European Network of
Transmission System Operators
for Electricity

NORDIC GRID DISTURBANCE STATISTICS 2013

06.11.2014

REGIONAL GROUP NORDIC

1 INTRODUCTION

This report is an overview of the Danish, Finnish, Icelandic, Norwegian and Swedish transmission grid disturbance statistics for the year 2013. 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. From now on the HVDC statistics will be published by ENTSO-E in a separate report.

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 2004–2013. 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 2013.

[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 2013 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.

There are no common Nordic disturbance statistics for voltage levels lower than 100 kV. However, Appendix 5 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 4.

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

FIGURE 1.3.1 THE NORDIC MAIN GRID [2]

TABLE 1.3.1 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**	-	-	-	-	-	-	300	90	-	-
220–300	**220**	220	100	220	100	220	100	220	10	220	100
110–150	**132**	150	62	110	100	132	100	132	98	130	100
110–150	**132**	132	38	-	-	-	-	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 tables in this report use the 132, 220 and 400 kV values to represent the nominal voltages, in accordance with Table 1.3.1.

1.4 SCOPE AND LIMITATIONS OF THE STATISTICS

Table 1.4.1 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.

The data, which the Transmission System Operators collect from the grid owners, is not necessarily one-hundred percent accurate because the collected values are not fully consistent.

TABLE 1.4.1 PERCENTAGE OF NATIONAL NETWORKS INCLUDED IN THE STATISTICS

Voltage level	Denmark	Finland[1)]	Iceland	Norway	Sweden[2)]
400 kV	100%	100%	-	100%	100%
220 kV	100%	100%	100%	100%	97%
132 kV	100%	96%	100%	100%	81%

1) Percentage for Finland is reduced due to some small regional grids not delivering complete data.
2) 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 voltage levels. 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 2013, 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 2004–2013. 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 2013. The corresponding annual averages are calculated for the period 2004–2013. In addition, the summaries present the most important issues in 2013 defined by each Transmission System Operator.

2.1 SUMMARY FOR DENMARK

For Denmark, the energy not supplied in 2013 was 14.8 MWh (ten-year average 16.3 MWh). The number of grid disturbances was 63 (ten-year average 63) and 11 of them caused ENS. On average, 6 disturbances per year caused ENS in 2004–2013.

In 2013, 35% of ENS was caused by faults in Technical equipment. Two disturbances with exploding voltage transformers caused most of the 35% ENS.

On October 10th 2013 at 8.23 AM maintenance was planned in the 150 kV substation Tange (TAN) in mid-eastern part of Jutland. Due to this maintenance, one of the 150 kV busbars in the TAN substation was taken out of service, and the whole load was moved to the other 150 kV busbar. By local maloperation the 150 kV busbar in service was accidentally earthed. The busbar protection made the circuit breaker trip causing an outage of two 150/60 kV substations. By this outage approximately 46 000 customers were interrupted in 7 minutes. This fault resulted in 2.56 MWh ENS.

On October 28th 2013 and December 5th 2013 two severe storms struck the country causing a number of faults on overhead lines within the statistical area. None of these faults did however lead to any ENS.

2.2 SUMMARY FOR FINLAND

For Finland, the energy not supplied in 2013 was 252 MWh (ten-year average 307 MWh). The number of grid disturbances was 444 (ten-year average 375) and 69 of them caused ENS. On average, 67 disturbances per year caused ENS in 2004–2013.

In 2013, 68.9% of ENS was caused by overhead lines faults and 30.9% by substation faults. The biggest reasons for ENS were "Other environmental causes "43% and "Operation and maintenance" 26%. The biggest number of the disturbances were caused by "Other environmental causes" and occurred during the summer months.

The highest amount of ENS (estimated 74 MWh) in a single disturbance was on 110 kV overhead line caused by one phase earth fault. The line was inspected but the fault location and reason was not found.

2.3 SUMMARY FOR ICELAND

For Iceland, the energy not supplied in 2013 was 238.9 MWh (ten-year average 749.5 MWh). The total number of disturbances was 22 (ten-year average 31) and 16 of them caused ENS. On average, 21 disturbances per year caused ENS in 2004–2013 (220 and 132 kV system).

Registered grid disturbances decreased in 2013 as compared to the preceding year. 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 January, September and December and most often due to weather.

February, a heavy load, about 330 MW, went out of operation at an industrial user in south-west Iceland. The transmission operation system met this by dividing the system into four island systems. During the build-up phase when the south-west and north-west systems were connected together one generator went out of operation and resulted in a blackout of the area from Blanda to Hólar.

September, a very bad weather swept the country with northern wind, rain/snow with ice build-up on transmission lines in Northeast Iceland. At the same time it was very windy in southern Iceland near Vatnajökull. Extra manpower was prepared to be available if there would be some outages. Also generation was set such that the system was in as good condition as possible to be able to handle outages.

September, A very large industrial user in south-western Iceland went out of operation without any notice and due to that some other users in the area had part of their load curtailed. In total 700 MW were disconnected from the system with large influence on the power system. The transmission operation system met this by dividing the system into two island systems which saved the north-eastern part of the system. The system frequency in the south-western island system increased to 52.97 Hz and also the voltage increased. As a result a few generators went out of operation in the south-west system such as two in the Þjórsá-Tungnaá area, six in Sog and three on Reykjanes. This influenced some consumption such as traffic lights in Reykjavík and some backup generators came into operation. Five hours later the system was again in normal condition. Energy not supplied was assessed at 46.5 MWh.

December, Sigöldulína 4/Prestbakkalína 1 tripped in a storm with wind over 45 m/s. The system operation split he system into two islands and low frequency in the south-west resulted in tripping of loads at heavy industrial users. Energy not supplied was assessed at 11 MWh.

2.4 SUMMARY FOR NORWAY

In Norway, the energy not supplied in 2013 was 10801 MWh (ten-year average 3423 MWh). The number of grid disturbances was 317 (ten-year average 280) and 92 of them caused ENS. On average, 85 disturbances per year caused ENS in 2009–2013.

Compared to the 10-year average, there was an increase of faults in two categories: weather related and reactive components.

In 2013 there was one major disturbance in the 400 kV network. It resulted in an outage of a gas pipeline terminal and it caused approximately 3/4 of the total ENS.

