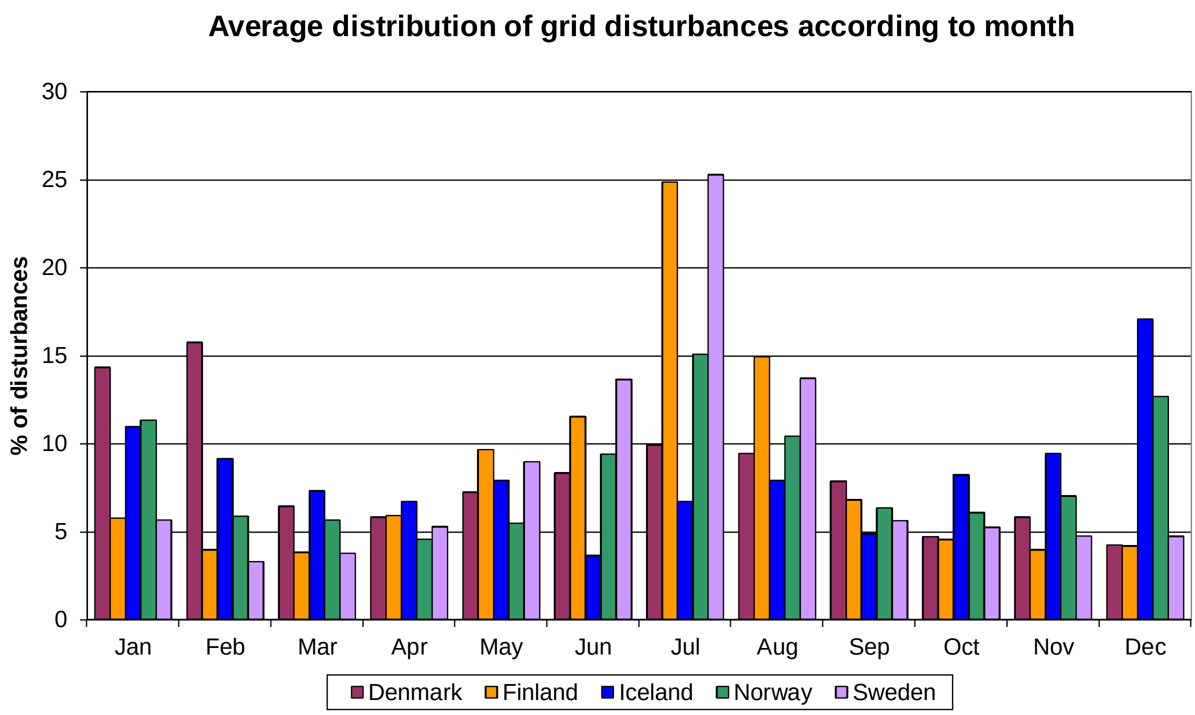

FIGURE 3.3 AVERAGE PERCENTAGE DISTRIBUTION OF GRID DISTURBANCES ACCORDING TO MONTH FOR THE PERIOD 2003–2012.

Table 3.2 and Table 3.3 present the numerical values behind Figure 3.2 and Figure 3.3. The numbers in the tables are sums of all the disturbances in the 100–400 kV networks. For all countries, except Iceland, the number of disturbances is usually greatest during the summer period. This is caused by lightning strokes during the summer.

TABLE 3.2 PERCENTAGE DISTRIBUTION OF GRID DISTURBANCES PER MONTH FOR EACH COUNTRY IN 2012

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Denmark	7	4	2	9	14	5	23	11	9	7	9	0
Finland	7	5	4	8	10	13	26	11	6	5	4	1
Iceland	25	2	0	2	0	0	0	0	5	3	30	33
Norway	15	6	6	6	6	6	11	7	6	9	9	13
Sweden	4	4	4	8	7	11	19	16	7	6	6	8
Nordic	8	5	4	8	8	11	20	12	6	6	6	6

TABLE 3.3 PERCENTAGE DIVISION OF GRID DISTURBANCES DURING THE YEARS 2003–2012

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Denmark	14	16	7	6	7	8	10	9	8	5	6	4
Finland	6	4	4	6	10	11	25	15	7	4	4	4
Iceland	11	9	7	7	8	4	7	8	5	8	9	17
Norway	11	6	6	5	6	9	15	10	6	6	7	13
Sweden	6	3	4	5	9	13	25	14	6	5	5	5
Nordic	7	5	4	5	8	12	22	13	6	5	5	8

3.3 DISTURBANCES DIVIDED ACCORDING TO CAUSE

There are some minor scale differences in the definitions of fault causes and disturbances between countries. Some countries use up to 40 different options, and others differentiate between initiating and underlying causes. The exact definitions are listed in Section 5.2.9 in the guidelines [1]. The Nordic statistics use seven different options for fault causes and list the initiating cause of the event as the starting point. Table 3.4 presents an overview of the causes of grid disturbances and energy not supplied in each country.

Each country that participates in the ENTSO-E Nordic statistics has its own detailed way of gathering data according to fault cause. The guidelines [1] describe the relations between the detailed fault causes and the common Nordic cause allocation.

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TABLE 3.4 GROUPING OF GRID DISTURBANCES AND ENERGY NOT SUPPLIED (ENS) BY CAUSE

Cause	**Country**	**Percentage distribution of disturbances**		**Percentage distribution of ENS[1)]**	
		2012	2003–2012	2012	2003–2012
Lightning	Denmark	18	14	0	0
	Finland	18	28	11	5
	Iceland	0	3	0	2
	Norway	14	22	3	4
	Sweden	25	38	10	13
Other environmental causes	Denmark	0	22	0	1
	Finland	33	13	18	23
	Iceland	63	35	64	53
	Norway	29	21	50	51
	Sweden	5	5	1	5
External influences	Denmark	34	17	0	0
	Finland	1	2	8	11
	Iceland	2	2	0	0
	Norway	3	2	0	1
	Sweden	2	2	0	4
Operation and maintenance	Denmark	18	15	68	1
	Finland	5	7	28	16
	Iceland	3	10	3	22
	Norway	9	12	10	9
	Sweden	6	8	36	8
Technical equipment	Denmark	2	13	21	0
	Finland	8	5	23	28
	Iceland	10	25	3	15
	Norway	26	23	7	20
	Sweden	18	15	48	50
Other	Denmark	7	6	10	98
	Finland	5	6	1	10
	Iceland	23	23	30	7
	Norway	18	14	18	12
	Sweden	12	10	3	10
Unknown	Denmark	21	13	1	0
	Finland[2)]	30	39	11	7
	Iceland	0	2	0	1
	Norway	1	6	12	3
	Sweden	33	22	2	10

[1)] Calculation of energy not supplied varies between different countries and is presented in Appendix 1.
[2)] Most of the Finnish unknown disturbances probably have other natural phenomenon or external influence as their cause.

Figure 3.4 identifies disturbances for all voltage levels in terms of the initial fault, and Figure 3.5 presents the respective ten-year average values.

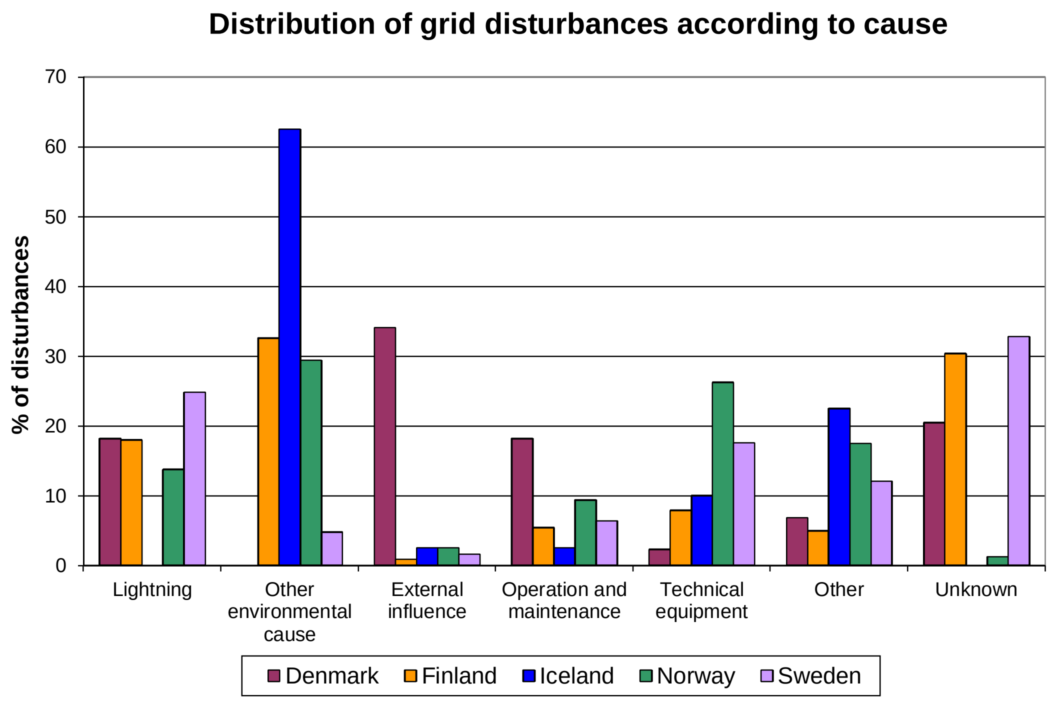

FIGURE 3.4 PERCENTAGE DISTRIBUTION OF GRID DISTURBANCES ACCORDING TO CAUSE IN 2012.

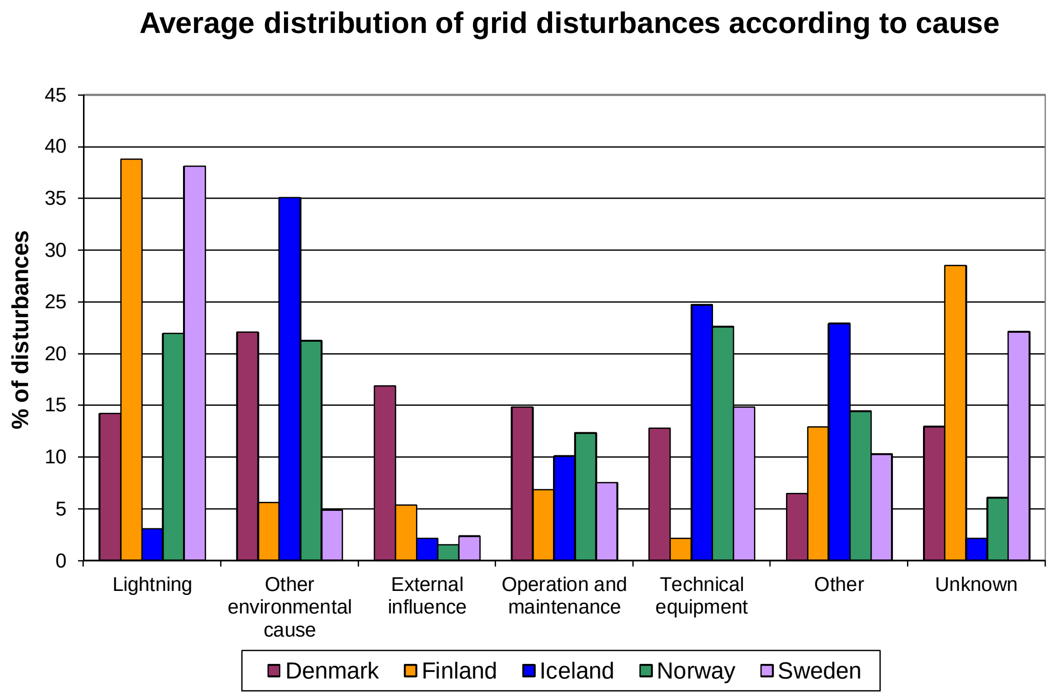

FIGURE 3.5 AVERAGE PERCENTAGE DISTRIBUTION OF GRID DISTURBANCES ACCORDING TO CAUSE DURING THE PERIOD 2003–2012.

A large number of disturbances with unknown cause probably have their real cause in the categories *other environmental cause* and *lightning*.

4 ENERGY NOT SUPPLIED (ENS)

This chapter presents an overview of energy not supplied in the Nordic countries. One should remember that the amount of energy not supplied is always an estimation. The accuracy of the estimation varies between companies in different countries and so does the calculation method for energy not supplied, as can be seen in Appendix 1.

Definition of energy not supplied:

The estimated energy which would have been supplied to end users if no interruption and no transmission restrictions had occurred [1, 3].

4.1 ENERGY NOT SUPPLIED (ENS) DIVIDED ACCORDING TO VOLTAGE LEVEL

Table 4.1 shows the amount of energy not supplied in the five countries and its division according to voltage level.

TABLE 4.1 ENERGY NOT SUPPLIED (ENS) ACCORDING TO THE VOLTAGE LEVEL OF THE INITIATING FAULT

Country	ENS MWh 2012	Annual average of ENS MWh 2003–2012	ENS divided into different voltage levels during the period 2003–2012 (%)			
			132 kV	220 kV	400 kV	Other[1)]
Denmark	18.0[2)]	817	2.0	0.0	98.0[3)]	0.0
Finland	158.4	298	91.7	3.3	4.1	0.9
Iceland	3462.2	1072	34.8	65.2	0.0	0.0
Norway	1165.0	2664	29.8	17.7	43.4	9.1
Sweden	1888.6	3017	52.6	9.7	35.7[3)]	2.0
Nordic	6692.2	7998	38.5	18.8	38.7	3.9

1) The category other contains energy not supplied from system faults, auxiliary equipment, lower voltage level networks and the connections to foreign countries, etc.
2) The further explanation for the low ENS in Denmark compared with other countries can be found in Appendix 1, which discusses the different calculation methods of ENS.
3) The high values for the 400 kV share of energy not supplied in Denmark and Sweden are the result of a major disturbance in southern Sweden on the 23rd of September in 2003.

Figure 4.1A and 4.2B summarise the energy not supplied according to the different voltage levels for the year 2012 and for the period 2003–2012, respectively. Voltage level refers to the initiating fault of the respective disturbance.

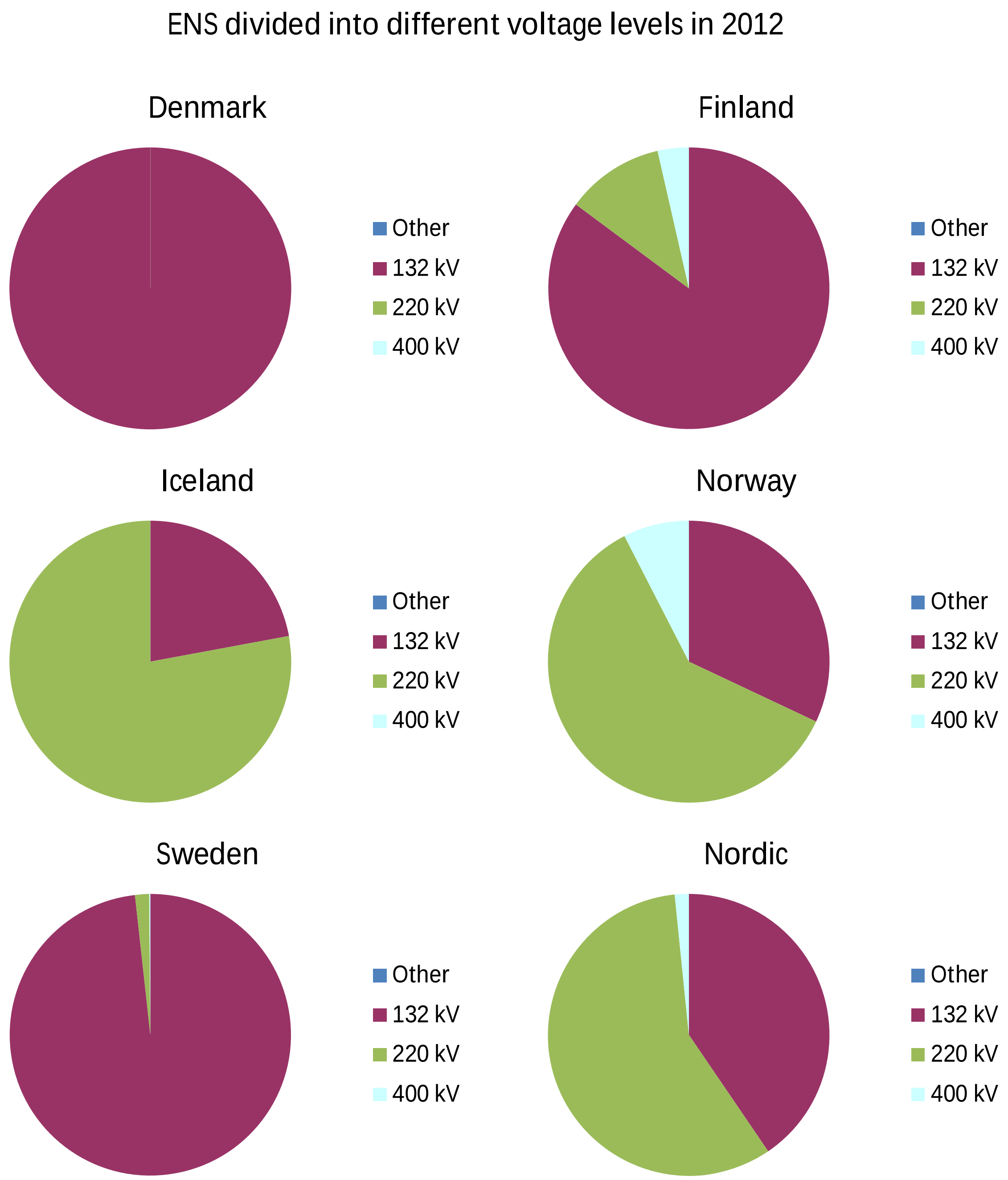

FIGURE 4.1A ENERGY NOT SUPPLIED (ENS) IN TERMS OF THE VOLTAGE LEVEL OF THE INITIATING FAULT IN 2012.

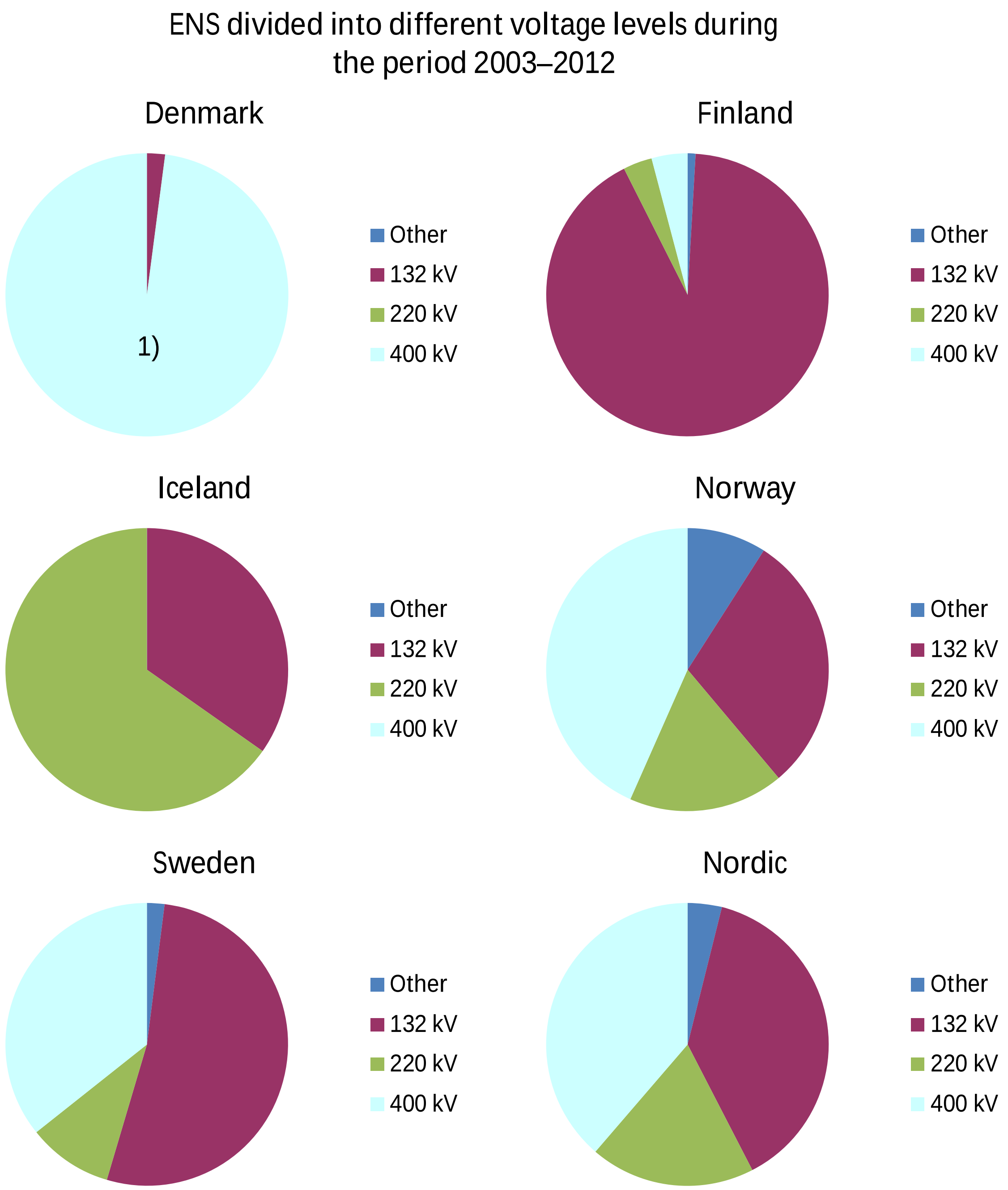

FIGURE 4.1B ENERGY NOT SUPPLIED (ENS) IN TERMS OF THE VOLTAGE LEVEL OF THE INITIATING FAULT DURING THE PERIOD 2003–2012.

1) The large amount of energy not supplied at 400 kV grid in Denmark is a consequence of the major disturbance in southern Sweden and Zealand on the 23rd of September in 2003. That disturbance caused 98% of the total amount of energy not supplied at the 400 kV level during that year.

4.2 ENERGY NOT SUPPLIED (ENS) AND TOTAL CONSUMPTION

Table 4.2 shows the energy not supplied in relation to the total consumption of energy in each respective country and its division according to installation.

TABLE 4.2 ENERGY NOT SUPPLIED (ENS) ACCORDING TO INSTALLATION

Country	Total con-sumption	ENS	ENS / consumption		ENS divided according to installation during the period 2003–2012 (%)			
	GWh 2012	MWh 2012	Ppm 2012	Ppm 2003–2012	Overhead line	Cable	Sta-tions	Other
Denmark	30960	18.03	0.6	24.3	0.4	0.0	1.3	98.3
Finland	85200[1)]	158.40	1.9	3.6	60.2	0.0	34.8	5.0
Iceland	17592	3462.20	196.8	80.7	31.3	0.8	54.9	13.0
Norway	128245	1165.0	9.1	21.0	56.4	0.4	34.7	8.5
Sweden	142400	1888.6	13.3	21.0	16.2	3.0	72.3	5.7
Nordic	404397	6692.2	16.5	19.6	31.9	1.4	48.4	17.2

Ppm (parts per million) represents ENS as a proportional value of the consumed energy, which is calculated: ENS (MWh) × 10^6 / consumption (MWh).

1) Data from Statistics Finland

Figure 4.1 presents the development of energy not supplied during the period 2003–2012. One should note that there is a considerable difference from year to year depending on occasional events, such as storms. These events have a significant effect on each country's yearly statistics.

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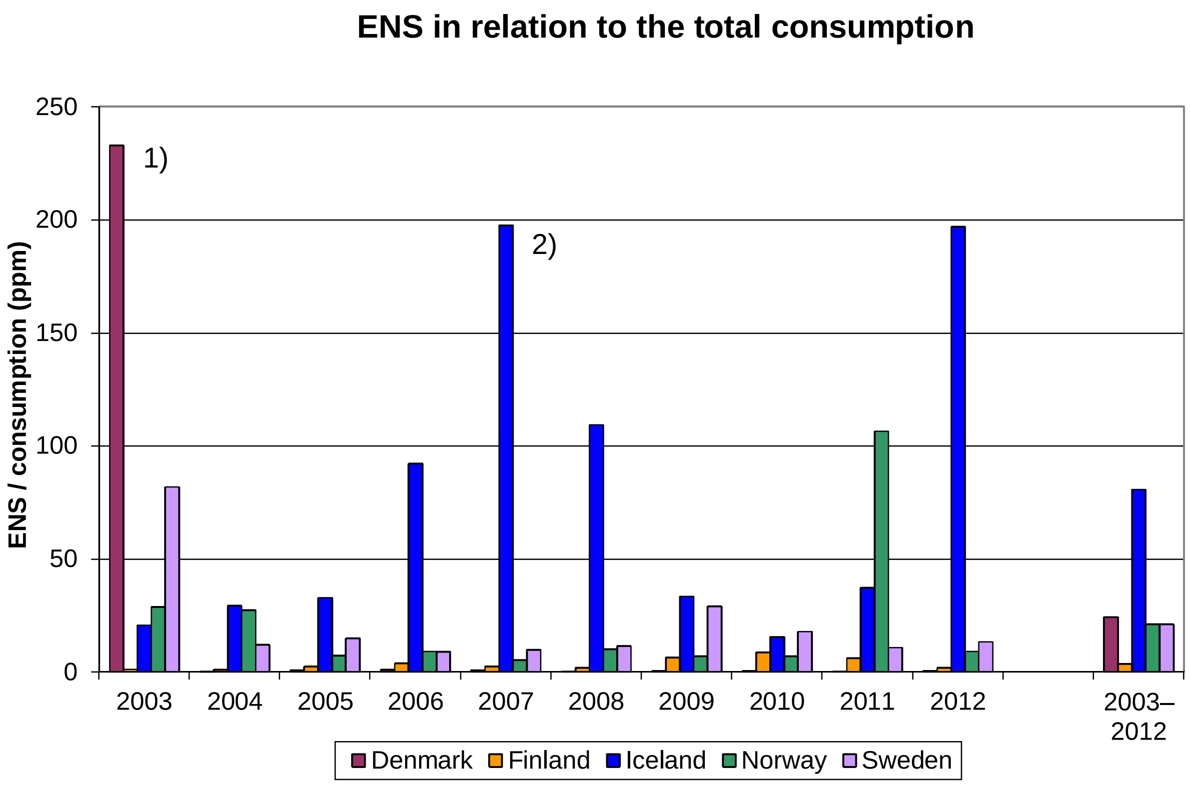

FIGURE 4.1 ENERGY NOT SUPPLIED (ENS) / CONSUMPTION (PPM).

1) The large amount of energy not supplied in Denmark is a consequence of the major disturbance in southern Sweden on the 23rd of September in 2003 that caused the whole of Zealand to lose its power.

2) An unusual number of disturbances, which had an influence on the power intensive industry, caused the high value of energy not supplied in Iceland during 2007.

4.3 ENERGY NOT SUPPLIED (ENS) DIVIDED ACCORDING TO MONTH

Figure 4.2 presents the distribution of energy not supplied according to month in the respective countries.

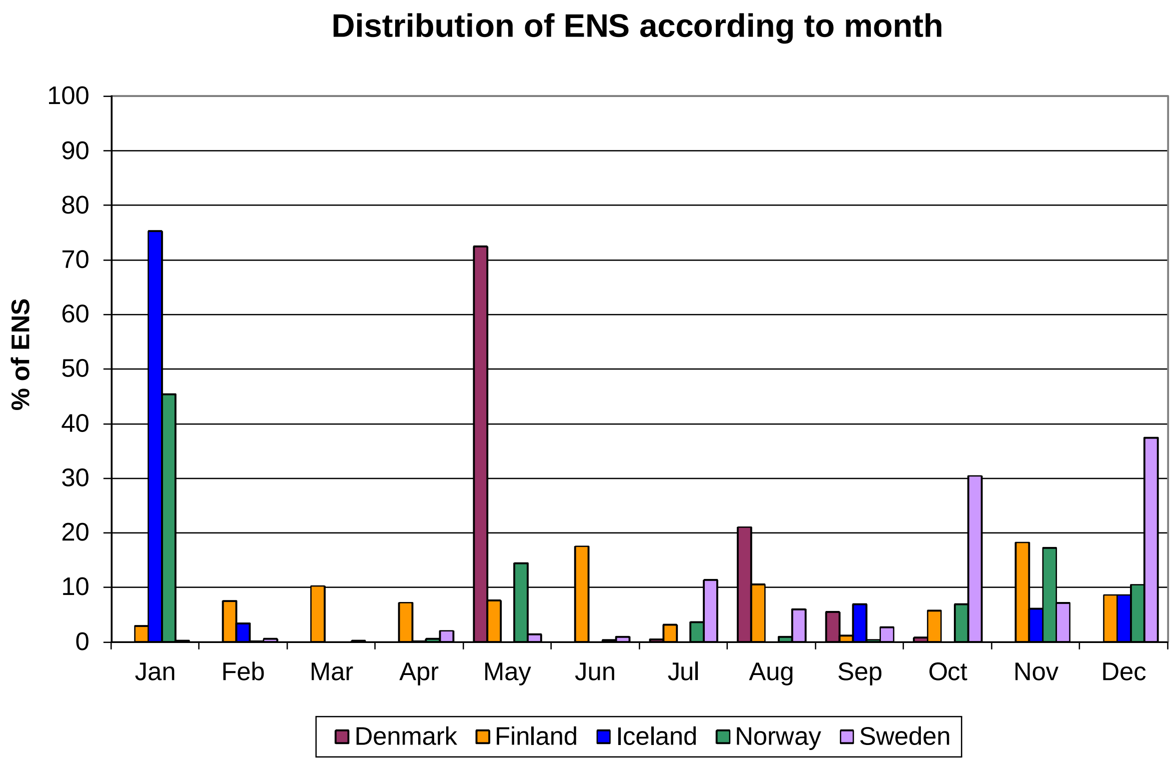

FIGURE 4.2 PERCENTAGE DISTRIBUTION OF ENERGY NOT SUPPLIED (ENS) ACCORDING TO MONTH IN 2012.

4.4 ENERGY NOT SUPPLIED (ENS) DIVIDED ACCORDING TO CAUSE

Figure 4.3 presents the distribution of energy not supplied according to cause in different countries.

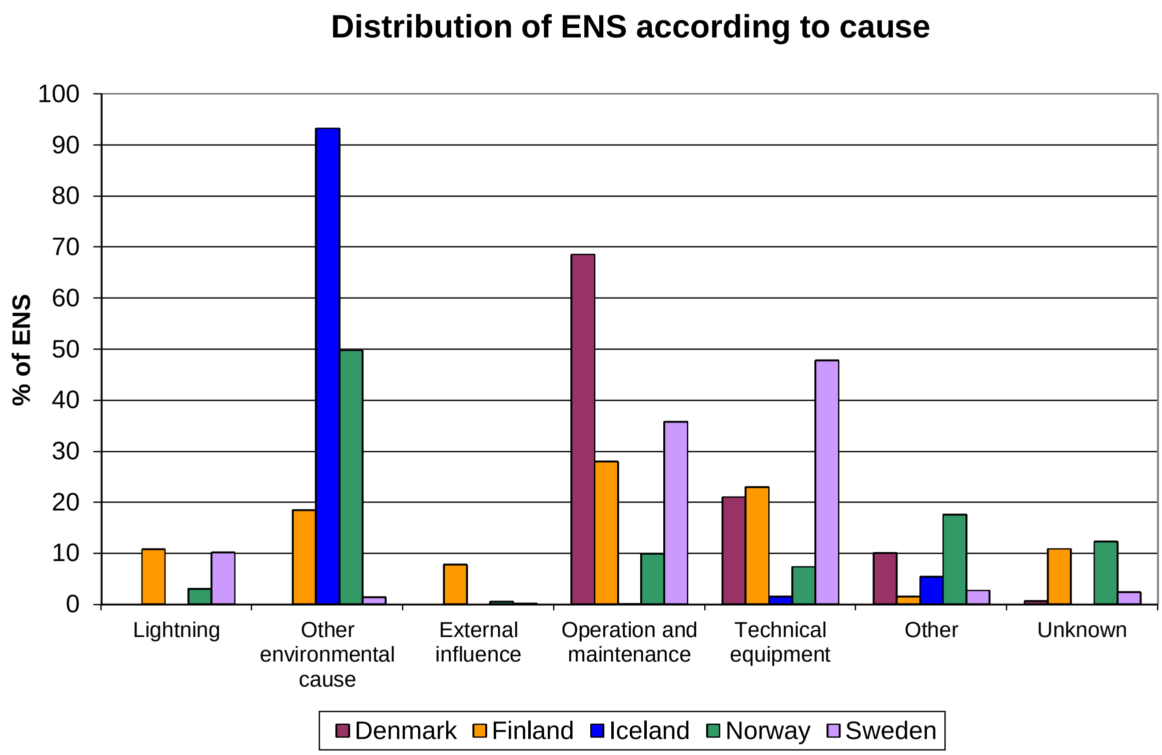

FIGURE 4.3 PERCENTAGE DISTRIBUTION OF ENERGY NOT SUPPLIED (ENS) ACCORDING TO THE CAUSE OF THE PRIMARY FAULT IN 2012.