2.5 SUMMARY FOR SWEDEN

In Sweden, the energy not supplied in 2013 was 1339 MWh (ten-year average 1884 MWh). Only 0.3 MWh originated from the 400 kV voltage level. The number of grid disturbances was 538 (ten-year average 531) and 154 of them caused ENS. On average, 128 disturbances per year caused ENS in 2004–2013.

In 2013, 63.5% of ENS was caused by line faults and 31.7% by substation faults. The main causes for ENS during 2013 were “technical equipment” 40% and “lightning” 27%. On April 18th arcing occurred in a failing load disconnector and the arc guard system tripped a 110 kV station. Smoke developed in the building causing delays while restoring power to the customers. The outage lasted 59 minutes and more than 42000 customers were affected. Total ENS was 140 MWh.

On July 27th a lightning strike tripped two parallel 132 kV lines causing an outage for more than 43000 customers during 45 minutes. The resulting ENS was nearly 100 MWh.

3 DISTURBANCES

This chapter includes an overview of disturbances in the Nordic countries. It also presents the connection between disturbances, energy not supplied, causes of faults, and division during the year 2013, together with the development of the number of disturbances over the ten-year period 2004–2013. 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 2004–2013

The number of disturbances during the year 2013 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 3.1.1 presents the sum of disturbances during the year 2013 and the annual average for the period 2004–2013 for the complete 100–400 kV grid in each respective country. Figure 3.1.1 shows the development of the number of disturbances in each respective country during the period 2004–2013.

TABLE 3.1.1 NUMBER OF GRID DISTURBANCES IN 2013 AND THE ANNUAL AVERAGE FOR THE PERIOD 2004–2013

	Denmark		Finland		Iceland		Norway		Sweden		Nordic	
Time period	2013	2004–2013	2013	2004–2013	2013	2004–2013	2013	2004–2013	2013	2004–2013	2013	2004–2013
Number of disturbances	63	63	444	375	22	31	317	280	538	531	1384	1280
No. of dist. causing ENS[1)]	11	7	69	81	16	15	92	85	154	148	342	336

[1)] The time period is 2009–2013 because every country does not have complete data before 2009

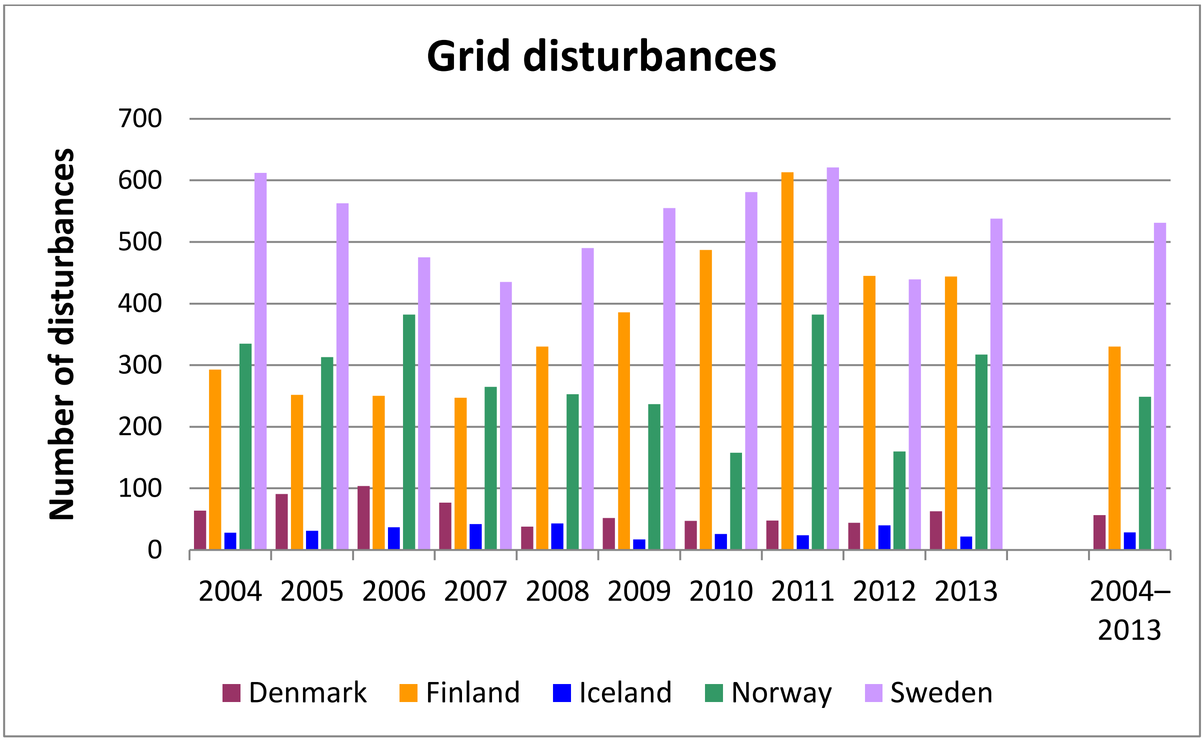

FIGURE 3.1.1 NUMBER OF GRID DISTURBANCES IN EACH NORDIC COUNTRY DURING THE PERIOD 2004–2013

3.2 DISTURBANCES DIVIDED ACCORDING TO MONTH

Figure 3.2.1 presents the percentage distribution of grid disturbances according to month in different countries in the year 2013 and Figure 3.2.2 the ten-year average distribution of disturbances during the period 2004–2013.