Also see Appendix 2 for more details about investigating faults.

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4.5 ENERGY NOT SUPPLIED (ENS) DIVIDED ACCORDING TO COMPONENT

Table 4.3 shows the amount of energy not supplied in 2012 and the annual average for the period 2003–2012. Table 4.4 shows the distribution of energy not supplied according to component.

TABLE 4.3 ENERGY NOT SUPPLIED (ENS) IN 2012 AND THE ANNUAL AVERAGE FOR THE PERIOD 2003–2012

	Denmark		**Finland**		**Iceland**		**Norway**		**Sweden[1)]**		**Nordic**	
Time period	2012	2003–2012	2012	2003–2012	2012	2003–2012	2012	2003–2012	2012	2003–2012	2012	2003–2012
ENS (MWh)	18	817	158	298	3462	1072	1165	2664	1127	2929	5930	7779

1) One regional grid in Sweden did not deliver complete data. 750 MWh of ENS has not been included, because the details of fault origin was not reported.

TABLE 4.4 PERCENTAGE DISTRIBUTION OF ENERGY NOT SUPPLIED IN TERMS OF COMPONENT

Fault location	Denmark		Finland		Iceland		Norway		Sweden		Nordic	
	2012	2003–2012	2012	2003–2012	2012	2003–2012	2012	2003–2012	2012	2003–2012	2012	2003–2012
Overhead line	0.0	0.4	63.9	60.3	16.2	31.2	24.9	56.4	14.2	16.7	18.7	32.2
Cable	0.0	0.0	0.1	0.0	0.0	0.8	0.0	0.4	50.3	3.1	9.6	1.4
Sum of line faults	**0.0**	**0.4**	**64.0**	**60.3**	**16.2**	**32.0**	**24.9**	**56.8**	**64.5**	**19.7**	**28.3**	**33.6**
Power transformer	0.0	0.4	2.2	2.0	1.3	0.5	5.2	3.8	8.1	5.0	3.4	3.4
Instrument transformer	21.0	0.0	9.5	2.9	0.0	0.0	1.8	2.1	2.2	3.5	1.1	2.1
Circuit breaker	1.3	0.2	3.4	2.9	75.6	26.8	0.2	1.5	9.1	2.8	46.0	5.4
Disconnector	67.2	0.3	1.7	2.5	0.0	9.1	5.0	1.9	0.0	39.4	1.2	16.8
Surge arrester and spark gap	0.0	0.0	0.0	4.5	0.0	0.0	0.8	1.8	0.0	0.1	0.2	0.8
Busbar	0.0	0.2	7.5	2.2	0.0	4.0	0.2	2.7	10.5	1.8	2.2	2.3
Control equipment	0.5	0.2	9.0	15.8	1.3	12.0	8.8	15.2	0.8	2.9	2.9	8.6
Common ancillary equipment	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other substation faults	0.0	0.0	1.6	1.3	0.0	0.0	53.1	5.7	4.4	18.7	11.3	9.1
Sum of substation faults	**90.0**	**1.3**	**34.9**	**34.8**	**78.2**	**52.4**	**75.1**	**34.7**	**35.1**	**74.3**	**68.3**	**48.5**
Shunt capacitor	0.0	0.0	0.0	0.0	0.0	2.6	0.0	0.0	0.0	1.1	0.0	0.8
Series capacitor	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Reactor	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SVC and statcom	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Synchronous compensator	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sum of compensation faults	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**2.6**	**0.0**	**0.0**	**0.0**	**1.1**	**0.0**	**0.8**
System fault	0.0	98.3	0.0	0.0	2.4	12.1	0.0	5.2	0.3	0.6	1.5	14.0
Faults in adjoining statistical area	10.0	0.0	1.1	5.0	3.2	1.0	0.0	3.3	0.1	4.2	1.9	3.1
Unknown	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sum of other faults	**10.0**	**98.3**	**1.1**	**5.0**	**5.6**	**13.1**	**0.0**	**8.5**	**0.4**	**4.8**	**3.4**	**17.1**

One should notice that some countries register the total amount of energy not supplied in a disturbance in terms of the initiating fault. Therefore, the data is not necessarily comparable.

5 FAULTS IN POWER SYSTEM COMPONENTS

5.1 DEFINITIONS AND SCOPE

Faults in a component imply that it may not perform its function properly. Faults can have many causes, for example, manufacturing defects or insufficient maintenance by the user. This chapter presents the fault statistics for different grid components. One should take note of both the causes and consequences of the fault when analysing the fault frequencies of different devices. For example, overhead lines normally have more faults than cables. On the other hand, cables normally have considerably longer repair times than overhead lines.

Definition of a component fault:

The inability of a component to perform its required function [4].

The scope of the statistics, according to the guidelines [1] is the following:

"The statistics comprise:
- *Grid disturbances*
- *Faults causing or aggravating a grid disturbance*
- *Disconnection of end users in connection with grid disturbances*
- *Outage in parts of the electricity system in conjunction with grid disturbances*

The statistics do not comprise:
- *Faults in production units*
- *Faults detected during maintenance*
- *Planned operational interruptions in parts of the electricity system*
- *Behaviour of circuit breakers and relay protection if they do not result in or extend a grid disturbance"*

This chapter gives an overview of all faults registered in the component groups used in the ENTSO-E Nordic statistics, followed by more detailed statistics relating to each specific component group. Ten-year average values have been calculated for most components. For overhead lines, even a longer period has been used due to their long lifetime. The averages are calculated on the basis of the number of components with the number of faults for each time period, which takes into consideration the annual variation in the number of components. This chapter also presents fault trend curves for some components. The trend curves show the variation in the fault frequencies of consecutive five-year periods. These curves are divided into 220–400 kV and 132 kV voltage levels for all the components except for cables, which are not divided. Readers who need more detailed data should use the national statistics published by the national regulators.

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5.2 OVERVIEW OF THE FAULTS CONNECTED TO DISTURBANCES

Table 5.1 presents the number of faults and disturbances during 2012. For Iceland, the fault statistics cover data from *Landsnet*, the only transmission company in Iceland. The Transmission System Operators of the other four countries collect data from several grid owners, and the representation of their statistics is not fully consistent.

TABLE 5.1 NUMBER OF FAULTS AND GRID DISTURBANCES IN 2012

	Denmark	Finland	Iceland	Norway	Sweden
Number of faults in 2012	49	467	47	197	459
Number of disturbances in 2012	44	445	40	160	439
Fault/disturbance ratio in 2012	1.11	1.05	1.18	1.23	1.05
The average fault/disturbance ratio during 2003–2012	1.15	1.07	1.30	1.26	1.04

5.2.1 OVERVIEW OF FAULTS DIVIDED ACCORDING TO VOLTAGE LEVEL

Table 5.2 presents the division of faults and energy not supplied in terms of voltage level and country. In addition, the table shows the line length and the number of power transformers in order to give a view of the grid size in each country. One should note that the number of faults includes all faults, not just faults in lines and power transformers.

TABLE 5.2 FAULTS IN DIFFERENT COUNTRIES IN TERMS OF VOLTAGE LEVEL

Voltage	Country	Size of the grid		Number of faults		ENS[2] (MWh)	
		Number of power transformers	Length of lines in km[1]	2012	2003–2012 (annual average)	2012	2003–2012 (annual average)
400 kV	Denmark	25	1595	0	7.7	0.0	220.0
	Finland	57	4804	39	23.6	5.6	12.3
	Iceland	0	0	0	0.0	0.0	0.0
	Norway	64	2708	36	53.4	87.7	1144.8
	Sweden	54	10991	100	116.5	1.8	1049.4
220 kV	Denmark	2	105	1	0.3	0.0	0.0
	Finland	24	2671	23	24.2	17.9	9.8
	Iceland	32	852	9	12.4	2696.7	703.5
	Norway	271	6165	66	98.8	704.6	486.2
	Sweden	66	4101	63	70.4	17.9	285.9
132 kV	Denmark	237	4516	46	63.7	18.0	16.5
	Finland	1118	18388	390	320.5	134.9	273.2
	Iceland	56	1339	30	28.4	765.5	375.8
	Norway	724	10677	95	178.2	372.7	881.0
	Sweden	534	13123	210	347.8	1106.8	1545.5

1) Length of lines is the sum of the length of cables and overhead lines.
2) Calculation of energy not supplied (ENS) varies between countries.

Table 5.3 shows the number of faults classified according to the component groups used in the ENTSO-E Nordic statistics for each respective country. One should note that not all countries have every type of equipment in their network, for example, SVCs or statcom installations. The distribution of the number of components can also vary from country to country, so one should be careful when comparing countries. Note that statistics also include faults that begin outside the voltage range of the ENTSO-E Nordic statistics (typically from networks with voltages lower than 100 kV) but that nevertheless have an influence on the ENTSO-E Nordic statistic area.

TABLE 5.3 PERCENTAGE DIVISION OF FAULTS ACCORDING TO COMPONENT

Fault location	Denmark		Finland		Iceland		Norway		Sweden		Nordic	
	2012	2003–2012	2012	2003–2012	2012	2003–2012	2012	2003–2012	2012	2003–2012	2012	2003–2012
Overhead line	65.3	57.2	80.7	76.3	44.7	20.6	38.6	40.9	61.3	56.7	64.8	56.2
Cable	0.0	3.1	0.5	0.1	0.0	0.5	0.0	0.6	1.3	0.7	0.6	0.6
Sum of line faults	**65.3**	**60.3**	**81.2**	**76.4**	**44.7**	**21.1**	**38.6**	**41.5**	**62.6**	**57.4**	**65.4**	**56.8**
Power transformer	2.0	3.8	1.5	1.3	8.5	3.2	3.6	2.5	7.2	4.8	4.1	3.2
Instrument transformer	8.2	1.4	0.4	0.6	0.0	0.0	5.6	1.8	0.3	1.0	1.6	1.1
Circuit breaker	6.1	6.0	1.3	1.1	8.5	3.2	4.1	3.4	0.0	3.2	1.8	2.9
Disconnector	8.2	1.6	0.2	0.5	0.0	0.1	2.0	1.8	0.0	0.7	0.8	1.0
Surge arresters and spark gap	0.0	0.5	0.0	0.3	0.0	0.3	2.0	1.4	0.3	0.3	0.4	0.6
Busbar	0.0	0.4	0.6	0.4	0.0	0.1	1.5	1.3	1.8	0.9	1.1	0.8
Control equipment[1)]	8.2	15.0	7.1	11.5	10.6	53.3	14.7	25.2	12.8	9.0	10.5	16.2
Common ancillary equipment	0.0	0.4	0.0	0.2	0.0	0.0	1.0	1.1	0.0	0.9	0.2	0.7
Other substation faults	0.0	2.0	2.6	1.7	0.0	3.8	15.2	9.6	0.3	8.0	3.7	6.2
Sum of substation faults	**32.7**	**31.2**	**13.7**	**17.6**	**27.7**	**64.1**	**49.7**	**48.0**	**22.6**	**28.8**	**24.3**	**32.5**
Shunt capacitor	0.0	0.1	0.2	0.5	2.1	1.5	3.0	1.3	0.3	0.7	0.8	0.8
Series capacitor	0.0	0.0	1.7	1.0	0.0	0.3	0.0	0.0	5.9	3.2	2.7	1.5
Reactor	0.0	2.3	0.0	0.2	0.0	0.0	1.0	0.5	2.3	1.5	1.0	0.9
SVC and statcom	0.0	0.1	0.0	0.0	0.0	0.0	7.1	1.8	2.6	1.7	2.1	1.1
Synchronous compensator	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.7	0.0	0.4	0.1	0.3
Sum of compen-sation faults	**0.0**	**2.5**	**1.9**	**1.7**	**2.1**	**1.8**	**11.7**	**4.3**	**11.0**	**7.5**	**6.6**	**4.6**
System fault	0.0	1.9	0.0	0.2	8.5	11.1	0.0	0.5	1.0	3.2	0.7	2.1
Faults in adjoining statistical area	2.0	4.1	3.2	4.1	17.0	1.5	0.0	5.7	2.8	3.3	3.0	4.0
Unknown	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Sum of other faults	**2.0**	**6.0**	**3.2**	**4.3**	**25.5**	**13.0**	**0.0**	**6.2**	**3.8**	**6.5**	**3.7**	**6.1**

1) The category *control equipment* includes also protection.

5.3 FAULTS IN OVERHEAD LINES

Overhead lines constitute a large part of the Nordic transmission grid. Therefore, the tables in this section show the division of faults in 2012 as well as the average values for the period 1996–2012. The tables also give the faults divided by cause during the period 1996–2012. Along with the tables, the annual division of faults and the number of permanent faults during the period 2003–2012 is presented graphically for all voltage levels. The section also presents the trend curves for overhead line faults. With the help of the trend curve, it may be possible to determine the trend of faults also in the future.

5.3.1 400 KV OVERHEAD LINES

Table 5.4 shows the line lengths, faults of 400 kV lines, the causes of faults and the percentage values of 1-phase faults and permanent faults. The data consists of the values for the year 2012 and for the 17-year period 1996–2012. Figure 5.1 presents the annual line fault values per line length during the 10-year period 2003–2012. Figure 5.2 presents the annual line permanent faults during the same period.

TABLE 5.4 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 400 KV OVERHEAD LINES

Country	Line km	Number of faults	Number of faults per 100 km		Faults divided by cause during the period 1996–2012 (%)								
	2012	2012	2012	1996–2012	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown	1-phase faults	Permanent faults
Denmark	1228	0	0.00	0.30	21.0	58.1	8.1	4.8	4.8	1.6	1.6	48.4	4.8
Finland	4804	10	0.21	0.25	73.9	8.3	1.7	6.1	2.2	2.2	5.6	59.4	7.8
Norway	2683	12	0.45	1.04	24.3	68.3	0.2	0.2	1.8	2.1	3.0	69.3	8.0
Sweden	10983	27	0.25	0.36	50.8	17.7	2.2	3.0	3.4	1.4	21.6	82.0	6.8
Nordic	19698	49	0.25	0.42	43.8	35.0	1.7	2.6	2.8	1.7	12.3	73.1	7.3

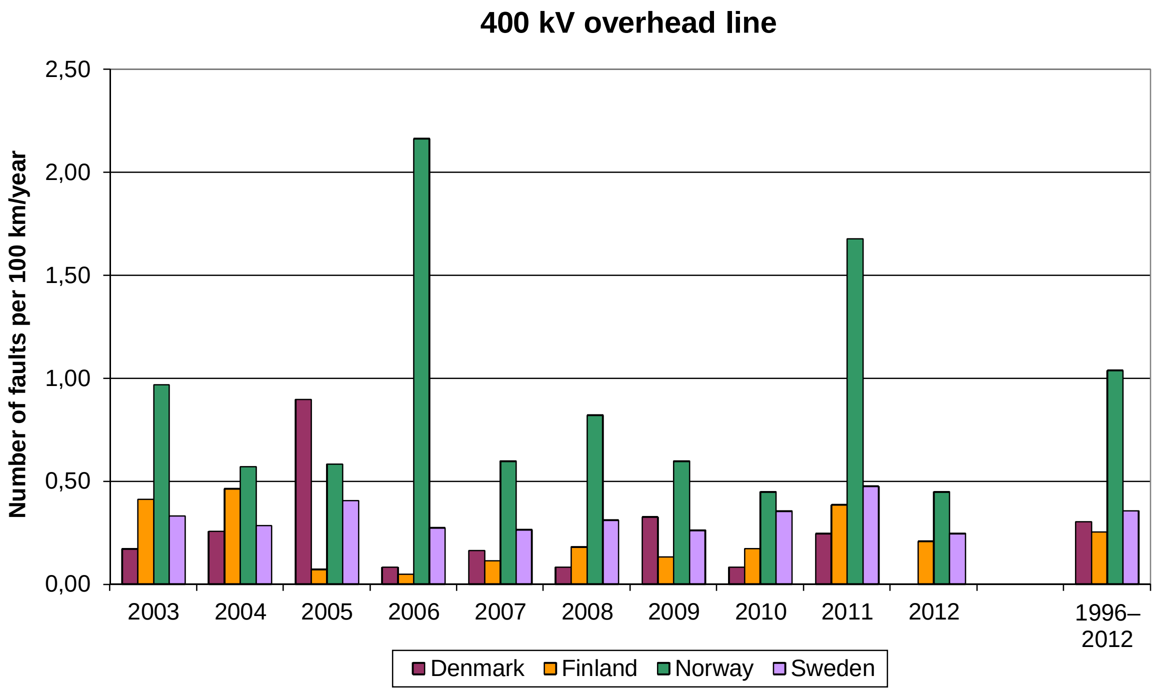

FIGURE 5.1 ANNUAL DIVISION OF FAULTS DURING THE PERIOD 2003–2012.

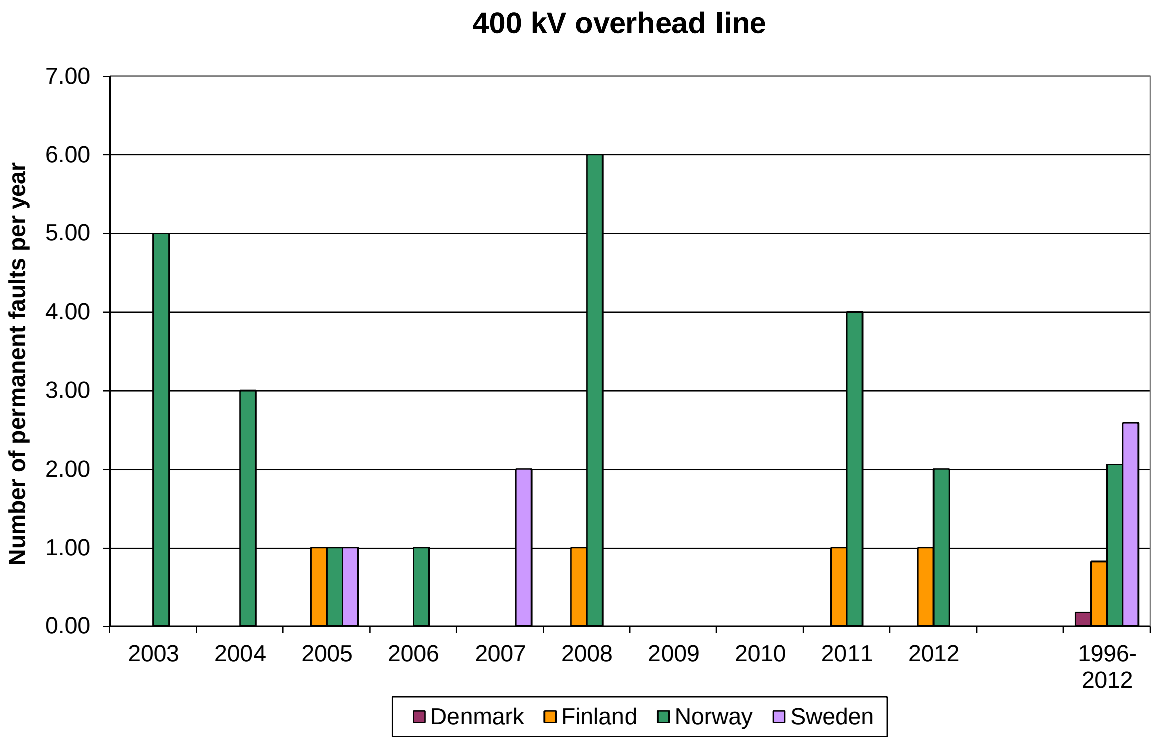

FIGURE 5.2 ANNUAL DIVISION OF PERMANENT FAULTS DURING THE PERIOD 2003-2012.

5.3.2 220 kV OVERHEAD LINES

Table 5.5 shows the line lengths, faults of 220 kV lines, the causes of faults and the percentage values of 1-phase faults and permanent faults. The data consists of the values for the year 2012 and for the 17-year period 1996–2012. Figure 5.3 presents the annual line fault values per line length during the 10-year period 2003–2012. Figure 5.4 presents the annual line permanent faults during the same period.

TABLE 5.5 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 220 KV OVERHEAD LINES

Country	Line km 2012	Number of faults 2012	Number of faults per 100 km 2012	Number of faults per 100 km 1996–2012	Faults divided by cause during the period 1996–2012 (%) Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown	1-phase faults	Permanent faults
Denmark	105	0	0.00	0.45	50.0	12.5	25.0	0.0	0.0	0.0	12.5	87.5	0.0
Finland	2671	16	0.60	0.77	45.8	7.1	1.8	1.5	0.6	0.9	42.2	72.3	3.7
Iceland	851	3	0.35	0.38	26.7	55.6	0.0	0.0	17.8	0.0	0.0	46.7	20.0
Norway	5715	28	0.49	0.69	52.2	35.6	1.0	0.6	2.1	2.7	5.8	63.7	11.6
Sweden	4044	34	0.84	0.89	67.3	4.7	3.9	4.4	3.3	1.1	15.3	56.4	6.7
Nordic	13386	81	0.61	0.75	56.1	18.7	2.4	2.2	2.7	1.6	16.3	62.2	8.4

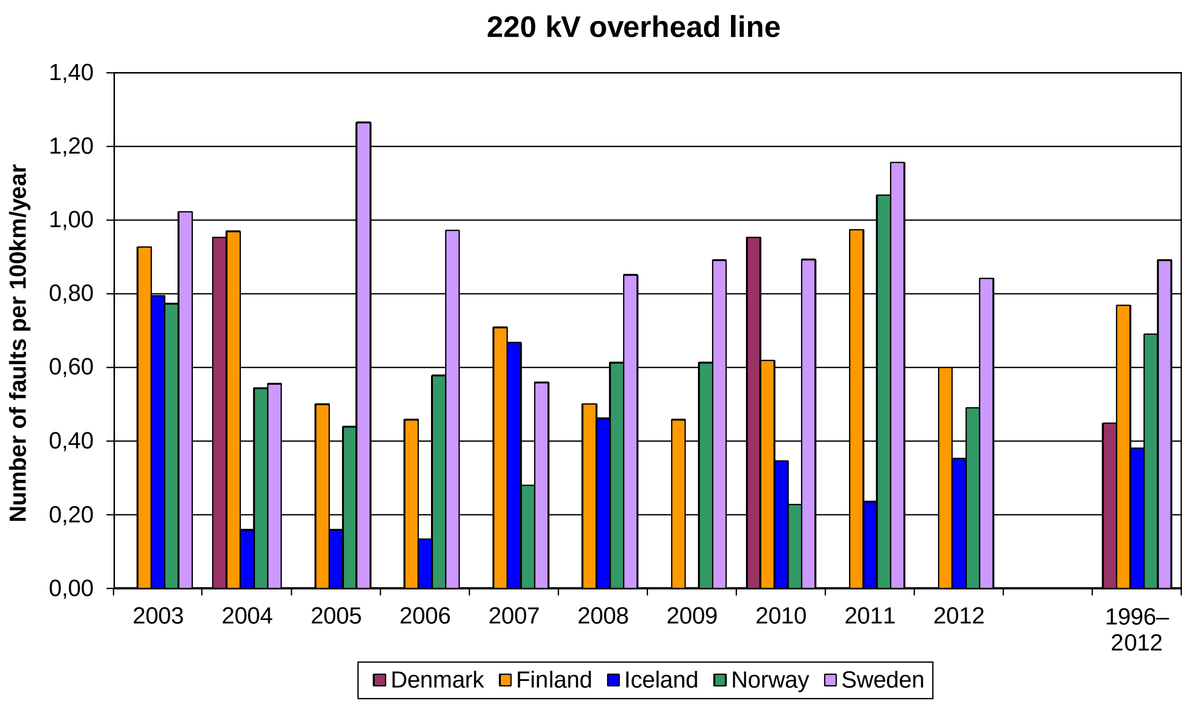

FIGURE 5.3 ANNUAL DIVISION OF FAULTS DURING THE PERIOD 2003–2012.

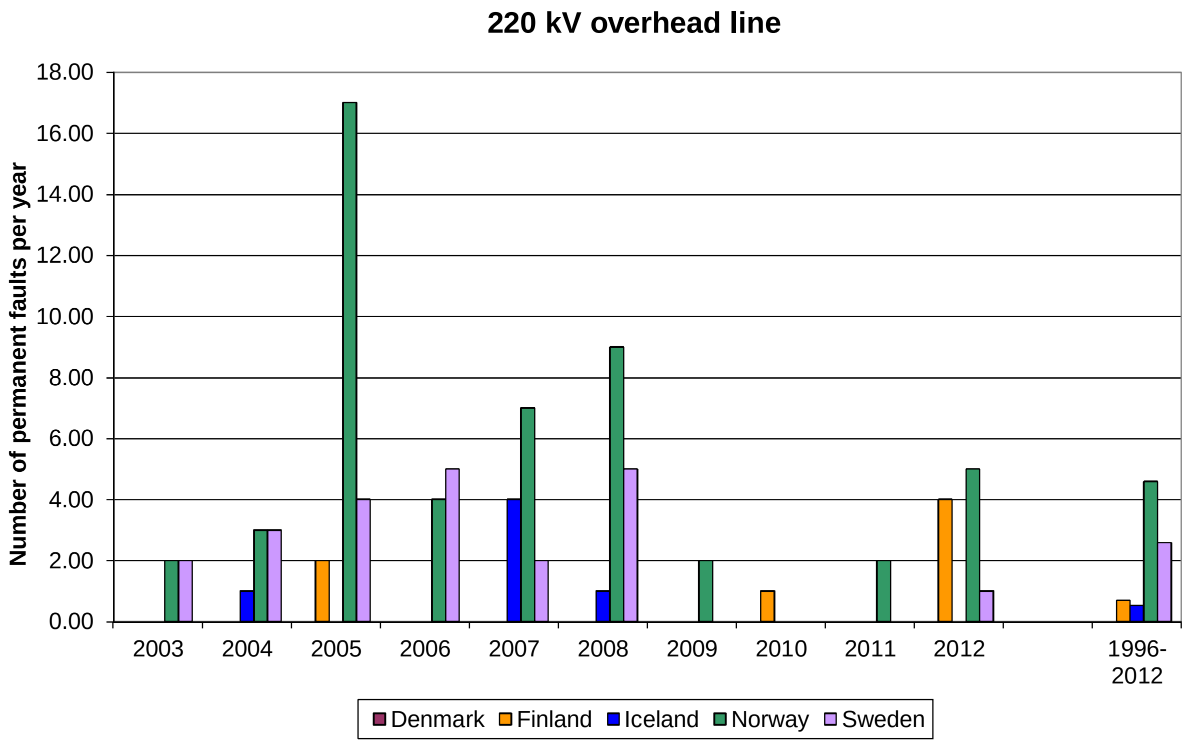

FIGURE 5.4 ANNUAL DIVISION OF PERMANENT FAULTS DURING THE PERIOD 2003-2012.

5.3.3 132 KV OVERHEAD LINES

Table 5.6 shows the line lengths, faults of 132 kV lines, the causes of faults and the percentage values of 1-phase faults and permanent faults. The data consists of the values for the year 2012 and for the 17-year period 1996–2012. Figure 5.5 presents the annual line fault values per line length during the 10-year period 2003–2012. Figure 5.6 presents the annual line permanent faults during the same period.

TABLE 5.6 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 132 KV OVERHEAD LINES

Country	Line km	Number of faults	Number of faults per 100 km		Faults divided by cause during the period 1996–2012 (%)								
	2012	2012	2012	1996–2012	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown	1-phase faults	Permanent faults
Denmark	3665	32	0.87	1.03	23.5	41.7	19.8	2.4	1.1	2.4	9.1	48.7	4.9
Finland	18170	351	1.93	2.01	38.1	13.4	1.5	1.2	0.4	0.8	44.7	78.6	3.1
Iceland	1231	18	1.46	1.26	2.7	86.4	3.0	0.8	6.8	0.0	0.4	37.9	11.0
Norway	10475	36	0.34	1.00	53.3	31.6	2.6	1.0	5.9	4.1	1.7	27.6 [1)]	18.1
Sweden	12846	175	1.36	2.17	61.5	4.9	2.3	2.8	2.7	1.7	24.1	38.1	5.1
Nordic	46387	612	1.32	1.69	48.3	16.0	3.1	1.9	2.3	1.7	26.7	51.7	6.5

[1)] The Norwegian grid includes a resonant earthed system, which has an effect on the low number of single-phase earth faults in Norway.

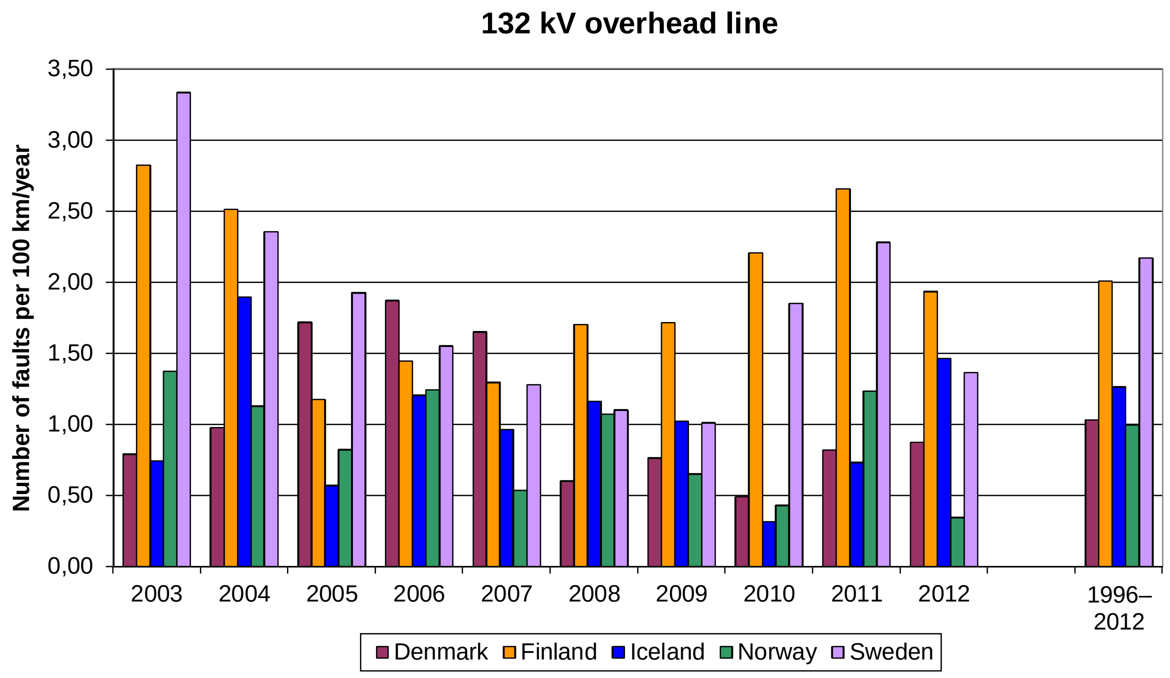

FIGURE 5.5 ANNUAL DIVISION OF FAULTS DURING THE PERIOD 2003–2012.