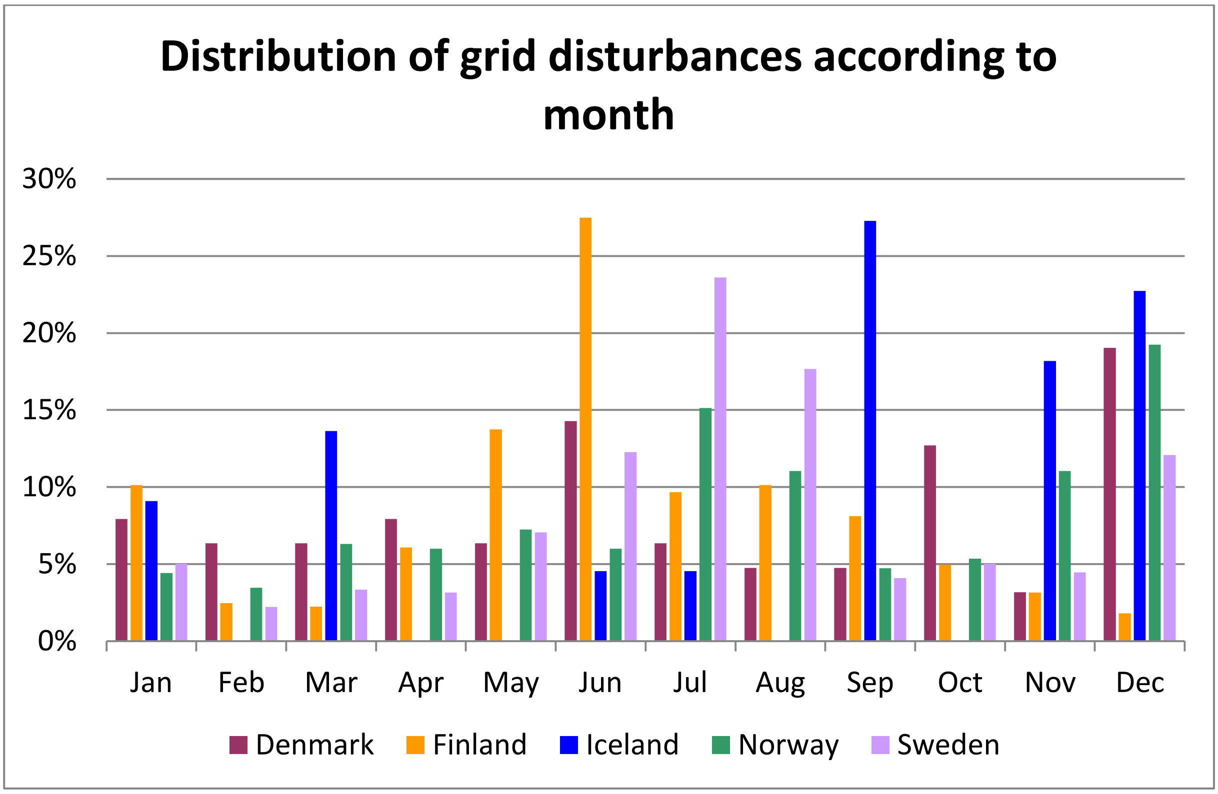

FIGURE 3.2.1 PERCENTAGE DISTRIBUTION OF GRID DISTURBANCES ACCORDING TO MONTH IN EACH COUNTRY IN 2013

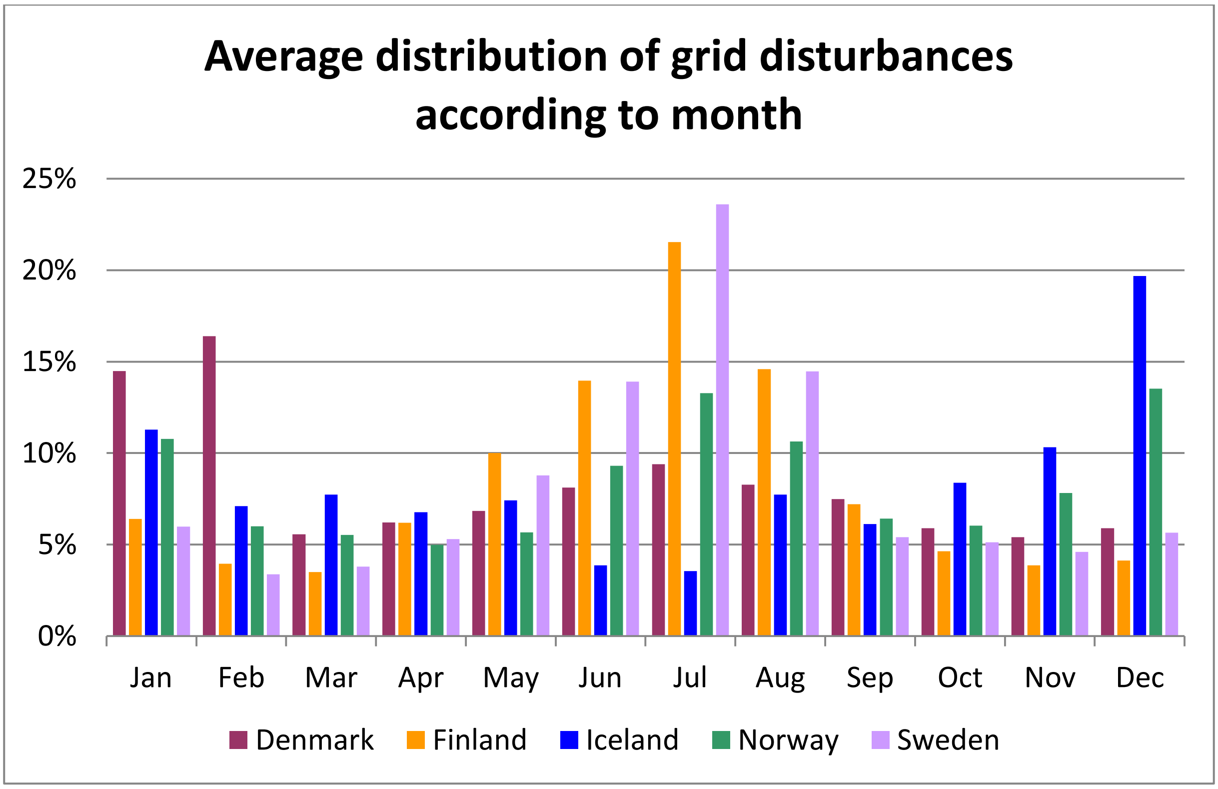

FIGURE 3.2.2 AVERAGE PERCENTAGE DISTRIBUTION OF GRID DISTURBANCES ACCORDING TO MONTH FOR THE PERIOD 2004–2013

Table 3.2.1 and Table 3.2.2 present the numerical values behind Figure 3.2.1 and Figure 3.2.2. 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 3.2.1 NUMBER OF GRID DISTURBANCES PER MONTH FOR EACH COUNTRY IN 2013