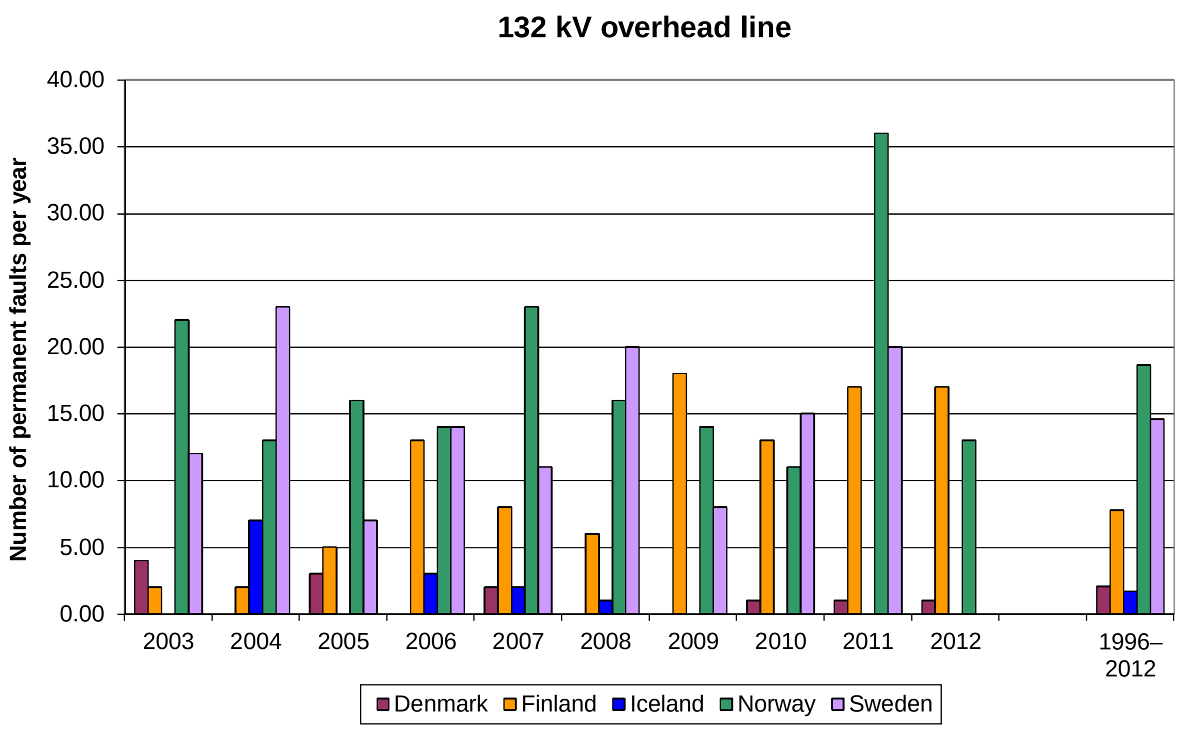

FIGURE 5.6 ANNUAL DIVISION OF PERMANENT FAULTS DURING THE PERIOD 2003-2012.

5.3.4 LINE FAULT TRENDS

Figure 5.7 and Figure 5.8 present faults divided by line length for 220–400 kV lines and 132 kV lines, respectively. The trend curve is proportioned to line length in order to get comparable results between countries.

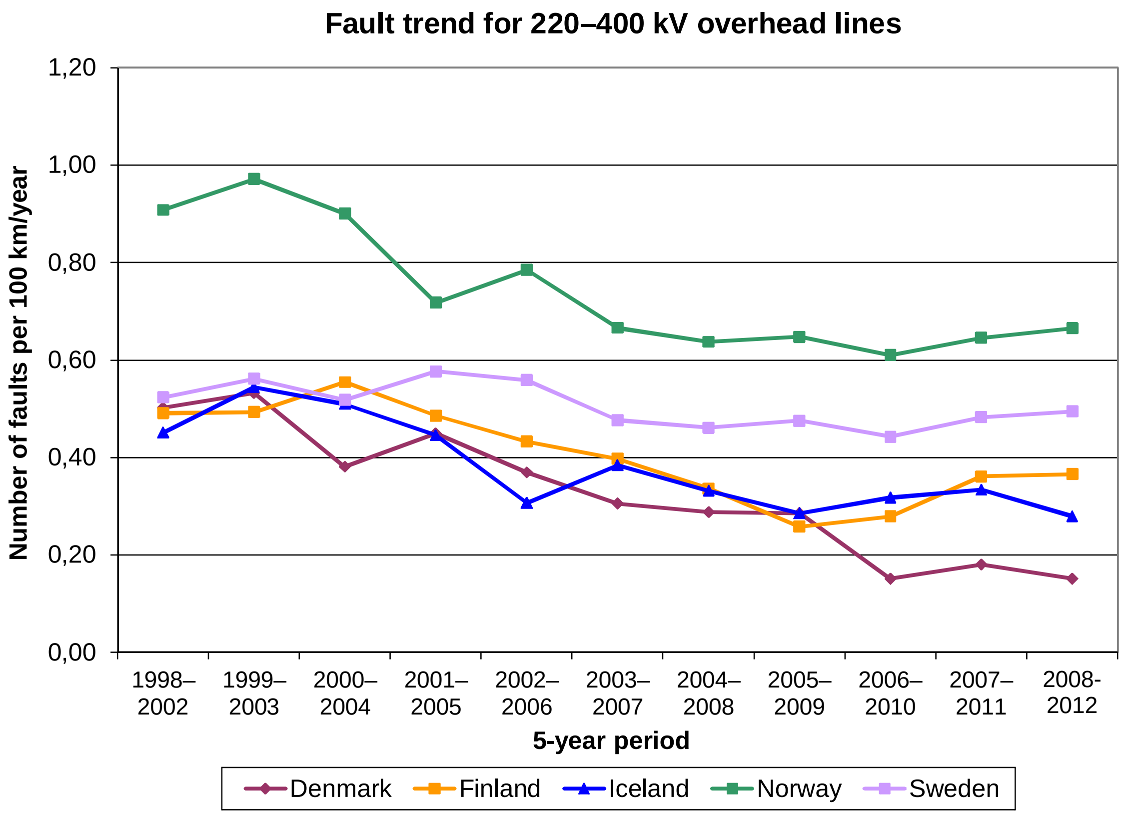

FIGURE 5.7 FAULT TREND FOR OVERHEAD LINES AT VOLTAGE LEVEL 220–400 KV.

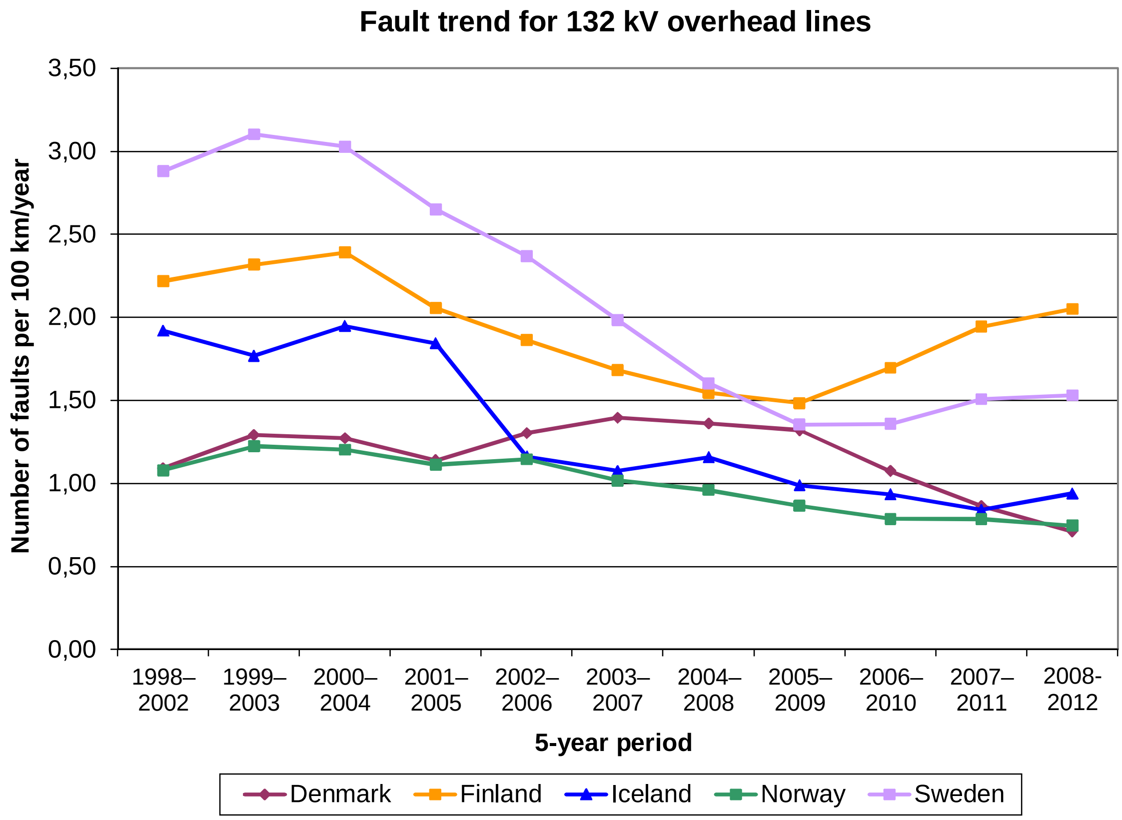

FIGURE 5.8 FAULT TREND FOR OVERHEAD LINES AT VOLTAGE LEVEL 132 KV.

5.4 FAULTS IN CABLES

The tables, in this section, present faults in cables at each respective voltage level, with fault division for the year 2012 and for the period 2003–2012. In addition, the division of faults according to cause is given for the whole ten-year period. The annual division of faults during the period 2003–2012 is presented graphically for 132 kV cables only. Also fault trends are presented.

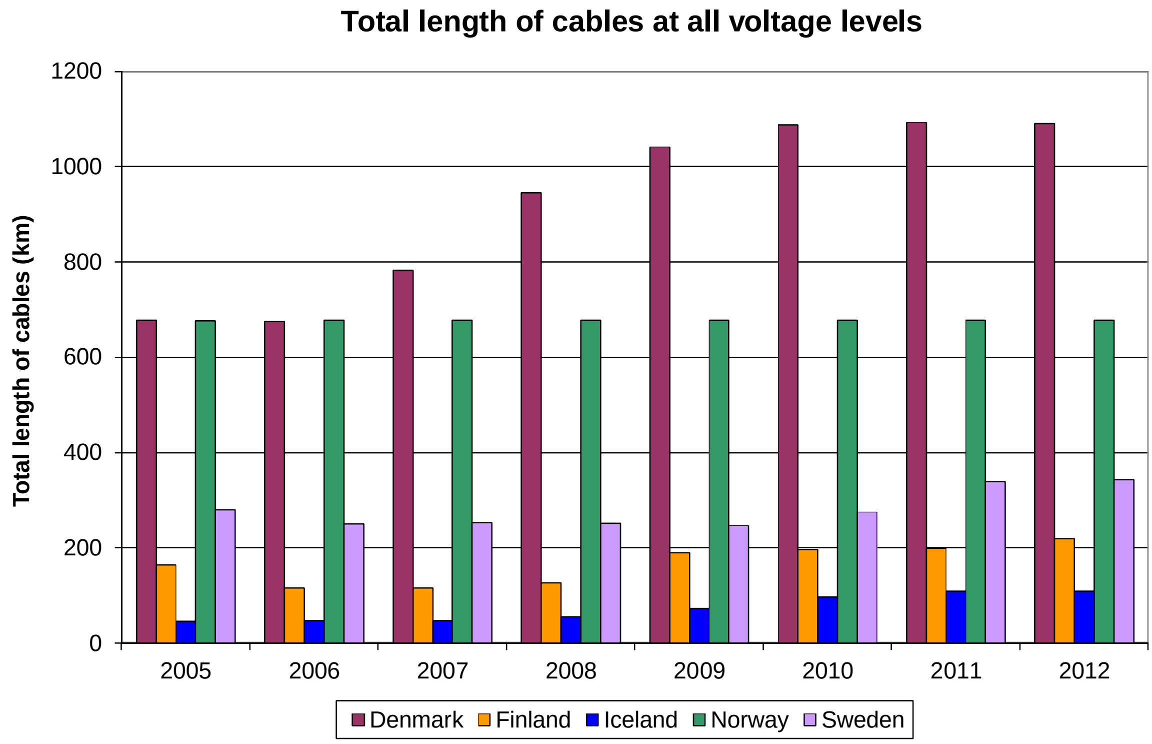

FIGURE 5.9 TOTAL LENGTH OF CABLES AT ALL VOLTAGE LEVELS DURING THE PERIOD 2005-2012.

TABLE 5.7 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 400 KV CABLES

Country	Line km 2012	Number of faults 2012	Number of faults per 100 km 2012	Number of faults per 100 km 2003–2012	Faults divided by cause during the period 2003–2012 (%) Lightning	Other environmental cause	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	239	0	0.00	0.04	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Norway	25	0	0.00	1.62	0.0	0.0	0.0	0.0	50.0	25.0	25.0
Sweden	8	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nordic	272	0	0.00	0.18	0.0	0.0	0.0	20.0	40.0	20.0	20.0

TABLE 5.8 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 220 KV CABLES

Country	Line km 2012	Number of faults 2012	Number of faults per 100 km 2012	Number of faults per 100 km 2003–2012	Faults divided by cause during the period 2003–2012 (%) Lightning	Other environmental cause	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Iceland	1	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Norway	450	0	0.00	0.02	0.0	0.0	0.0	0.0	0.0	0.0	100.0
Sweden	57	1	1.75	2.85	0.0	0.0	0.0	10.0	80.0	0.0	10.0
Nordic	508	1	0.20	0.23	0.0	0.0	0.0	9.1	72.7	0.0	18.2

TABLE 5.9 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 132 KV CABLES

Country	Line km 2012	Number of faults 2012	Number of faults per 100 km 2012	Number of faults per 100 km 2003–2012	Faults divided by cause during the period 2003–2012 (%): Lightning	Other environmental cause	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	851	0	0.00	0.35	0.0	0.0	22.7	9.1	54.5	9.1	4.5
Finland	219	2	0.91	0.30	0.0	0.0	0.0	0.0	50.0	0.0	50.0
Iceland	108	0	0.00	0.64	0.0	0.0	0.0	25.0	75.0	0.0	0.0
Norway[1)]	202	0	0.00	0.75	6.7	0.0	6.7	33.3	26.7	6.7	20.0
Sweden	277	4	1.44	0.90	0.0	0.0	16.7	8.3	50.0	0.0	25.0
Nordic	1656	6	0.36	0.53	1.4	0.0	14.5	14.5	47.8	4.3	17.4

[1)] Cables in Norway include resonant earthed cables.

Figure 5.10 presents the annual cable fault values per cable length faults during the 10-year period 2003-2012 for 132 kV cables.

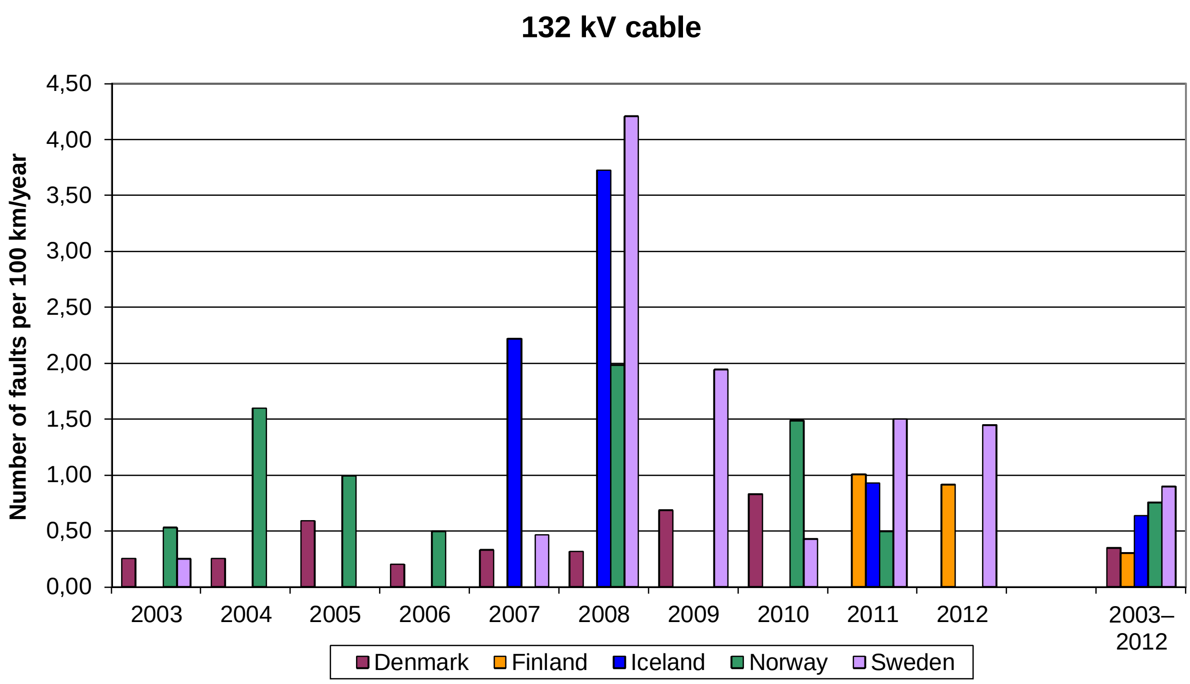

FIGURE 5.10 ANNUAL DIVISION OF FAULTS DURING THE PERIOD 2003–2012.

Figure 5.11 presents the cable fault trends only for Denmark, Norway and Sweden. Due to the low number of cables in Finland and Iceland there is not enough data for a trend curve.

With due caution, the trend curve can be used to estimate the likely fault frequencies in the future.

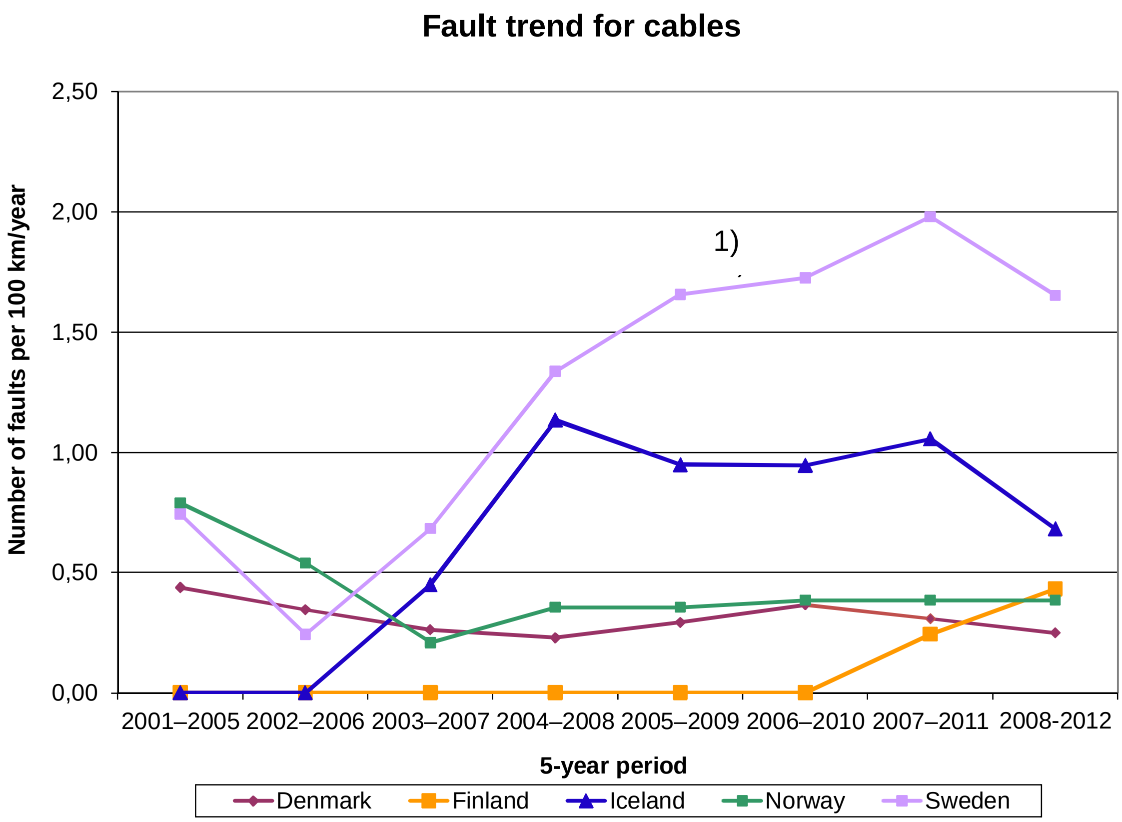

FIGURE 5.11 FAULT TREND FOR CABLES AT ALL VOLTAGE LEVEL.

[1)] The explanation for the increasing fault trend for Sweden is that there were several cable faults in 2008, as seen in Figure 5.10.

5.5 FAULTS IN POWER TRANSFORMERS

The tables in this section present the division of faults for the year 2012 and for the period 2003–2012 in power transformers at each respective voltage level. In addition, the tables present the division of faults according to cause during the ten-year period 2003–2012. The annual division of faults during the period 2003–2012 is presented graphically for all voltage levels. For power transformers, the statistics state the rated voltage of the winding with the highest voltage, as stated in Section 6.2 in the guidelines [1]. Each transformer is counted only once. The trends for transformer faults are presented too.

TABLE 5.10 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 400 KV POWER TRANSFORMERS

Country	Number of devices 2012	Number of faults 2012	Number of faults per 100 devices		Faults divided by cause during the period 2003–2012 (%)						
			2012	2003–2012	Lightning	Other environmental cause	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	25	0	0.00	2.54 1)	0.0	0.0	0.0	16.7	33.3	0.0	50.0
Finland	57	2	3.51	2.49	0.0	25.0	0.0	16.7	50.0	0.0	8.3
Norway	64	0	0.00	2.22	0.0	0.0	0.0	21.4	42.9	21.4	14.3
Sweden	54	4	7.41	0.96	0.0	0.0	0.0	45.5	9.1	45.4	0.0
Nordic	200	6	3.00	2.07	0.0	7.0	0.0	25.6	34.9	18.6	14.0

1) The high number of faults in Denmark was caused by a transformer that inflicted three out of the seven faults registered during the period 2003–2005.

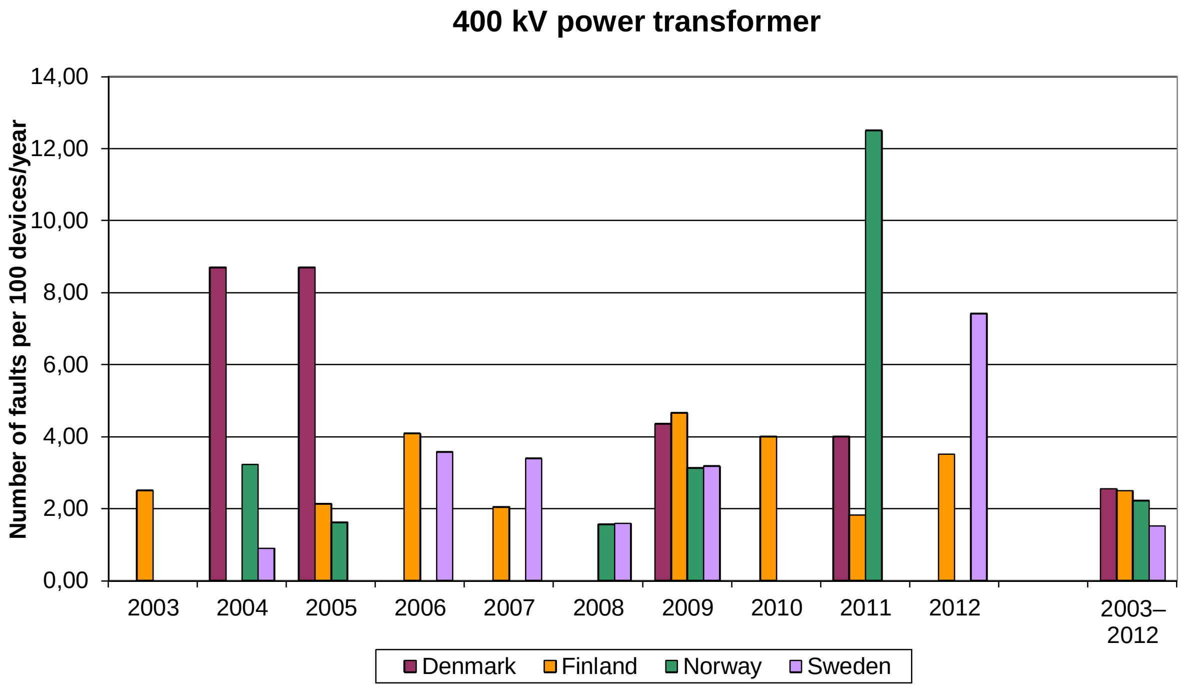

FIGURE 5.12 ANNUAL DIVISION OF FAULTS DURING THE PERIOD 2003–2012.

TABLE 5.11 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 220 KV POWER TRANSFORMERS

Country	Number of devices 2012	Number of faults 2012	Number of faults per 100 devices		Faults divided by cause during the period 2003–2012 (%)						
			2012	2003–2012	Lightning	Other environmental cause	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	2	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Finland	24	1	4.17	1.28	0.0	0.0	0.0	33.3	33.3	0.0	33.3
Iceland	32	2	6.25	3.73	0.0	9.1	0.0	0.0	81.8	0.0	9.1
Norway	271	3	1.11	1.21	0.0	3.0	0.0	18.2	48.5	24.2	6.1
Sweden	66	2	3.03	3.45	33.3	2.8	8.3	13.9	16.7	2.8	22.2
Nordic	395	8	2.03	1.92	14.5	3.6	3.6	14.5	38.6	10.8	14.5

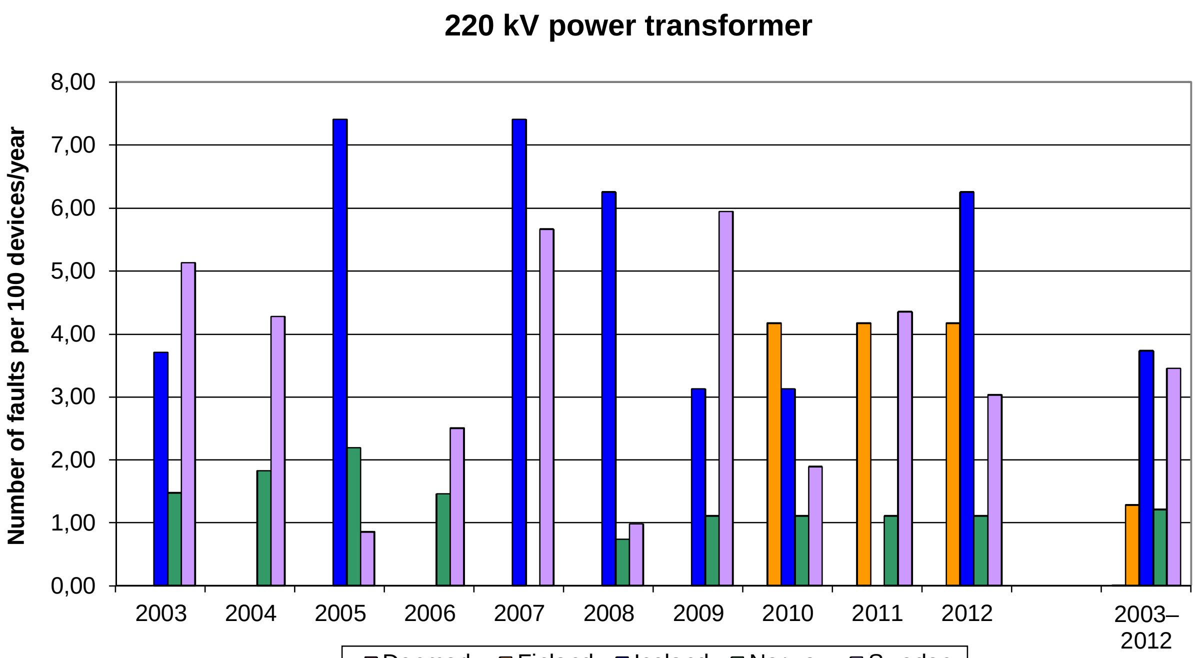

FIGURE 5.13 ANNUAL DIVISION OF FAULTS DURING THE PERIOD 2003–2012.

TABLE 5.12 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 132 KV POWER TRANSFORMERS

Country	Number of devices 2012	Number of faults 2012	Number of faults per 100 devices		Faults divided by cause during the period 2003–2012 (%)						
			2012	2003–2012	Lightning	Other environmental cause	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	237	1	0.42	0.95	9.1	9.1	4.5	31.8	22.7	4.5	18.2
Finland	1118	4	0.36	0.55	8.3	2.8	16.7	19.4	25.0	0.0	27.8
Iceland	56	2	3.57	1.22	0.0	33.3	0.0	33.3	33.3	0.0	0.0
Norway	724	4	0.55	0.57	0.0	31.7	4.9	14.6	26.8	17.1	4.9
Sweden[1)]	534	21	3.93	3.36	14.6	3.2	1.8	20.1	28.3	5.5	26.5
Nordic	2669	32	1.20	1.40	11.4	7.7	4.0	20.4	27.5	6.2	22.8

[1)] The high number of faults shown for Sweden during the period 2003–2004 was caused by the misinterpretation of Nordel's guidelines [1]. The old data is not corrected for Table 5.12, Figure 5.10 or Figure 5.12.

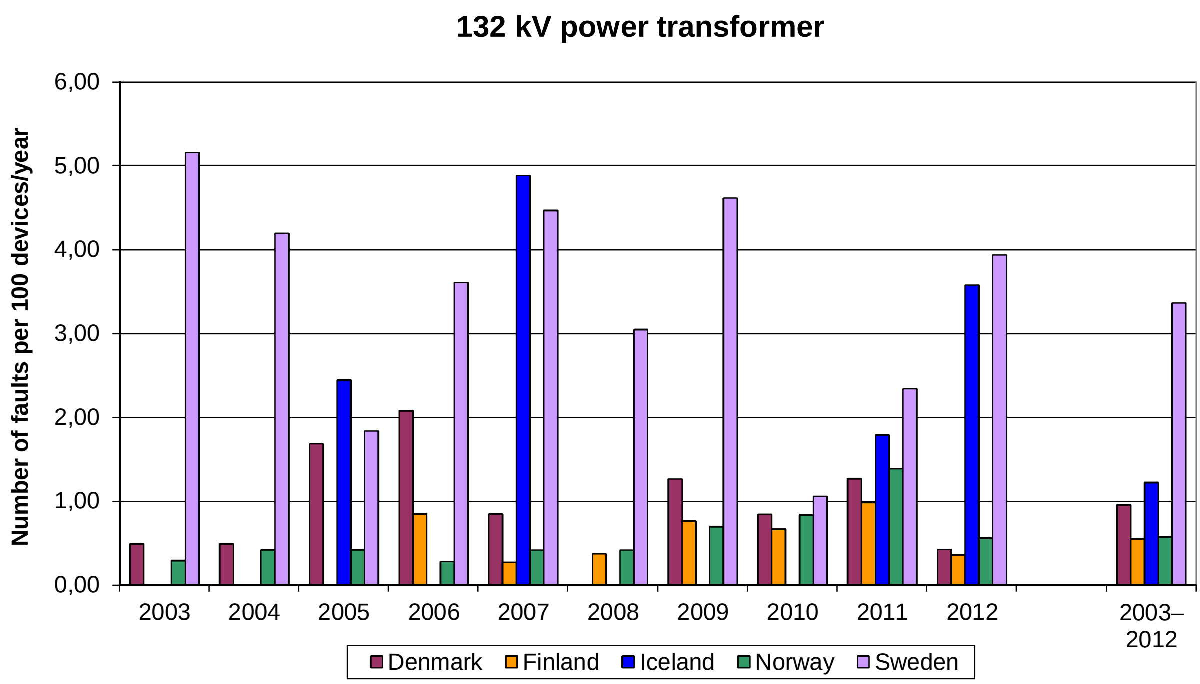

FIGURE 5.14 ANNUAL DIVISION OF FAULTS DURING THE PERIOD 2003–2012.

Figure 5.15 and Figure 5.16 present the trend of faults for power transformers. This allows the trend to be estimated in the future.