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Denmark	5	4	4	5	4	9	4	3	3	8	2	12
Finland	45	11	10	27	61	122	43	45	36	22	14	8
Iceland	2	0	3	0	0	1	1	0	6	0	4	5
Norway	14	11	20	19	23	19	48	35	15	17	35	61
Sweden	27	12	18	17	38	66	127	95	22	27	24	65
Nordic	93	38	55	68	126	217	223	178	82	74	79	151

TABLE 3.2.2 AVERAGE NUMBER OF GRID DISTURBANCES PER MONTH DURING THE YEARS 2004–2013

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Denmark	9	10	4	4	4	5	6	5	5	4	3	4
Finland	24	15	13	23	38	52	81	55	27	17	15	16
Iceland	4	2	2	2	2	1	1	2	2	3	3	6
Norway	30	17	16	14	16	26	37	30	18	17	22	38
Sweden	32	18	20	28	47	74	125	77	29	27	24	30
Nordic	99	62	55	71	107	159	250	169	80	68	67	93

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 Nordel 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 3.3.1 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.

TABLE 3.3.1 GROUPING OF GRID DISTURBANCES AND ENERGY NOT SUPPLIED (ENS) BY CAUSE

Cause	Country	Percentage distribution of disturbance		Percentual distribution of disturbances that caused ENS[1]		Percentual distribution of ENS[2]	
		2013	2004–2013	2013	2009–2013	2013	2004–2013
Lightning	Denmark	16	14	0	4	0	4
	Finland	25	26	22	20	5	5
	Iceland	5	3	6	4	18	1
	Norway	28	22	30	21	3	3
	Sweden	38	37	42	33	27	21
Other environmental causes	Denmark	11	23	0	6	0	16
	Finland	34	16	25	18	43	24
	Iceland	59	38	69	57	17	65
	Norway	24	22	28	26	82	61
	Sweden	9	5	3	4	2	7
External influence	Denmark	16	17	0	4	0	3
	Finland	1	2	3	5	5	11
	Iceland	5	2	6	1	15	0
	Norway	1	2	3	2	0	0
	Sweden	1	2	3	4	3	6
Operation and maintenance	Denmark	11	14	36	25	25	33
	Finland	6	7	19	10	26	17
	Iceland	14	10	6	9	31	15
	Norway	9	12	12	10	0	6
	Sweden	6	8	6	10	6	12
Technical equipment	Denmark	11	12	27	15	35	11
	Finland	4	5	3	7	7	27
	Iceland	9	22	6	8	0	10
	Norway	28	24	14	14	9	17
	Sweden	15	15	13	9	40	24
Other	Denmark	16	8	18	18	18	20
	Finland	18	7	6	4	5	9
	Iceland	9	23	6	20	19	6
	Norway	9	13	12	17	6	10
	Sweden	11	11	5	6	6	15
Unknown	Denmark	19	13	18	8	23	13
	Finland	11	36	23	36	9	7
	Iceland	0	2	0	0	0	1
	Norway	0	6	0	9	0	2
	Sweden	20	22	27	22	18	16

1) The time period is 2009–2013 because every country does not have complete data before 2009.

2) Calculation of ENS varies between different countries and is presented in Appendix 1.

Figure 3.3.1 identifies disturbances for all voltage levels in terms of the initial fault, and Figure 3.3.2 presents the respective ten-year average values.