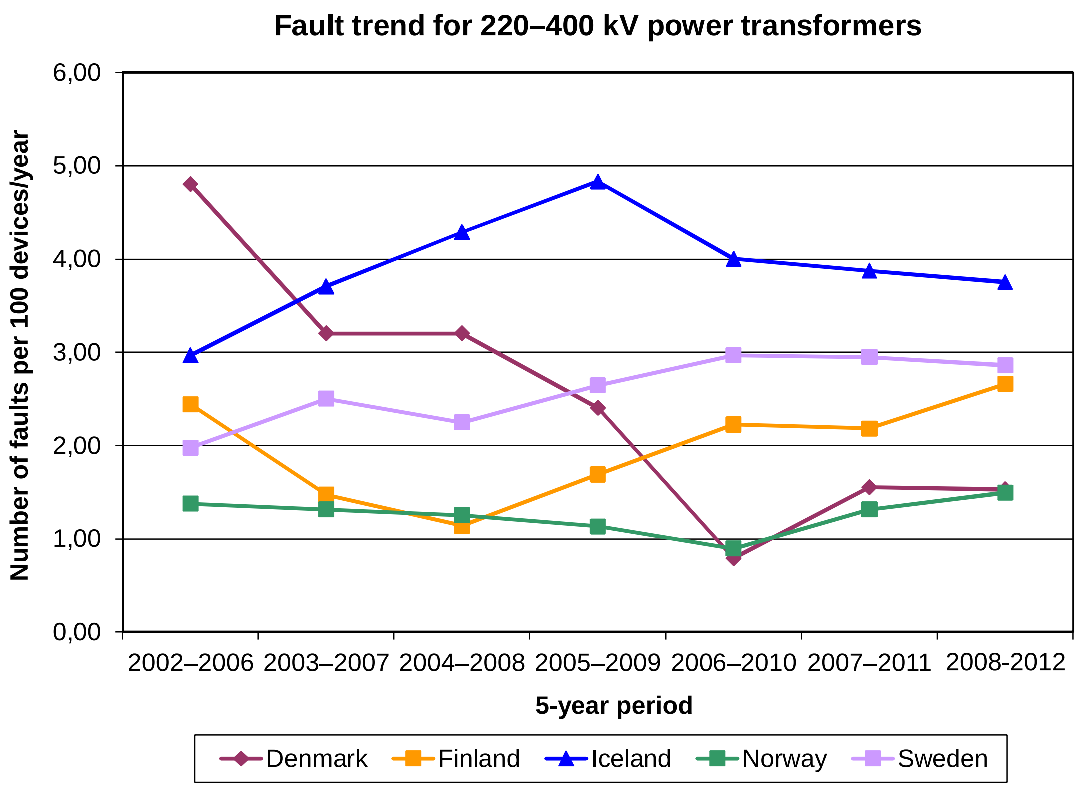

FIGURE 5.15 FAULT TREND FOR POWER TRANSFORMERS AT VOLTAGE LEVEL 220–400 KV.

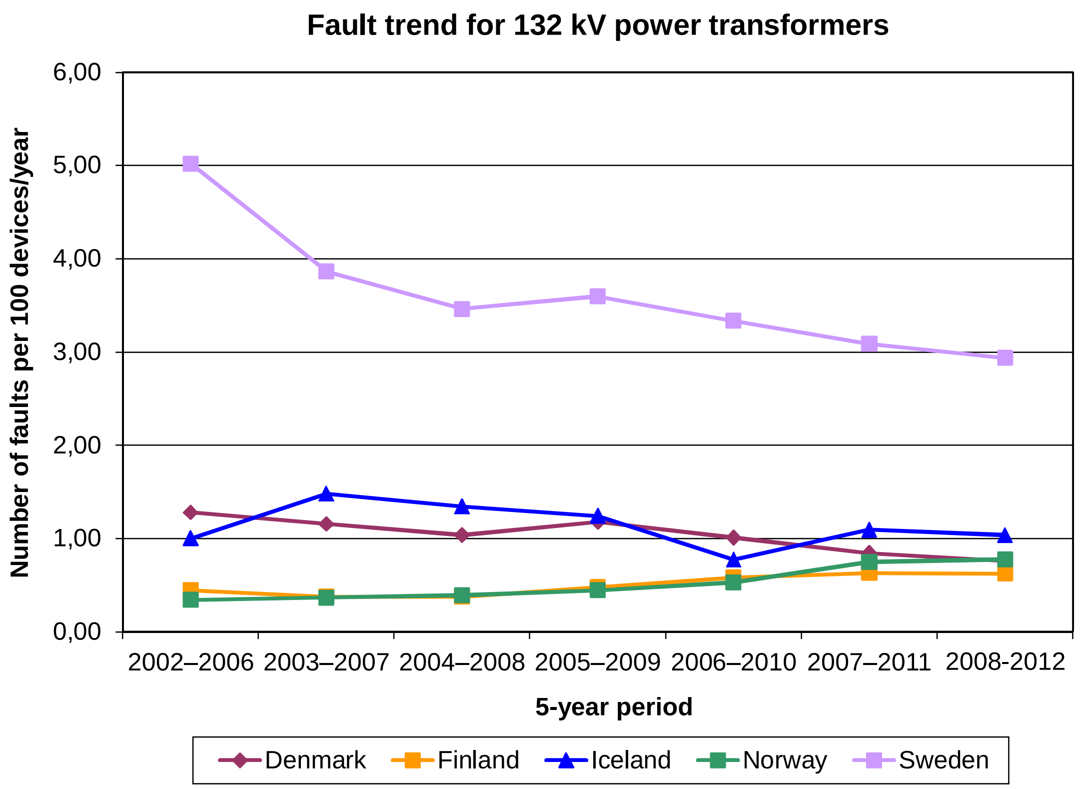

FIGURE 5.16 FAULT TREND FOR POWER TRANSFORMERS AT VOLTAGE LEVEL 132 KV.

5.6 FAULTS IN INSTRUMENT TRANSFORMERS

This section presents the faults in instrument transformers for the year 2012 and for the period 2003–2012 at each respective voltage level. In addition, the tables present the division of faults according to cause during the ten-year period. Both current and voltage transformers are included among instrument transformers. A three-phase instrument transformer is treated as one unit. If a single-phase transformer is installed, it is also treated as a single unit.

TABLE 5.13 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 400 KV INSTRUMENT TRANSFORMERS

Country	Number of devices 2012	Number of faults 2012	Number of faults per 100 devices		Faults divided by cause during the period 2003–2012 (%)						
			2012	2003–2012	Lightning	Other environmental cause	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	537	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Finland	460	1	0.22	0.03	0.0	0.0	0.0	0.0	100.0	0.0	0.0
Norway	930	2	0.22	0.08	0.0	0.0	0.0	28.6	71.4	0.0	0.0
Sweden	1093	0	0.00	0.10	0.0	0.0	0.0	33.3	55.6	0.0	11.1
Nordic	3020	3	0.10	0.06	0.0	0.0	0.0	29.4	64.7	0.0	5.9

TABLE 5.14 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 220 KV INSTRUMENT TRANSFORMERS

Country	Number of devices 2012	Number of faults 2012	Number of faults per 100 devices		Faults divided by cause during the period 2003–2012 (%)						
			2012	2003–2012	Lightning	Other environmental cause	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	12	1	8.33	0.83	0.0	0.0	0.0	0.0	0.0	0.0	100.0
Finland	154	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Iceland	444	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Norway	2805	1	0.04	0.07	10.0	10.0	0.0	5.0	55.0	10.0	10.0
Sweden	667	1	0.15	0.08	12.5	0.0	0.0	0.0	87.5	0.0	0.0
Nordic	4082	3	0.07	0.07	10.3	6.9	0.0	3.4	62.1	6.9	10.3

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TABLE 5.15 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 132 KV INSTRUMENT TRANSFORMERS

Country	Number of devices 2012	Number of faults 2012	Number of faults per 100 devices 2012	2003–2012	Faults divided by cause during the period 2003–2012 (%) Lightning	Other environmental cause	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	4553	3	0.07	0.02	0.0	0.0	0.0	11.1	66.7	0.0	22.2
Finland	3398	1	0.03	0.10	10.5	0.0	5.3	0.0	57.9	5.3	21.1
Iceland	611	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Norway	7768	8	0.10	0.05	15.4	0.0	0.0	10.3	43.6	20.5	10.3
Sweden	3969	1	0.03	0.07	10.5	0.0	2.6	10.5	65.8	2.6	7.9
Nordic	20299	13	0.06	0.03	11.4	0.0	1.9	8.6	56.2	9.5	12.4

Figure 5.17 and Figure 5.18 present the fault trends for instrument transformers at voltage levels 220–400 kV and 132 kV, respectively.

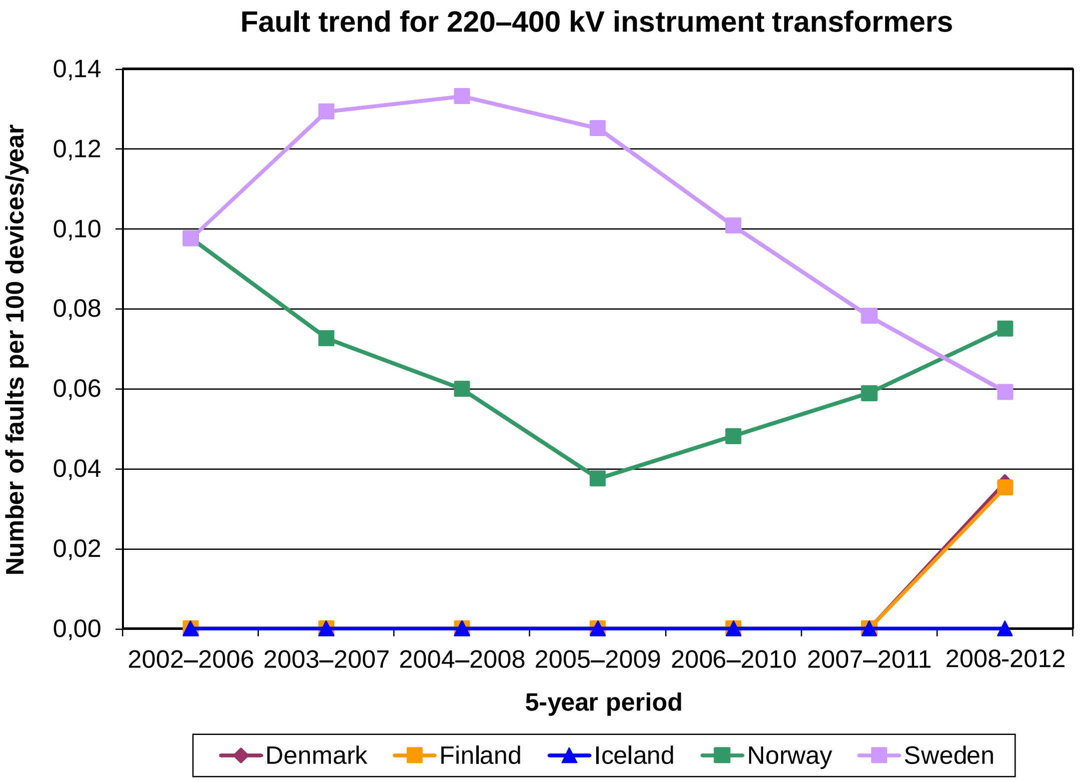

FIGURE 5.17 FAULT TREND FOR INSTRUMENT TRANSFORMERS AT VOLTAGE LEVEL 220–400 KV.

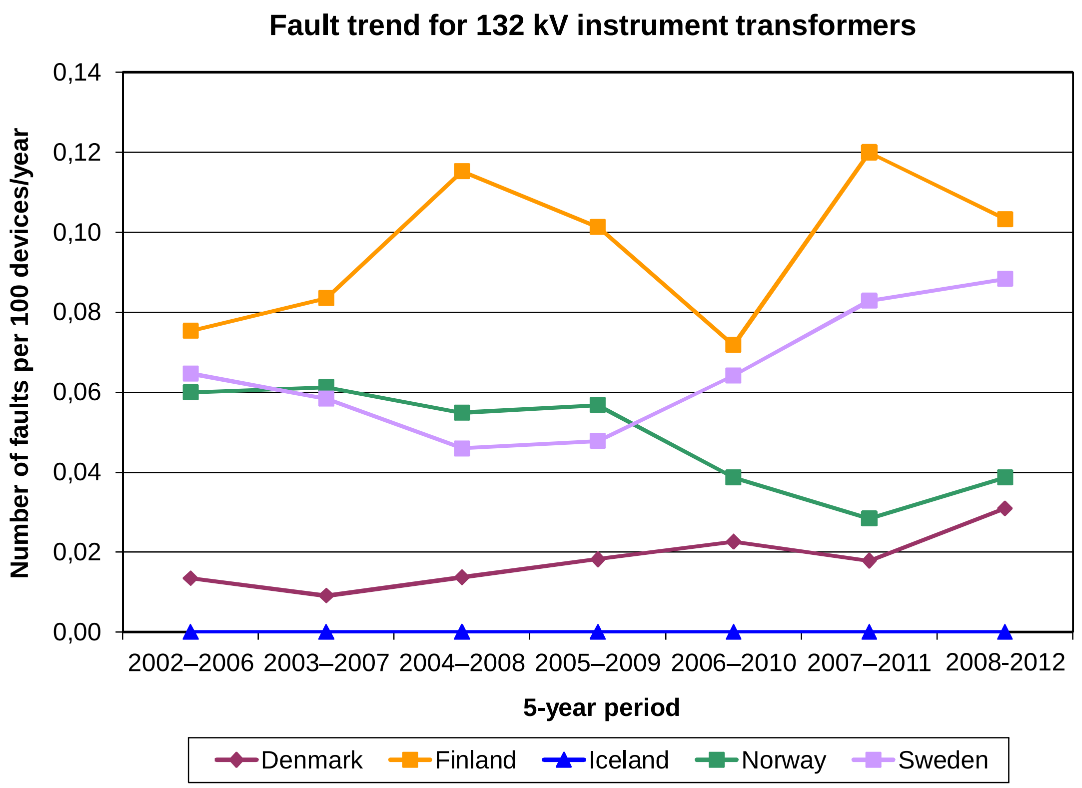

FIGURE 5.18 FAULT TREND FOR INSTRUMENT TRANSFORMERS AT VOLTAGE LEVEL 132 KV.

5.7 FAULTS IN CIRCUIT BREAKERS

The tables in this section present circuit breaker faults for the year 2012 and for the 10-year period 2003–2012 at each respective voltage level. The tables also present the division of faults according to cause during the ten-year period.

One should note that a significant part of the faults are caused by 400 kV shunt reactor circuit breakers, which usually operate very often compared with other circuit breakers. Disturbances caused by erroneous circuit breaker operations are registered as faults in circuit breakers, with operation and maintenance as their cause.

TABLE 5.16 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 400 KV CIRCUIT BREAKERS

Country	Number of devices 2012	Number of faults 2012	Number of faults per 100 devices		Faults divided by cause during the period 2003–2012 (%)						
			2012	2003–2012	Lightning	Other environmental cause	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	171	0	0.00	0.67	0.0	0.0	10.0	20.0	60.0	10.0	0.0
Finland	266	3	1.13	0.37	0.0	0.0	12.5	0.0	87.5	0.0	0.0
Norway	262	3	1.15	0.74	0.0	0.0	0.0	42.1	47.4	5.3	5.3
Sweden[1)]	534	7	1.31	1.60	0.0	2.8	0.0	4.2	84.7	1.4	6.9
Nordic	1233	13	1.05	1.01	0.0	1.8	1.8	11.9	76.1	2.8	5.5

[1)] For Sweden, the breaker failures at the 400 kV level most often occurred in breakers used to switch the reactors. This is the reason for the high number of circuit breaker faults in Sweden, because a reactor breaker is operated significantly more often than a line breaker.

TABLE 5.17 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 220 KV CIRCUIT BREAKERS

Country	Number of devices 2012	Number of faults 2012	Number of faults per 100 devices		Faults divided by cause during the period 2003–2012 (%)						
			2012	2003–2012	Lightning	Other environmental cause	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	2	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Finland	96	0	0.00	0.53	0.0	0.0	0.0	0.0	100.0	0.0	0.0
Iceland	79	1	1.27	1.94	0.0	14.3	0.0	7.1	78.6	0.0	0.0
Norway	724	2	0.28	0.60	0.0	0.0	0.0	32.6	58.1	0.0	9.3
Sweden	263	1	0.38	0.45	5.9	0.0	0.0	17.6	58.8	0.0	17.6
Nordic	1164	4	0.34	0.63	1.3	2.5	0.0	22.8	64.6	0.0	8.9

TABLE 5.18 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 132 KV CIRCUIT BREAKERS

Country	Number of devices 2012	Number of faults 2012	Number of faults per 100 devices 2012	Number of faults per 100 devices 2003–2012	Faults divided by cause during the period 2003–2012 (%) Lightning	Other environmental cause	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	820	3	0.37	0.46	0.0	2.7	0.0	24.3	64.9	8.1	0.0
Finland	2268	3	0.13	0.17	20.0	6.7	3.3	30.0	33.3	3.3	3.3
Iceland	146	3	2.05[1)]	0.76	0.0	10.0	0.0	10.0	80.0	0.0	0.0
Norway	2119	3	0.14	0.30	4.8	0.0	0.0	54.8	33.9	3.2	3.2
Sweden	1450	3	0.21	0.60	29.4	3.9	2.9	21.6	30.4	2.9	8.8
Nordic	6803	15	0.22	0.37	16.2	3.3	1.7	31.1	39.0	3.7	5.0

1) In Iceland, a very few incidents will cause a large increase in these numbers due to few devices in their system.

Figure 5.19 and Figure 5.20 present the fault trends for circuit breakers at voltage levels 220–400 kV and 132 kV, respectively.

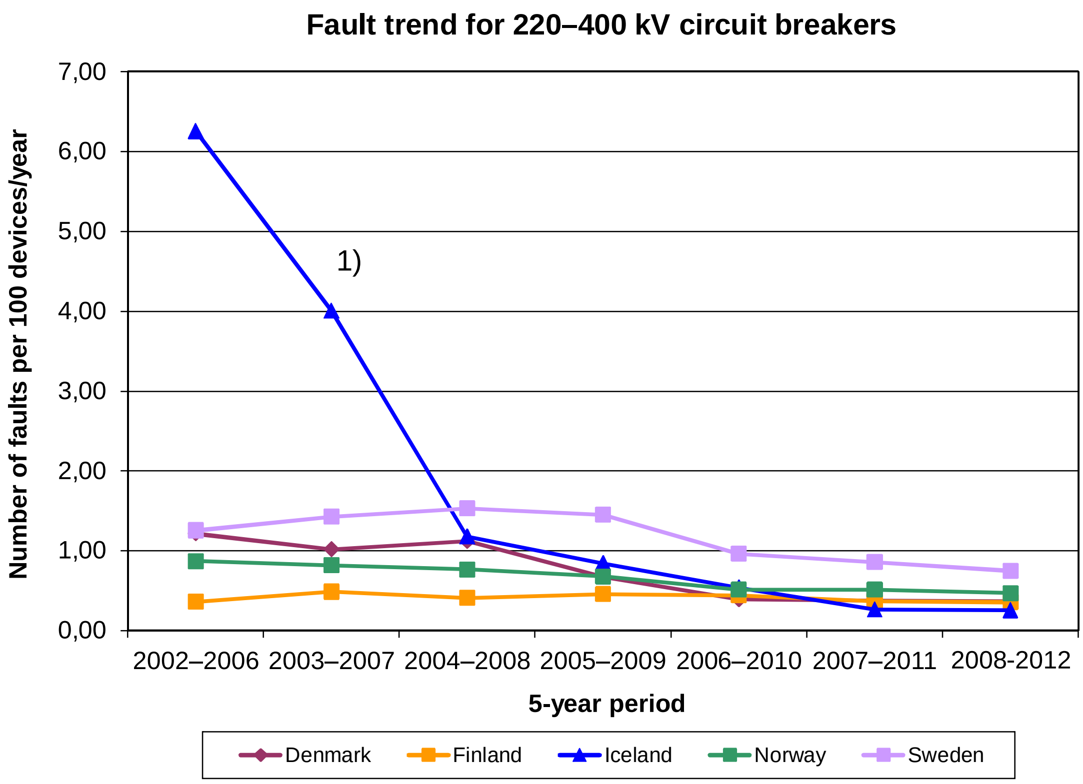

FIGURE 5.19 FAULT TREND FOR CIRCUIT BREAKERS AT VOLTAGE LEVEL 220–400 KV.

1) The explanation for the remarkable improvement on the fault trend of Iceland is that most of the disturbances on circuit breakers up to 2003 in the 220 kV network were in one substation. These breakers caused problems due to gas leaks and were repaired in 2003. In addition, two new substations were installed with total of 18 circuit breakers (from 56 breakers to 74 breakers total).

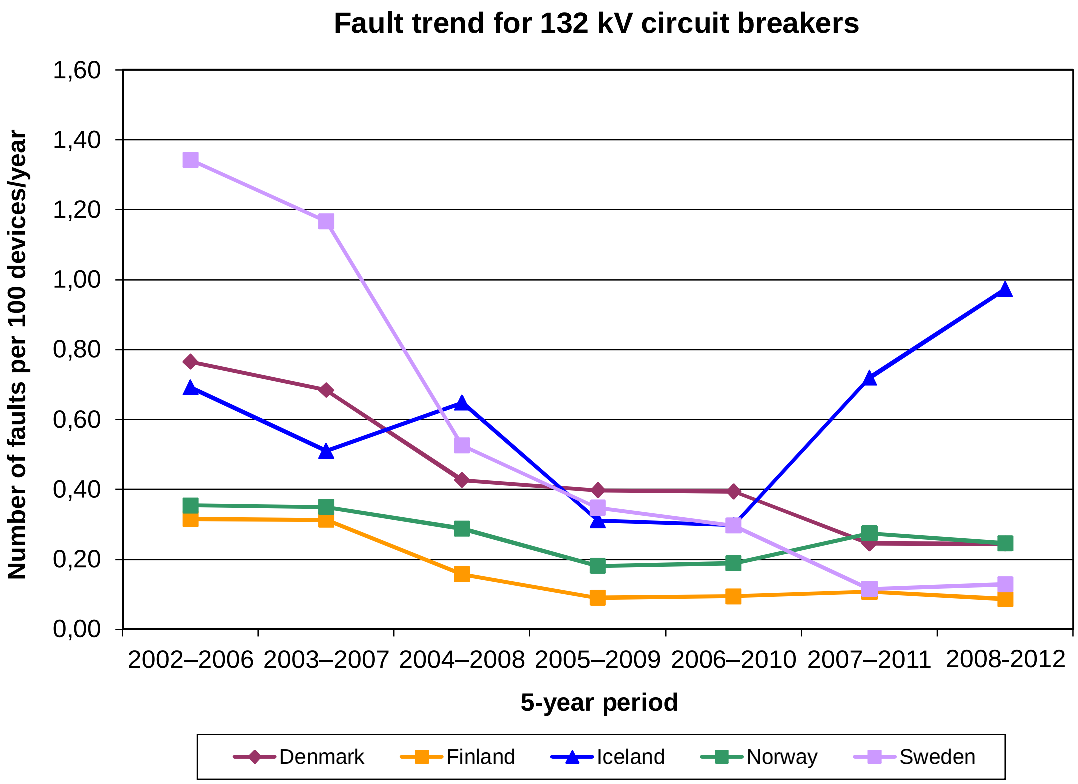

FIGURE 5.20 FAULT TREND FOR CIRCUIT BREAKERS AT VOLTAGE LEVEL 132 KV.

5.8 FAULTS IN CONTROL EQUIPMENT

The tables in this section present faults in control equipment at each respective voltage level for the year 2012 and for the period 2003–2012. In addition, the tables present the division of faults according to cause during the ten-year period.

When parts of the control system are integrated into the component, it may be uncertain whether a fault really is registered in the control equipment or in the actual component. Faults in control equipment that is integrated in another installation will normally be counted as faults in that installation. However, this definition has not been applied in all the countries. The Nordic guidelines [1] give more detailed definitions.

TABLE 5.19 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 400 KV CONTROL EQUIPMENT

Country	Number of devices 2012	Number of faults 2012	Number of faults per 100 devices		Faults divided by cause during the period 2003–2012 (%)						
			2012	2003–2012	Lightning	Other environmental cause	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	131	0	0.00	0.84	0.0	0.0	0.0	27.3	54.5	0.0	18.2
Finland	266	11	4.14	3.71	0.0	0.0	0.0	63.0	19.8	1.2	16.0
Norway	261	3	1.15	5.43	0.0	1.4	0.0	35.3	46.0	3.6	13.7
Sweden	535	33	6.17	6.24	0.4	2.2	0.0	10.2	81.8	3.6	1.8
Nordic	1193	47	3.94	4.84	0.2	1.6	0.0	25.9	61.4	3.2	7.7

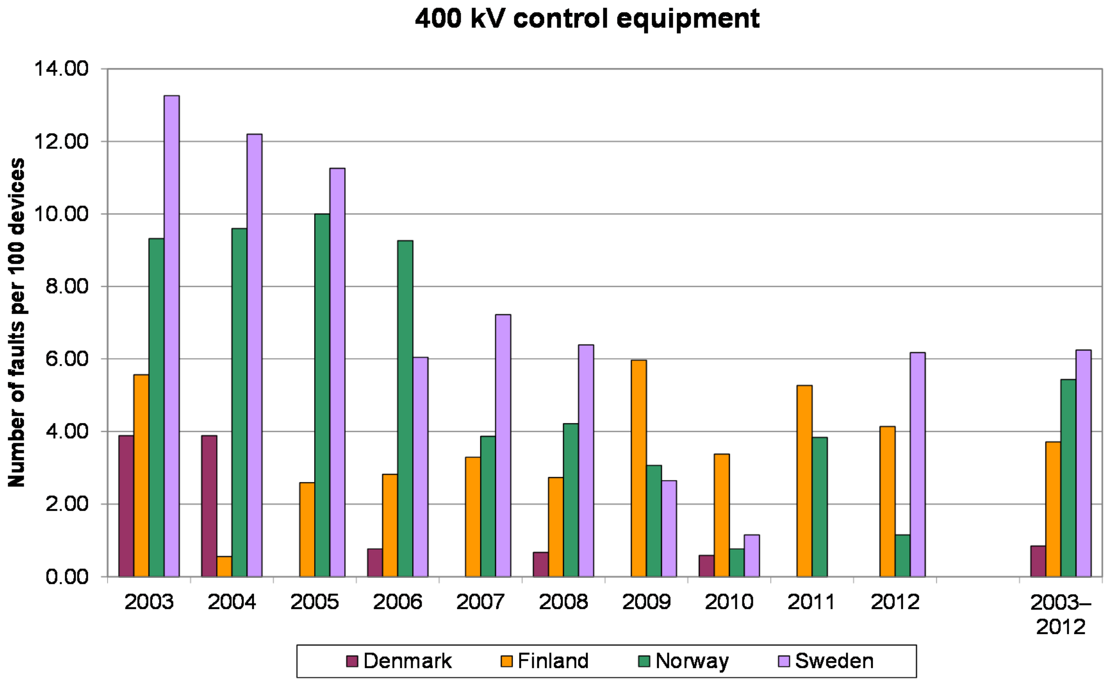

FIGURE 5.21 ANNUAL DIVISION OF FAULTS DURING THE PERIOD 2003-2012.

TABLE 5.20 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 220 KV CONTROL EQUIPMENT

Country	Number of devices 2012	Number of faults 2012	Number of faults per 100 devices 2012	Number of faults per 100 devices 2003–2012	Faults divided by cause during the period 2003–2012 (%) Lightning	Other environmental cause	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	2	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Finland	96	5	5.21	5.26	0.0	0.0	0.0	46.0	42.0	4.0	8.0
Iceland	79	1	1.27	7.22	5.8	1.9	0.0	26.9	57.7	7.7	0.0
Norway	721	10	1.39	4.93	0.9	0.9	0.6	33.2	44.6	4.5	15.3
Sweden	258	11	4.26	2.64	0.0	0.0	3.0	31.3	46.5	14.1	5.1
Nordic	1156	25	2.34	4.40	1.1	0.7	0.9	33.5	45.9	6.5	11.4

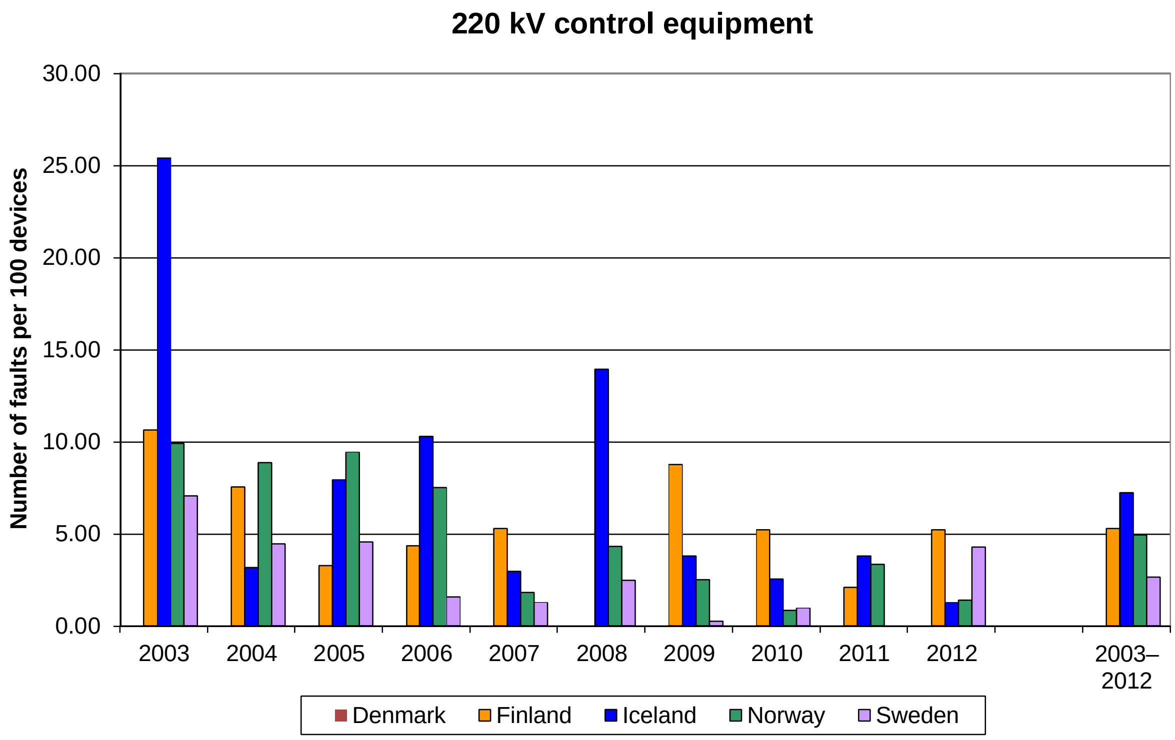

FIGURE 5.22 ANNUAL DIVISION OF FAULTS DURING THE PERIOD 2003-2012.

TABLE 5.21 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 132 KV CONTROL EQUIPMENT

Country	Number of devices 2012	Number of faults 2012	Number of faults per 100 devices		Faults divided by cause during the period 2003–2012 (%)						
			2012	2003–2012	Lightning	Other environmental cause	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	814	4	0.49	1.04	6.2	7.5	2.5	42.5	25.0	7.5	8.7
Finland	2268	17	0.75	1.73	2.6	0.0	1.6	42.8	28.6	4.8	19.6
Iceland	144	4	2.78	4.16	0.0	0.0	1.9	20.4	74.1	1.9	1.9
Norway	2064	16	0.78	2.02	1.2	2.2	0.2	31.8	33.7	7.2	23.6
Sweden	1380	4	0.29	0.60	7.1	0.0	0.0	45.5	27.3	7.1	13.1
Nordic	6670	45	0.67	1.50	2.6	1.6	0.9	37.0	33.0	6.2	18.8

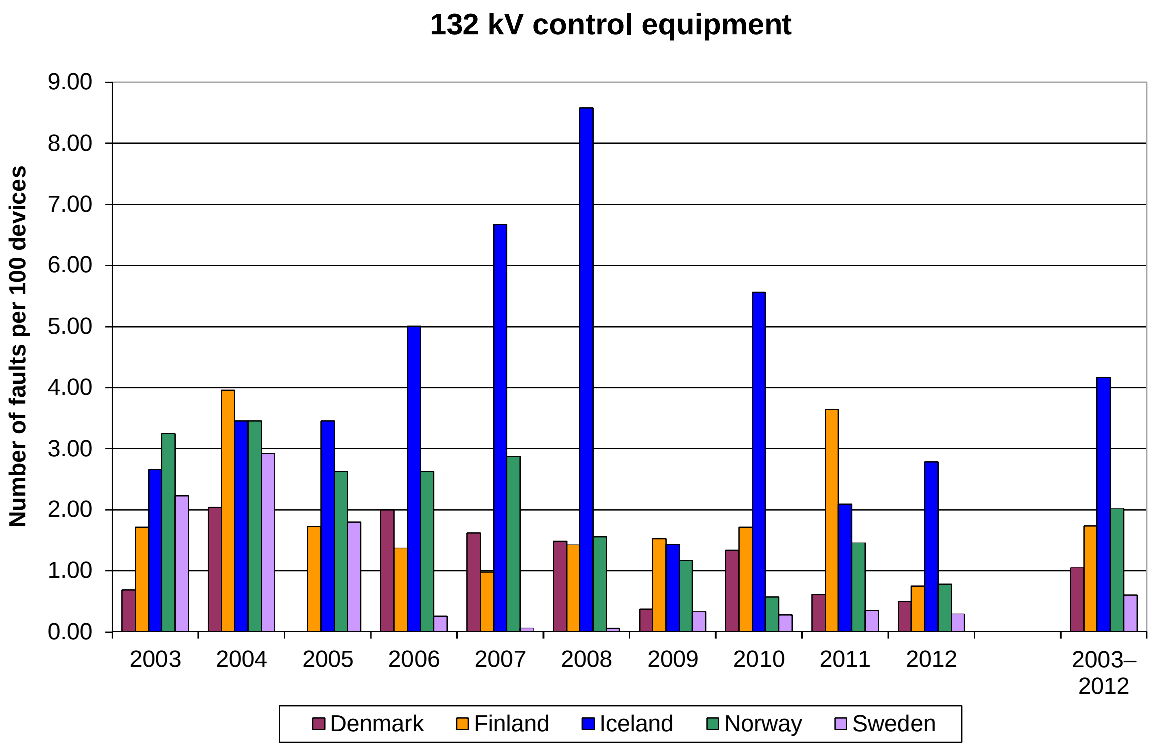

FIGURE 5.23 ANNUAL DIVISION OF FAULTS DURING THE PERIOD 2003-2012.

5.9 Faults in Compensation Devices

In 2000, Nordel's guidelines for compensation equipment changed. Therefore, the following four categories are used: reactors, series capacitors, shunt capacitors and SVC devices. The following tables present the faults in compensation devices for the year 2012 and for the period 2003–2012. In addition, the tables present the division of faults according to cause during the ten-year period 2003–2012.

Table 5.22 Division of faults according to cause for reactors

Country	Number of devices 2012	Number of faults 2012	Number of faults per 100 devices		Faults divided by cause during the period 2003–2012 (%)						
			2012	2003–2012	Lightning	Other environmental cause	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	18	0	0.00	6.64	0.0	0.0	0.0	23.5	58.8	0.0	17.6
Finland[1)]	71	0	0.00	1.48	0.0	0.0	0.0	0.0	88.9	0.0	11.1
Norway	36	2	5.56	5.00	0.0	5.6	0.0	27.8	55.6	5.6	5.6
Sweden	72	9	12.50	13.79	0.0	34.9	2.4	7.2	34.9	15.7	4.8
Nordic	197	9	5.58	6.95	0.0	24.0	1.6	11.8	44.9	11.0	7.1

1) In Finland, reactors compensating the reactive power of 400 kV lines are connected to the 20 kV tertiary winding of the 400/110/20 kV power transformers.

Table 5.23 Division of faults according to cause for series capacitors

Country	Number of devices 2012	Number of faults 2012	Number of faults per 100 devices		Faults divided by cause during the period 2003–2012 (%)						
			2012	2003–2012	Lightning	Other environmental cause	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Finland	9	8	88.89	47.44	0.0	0.0	5.4	5.4	48.6	0.0	40.5
Iceland	1	0	0.00	20.00	0.0	50.0	0.0	0.0	50.0	0.0	0.0
Norway	3	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sweden	12	23	191.67	150.00	0.6	0.6	0.0	1.1	14.4	76.7	6.7
Nordic	25	20	124.00	92.02	0.5	0.9	0.9	1.8	20.5	63.0	12.3

TABLE 5.24 DIVISION OF FAULTS ACCORDING TO CAUSE FOR SHUNT CAPACITORS

Country	Number of devices 2012	Number of faults 2012	Number of faults per 100 devices		Faults divided by cause during the period 2003–2012 (%)						
			2012	2003–2012	Lightning	Other environmental cause	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	15	0	0.00	1.32	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Finland	67	1	1.49	4.41	0.0	21.1	63.2	0.0	5.3	0.0	10.5
Iceland	10	1	10.00	11.58	0.0	18.2	9.1	0.0	72.7	0.0	0.0
Norway	194	6	3.09	2.33	2.2	0.0	2.2	8.9	53.3	31.1	2.2
Sweden	121	1	0.83	2.72	5.4	8.1	10.8	2.7	40.5	0.0	32.4
Nordic	407	9	2.21	2.87	2.6	7.9	17.5	4.4	42.1	12.3	13.2

TABLE 5.25 DIVISION OF FAULTS ACCORDING TO CAUSE FOR SVC DEVICES

Country	Number of devices 2012	Number of faults 2012	Number of faults per 100 devices		Faults divided by cause during the period 2003–2012 (%)						
			2012	2003–2012	Lightning	Other environmental cause	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	1	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Finland	1	0	0.0	25.00	0.0	0.0	0.0	0.0	100.0	0.0	0.0
Norway	15	14	93.33	44.22	0.0	1.5	0.0	4.6	56.9	27.7	9.2
Sweden	3	10	333.33	285.29	0.0	6.2	3.1	13.4	66.0	3.1	8.2
Nordic	20	24	120.00	85.79	0.0	4.3	1.8	9.8	62.6	12.9	8.6

SVC devices are often subjects to temporary faults. A typical fault is an error in the computer of the control system that leads to the tripping of the circuit breaker of the SVC device. After the computer is restarted, the SVC device works normally. This explains the high number of faults in SVC devices.

6 OUTAGES

The presentation of outages in power system units was introduced in the Nordel's statistics in 2000. More information can be found in Section 5.3 in the guidelines [1]. For the most part, this chapter covers statistics only for the year 2012. However, a ten-year trend line for the reliability of some power system components is presented at the end of the chapter.

Definition of a system unit is

"*a group of components which are delimited by one or more circuit breakers"* [1 page 8].

Definition of an outage state is

"the component or unit is not in the in-service state; that is, it is partially or fully isolated from the system" [1 page 8, 5].

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6.1 OUTAGES IN POWER SYSTEM UNITS

The tables and figures in this section present outages in the following power system units: lines, transformers, busbars, reactors, and shunt capacitors.

TABLE 6.1 GROUPING OF LINES ACCORDING TO THE NUMBER OF OUTAGES IN 2012

Line[1)]		Number of system units grouped by number of outages						
Country	**Number of system units**	**No outages**	**1 outage**	**2 outages**	**3 outages**	**4 outages**	**5 outages**	**>5 outages**
Denmark	341	305	30	5	1	0	0	0
Finland	562	381	96	40	13	15	8	9
Iceland	58	45	9	1	1	2	0	0
Norway	1233	1190	34	3	2	3	1	0
Sweden	403	309	72	15	5	1	1	0

[1)] Note that the concept of *line* in power system units can consist of both overhead lines and cables.

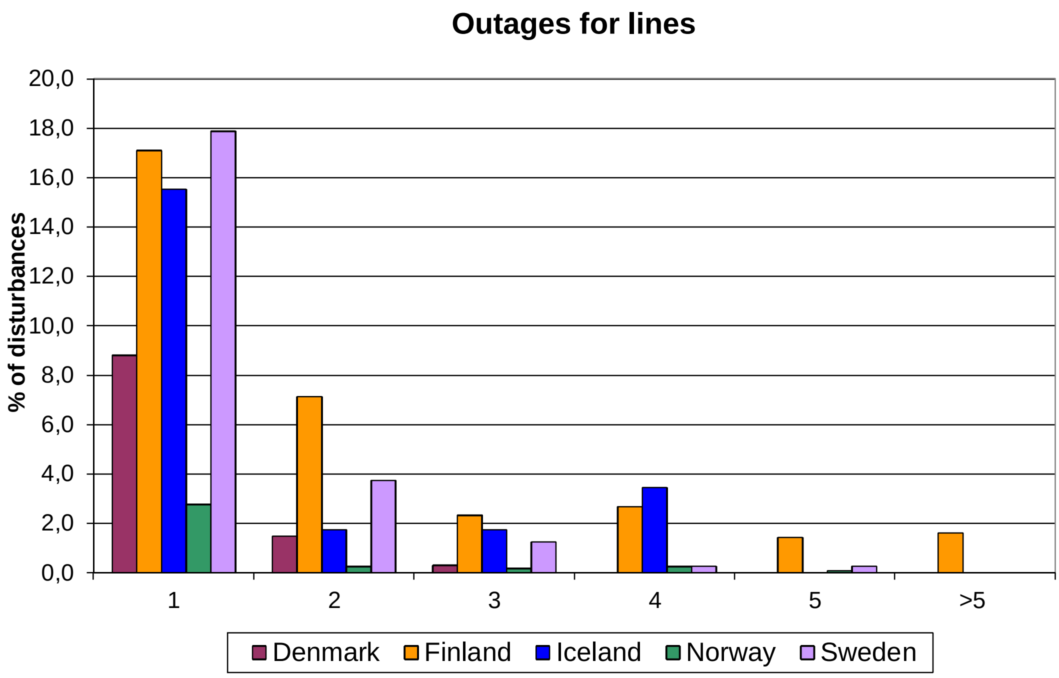

FIGURE 6.1 GROUPING OF LINES ACCORDING TO NUMBER OF OUTAGES IN 2012.

TABLE 6.2 GROUPING OF TRANSFORMERS ACCORDING TO THE NUMBER OF OUTAGES IN 2012

Transformer		Number of system units grouped by number of outages						
Country	Number of system units	No outages	1 outage	2 outages	3 outages	4 outages	5 outages	>5 outages
Denmark	268	256	9	0	1	2	0	0
Finland	1199	1191	8	0	0	0	0	0
Iceland	88	84	4	0	0	0	0	0
Norway	1059	1052	7	0	0	0	0	0
Sweden	289	270	13	6	0	0	0	0

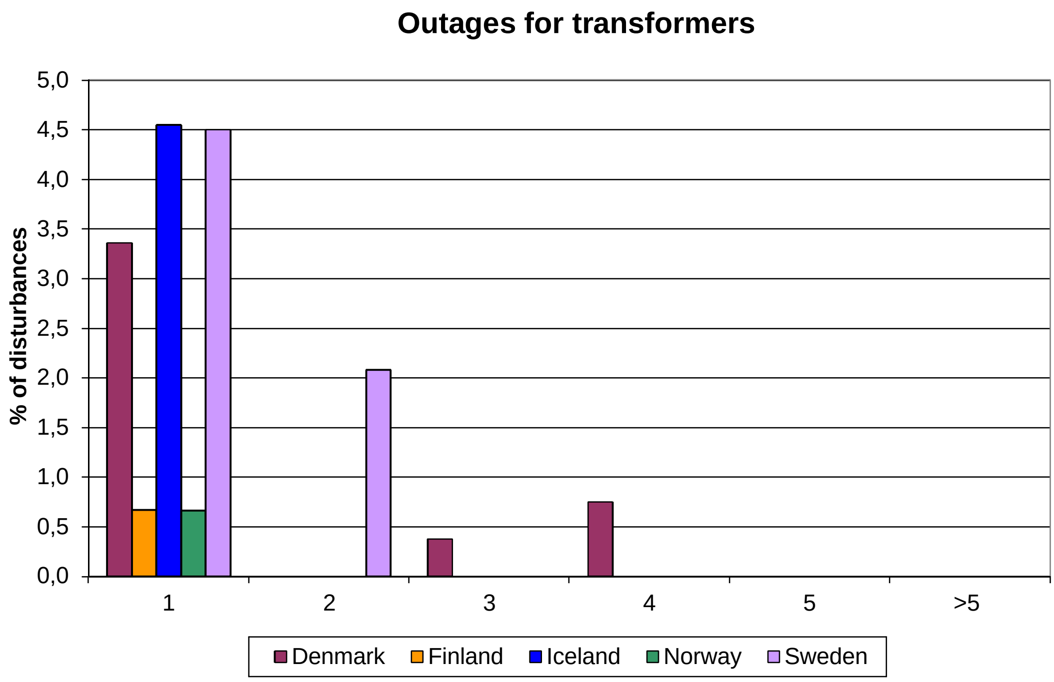

FIGURE 6.2 GROUPING OF TRANSFORMERS ACCORDING TO NUMBER OF OUTAGES IN 2012.

TABLE 6.3 GROUPING OF BUSBARS ACCORDING TO THE NUMBER OF OUTAGES IN 2012

Busbar		Number of system units grouped by number of outages						
Country	Number of system units	No outages	1 outage	2 outages	3 outages	4 outages	5 outages	>5 outages
Denmark	299	292	5	0	0	2	0	0
Finland	964	961	3	0	0	0	0	0
Iceland	52	45	5	2	0	0	0	0
Norway	435	432	3	0	0	0	0	0
Sweden	261	250	9	2	0	0	0	0

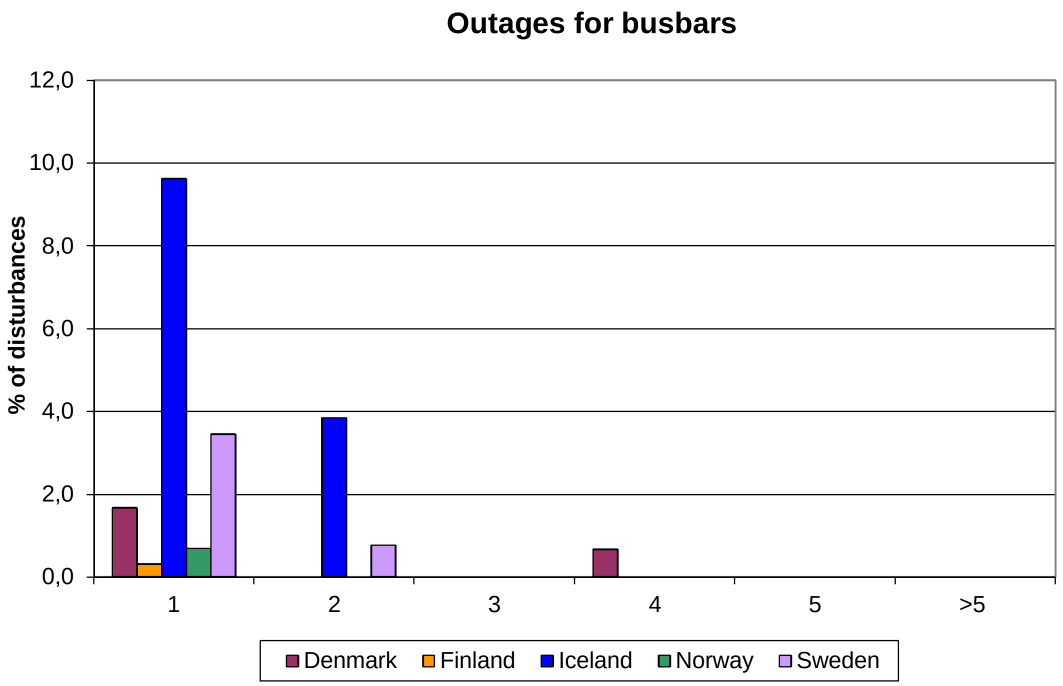

FIGURE 6.3 GROUPING OF BUSBARS ACCORDING TO NUMBER OF OUTAGES IN 2012.

TABLE 6.4 GROUPING OF REACTORS ACCORDING TO THE NUMBER OF OUTAGES IN 2012

Reactor		Number of system units grouped by number of outages						
Country	Number of system units	No outages	1 outage	2 outages	3 outages	4 outages	5 outages	>5 outages
Denmark	14	13	0	1	0	0	0	0
Finland	71	71	0	0	0	0	0	0
Norway	36	34	2	0	0	0	0	0
Sweden	45	34	8	3	0	0	0	0

TABLE 6.5 GROUPING OF SHUNT CAPACITORS ACCORDING TO THE NUMBER OF OUTAGES IN 2012

Shunt capacitor		Number of system units grouped by number of outages						
Country	Number of system units	No outages	1 outage	2 outages	3 outages	4 outages	5 outages	>5 outages
Denmark	13	13	0	0	0	0	0	0
Finland	67	66	1	0	0	0	0	0
Iceland	10	9	1	0	0	0	0	0
Norway	194	190	0	4	0	0	0	0
Sweden	49	47	2	0	0	0	0	0

6.2 DURATION OF OUTAGES IN DIFFERENT POWER SYSTEM UNITS

Outage duration is registered from the start of the outage to the time when the system is ready to be taken into operation. If the connection is intentionally postponed, the intentional waiting time is not included in the duration of the outage. The section presents the outage duration statistics for lines, transformers, busbars, reactors, and shunt capacitors.

TABLE 6.6 NUMBER OF LINES WITH DIFFERENT OUTAGE DURATIONS IN 2012

Line[1)]		Number of system units grouped by total outage duration time								
Country	Number	No outages	<3 minutes	3–10 minutes	10–30 minutes	30–60 minutes	60–120 minutes	120–240 minutes	240–480 minutes	>480 minutes
Denmark	341	305	28	2	0	1	1	0	0	4
Finland	562	381	139	9	12	3	3	2	3	10
Iceland	58	45	2	0	2	2	0	2	1	4
Norway	1233	1190	20	5	6	3	2	2	3	2
Sweden	403	309	73	5	3	2	1	1	3	6

[1)] Note that the concept of *line* in power system units consists of both overhead lines and cables.

TABLE 6.7 NUMBER OF TRANSFORMERS WITH DIFFERENT OUTAGE DURATIONS IN 2012

Transformer		Number of system units grouped by total outage duration time								
Country	Number	No outages	<3 minutes	3–10 minutes	10–30 minutes	30–60 minutes	60–120 minutes	120–240 minutes	240–480 minutes	>480 minutes
Denmark	268	256	3	3	5	0	0	0	0	1
Finland	1199	1191	3	0	1	0	1	2	0	1
Iceland	88	84	0	0	1	0	1	0	0	2
Norway	1059	1052	1	1	0	0	0	1	1	3
Sweden	289	270	1	2	5	4	1	1	1	4

TABLE 6.8 NUMBER OF BUSBARS WITH DIFFERENT OUTAGE DURATIONS IN 2012

Busbar		Number of system units grouped by total outage duration time								
Country	Number	No outages	<3 minutes	3–10 minutes	10–30 minutes	30–60 minutes	60–120 minutes	120–240 minutes	240–480 minutes	>480 minutes
Denmark	299	292	2	2	2	0	0	0	1	0
Finland	964	961	1	1	1	0	0	0	0	0
Iceland	52	45	0	0	2	1	2	0	0	2
Norway	435	432	0	0	0	3	0	0	0	0
Sweden	261	250	0	2	1	1	4	0	0	3

TABLE 6.9 NUMBER OF REACTORS WITH DIFFERENT OUTAGE DURATIONS IN 2012

Reactor		Number of system units grouped by total outage duration time								
Country	Number	No outages	<3 minutes	3–10 minutes	10–30 minutes	30–60 minutes	60–120 minutes	120–240 minutes	240–480 minutes	>480 minutes
Denmark	14	13	0	0	1	0	0	0	0	0
Finland	71	71	0	0	0	0	0	0	0	0
Norway	36	34	0	0	0	0	0	0	2	0
Sweden	45	34	0	0	1	0	2	4	0	4

TABLE 6.10 NUMBER OF SHUNT CAPACITORS WITH DIFFERENT OUTAGE DURATIONS IN 2012

Shunt capacitor		Number of system units grouped by total outage duration time								
Country	Number	No outages	<3 minutes	3–10 minutes	10–30 minutes	30–60 minutes	60–120 minutes	120–240 minutes	240–480 minutes	>480 minutes
Denmark	13	13	0	0	0	0	0	0	0	0
Finland	67	66	1	0	0	0	0	0	0	0
Iceland	10	9	0	0	0	0	0	0	0	1
Norway	194	190	0	2	2	0	0	0	0	0
Sweden	49	47	0	0	0	0	1	0	1	0

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6.3 CUMULATIVE DURATION OF OUTAGES IN SOME POWER SYSTEM UNITS

Figure 6.4 presents the cumulative distribution curve for outage durations in the following power system units: lines, busbars and transformers. All five countries are included in the data of Figure 6.4.

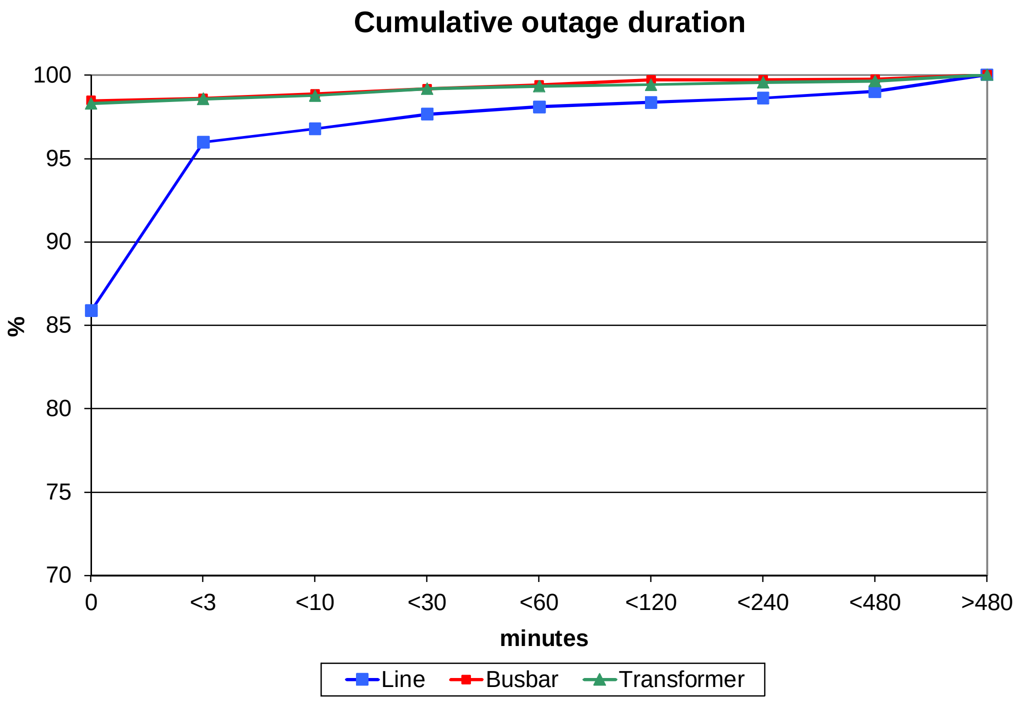

FIGURE 6.4 PERCENTAGE OF COMPONENTS WITH DIFFERENT OUTAGE DURATION IN 2012 .

Figure 6.4 shows that approximately 86% of lines, 98% of transformers and 98% of busbars had no outages in 2012.

6.4 RELIABILITY TRENDS FOR SOME POWER SYSTEM UNITS

Figure 6.5 presents a reliability trend for lines, busbars and transformers during the ten-year period 2003–2012. All five countries are included in the data of Figure 6.5.

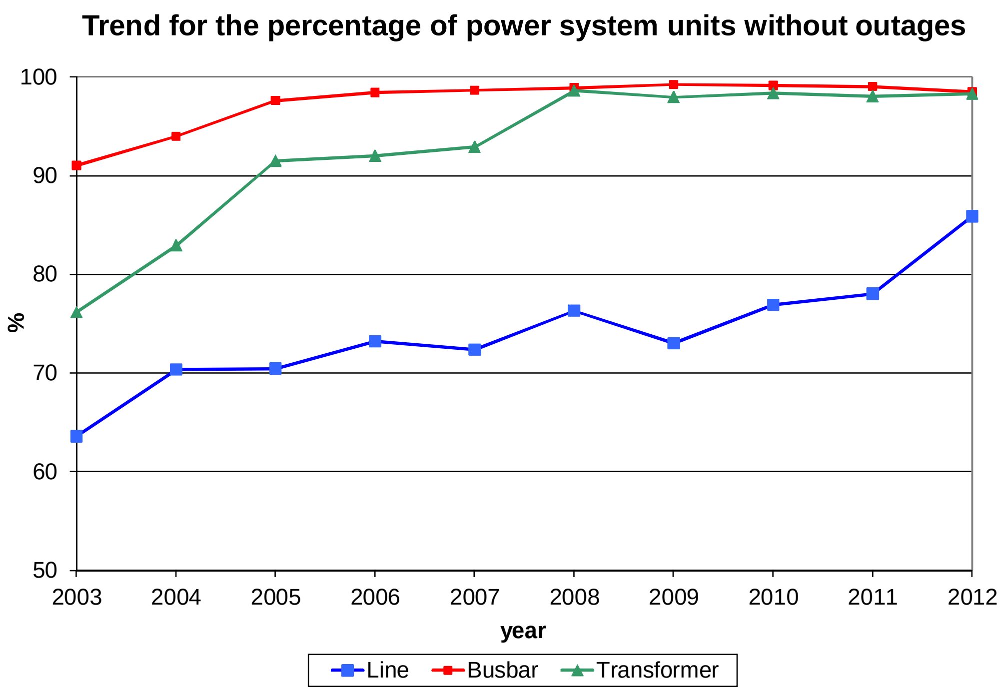

FIGURE 6.5 THE YEARLY PERCENTAGE OF THE POWER SYSTEM UNITS THAT HAD NO OUTAGES DURING THE PERIOD 2003–2012.

7 HVDC STATISTICS

This section presents the statistics of the availability and utilization of HVDC links connected to the Nordic countries in 2012. These statistics are 'work in progress' and the detail level of the presentation are planned to be enhanced and improved in the following years.

The scope of these statistics differs from the scope of the CIGRÉ HVDC statistics, which concentrate on outages, faults and disturbances of the HVDC links, including the converter stations.

The main interest of the DISTAC HVDC statistics is a macro view on the *availability* and *utilization* of the HVDC links, including total outages and limitations. The following chapter explains the categories of the DISTAC HVDC statistics. Interesting details in the collected data will be emphasized in specially adapted presentations.

7.1 CONTENTS OF HVDC STATISTICS – METHODS, DEFINITIONS AND CALCULATIONS

The utilization of HVDC link capacities can be calculated by using the data received from SCADA, grid operation, market departments, Urgent Market Messages (UMMs) of the Nord Pool Spot and measurements on each side of a links.

The process of collecting and sorting data for these statistics will be described in the guidelines of this report. This chapter describes how the collected data is defined and used in calculations.

The **technical capacity E_{max}** of the HVDC link is the maximum energy that can be transmitted from the AC grid to the converter station on the exporting side, including all HVDC link losses, if there are no outages or limitations:

$$E_{\max} = P_{\mathrm{R}} \times 24 \times d \qquad (7.1)$$

P_R is the rated power capacity and d is the number of days in the reported time period (month or year). The column in Figure 7.1 describes the nine main categories of these statistics, as well as aggregated categories used for simplified presentations.

In Figure 7.1, E_{max} is represented as the total height of the column. This section explains the mutual exclusivity and mathematical consistence of all categories used in the DISTAC HVDC statistics.

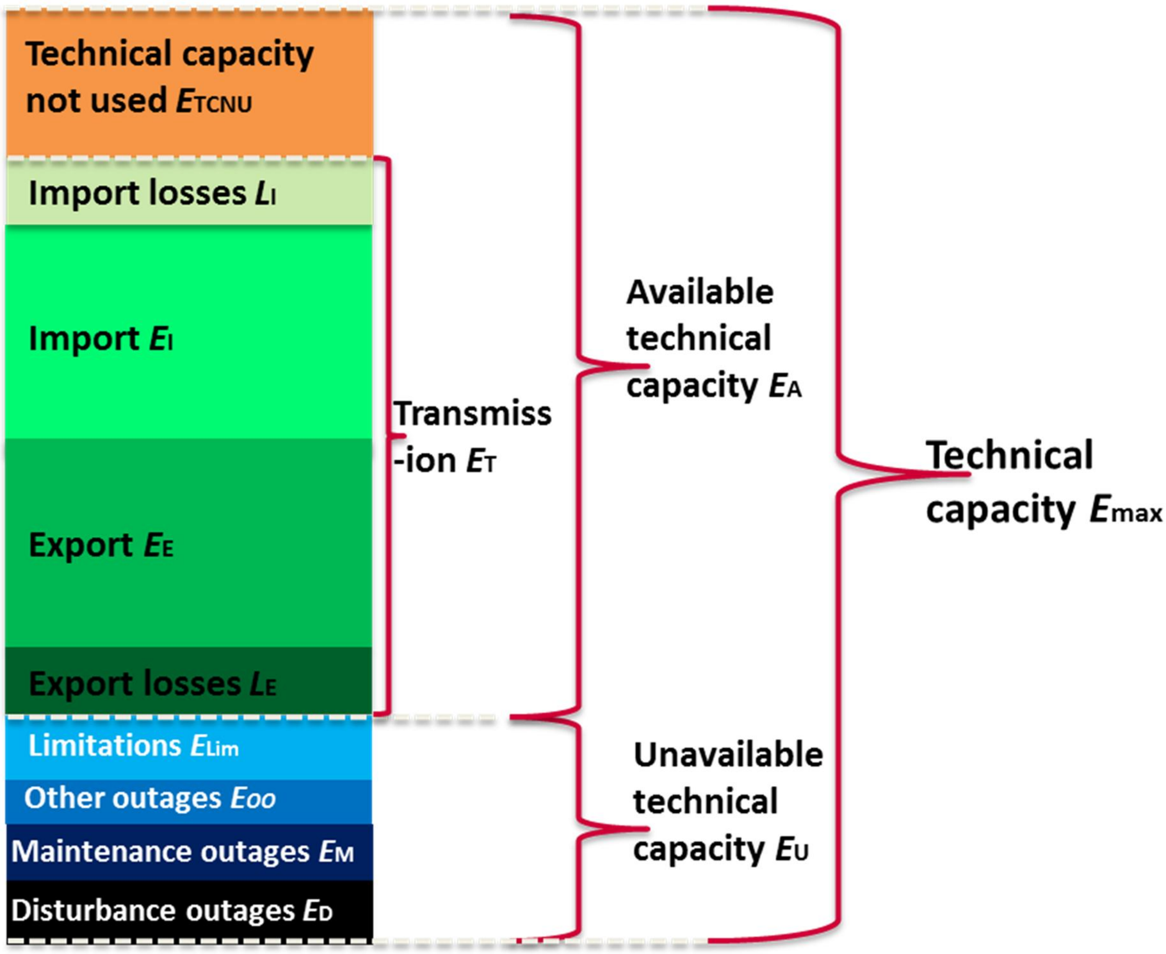

FIGURE 7.1 THE CATEGORIES USED IN THE DISTAC HVDC STATISTICS. DEFINITIONS AND CALCULATIONS ARE EXPLAINED IN THIS CHAPTER. EVERY VALUE IS AN ENERGY VALUE AND REPRESENTS A PART OF THE AVAILABLE OR UNAVAILABLE TECHNICAL CAPACITY. THE NINE CATEGORIES OF THE COLUMN TO THE LEFT ARE INTERNALLY EXCLUSIVE AND THEIR SUM AMOUNTS TO THE TOTAL TECHNICAL CAPACITY.

The technical capacity of the link is a theoretical value, and can be divided into **available (E_A) or unavailable (E_U) technical capacity**. The technical unavailability is due to outages or limitations.

An **outage** is *any* state when a component is disconnected from the system, and the transfer capacity is reduced to zero. There are different types of outages:

- **Disturbance outages (E_D)** are *total outages* due to a fault on the HVDC link or in the AC grid causing a *total outage* of the link.
- **Maintenance outages (E_M)** are *total outages* due to all technically motivated actions on the HVDC link or in the AC grid intended to retain an entity in, or restore it to, a state where it can perform its required function.
- **Other outages (E_{OO})** are *total outages* due to any other reason than those mentioned above.

The energy transfer E_D, E_M and E_{OO} made unavailable due to disturbance, maintenance and other outages are calculated by multiplying the rated power P_R by the duration of the outage, respectively h_D, h_M and h_{OO}:

$$E_{\mathrm{D}} = P_{\mathrm{R}} \times h_{\mathrm{D}} \tag{7.2}$$

$$E_{\mathrm{M}} = P_{\mathrm{R}} \times h_{\mathrm{M}} \tag{7.3}$$

$$E_{\mathrm{OO}} = P_{\mathrm{R}} \times h_{\mathrm{OO}} \tag{7.4}$$

A **limitation (E_{Lim})** is a condition when the transmission capacity of an HVDC link is limited, i.e. the power transmission capacity of the link is less than the rated power. The limitation is always motivated from a technical perspective, but not always concerning the link itself. The most common causes of limitations are:

- Faults on any HVDC link component as long as they do not cause a total outage.
- Faults, congestions or outages in the AC grid causing a limitation in the transmission capacity of the link.
- Seasonal variations on the transmission capacity of the DC link.[2]
- Link capacity reserved as power reserves.