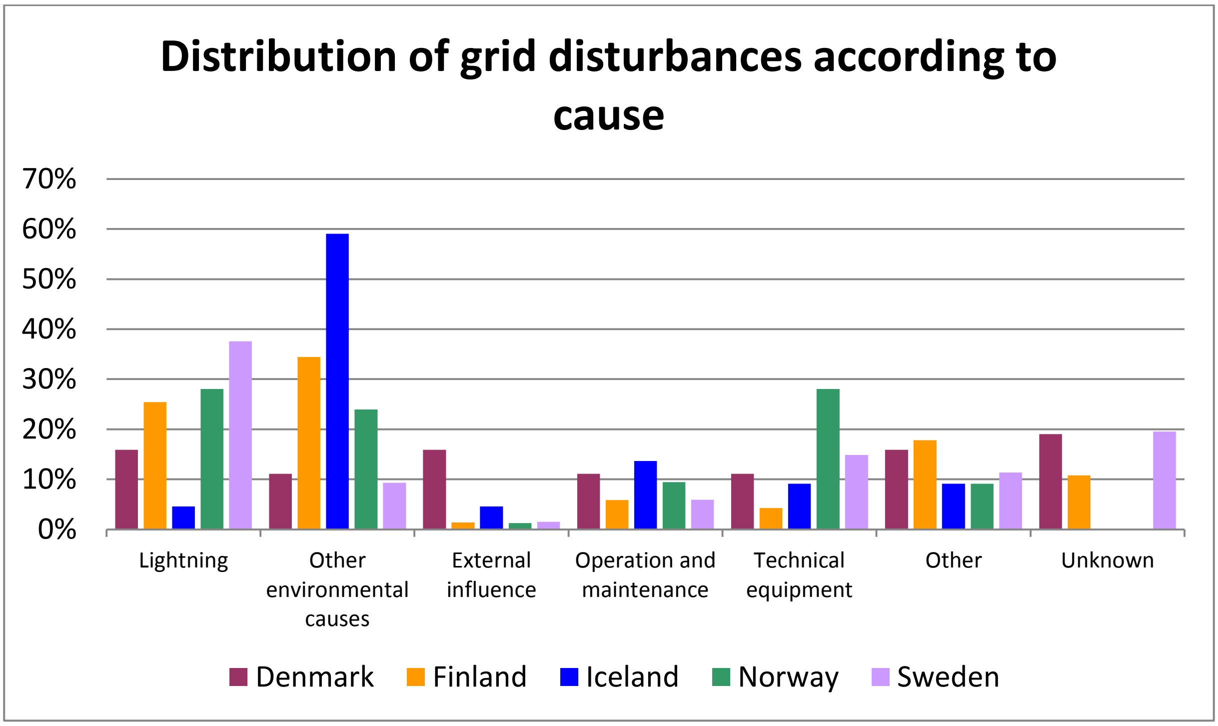

FIGURE 3.3.1 PERCENTAGE DISTRIBUTION OF GRID DISTURBANCES ACCORDING TO CAUSE IN 2013

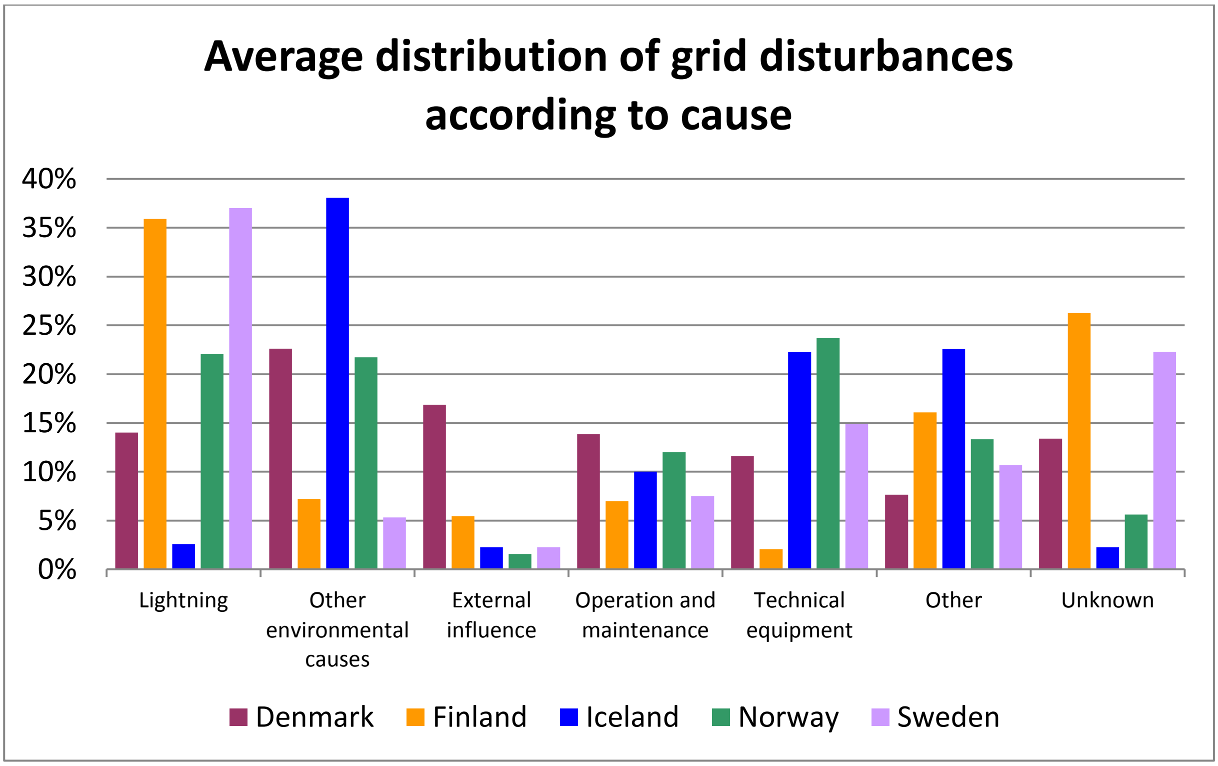

FIGURE 3.3.2 AVERAGE PERCENTAGE DISTRIBUTION OF GRID DISTURBANCES ACCORDING TO CAUSE DURING THE PERIOD 2004–2013

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

TABLE 4.1.1 ENERGY NOT SUPPLIED (ENS) ACCORDING TO THE VOLTAGE LEVEL OF THE INITIATING FAULT

Country	Energy not supplied (MWh) 2013	Average ENS 2004–2013 (MWh)	ENS divided into different voltage levels, 2004–2013 (%)			
			132 kV	220 kV	>400 kV	Other 1)
Denmark	14.8	16.7	98.9	0.0	0.0	1.1
Finland	252.4	313.8	92.7	2.7	3.9	0.7
Iceland	238.9	1078.2	35.5	64.5	0.0	0.0
Norway	10800.7	3422.5	26.6	9.6	58.3	5.5
Sweden	1338.9	1884.0	84.5	15.0	0.4	0.2
Nordic	12645.7	6715.2	47.5	19.6	30.0	2.9

1) The category other contains energy not supplied from system faults, auxiliary equipment, lower voltage level networks and the connections to foreign countries, etc.

Figure 4.1.1 and Figure 4.1.2 summarise the energy not supplied according to the different voltage levels for the year 2013 and for the period 2004–2013, respectively. Voltage level refers to the initiating fault of the respective disturbance.