Limitations lasting less than 10 minutes should not be reported. In the scope of this statistics report, these limitations are too small to have an actual significance on the presented data. Hence; short ramping limitations and commutation failures are not cases included in this category.

Limitations are calculated by multiplying the limited power capacity (P_{Lim}) by the duration of the limitation in hours (h_{Lim}):

$$E_{\mathrm{Lim}} = P_{\mathrm{Lim}} \times h_{\mathrm{Lim}} \tag{7.5}$$

This allows a mathematical description of the **unavailable technical capacity E_U** as the part of technical capacity that is *not* available for transmission due to outages (disturbance, maintenance, other) and limitations:

$$E_U = E_{\mathrm{D}} + E_{\mathrm{M}} + E_{\mathrm{OO}} + E_{\mathrm{Lim}} = P_{\mathrm{R}} \times (h_{\mathrm{D}} + h_{\mathrm{M}} + h_{\mathrm{OO}}) + P_{\mathrm{Lim}} \times h_{\mathrm{Lim}} \tag{7.6}$$

The counterpart to E_U is the **available technical capacity E_A**, which consists of the remaining of the maximum technical capacity E_{MAX}. This equals the capacity used for **transmission (E_T)** and a remaining category; **technical capacity not used E_{TCNU}**.

$$E_{\mathrm{A}} = E_{\mathrm{MAX}} - E_{\mathrm{U}} = E_{\mathrm{T}} + E_{\mathrm{TCNU}} \tag{7.7}$$

[2] The transmission capacity of some links is limited during the summer season, due to less convection of heat from transmission losses. Full capacity is as rated by the manufacturer, and is given for all links in Table 7.1.

Transmission E_T is the sum of exported and imported energy including losses:

$$E_{\mathrm{T}} = E_{\mathrm{E}} + L_{\mathrm{E}} + E_{\mathrm{I}} + L_{\mathrm{I}} \qquad (7.8)$$

Imported energy E_I is energy transferred from the HVDC link to the importing AC side. It does not include **import losses L_I**; energy losses in any of the HVDC link components during import.

Exported energy E_E and **export losses L_E** are explained likewise, with an opposite point of view. E_E from one side of the link equals E_I considered from the opposite side of the link.

Technical capacity not used E_{TCNU} can now be calculated:

$$\begin{aligned} E_{\mathrm{TCNU}} &= E_{\mathrm{MAX}} - E_{\mathrm{U}} - E_{T} = \\ &E_{\mathrm{MAX}} - (P_{\mathrm{R}} \times (h_{\mathrm{D}} + h_{\mathrm{M}} + h_{\mathrm{OO}}) + P_{\mathrm{Lim}} \times h_{\mathrm{Lim}}) - (E_{\mathrm{E}} + L_{\mathrm{E}} + E_{\mathrm{I}} + L_{\mathrm{I}}) \end{aligned} \qquad (7.9)$$

Technical capacity not used (A_{TCNU}) is what remains when all other categories are mapped and calculated. The content of this category is complex and consists of both technical and market related details. The most important of these are:

- When price differences between the markets on each side of the HVDC link are too small to promote transmission, in spite of technical availability. The link is still available in case of need for balancing or emergency power, and hence not disconnected.
- Any limitations lasting less than 10 minutes (does not include total outages):
  - Ramping time: When the power flow is changed, the capacity is fully released to the market, but the nominal voltage, and hence the full transmission capacity, is not always immediately obtained, depending on the type of converter technology.
  - Commutation failures may interrupt the power transmission. In the CIGRÉ statistics, commutation failures are categorized as 'transient disturbances'.
  - Emergency power is not usually used longer than 10 minutes for a given event. Longer lasting disturbances will be registered as outages or limitations.

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7.1.1 TECHNICAL DETAILS OF THE HVDC LINKS

Tables 7.1 and 7.2 present the main properties of the HVDC links covered in the statistics.

TABLE 7.1 TECHNICAL DETAILS OF THE HVDC LINKS

<table>
<tr><th>Name of the link</th><th>Com-mis-sioning year</th><th>Market connec-tion (Y/N)</th><th>Type of HVDC conver-ter</th><th>Rated power, mono-polar (MW)</th><th>Parallel mono-polar capacity (MW)</th><th>Bipolar capacity (MW)</th><th>Direction of power (N–S, E–W)</th></tr>
<tr><td>Baltic Cable</td><td>1994</td><td>Y</td><td>LCC</td><td>600/600</td><td></td><td></td><td>N–S</td></tr>
<tr><td>Estlink 1</td><td>2006</td><td>Y</td><td>VSC</td><td>350</td><td></td><td></td><td>N–S</td></tr>
<tr><td>Fenno-Skan 1</td><td>1989</td><td>Y</td><td>LCC</td><td>550 / 550</td><td rowspan="2">1350/1350</td><td rowspan="2">1350/1350</td><td>E–W</td></tr>
<tr><td>Fenno-Skan 2</td><td>2011</td><td>Y</td><td>LCC</td><td>800/800</td><td>E–W</td></tr>
<tr><td>Kontek</td><td>1986</td><td>Y</td><td>LCC</td><td>600/600</td><td></td><td></td><td>N–S</td></tr>
<tr><td>Konti-Skan 1</td><td>2008</td><td>Y</td><td>LCC</td><td>370 / 370</td><td>740/740</td><td></td><td>E–W</td></tr>
<tr><td>Konti-Skan 2</td><td>1988</td><td>Y</td><td>LCC</td><td>370 / 370</td><td>740/740</td><td></td><td>E–W</td></tr>
<tr><td>NorNed</td><td>2008</td><td>Y</td><td>LCC</td><td>700 / 700</td><td></td><td></td><td>N–S</td></tr>
<tr><td>Skagerrak 1</td><td rowspan="2">1976–1977</td><td>Y</td><td>LCC</td><td>250 / 250</td><td rowspan="3">1000 / 950</td><td rowspan="3">1000 / 950</td><td>N–S</td></tr>
<tr><td>Skagerrak 2</td><td>Y</td><td>LCC</td><td>250 / 250</td><td>N–S</td></tr>
<tr><td>Skagerrak 3</td><td>1993</td><td>Y</td><td>LCC</td><td>500 / 500</td><td>N–S</td></tr>
<tr><td>Storebaelt</td><td>2010</td><td>Y</td><td>LCC</td><td>600/600</td><td></td><td></td><td>E–W</td></tr>
<tr><td>SwePol</td><td>2000</td><td>Y</td><td>LCC</td><td>600/600</td><td></td><td></td><td>N–S</td></tr>
<tr><td>Vyborg link</td><td>1981, 1982, 1984, 2000</td><td></td><td></td><td>1400</td><td></td><td></td><td>E–W</td></tr>
</table>

TABLE 7.2 TECHNICAL DETAILS OF THE HVDC LINKS

Name of the link	Total length of the link (km)	Length of mass cable (km)	Length of PEX cable (km)	Length of DC overhead line (km)	Length of DC back-to-back connection (km)
Baltic Cable	262	250		12	
Estlink 1	105		105		
Fenno-Skan 1	233	200		33	
Fenno-Skan 2	299	196		103	
Kontek			160		
Konti-Skan 1	150	89		61	
Konti-Skan 2	150	89		61	
NorNed	580	580			
Skagerrak 1	240	128.5		111.5	
Skagerrak 2	240	128.5		111.5	
Skagerrak 3	240	128.5		111.5	
Storebaelt			57		
SwePol	254	254			
Vyborg link	< 1				< 1

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7.2 PRESENTATION OF RESULTS

For an overview of all HVDC data; the statistics are presented in Figure 7.2 on an aggregated level. This makes a comparison between the cables possible. It should be kept in mind that the usages of the cables show big variations, from the most market dependent cables, to cables mostly used in one direction and cables used for technical reasons; to control power flow for system stability and according to set agreements.

The categories used for the overview presentation are presented in chapter 7.1:

- Unavailable technical capacity
- Transmission
- Technical capacity not used

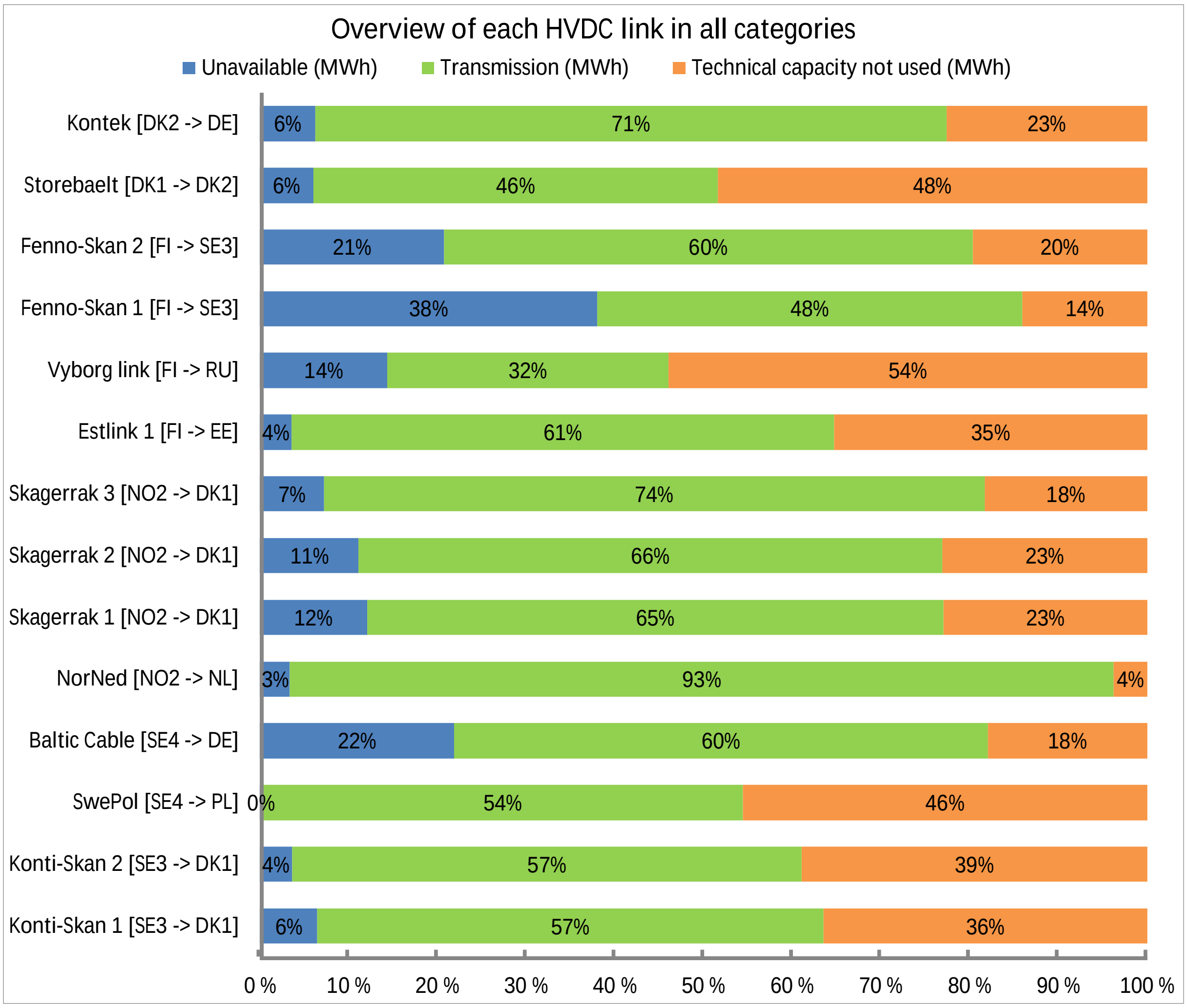

FIGURE 7.2 ANNUAL OVERVIEW OF EACH HVDC LINK IN YEAR 2012.

Figure 7.3 presents the number of disturbances that caused outages in year 2012, separately for each HVDC link. Figure 7.4 presents the unavailability over the annual E_{max} due to the outages.

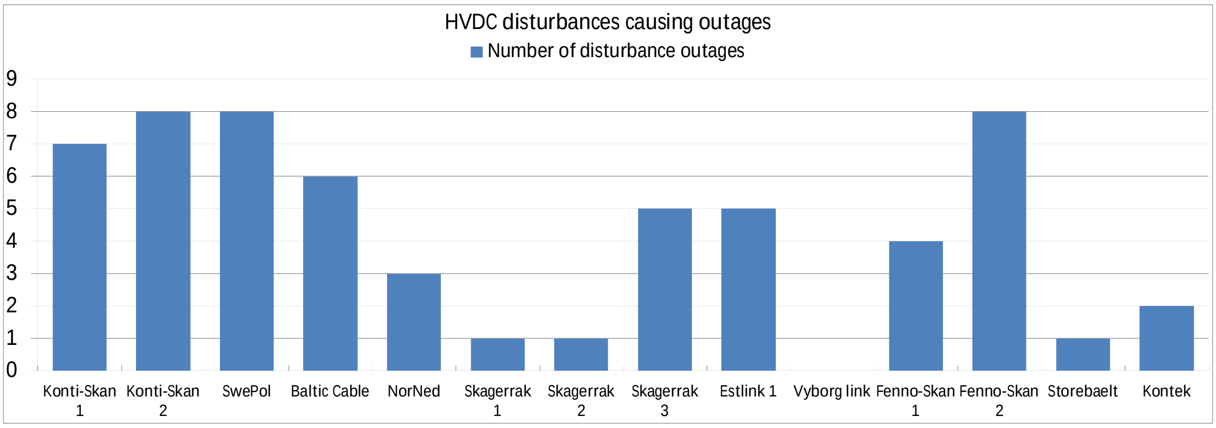

FIGURE 7.3 NUMBER OF HVDC DISTURBANCES CAUSING OUTAGES IN 2012.

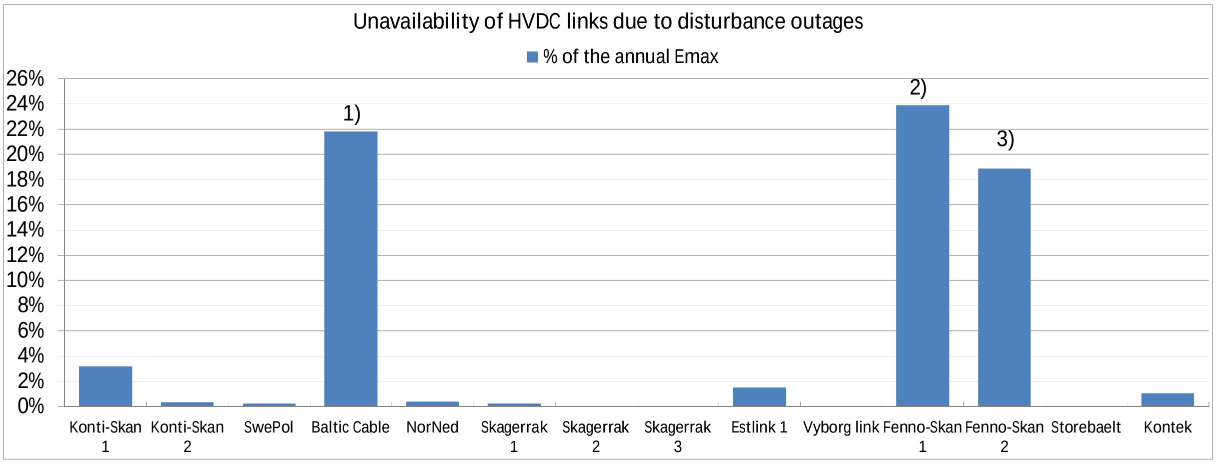

FIGURE 7.4 PERCENTAGE DISTRIBUTION OF UNAVAILABILITY DUE TO DISTURBANCE OUTAGES IN 2012.

1) During the autumn of 2012 there were two long outages in Baltic Cable due to cable faults. The outages had durations of 7 weeks and 5 weeks.

2) During 2012 there was a maintenance outage in Fenno-Skan 1 for 6 weeks (21.8 – 2.10.2012) while installing a new control system. When back in operation there was a fire in the thyristor hall causing another outage for 12 weeks (6.10 – 31.12.2012).

3) During 2012 there was a sea cable fault in Fenno-Skan 2 due to a ship anchor. The outage lasted almost 10 weeks (17.2 – 25.4.2012).

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7.2.1 KONTI-SKAN 1 HVDC LINK

Figure 7.5 presents the results of Konti-Skan 1 in year 2012 according to Figure 7.1 in a monthly view, also with a separate annual perspective. Konti-Skan 1 is a HVDC link between Lindome in south west Sweden (SE3) and Vester Hassing in Denmark (DK1). It was originally taken into operation in 1965. Today the transmission capacity is 370 MW and the upgraded converter stations were commissioned in 2008.

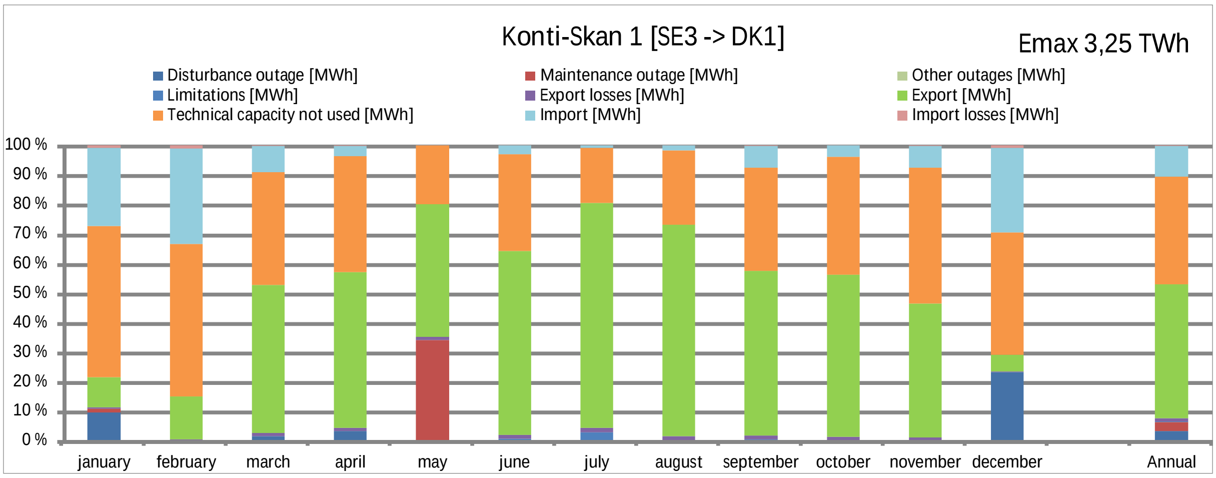

FIGURE 7.5 HVDC PRESENTATION OF KONTI-SKAN 1 IN 2012. . KONTI-SKAN 1 HAS BEEN 94 % TECHNICALLY AVAILABLE AND THE TECHNICAL CAPACITY NOT USED WAS 36 %. IN MAY THERE WAS AN OUTAGE DURING 11 DAYS FOR YEARLY MAINTENANCE AND IN DECEMBER THERE WAS A FAULT IN A CURRENT TRANSFORMER THAT CAUSED AN OUTAGE FOR 7 DAYS.

7.2.2 KONTI-SKAN 2 HVDC LINK

Figure 7.6 presents the results of Konti-Skan 2 in year 2012 according to Figure 7.1 in a monthly view, also with a separate annual perspective. Konti-Skan 2 is a HVDC link between Sweden and Denmark in parallel to Konti-Skan 1. The transmission capacity is 370 MW and it has been in operation since 1988.

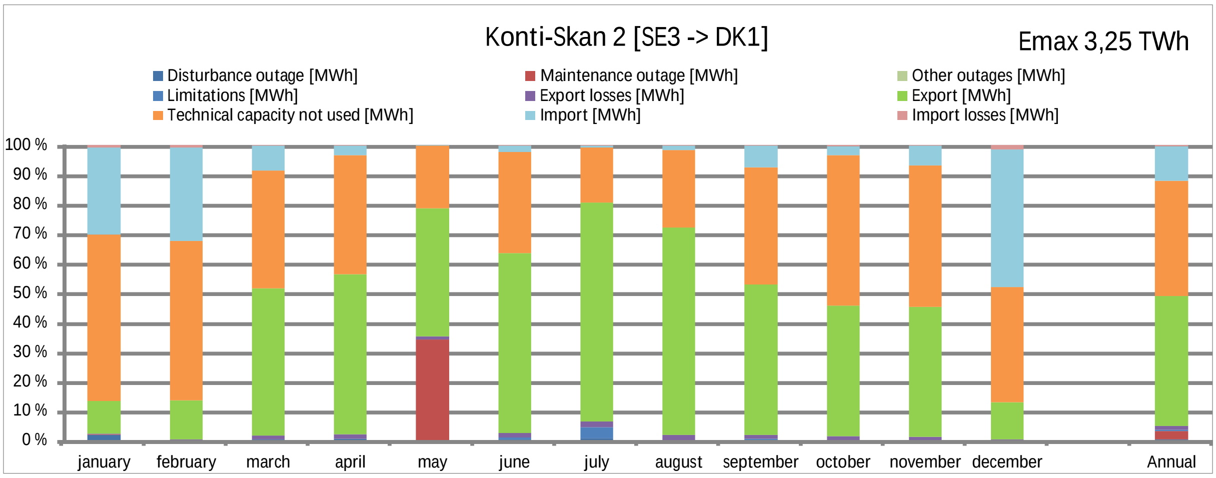

FIGURE 7.6 HVDC PRESENTATION OF KONTI-SKAN 2 IN 2012. KONTI-SKAN 2 HAS BEEN 96 % TECHNICALLY AVAILABLE AND THE TECHNICAL CAPACITY NOT USED WAS 39 %. PERFORMANCE WAS FAIRLY GOOD DURING 2012. IN MAY THERE WAS AN OUTAGE DURING 11 DAYS FOR YEARLY MAINTENANCE.

7.2.3 SWEPOL HVDC LINK

Figure 7.7 presents the results of SwePol in year 2012 according to Figure 7.1 in a monthly view, also with a separate annual perspective. SwePol link is a HVDC link between Stärnö in southeast Sweden and Slupsk in Poland. The transmission capacity is 600MW.

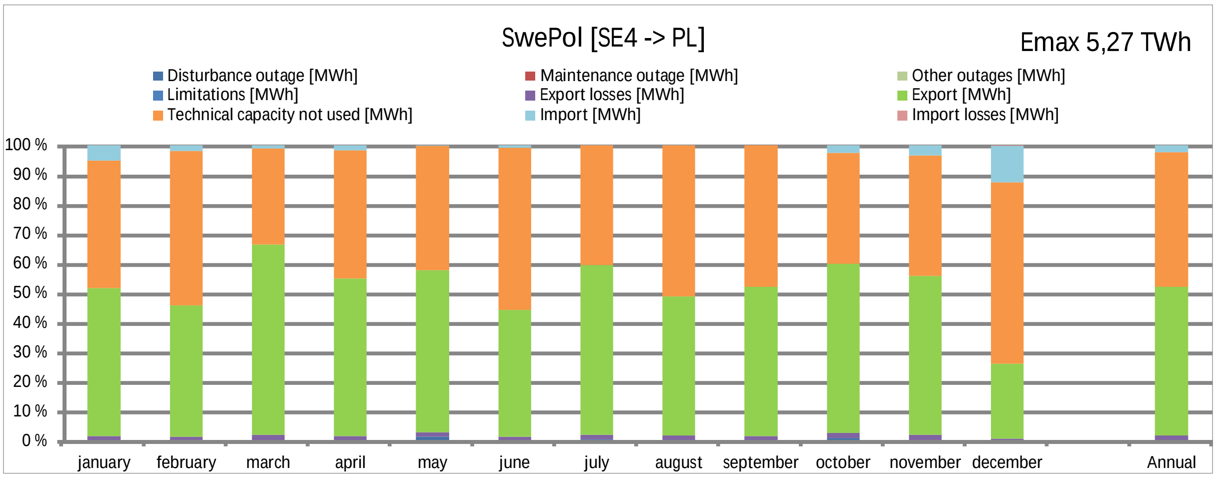

FIGURE 7.7 HVDC PRESENTATION OF SWEPOL IN 2012. SWEPOL HAS BEEN 100% TECHNICALLY AVAILABLE. THE TECHNICAL CAPACITY NOT USED WAS 46%. DURING 2012 PERFORMANCE OF THE LINK HAS BEEN GOOD AND ONLY MINOR DISTURBANCES HAVE OCCURRED.

7.2.4 BALTIC CABLE

Figure 7.8 presents the results of Baltic Cable in year 2012 according to Figure 7.1 in a monthly view, also with a separate annual perspective. Baltic Cable is a HVDC link between southern Sweden and Germany. The transmission capacity is 600 MW.

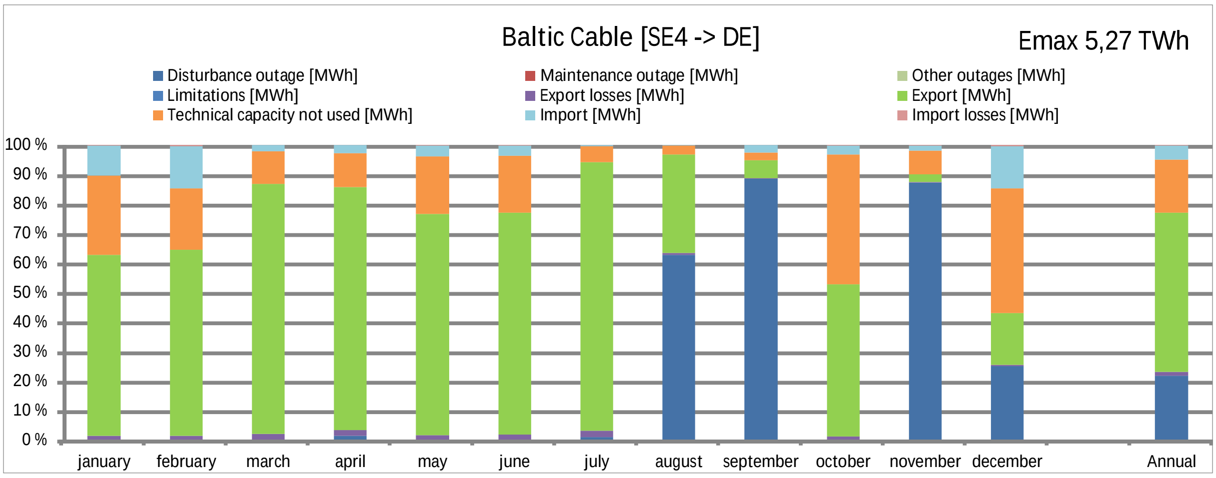

FIGURE 7.8 HVDC PRESENTATION OF BALTIC CABLE IN 2012. BALTIC CABLE HAS BEEN 78% TECHNICALLY AVAILABLE. THE TECHNICAL CAPACITY NOT USED WAS 18%. DURING THE AUTUMN OF 2012 THERE WERE TWO LONG OUTAGES DUE TO CABLE FAULTS. THE OUTAGES HAD DURATIONS OF 7 WEEKS AND 5 WEEKS.

7.2.5 NORNED HVDC LINK

Figure 7.9 presents the results of NorNed in year 2012 according to Figure 7.1 in a monthly view, also with a separate annual perspective. NorNed has been in operation since 2008. It is the longest HVDC link in the Nordic countries (580 km). It is connected in Feda, on the south-west coast of Norway in the NO2 price zone, and in Eemshaven, Netherlands, in the APX NL price zone. The transmission capacity is 730 MW.

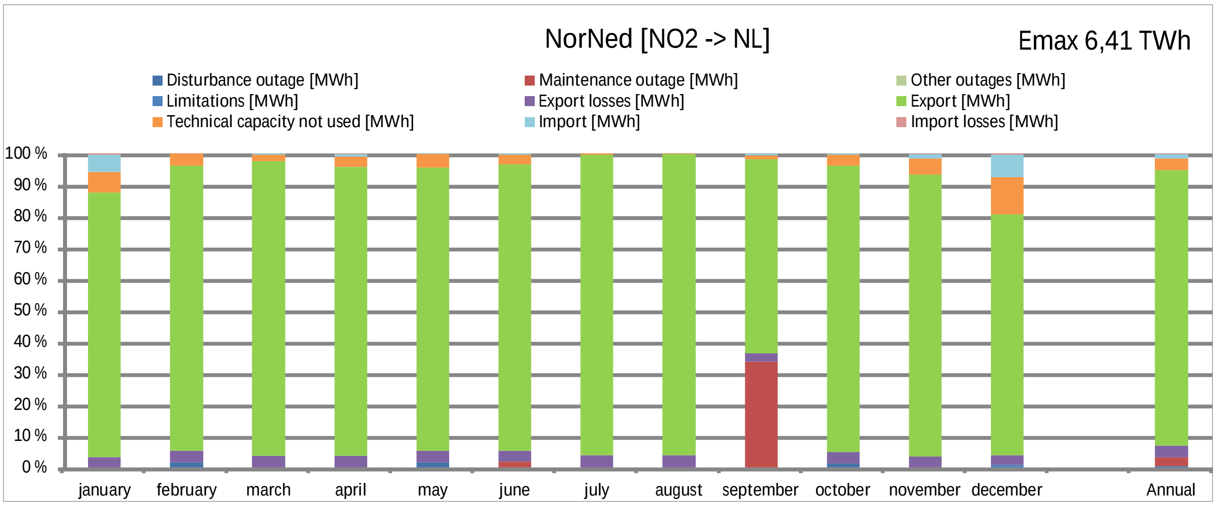

FIGURE 7.9 HVDC PRESENTATION OF NORNED IN 2012. NORNED HAS BEEN 97% TECHNICALLY AVAILABLE. THE TECHNICAL CAPACITY NOT USED WAS 4%. THE UNAVAILABILITY IS MOSTLY DUE TO PLANNED MAINTENANCE LASTING FOR TEN DAYS IN EARLY SEPTEMBER. THERE HAS NOT BEEN ANY SIGNIFICANT DISTURBANCES.

7.2.6 SKAGERRAK 1 HVDC LINK

Figure 7.10 presents the results of Skagerrak 1 in year 2012 according to Figure 7.1 in a monthly view, also with a separate annual perspective. Skagerrak 1 and 2 have been in operation since 1976 and are the oldest HVDC links in operation in the Nordic countries. They are connected at Kristiansand, on the south coast of Norway in the NO2 price zone, and at Tjele, approximately 15 km east of the town of Viborg in the northern part of Jutland. The transmission capacity of each of the links is 250 MW.

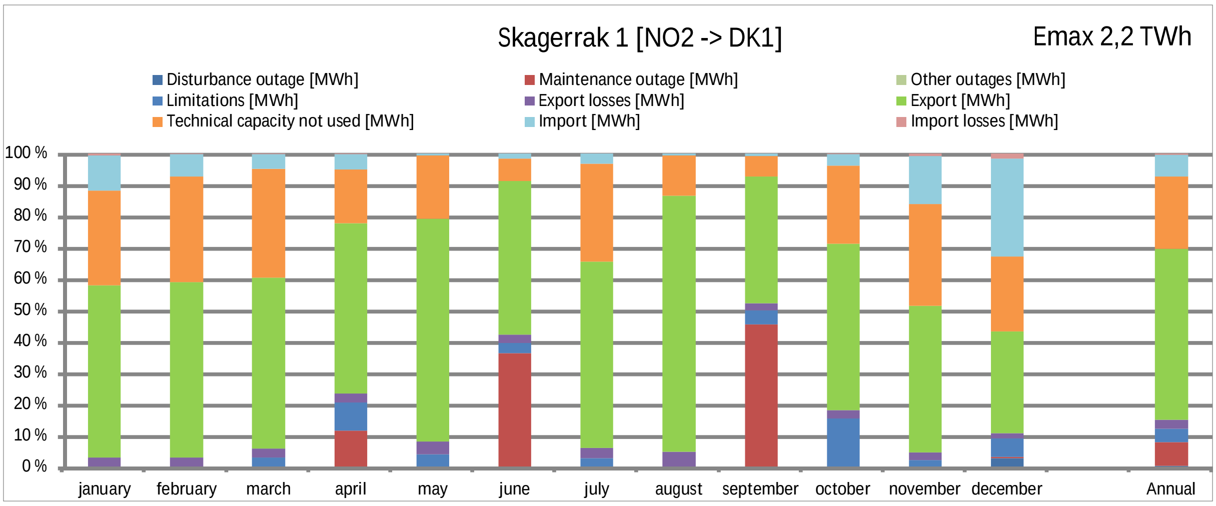

FIGURE 7.10 HVDC PRESENTATION OF SKAGERRAK 1 IN 2012. SKAGERRAK 1 HAS BEEN 88% TECHNICALLY AVAILABLE. THE TECHNICAL CAPACITY NOT USED WAS 23%.THE UNAVAILABILITY IS MOSTLY DUE TO PLANNED MAINTENANCE IN APRIL, JUNE AND SEPTEMBER. THERE HAS NOT BEEN ANY SIGNIFICANT DISTURBANCES.

7.2.7 SKAGERRAK 2 HVDC LINK

Figure 7.11 presents the results of Skagerrak 2 in year 2012 according to Figure 7.1 in a monthly view, also with a separate annual perspective. Skagerrak 1 and 2 have been in operation since 1976 and are the oldest HVDC links in operation in the Nordic countries. They are connected at Kristiansand, on the south coast of Norway in the NO2 price zone, and at Tjele, approximately 15 km east of the town of Viborg in the northern part of Jutland. The transmission capacity of each of the links is 250 MW.

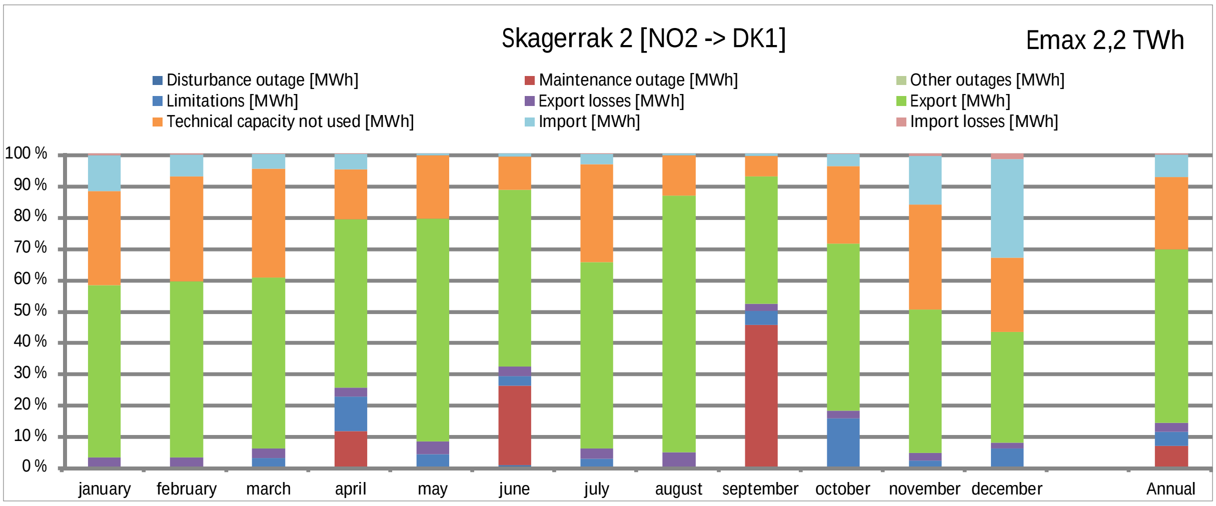

FIGURE 7.11 HVDC PRESENTATION OF SKAGERRAK 2 IN 2012. SKAGERRAK 2 HAS BEEN 89% TECHNICALLY AVAILABLE. THE TECHNICAL CAPACITY NOT USED WAS 23%.THE UNAVAILABILITY IS MOSTLY DUE TO PLANNED MAINTENANCE IN APRIL, JUNE AND SEPTEMBER. THERE HAS NOT BEEN ANY SIGNIFICANT DISTURBANCES.

7.2.8 SKAGERRAK 3 HVDC LINK

Figure 7.12 presents the results of Skagerrak 3 in year 2012 according to Figure 7.1 in a monthly view, also with a separate annual perspective. Skagerrak 3 has been in operation since 1993. It is connected in Kristiansand, Norway, and in Tjele, Denmark. The transmission capacity is 500 MW.

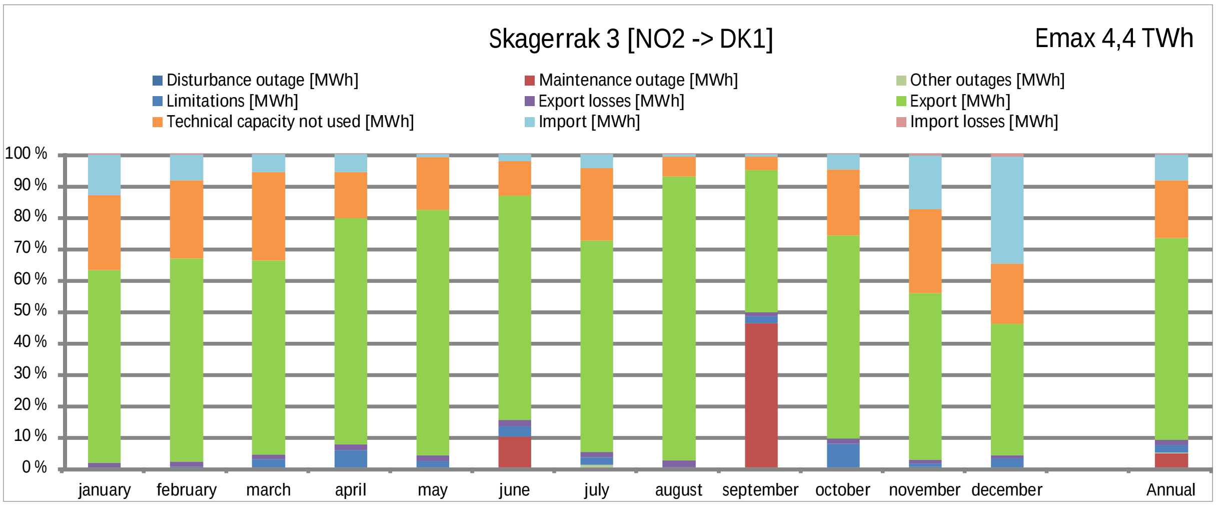

FIGURE 7.12 HVDC PRESENTATION OF SKAGERRAK 3 IN 2012. SKAGERRAK 3 HAS BEEN 93% TECHNICALLY AVAILABLE. THE TECHNICAL CAPACITY NOT USED WAS 18%. THE UNAVAILABILITY IS MOSTLY DUE TO PLANNED MAINTENANCE IN JUNE AND SEPTEMBER. THERE HAS NOT BEEN ANY SIGNIFICANT DISTURBANCES.

7.2.9 ESTLINK 1 HVDC LINK

Figure 7.13 presents the results of Estlink 1 in year 2012 according to Figure 7.1 in a monthly view, also with a separate annual perspective. Estlink 1 has been in operation since 2006 and is the first HVDC connection between Finland and Estonia. It's connected to Espoo in Finland in the FI price zone and Harku in Estonia in the EE price zone. The transmission capacity is 350 MW. Estlink 2 (650 MW) is planned to be in commercial use Q1/2014.

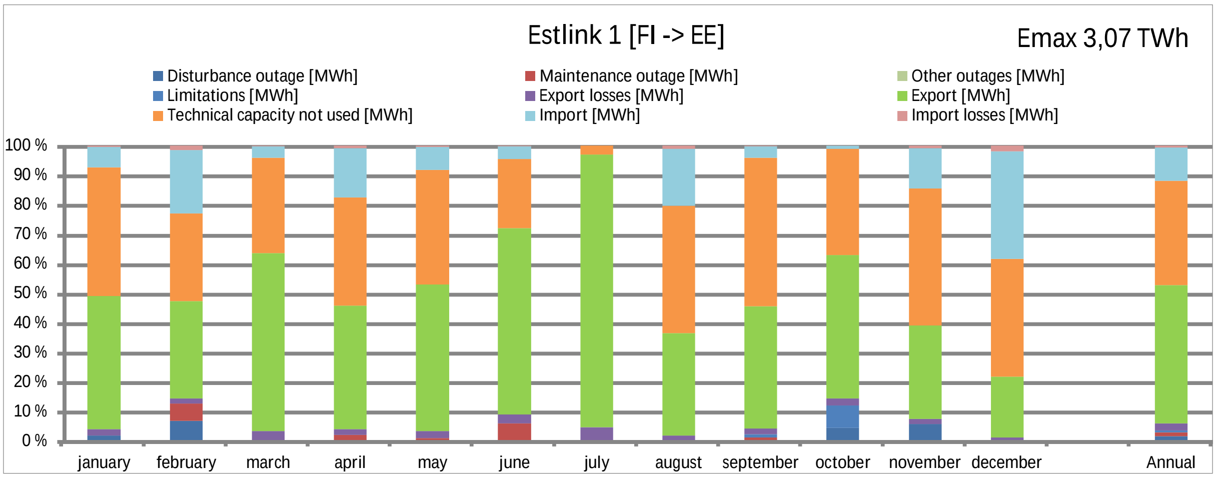

FIGURE 7.13 HVDC PRESENTATION OF ESTLINK 1 IN 2012. ESTLINK 1 HAS BEEN 96 % TECHNICALLY AVAILABLE. THE TECHNICAL CAPACITY NOT USED WAS 35 %. TRANSMISSION HAS MAINLY BEEN EXPORT TO ESTONIA (81 %). THERE WERE NOT ANY SIGNIFICANT DISTURBANCES, A COUPLE OF DUE TO CONVERTER COOLING SYSTEM FAULTS.

7.2.10 VYBORG LINK

Figure 7.14 presents the results of Vyborg link in year 2012 according to Figure 7.1 in a monthly view, also with a separate annual perspective. Vyborg link is a back-to-back HVDC connection between Finland and Russia. The HVDC substation is situated in Vyborg, Russia. 400 kV lines from Vyborg are connected to substations Yllikkälä and Kymi in Southern Finland. Commissioning years (350 MW / each) have been 1981, 1982, 1984 and 2000. The total technical capacity today is 4 x 350 MW and the commercial transmission capacity is 1,300 MW. Fingrid allocates 100 MW for reserves. The direction of transmission has until now been possible only to Finland but during September 2013 one 350 MW unit has successfully been tested to be able to export electricity to Russia.

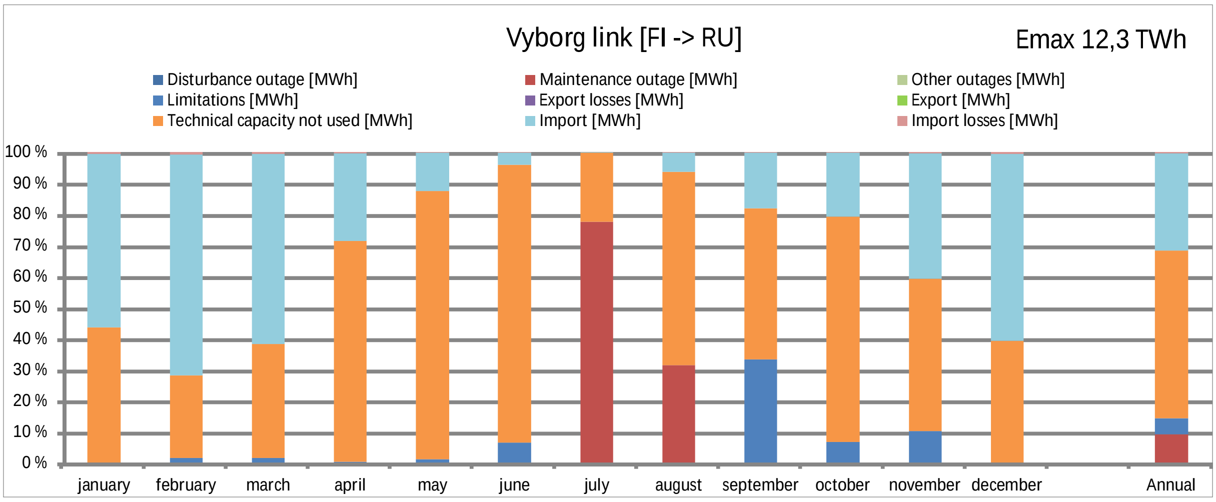

FIGURE 7.14 HVDC PRESENTATION OF VYBORG LINK IN 2012. VYBORG LINK HAS BEEN 86 % TECHNICALLY AVAILABLE. THE TECHNICAL CAPACITY NOT USED WAS 54 %. TRADITIONALLY, DURING THREE DECADES, FINLAND HAS IMPORTED ELECTRICITY FROM SOVIET UNION AND RUSSIA WITH ALMOST FULL AVAILABLE TECHNICAL CAPACITY. YEAR 2012 IMPORT TO FINLAND COLLAPSED BECAUSE RUSSIA HAD STARTED TO USE THE CAPACITY FEE DURING WORKDAYS YEAR 2011. THE LINK'S YEARLY MAINTENANCE WAS 7.7.-10.8.2012. THERE HAVE NOT BEEN ANY DISTURBANCES DURING 2012.

7.2.11 FENNO-SKAN 1 HVDC LINK

Figure 7.15 presents the results of Fenno-Skan 1 in year 2012 according to Figure 7.1 in a monthly view, also with a separate annual perspective. Fenno-Skan 1 has been in operation since 1989 is the first HVDC connection between Finland and Sweden. Fenno-Skan 1 is connected from Rauma in Finland in the FI price zone to Dannebo in Sweden in the SE3 price zone. The transmission capacity is 500 MW during summer and 550 MW during winter.

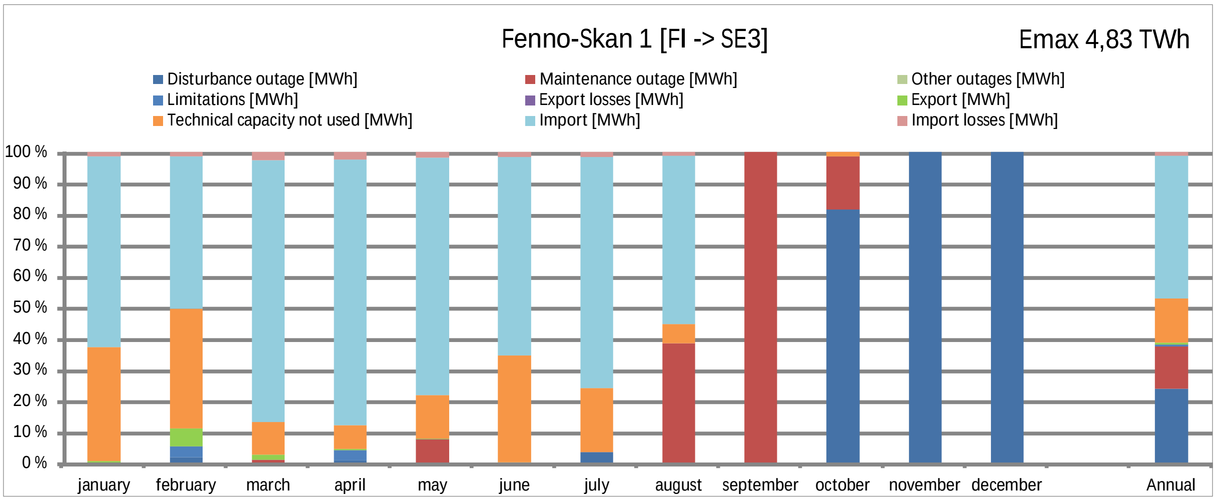

FIGURE 7.15 HVDC PRESENTATION OF FENNO-SKAN 1 IN 2012. FENNO-SKAN 1 HAS BEEN 62 % TECHNICALLY AVAILABLE. THE TECHNICAL CAPACITY NOT USED WAS 14 %. TRANSMISSION HAS ALMOST TOTALLY BEEN IMPORT TO FINLAND (99 %). DURING 2012 THERE WAS A MAINTENANCE OUTAGE FOR 6 WEEKS (21.8 – 2.10.2012) WHILE INSTALLING A NEW CONTROL

SYSTEM. WHEN BACK IN OPERATION THERE WAS A FIRE IN THE THYRISTOR HALL CAUSING ANOTHER OUTAGE FOR 12 WEEKS (6.10 – 31.12.2012).

7.2.12 FENNO-SKAN 2 HVDC LINK

Figure 7.16 presents the results of Fenno-Skan 2 in year 2012 according to Figure 7.1 in a monthly view, also with a separate annual perspective. Fenno-Skan 2 has been in operation since 2011 and is the second HVDC connection between Finland and Sweden. Fenno-Skan 2 is connected from Rauma in Finland in the FI price zone to Finnböle in Sweden (about 100 km from the Swedish coast line) in the SE3 price zone. The transmission capacity is 800 MW.

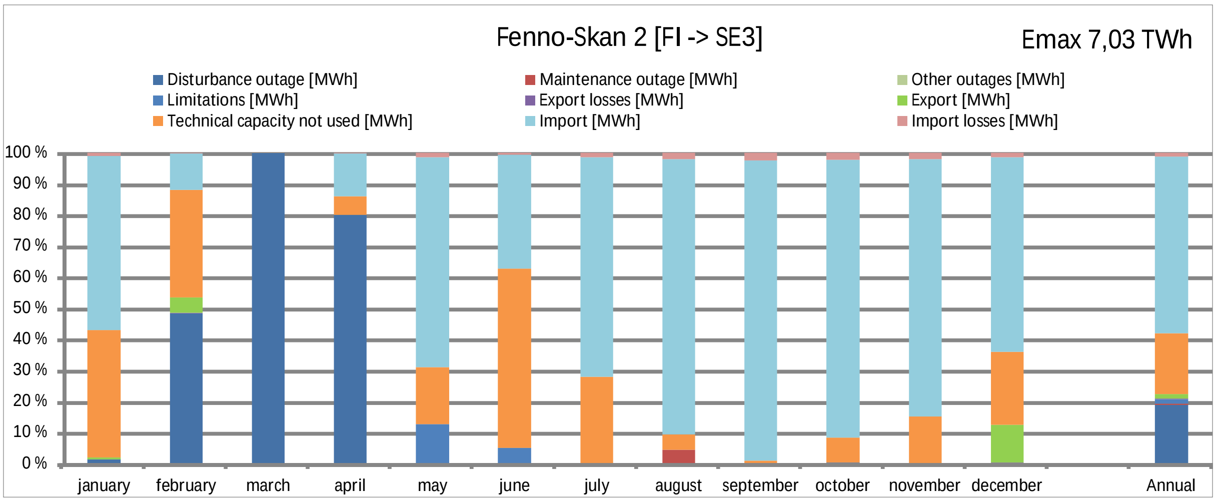

FIGURE 7.16 HVDC PRESENTATION OF FENNO-SKAN 2 IN 2012. FENNO-SKAN 2 HAS BEEN 79 % TECHNICALLY AVAILABLE. THE TECHNICAL CAPACITY NOT USED WAS 20 %. TRANSMISSION HAS ALMOST TOTALLY BEEN IMPORT TO FINLAND (97 %). DURING 2012 THERE WAS A SEA CABLE FAULT DUE TO A SHIP ANCHOR. THE OUTAGE LASTED ALMOST 10 WEEKS (17.2 – 25.4.2012).

7.2.13 STOREBAELT HVDC LINK

Figure 7.17 presents the results of Storebaelt in year 2012 according to Figure 7.1 in a monthly view, also with a separate annual perspective. Storebaelt has been in operation since 2010. It is connected at Fraugde on Funen in the DK1 price zone and at Herslev on Sealand in the DK2 price zone. The transmission capacity is 600 MW.

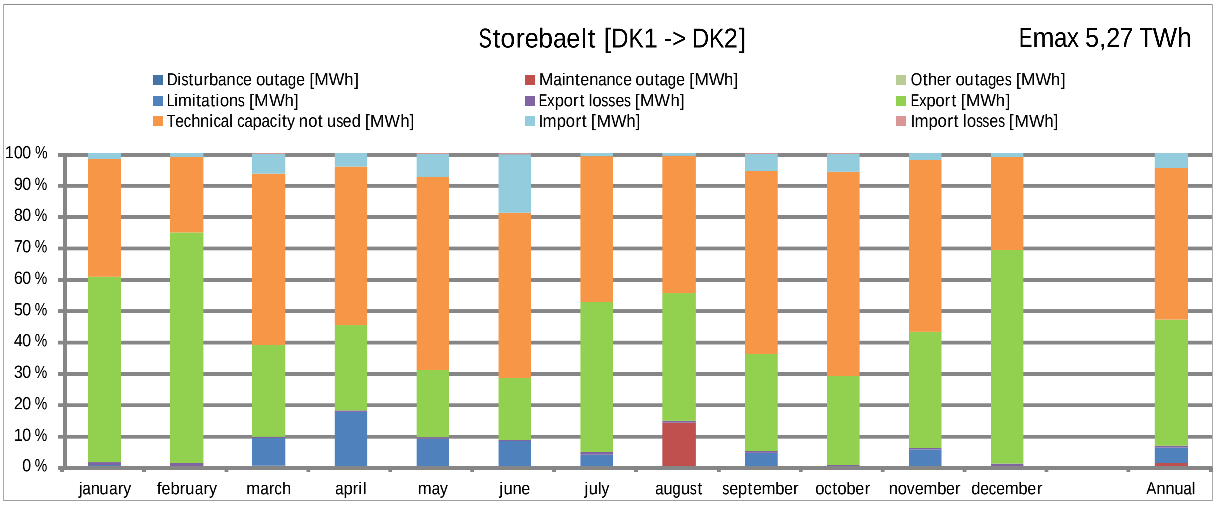

FIGURE 7.17 HVDC PRESENTATION OF STOREBAELT IN 2012. STOREBAELT HAS BEEN 94% TECHNICALLY AVAILABLE. THE TECHNICAL CAPACITY NOT USED WAS 48%. THE REASON SEEMS TO BE STABLE PRICE DIFFERENCES AND DUE TO THE FACT THAT THE LINK IS WIDELY USED FOR BALANCING POWER TRADE BETWEEN DK1 AND DK2. THE UNAVAILABILITY IS MAINLY DUE TO PLANNED MAINTENANCE IN AUGUST AND A SIGNIFICANT AMOUNT OF LIMITATIONS IN THE PERIOD MARCH – JUNE DUE TO WORK ON AC SUBSTATIONS AND LINES IN BOTH DK1 AND DK2. THERE WERE NOT ANY SIGNIFICANT DISTURBANCES IN 2012.

7.2.14 KONTEK HVDC LINK

Figure 7.17 presents the results of Kontek in year 2012 according to Figure 7.1 in a monthly view, also with a separate annual perspective. Kontek has been in operation since 1986. It is connected at Bjaeverskov, Denmark, and at Bentwisch, Germany. The transmission capacity is 600 MW.

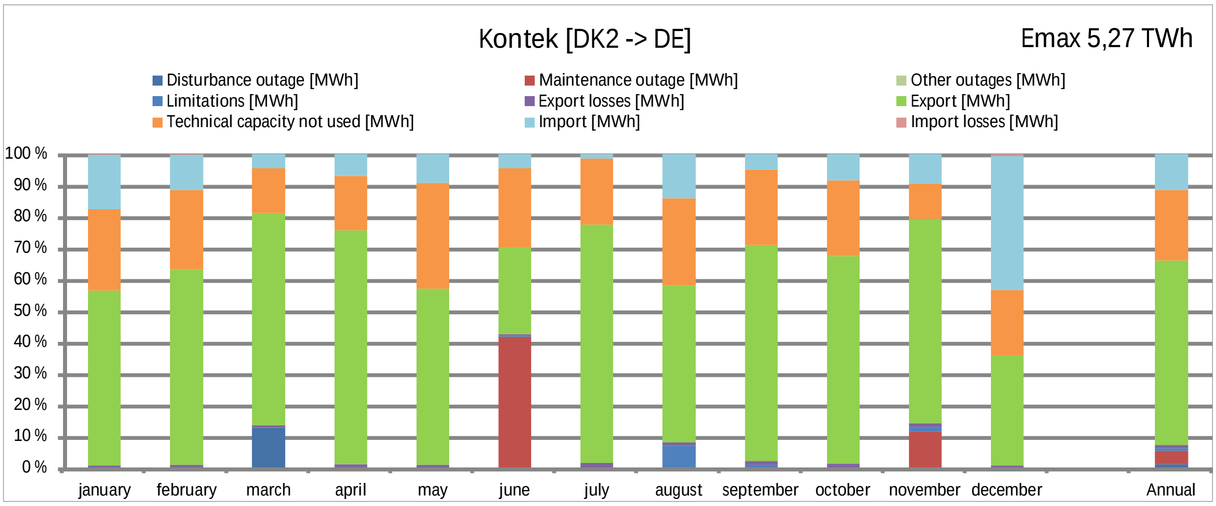

FIGURE 7.17 HVDC PRESENTATION OF KONTEK IN 2012. KONTEK HAS BEEN 94% TECHNICALLY AVAILABLE. THE TECHNICAL CAPACITY NOT USED WAS 23%. THE UNAVAILABILITY IS MAINLY DUE TO PLANNED MAINTENANCE IN JUNE AND NOVEMBER. THERE WERE NOT ANY SIGNIFICANT DISTURBANCES IN 2012.

8 REFERENCES

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3. **The Energy Concern's National League, The Norwegian Water Supply and Energy Department, Statnett and Sintef Energy Research.** Definisjoner knyttet til feil og avbrudd i det elektriske kraftsystemet – Versjon 2 (In English: Definitions in relation to faults and outages in the electrical power system – Version 2). [Online] 2001. http://www.sintef.no/Projectweb/KILE/Definisjoner-feil-og-avbrudd/

4. **IEC 50(191-05-01).** International Electrotechnical Vocabulary, Dependability and Quality of Service. 50(191-05-01)

5. **IEEE.** Standard Terms for Reporting and Analyzing Outage Occurrence and Outage States of Electrical Transmission Facilities. IEEE Std 859-1987. IEEE Std 859-1987

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Appendix 1: The calculation of energy not supplied

Energy not supplied (ENS) is calculated in various ways in different countries.

In Denmark, the ENS of the transmission grid is calculated as the transformer load just before the grid disturbance or interruption multiplied by the outage duration. Transformer load covers load/consumption and generation at lower/medium voltage.

In Finland, the ENS in the transmission grid is counted for those faults that caused outage at the point of supply. The point of supply means the high voltage side of the transformer. ENS is calculated individually for all points of supply and is linked to the fault that caused the outage. ENS is counted by multiplying the outage duration and the power before the fault. Outage duration is the time that the point of supply is dead or the time until the delivery of power to the customer can be arranged via another grid connection.

In Iceland, ENS is computed according to the delivery from the transmission grid. ENS is calculated at the points of supply in the 220 kV or 132 kV systems. ENS is linked to the fault that caused the outage. In the data of the ENTSO-E Nordic statistics, ENS that was caused by the generation or distribution systems has been left out. In the distribution systems, the outages in the transmission and distribution systems that affect the end user and ENS are also registered. Common rules for registration of faults and ENS in all grids are used in Iceland.

In Norway, ENS is referred to the end user. ENS is calculated at the point of supply that is located on the low voltage side of the distribution transformer (1 kV) or in some other location where the end user is directly connected. All ENS is linked to the fault that caused the outage. ENS is calculated according to a standardized method that has been established by the authority.

In Sweden, the ENS of the transmission grid is calculated by using the outage duration and the cut-off power that was detected at the instant when the outage occurred. Because the cut-off effect is often not registered, some companies use the rated power of the point of supply multiplied by the outage duration.

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Appendix 2: Policies for examining the cause for line faults

In Denmark the quality of data from disturbance recorders and other information that has been gathered is not always good enough to pinpoint the cause of the disturbance. In this case it leads to a cause stated as unknown. This is mainly the case on the sub-transmission level as Energinet.dk does not have full access to disturbance recorders and event lists due to the fact that Energinet.dk does not fully own the 132 kV network. It is also a fact that not all line faults are inspected which also in turns could lead to a cause stated as unknown.

In Finland Fingrid has changed the classification policy of faults in July 2011. More effort is put to clarify causes. Even if the cause is not 100 % certain but if the expert opinion is that the cause was lightning, the reported cause will be lightning. Therefore the number of unknown faults has decreased.

In Iceland disturbances in Landsnet‘s transmission system are classified into two categories; sudden disturbances in transmission network and sudden disturbances in other systems. Every month the listings for interference are analyzed by the staff of system operation and corrections made to the data if needed. In 2013, Landsnet started to hold meetings three times a year, with representatives from Asset management and maintenance department to review the registration of interference and corrections made if the cause other than originally reported. This also leads to better understanding for these parties to understand how disturbances are listed in the disturbance database.

In Norway primarily for the DISTAC HVAC statistics the reporting TSO's need to distinguish between 6 fault categories + unknown. Norway has at least single sided distance to fault on most lines on this reporting level and we also inspect all line faults. The fault categories: External influence (people), Operation and maintenance (people), Technical equipment and other, will normally be detected during the disturbance and the post-inspection of the line. So the two categories remaining are the environmental ones (lightning and other environmental). To distinguish between those Statnett uses waveform analysis on fault records, the lightning detection system and weather information to sort out the lightning. If the weather is good and no other categories fits, Statnett's sets unknown. The unknown factor for Statnett is about 10 %.

In Sweden, many cases data from disturbance recorders and other information that has been gathered is not enough to pinpoint the cause of the disturbance. At SvK one does not have full access to raw data from the lightning detection system and if a successful reclosing has taken place we prefer to declare the cause unknown instead of lightning (which may be the most probable cause).

Appendix 3: Division of the annual Emax for each HVDC category in a monthly view

Table 7.3-7.16 represents the numerical values of the annual Emax for each category separately in a monthly view.