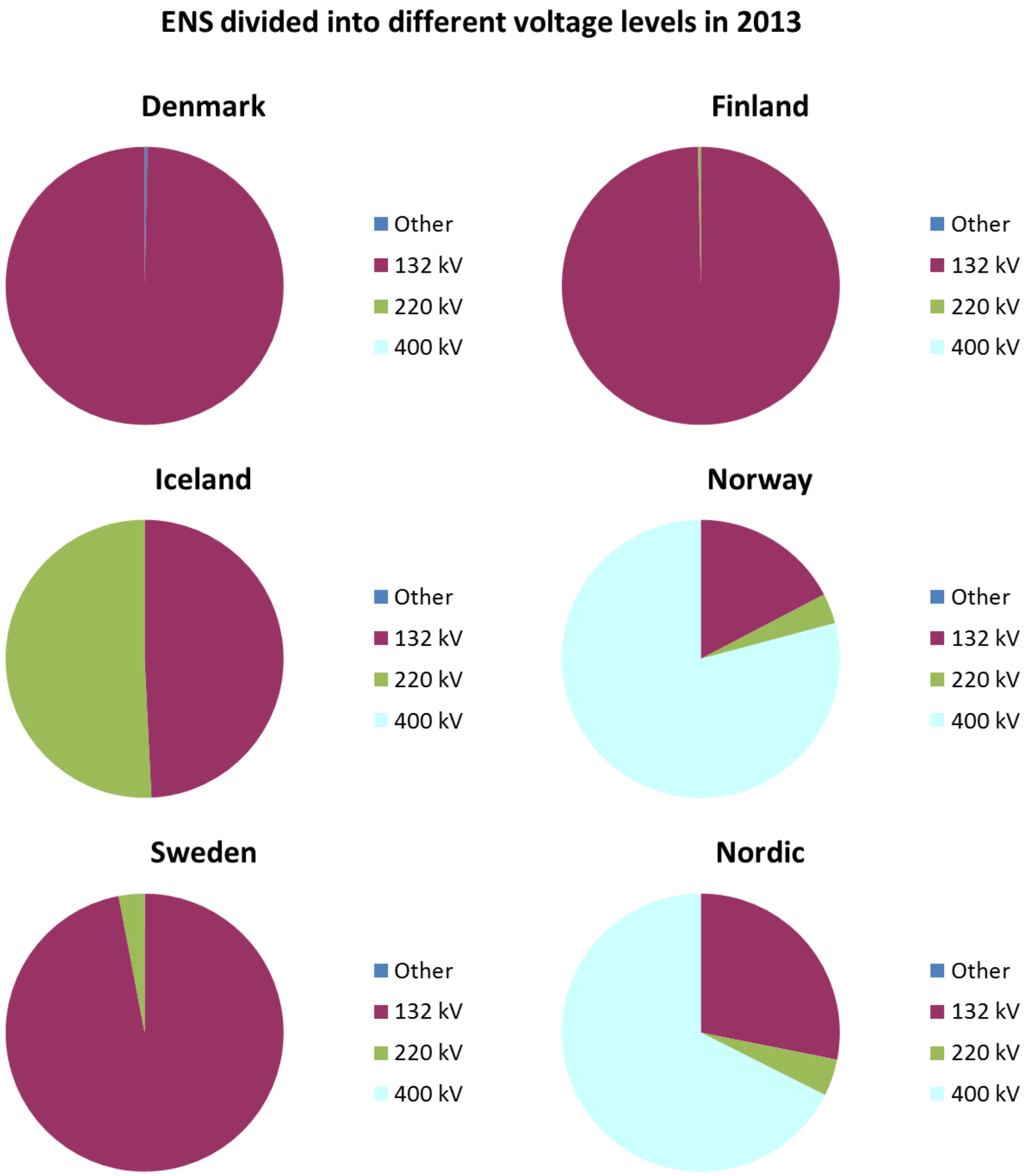

FIGURE 4.1.1 ENERGY NOT SUPPLIED (ENS) IN TERMS OF THE VOLTAGE LEVEL OF THE INITIATING FAULT IN 2013

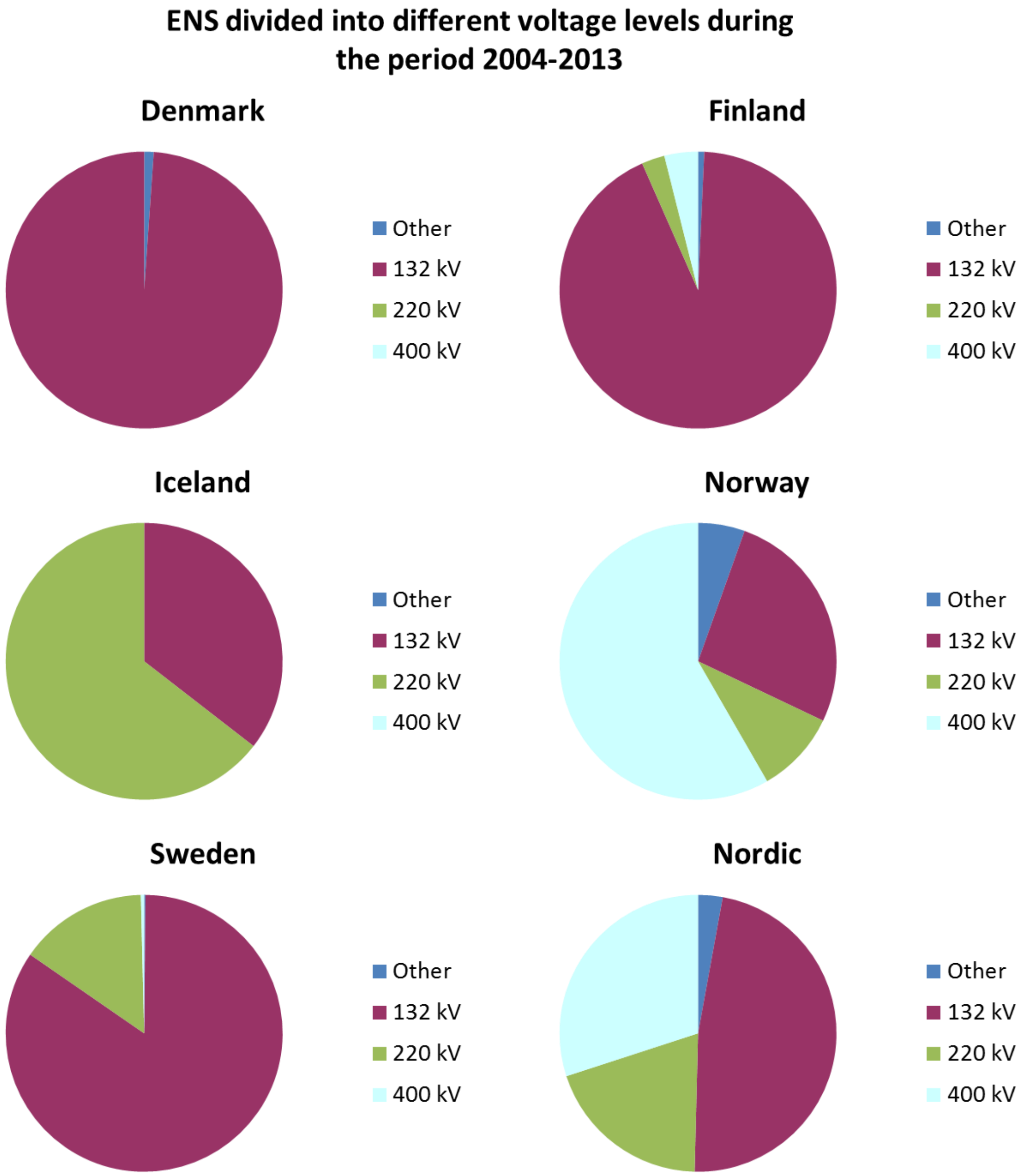

FIGURE 4.1.2 ENERGY NOT SUPPLIED IN TERMS OF THE VOLTAGE LEVEL OF THE INITIATING FAULT DURING THE PERIOD 2004–2013

4.2 ENERGY NOT SUPPLIED (ENS) AND TOTAL CONSUMPTION

Table 4.2.1 shows the energy not supplied in relation to the total consumption of energy in each respective country and its division according to installation.

TABLE 4.2.1 ENERGY NOT SUPPLIED (ENS) ACCORDING TO INSTALLATION

Country	Consumption GWh 2013	ENS MWh 2013	ENS / consumption ppm 2013	ENS / consumption ppm 2004–2013	ENS divided according to installation during period 2004–2013 (%) Overhead lines	Cable	Station	Other
Denmark	32774	14,8	0,5	0,5	21,1	0,0	63,4	15,6
Finland	83866	252,4	3,0	3,7	62,1	0,0	34,3	3,6
Iceland	17592	238,9	13,6	76,0	30,6	0,8	55,2	13,4
Norway	128104	10800,7	84,3	26,6	67,0	2,0	26,0	5,1
Sweden	139600	1339,9	9,6	13,7	28,2	4,7	56,7	6,1
Total	401936	12646,8	31,5	16,8	49,7	2,5	39,9	6,6

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

Figure 4.2.1 presents the development of energy not supplied during the period 2004–2013. 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.

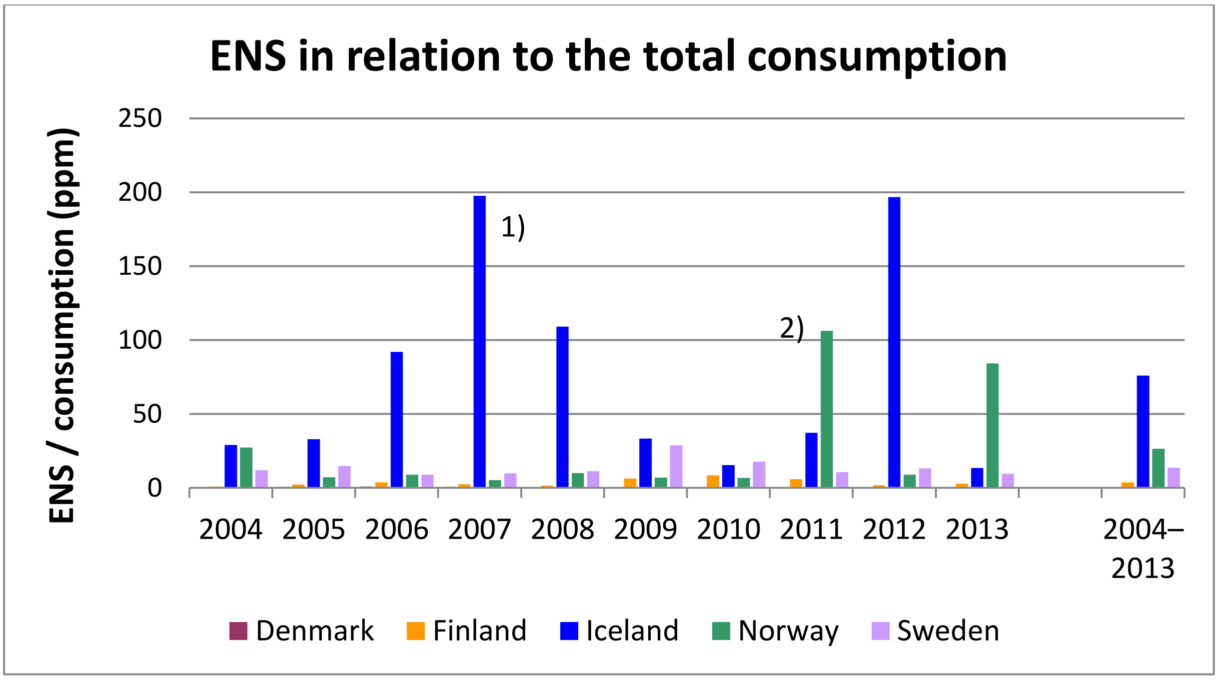

FIGURE 4.2.1 ENERGY NOT SUPPLIED (ENS) / CONSUMPTION (PPM)

[1)] 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 and 2012.

[2)] The unusually high ENS / consumption in 2011 in Norway were caused by extreme weather conditions in December (aka Dagmar).

4.3 ENERGY NOT SUPPLIED (ENS) DIVIDED ACCORDING TO MONTH

Figure 4.3.1 presents the distribution of energy not supplied according to month in the respective countries.