TABLE 7.3 MONTHLY DIVISION OF EMAX IN KONTI-SKAN 1 HVDC LINK IN YEAR 2012

Konti-Skan 1 [SE3 -> DK1]	january	february	march	april	may	june	july	august	september	october	november	december	
Disturbance outage [MWh]	26455	0	3953	8313	333	0	123	0	0	0	0	64108	103285
Maintenance outage [MWh]	3700	0	0	0	93604	0	0	0	0	0	0	0	97304
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0
Limitations [MWh]	40	0	0	0	0	1800	7400	0	1160	0	0	0	10400
Export losses [MWh]	834	1162	2903	2991	2642	3309	4678	4221	3337	3310	2598	543	32528
Export [MWh]	28521	37473	137955	141037	124109	166247	210971	196776	148684	151336	120885	15619	1479613
Technical capacity not used [MWh]	142602	133058	105470	104638	54695	87205	51982	69326	92747	110035	122834	114413	1189004
Import [MWh]	74052	83593	24466	9576	290	7847	2441	4820	19943	10283	19564	78801	335678
Import losses [MWh]	2419	2761	830	466	91	286	134	154	717	452	751	2510	11571
Emax (370MW)	278622	258047	275578	267021	275764	266695	277729	275297	266587	275416	266633	275994	3259383

TABLE 7.4 MONTHLY DIVISION OF EMAX IN KONTI-SKAN 2 HVDC LINK IN YEAR 2012

Konti-Skan 2 [SE3 -> DK1]	january	february	march	april	may	june	july	august	september	october	november	december	
Disturbance outage [MWh]	5040	0	748	1555	364	752	2121	0	0	0	0	0	10580
Maintenance outage [MWh]	700	0	0	0	93604	0	0	0	0	0	0	0	94304
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0
Limitations [MWh]	20	0	0	0	0	1680	9990	0	1210	0	0	0	12900
Export losses [MWh]	765	892	3625	3805	3243	4263	5908	5326	3738	3593	3104	957	39218
Export [MWh]	30111	34116	137335	144612	119183	163082	205811	193139	135776	122224	117469	34787	1437646
Technical capacity not used [MWh]	155313	139201	109924	107765	58734	91532	51685	72551	105920	140075	127554	107540	1267793
Import [MWh]	81496	81351	23183	8505	450	5758	2176	4141	19203	8793	17767	128981	381804
Import losses [MWh]	2196	2156	586	228	52	211	134	152	632	722	589	3652	11309
Emax (370MW)	275640	257717	275401	266470	275630	267278	277826	275309	266478	275407	266482	275917	3255553

TABLE 7.5 MONTHLY DIVISION OF EMAX IN SWEPOL HVDC LINK IN YEAR 2012

SwePol [SE4 -> PL]	january	february	march	april	may	june	july	august	september	october	november	december	
Disturbance outage [MWh]	0	750	0	0	5674	0	1657	1312	0	3629	0	0	13022
Maintenance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0
Limitations [MWh]	0	0	0	0	0	0	0	0	0	0	677	0	677
Export losses [MWh]	6349	5133	8456	6500	7207	5219	7556	6113	6403	7981	7525	2935	77378
Export [MWh]	226920	187237	292198	232971	248790	186829	259164	212933	220416	257424	234371	113612	2672865
Technical capacity not used [MWh]	194381	219345	148059	189006	190882	239072	183107	229758	209685	168914	176506	274810	2423525
Import [MWh]	23052	8479	4467	7120	629	3678	117	290	0	11088	15164	55144	129228
Import losses [MWh]	526	237	183	229	123	184	118	140	95	320	436	1162	3754
Emax (600MW)	451227	421182	453362	435827	453305	434982	451720	450546	436598	449356	434678	447663	5320448

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TABLE 7.6 MONTHLY DIVISION OF EMAX IN BALTIC CABLE HVDC LINK IN YEAR 2012

Baltic Cable [SE4 -> DE]	january	february	march	april	may	june	july	august	september	october	november	december	
Disturbance outage [MWh]	0	0	0	5960	0	0	4210	281800	383400	0	377990	111660	1165020
Maintenance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0
Limitations [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0
Export losses [MWh]	6324	6109	8844	8310	7554	7484	9575	3403	653	5364	403	1933	65954
Export [MWh]	277118	267684	386057	363398	339834	330068	415716	149468	26751	231722	11855	78620	2878291
Technical capacity not used [MWh]	121961	87631	50294	51077	88458	84679	24858	14508	11079	197724	34281	189392	955943
Import [MWh]	45560	61271	9637	11910	16688	15825	1277	288	10586	14451	8002	65032	260527
Import losses [MWh]	893	1305	207	243	353	336	40	18	247	373	257	1168	5440
Emax (600MW)	451856	423999	455038	440898	452887	438392	455677	449485	432717	449635	432788	447804	5331175

TABLE 7.7 MONTHLY DIVISION OF EMAX IN NORNED HVDC LINK IN YEAR 2012

NorNed [NO2 -> NL]	january	february	march	april	may	june	july	august	september	october	november	december	
Disturbance outage [MWh]	0	8675	0	0	9247	0	0	0	0	6461	0	0	24383
Maintenance outage [MWh]	0	0	0	0	0	9490	0	0	178120	0	0	0	187610
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0
Limitations [MWh]	0	0	0	0	0	0	0	0	0	0	0	4960	4960
Export losses [MWh]	18370	18460	20219	19274	19574	19113	20988	21054	13228	20041	18837	16300	225458
Export [MWh]	458535	462194	510125	484407	490715	480110	522610	522431	326621	497522	472457	417948	5645675
Technical capacity not used [MWh]	35119	19327	11343	16918	23651	16846	1476	354	6494	19048	27044	64170	241790
Import [MWh]	30464	48	1761	5110	332	1227	0	0	2357	1843	7725	39151	90018
Import losses [MWh]	1130	5	66	179	19	47	0	0	89	55	276	1499	3365
Emax (730MW)	543618	508708	543515	525889	543539	526833	545074	543839	526908	544970	526339	544027	6423259

TABLE 7.8 MONTHLY DIVISION OF EMAX IN SKAGERRAK 1 HVDC LINK IN YEAR 2012

Skagerrak 1 [NO2 -> DK1]	january	february	march	april	may	june	july	august	september	october	november	december	
Disturbance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	5083	5083
Maintenance outage [MWh]	0	0	0	21000	0	65496	0	0	81750	0	0	850	169096
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0
Limitations [MWh]	0	0	5332	16048	7478	5760	5084	0	8200	28700	3800	11000	91402
Export losses [MWh]	5566	5177	5570	5269	7572	5008	6079	8745	3986	4913	4511	3018	65414
Export [MWh]	102234	97434	101505	98496	132076	88747	110505	152172	73135	98834	84610	60656	1200401
Technical capacity not used [MWh]	56155	58684	64752	31009	37740	12667	58149	23968	11758	46461	58708	44463	504514
Import [MWh]	21061	12152	8738	8769	1162	3050	6123	1079	1427	7013	27918	58052	156543
Import losses [MWh]	1114	605	432	454	59	152	252	42	93	326	1521	3230	8281
Emax (250MW)	186129	174051	186330	181045	186087	180880	186192	186005	180350	186245	181068	186353	2200734

TABLE 7.9 MONTHLY DIVISION OF EMAX IN SKAGERRAK 2 HVDC LINK IN YEAR 2012

Skagerrak 2 [NO2 -> DK1]	january	february	march	april	may	june	july	august	september	october	november	december	
Disturbance outage [MWh]	0	0	0	0	0	992	0	0	0	0	0	0	992
Maintenance outage [MWh]	0	0	0	20750	0	46250	0	0	81750	0	0	0	148750
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0
Limitations [MWh]	0	0	5269	20248	7478	5760	5022	0	8200	28700	3800	11000	95477
Export losses [MWh]	5568	5180	5551	5032	7560	5719	6063	8697	3966	4881	4376	3280	65873
Export [MWh]	102445	97812	101669	97541	132351	102851	110694	152248	73162	99004	82533	66036	1218346
Technical capacity not used [MWh]	55858	58249	64626	29101	37454	19568	57997	23929	11750	46281	60105	44289	509206
Import [MWh]	21184	12216	8786	8813	1177	1633	6170	1089	1431	7064	28047	58769	156378
Import losses [MWh]	1121	608	435	460	59	81	254	42	93	327	1528	3257	8264
Emax (250MW)	186176	174064	186335	181944	186079	182854	186200	186006	180352	186258	180389	186630	2203286

TABLE 7.10 MONTHLY DIVISION OF EMAX IN SKAGERRAK 3 HVDC LINK IN YEAR 2012

Skagerrak 3 [NO2 -> DK1]	january	february	march	april	may	june	july	august	september	october	november	december	
Disturbance outage [MWh]	133	1025	0	0	0	358	0	0	0	0	617	0	2133
Maintenance outage [MWh]	0	0	0	0	0	35434	0	0	166125	0	0	0	201559
Other outages [MWh]	0	0	0	0	0	0	3200	0	0	0	0	0	3200
Limitations [MWh]	0	0	9998	20198	7478	11700	9375	0	8200	28700	3800	11000	110449
Export losses [MWh]	5474	5433	5637	6626	7282	7003	6248	8679	4060	5810	4593	3649	70494
Export [MWh]	228715	225555	230883	260073	290740	258362	251331	336412	163925	241904	192395	155731	2836024
Technical capacity not used [MWh]	88668	86427	104699	53455	62313	40113	86022	24013	15271	78653	96175	71519	807325
Import [MWh]	48021	28946	21304	20532	4421	8200	16615	3122	3119	18298	62551	127140	362270
Import losses [MWh]	1262	739	559	542	126	227	413	75	103	475	1645	3356	9523
Emax (500MW)	372272	348124	373080	361426	372360	361397	373205	372300	360803	373841	361775	372394	4402976

TABLE 7.11 MONTHLY DIVISION OF EMAX IN ESTLINK 1 HVDC LINK IN YEAR 2012

Estlink 1 [FI -> EE]	january	february	march	april	may	june	july	august	september	october	november	december	
Disturbance outage [MWh]	4480	16803	0	0	0	0	0	0	0	11533	14712	0	47528
Maintenance outage [MWh]	0	14000	0	4900	2100	15050	0	0	2800	0	0	0	38850
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0
Limitations [MWh]	0	0	0	0	0	0	0	0	2450	20650	0	0	23100
Export losses [MWh]	6012	4665	8402	5245	6510	7585	11693	4577	5235	6448	4288	2890	73552
Export [MWh]	118208	81045	159047	105668	129780	158935	241174	90070	104206	130051	82626	53844	1454653
Technical capacity not used [MWh]	114291	73170	85128	92715	101238	58879	7899	112897	126567	96612	120466	104979	1094841
Import [MWh]	18292	52925	10208	41930	20139	11117	0	49996	10050	2639	35573	95266	348134
Import losses [MWh]	1559	4105	1069	2581	1628	717	0	3031	782	380	2395	5372	23620
Emax (350MW)	262842	246712	263854	253039	261395	252283	260767	260571	252090	268314	260060	262350	3104277

TABLE 7.12 ANNUAL DIVISION OF EMAX IN VYBORG LINK IN YEAR 2012

Vyborg link [FI -> RU]	january	february	march	april	may	june	july	august	september	october	november	december	
Disturbance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0
Maintenance outage [MWh]	0	0	0	0	0	0	809200	327600	0	0	0	0	1136800
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0
Limitations [MWh]	0	16652	18040	4950	12595	66930	0	0	336000	71500	104000	0	630667
Export losses [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0
Export [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0
Technical capacity not used [MWh]	454704	259150	382283	715320	899148	901192	231088	647581	490133	755018	496434	410501	6642552
Import [MWh]	581085	695354	638507	284881	128571	39483	1309	65761	180238	212952	406424	625044	3859608
Import losses [MWh]	5811	6954	6385	2849	1286	395	13	658	1802	2130	4064	6250	38596
Emax (1400MW)	1041600	978110	1045215	1008000	1041600	1008000	1041609	1041600	1008173	1041600	1010921	1041795	12308224

TABLE 7.13 MONTHLY DIVISION OF EMAX IN FENNO-SKAN 1 HVDC LINK IN YEAR 2012

Fenno-Skan 1 [FI -> SE3]	january	february	march	april	may	june	july	august	september	october	november	december	
Disturbance outage [MWh]	0	7122	0	3437	0	0	13768	0	0	333456	396000	409200	1162983
Maintenance outage [MWh]	0	0	3997	0	31396	0	0	158400	396000	69850	0	0	659643
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0
Limitations [MWh]	0	13182	0	13182	0	0	0	0	0	0	0	0	26364
Export losses [MWh]	49	399	142	47	2	18	0	0	0	0	0	0	657
Export [MWh]	2398	21865	6918	1949	1	445	0	0	0	0	0	0	33576
Technical capacity not used [MWh]	150470	150100	42855	31154	57542	136204	84951	25234	0	5893	0	0	684402
Import [MWh]	251657	190519	349453	351400	313580	253778	303801	222781	0	0	0	0	2236969
Import losses [MWh]	5822	5423	10576	10335	7848	6339	7046	5260	0	0	0	0	58648
Emax (550MW)	410396	388608	413941	411504	410368	396784	409566	411674	396000	409200	396000	409200	4863241

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TABLE 7.14 MONTHLY DIVISION OF EMAX IN FENNO-SKAN 2 HVDC LINK IN YEAR 2012

Fenno-Skan 2 [FI -> SE3]	january	february	march	april	may	june	july	august	september	october	november	december	
Disturbance outage [MWh]	7960	269356	595200	461240	0	0	0	0	0	1347	0	0	1335103
Maintenance outage [MWh]	0	0	0	0	0	0	0	25920	0	0	0	0	25920
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0
Limitations [MWh]	0	0	0	0	75598	28797	0	0	0	0	0	0	104395
Export losses [MWh]	70	473	1	0	0	7	0	0	0	0	0	1691	2242
Export [MWh]	3858	27545	1	0	0	459	0	0	0	0	0	72300	104163
Technical capacity not used [MWh]	243207	193229	2	34529	110179	331633	166001	29762	4555	47831	87969	142379	1391277
Import [MWh]	334186	65641	0	79846	407569	211723	421041	535683	559938	534425	484205	375826	4010083
Import losses [MWh]	6367	1249	1	1574	8589	3619	8467	13486	15279	14110	12454	9341	94537
Emax (800MW)	595647	557494	595205	577191	601936	576238	595509	604851	579773	597713	584628	601536	7067721

TABLE 7.15 MONTHLY DIVISION OF EMAX IN STOREBAELT HVDC LINK IN YEAR 2012

Storebaelt [DK1 -> DK2]	january	february	march	april	may	june	july	august	september	october	november	december	
Disturbance outage [MWh]	0	0	1980	0	0	0	0	0	0	0	0	0	1980
Maintenance outage [MWh]	0	0	0	0	0	0	0	62850	0	0	0	0	62850
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0
Limitations [MWh]	2400	0	39000	75600	40200	35340	17100	0	19500	0	23400	0	252540
Export losses [MWh]	4036	4590	2110	1943	1588	1387	3222	2839	2142	2076	2487	4650	33069
Export [MWh]	264647	307468	130404	117362	95946	85445	214257	180968	134723	126889	161250	304377	2123737
Technical capacity not used [MWh]	168035	100672	244620	218846	275498	228022	207984	196857	253848	291065	238422	132388	2556255
Import [MWh]	8298	5078	28657	18315	32712	80662	4049	3097	24223	25774	9705	5129	245700
Import losses [MWh]	197	117	624	420	778	1590	123	99	555	621	264	131	5519
Emax (600MW)	447612	417924	447396	432486	446722	432446	446735	446711	434991	446425	435528	446675	5281651

TABLE 7.16 MONTHLY DIVISION OF EMAX IN KONTEK HVDC LINK IN YEAR 2012

Kontek [DK2 -> DE]	january	february	march	april	may	june	july	august	september	october	november	december	
Disturbance outage [MWh]	0	0	56840	0	0	0	0	0	0	0	0	0	56840
Maintenance outage [MWh]	0	0	0	0	0	180600	0	0	0	0	49800	0	230400
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0
Limitations [MWh]	0	0	0	0	0	1800	0	31200	3600	300	6000	0	42900
Export losses [MWh]	3138	3315	4019	4533	4015	1911	6425	4308	5504	5143	5169	2799	50278
Export [MWh]	248547	260697	301861	322021	250720	118446	339001	223168	296877	295157	282529	156721	3095744
Technical capacity not used [MWh]	115692	105740	63623	74891	149947	110124	93786	123999	104587	108360	48685	93669	1193101
Import [MWh]	77424	46890	20318	30001	41002	19295	7135	62963	21114	36759	40094	189983	592978
Import losses [MWh]	1600	958	426	554	717	323	54	796	322	683	654	3234	10322
Emax (600MW)	446401	417601	447087	432001	446401	432497	446400	446434	432003	446402	432929	446406	5272562

Appendix 4: Incident classification scale (ICS) reporting to ENTSO-E during 2012

Nordic synchronous area recorded 21 incidents which belong to scale 1. All incidents are “final tripping of equipment”. Reports were delivered from Denmark, Sweden and Finland. No data from Norway was available.

In 86%, the final tripping of equipment led to a reduction of exchange capacity. The major part of the 21 events comes from problems with the HVDC-interconnection Fenno-Skan 1 (between Finland and Sweden) which existed through the whole winter period. This restricted import from Sweden to Finland, but did not endanger the system adequacy. A cable fault on one of the interconnectors between Sweden and East Denmark also reduced the capacity between the two countries.

During the first half of December - which was colder than normal - some parts of the Peak Load Reserve in Sweden were activated to maintain a sufficient margin between demand and production."

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Appendix 5: Nordic grid map showing the locations of the HVDC links

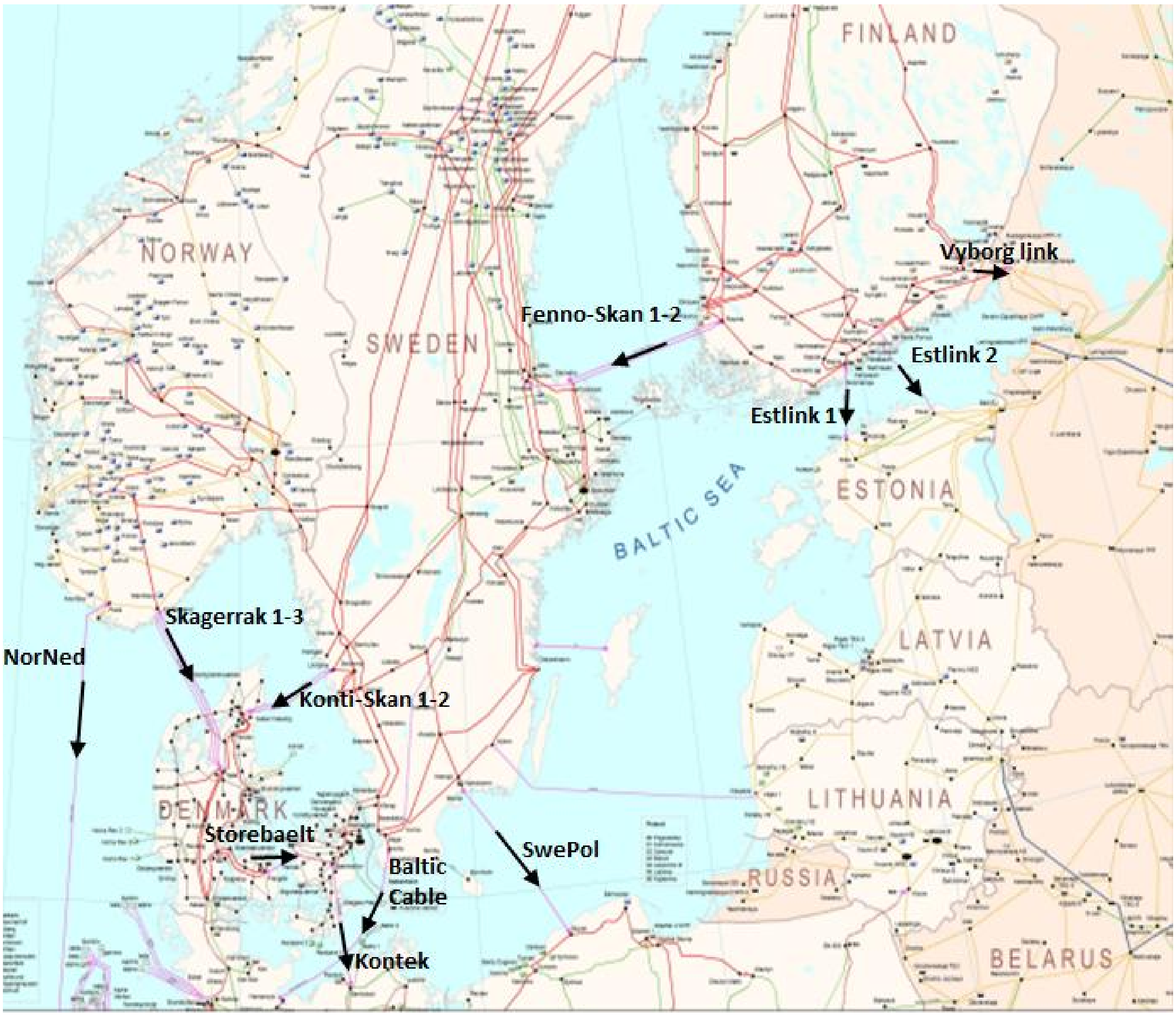

FIGURE 7.19 PART OF THE NORDIC GRID MAP SHOWING THE HVDC LINKS. THE ARROW INDICATES THE DIRECTION OF EXPORT.

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Appendix 6: Single-line diagrams of the HVDC links

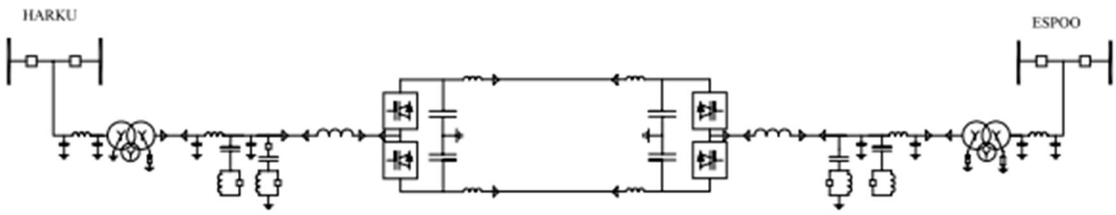

FIGURE 7.20 ESTLINK 1 SINGLE-LINE DIAGRAM.

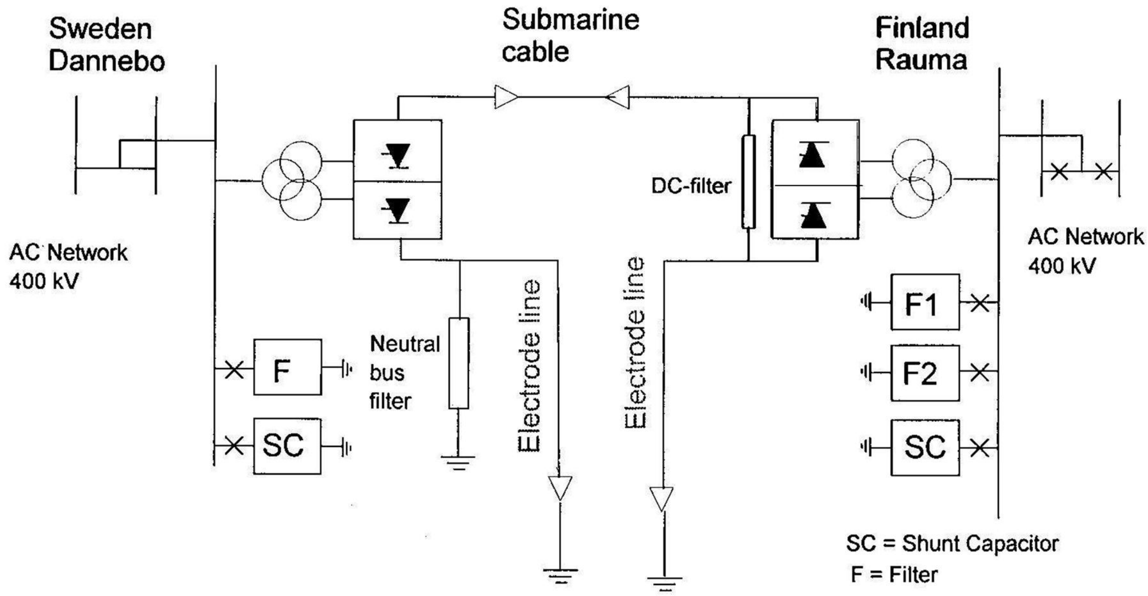

FIGURE 7.21 FENNO-SKAN 1 SINGLE-LINE DIAGRAM.

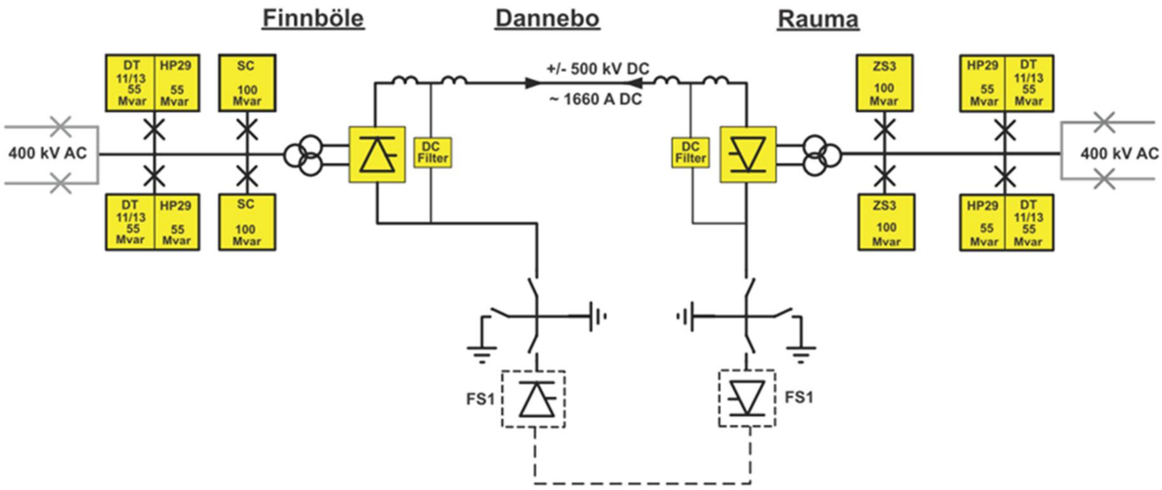

FIGURE 7.22 FENNO-SKAN 2 SINGLE-LINE DIAGRAM.

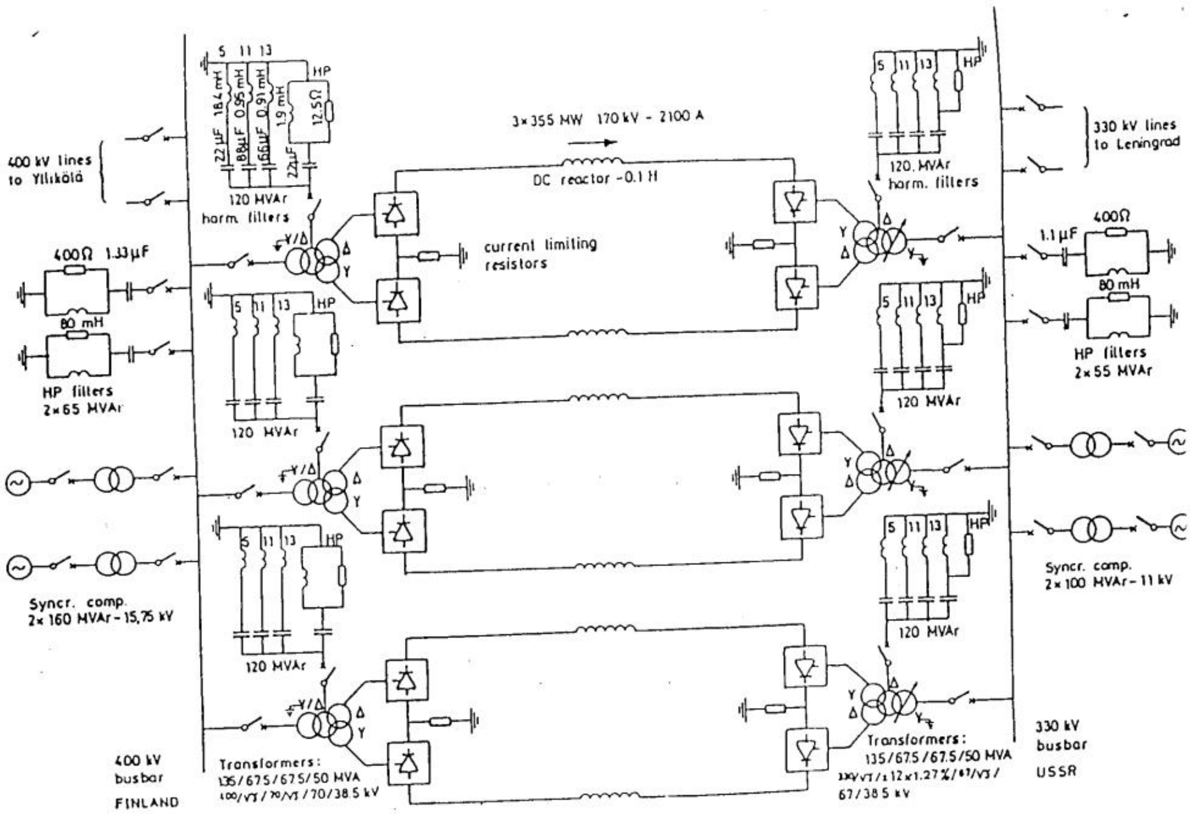

FIGURE 7.23 VYBORG LINK SINGLE-LINE DIAGRAM YEAR 1984. TODAY THE LINK HAS THE CAPACITY 4 X 350 MW.

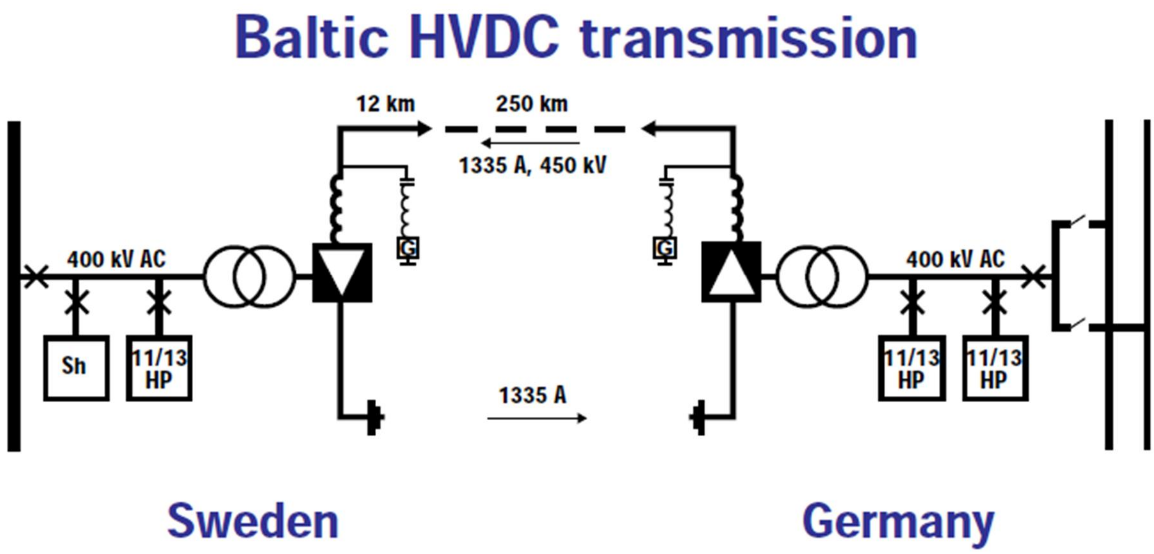

FIGURE 7.24 BALTIC CABLE SINGLE-LINE DIAGRAM.

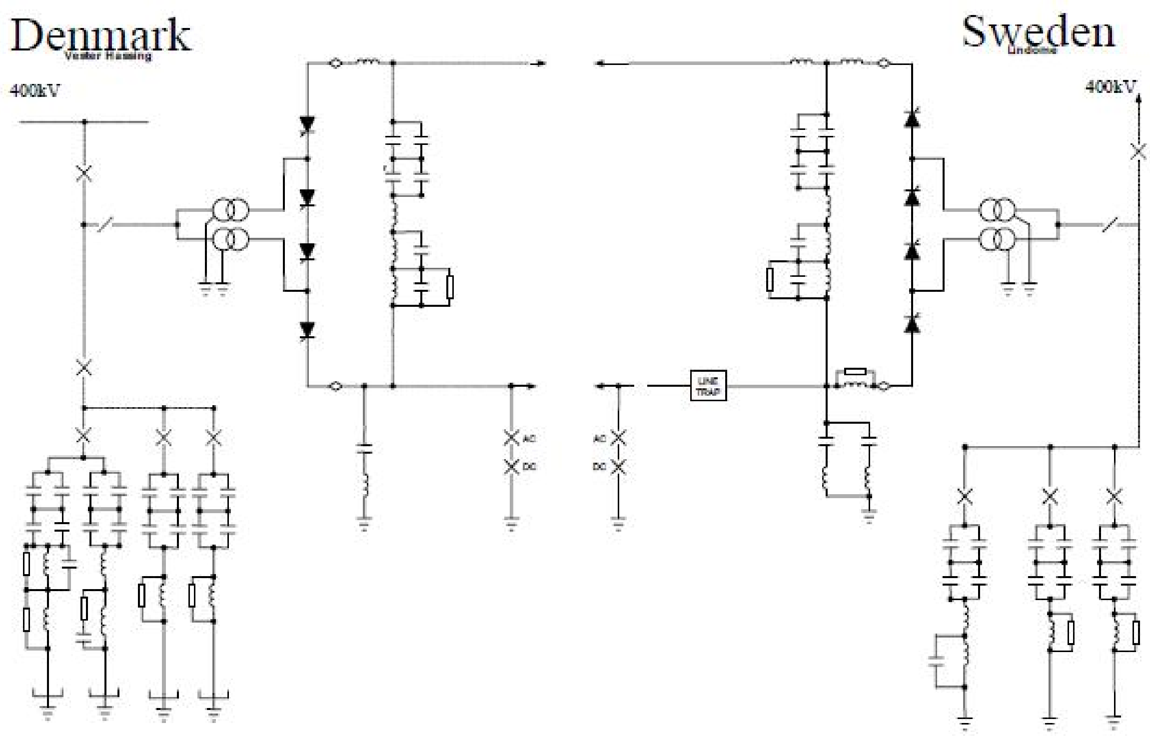

FIGURE 7.25 KONTI-SKAN 1 SINGLE-LINE DIAGRAM.

Appendix 7: Contact persons in the Nordic countries

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Appendix 8: Contact persons for the distribution network statistics

ENTSO-E Regional Group Nordic provides no statistics for distribution networks (voltage <100 kV). However, there are more or less developed national statistics for these voltage levels.

More detailed information regarding these statistics can be obtained from the representatives of the Nordic countries which are listed below:

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