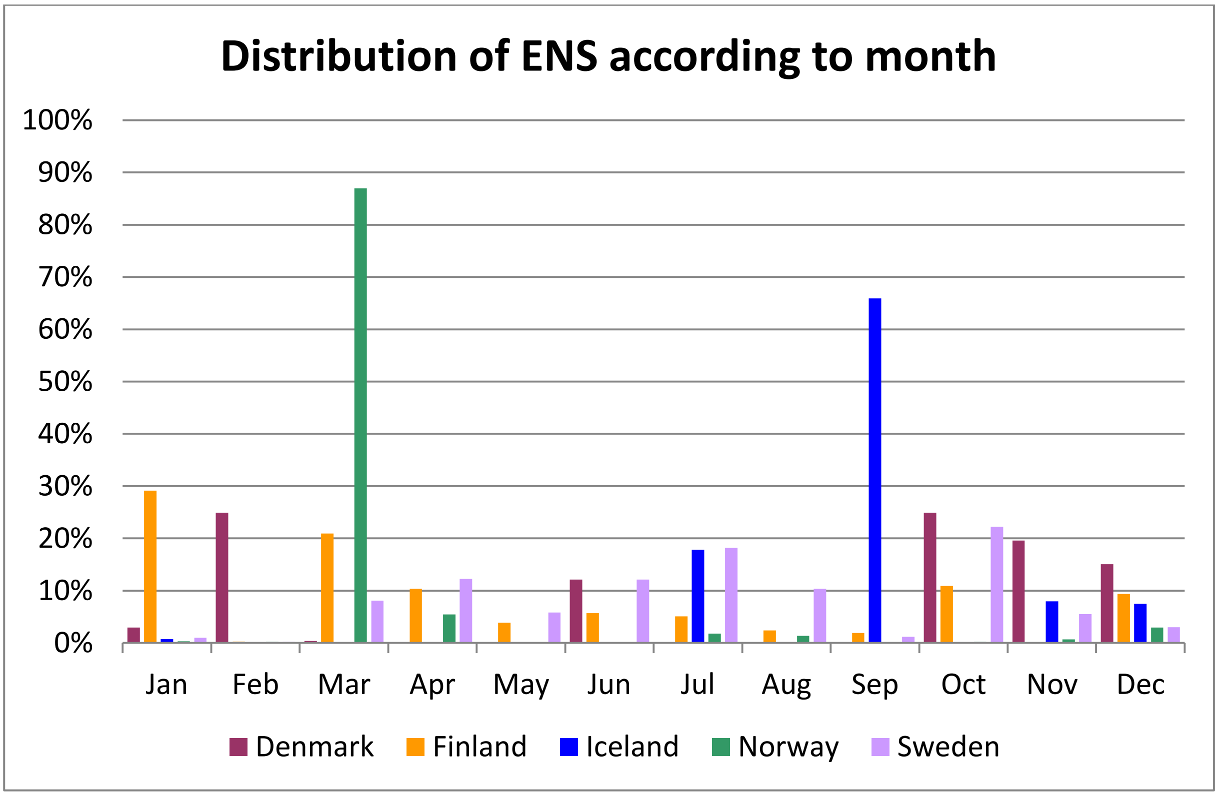

FIGURE 4.3.1 PERCENTAGE DISTRIBUTION OF ENERGY NOT SUPPLIED (ENS) ACCORDING TO MONTH IN 2013

4.4 Energy not supplied (ENS) divided according to cause

Figure 4.4.1 presents the distribution of energy not supplied according to cause in different countries.

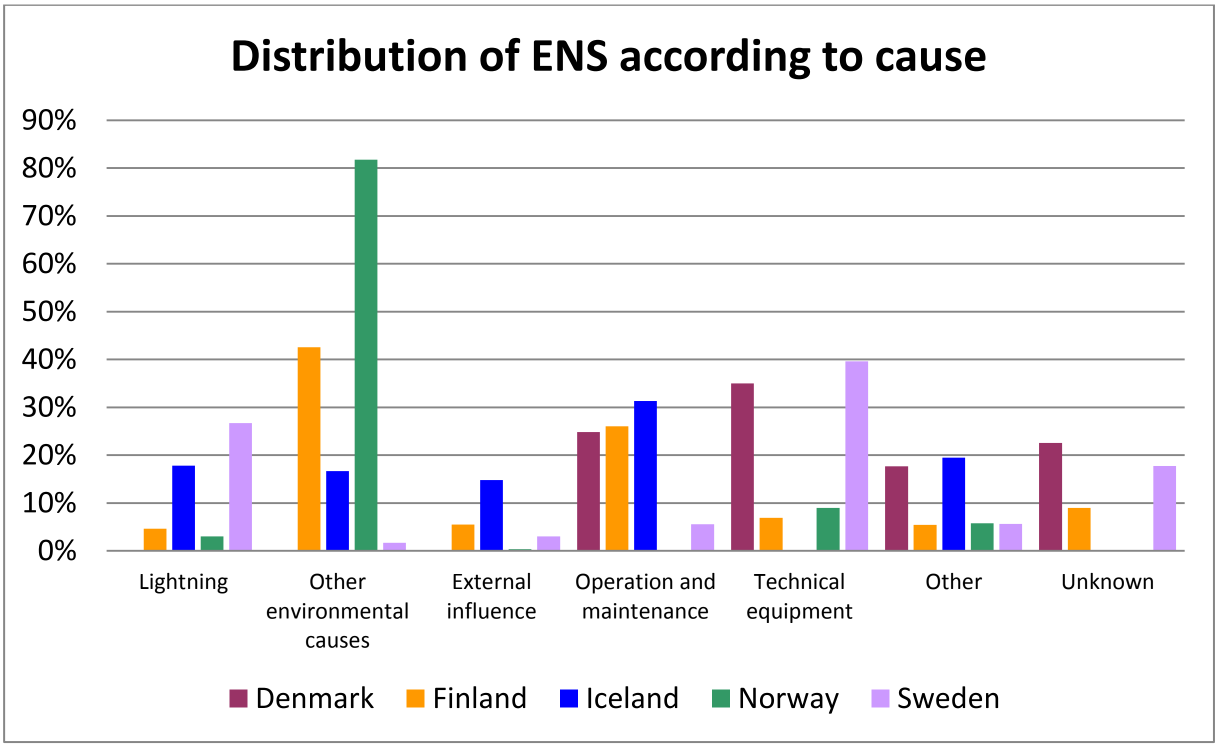

Figure 4.4.1 Percentage distribution of energy not supplied according to the cause of the primary fault in 2013

Also see Appendix 2 for more details about investigating faults.

4.5 Energy not supplied (ENS) divided according to component

Table 4.5.1 shows the amount of energy not supplied in 2013 and the annual average for the period 2004–2013. Table 4.5.2 shows the distribution of energy not supplied according to component.

Table 4.5.1 Energy not supplied (ENS) in 2013 and the annual average for the period 2004–2013

	Denmark		Finland		Iceland		Norway		Sweden		Nordic	
Time period	2013	2004–2013	2013	2004–2013	2013	2004–2013	2013	2004–2013	2013	2004–2013	2013	2004–2013
ENS (MWh)	15	17	252	315	239	1078	10801	3422	1340	1873	12647	6705

[1)] One regional grid in Sweden did not deliver complete data in 2012. 750 MWh of ENS has not been included, because the details of fault origin were not reported.

TABLE 4.5.2 PERCENTAGE DISTRIBUTION OF ENERGY NOT SUPPLIED IN TERMS OF COMPONENT

	Denmark		Finland		Iceland		Norway		Sweden		Nordic	
Fault location	2013	2004–2013	2013	2004–2013	2013	2004–2013	2013	2004–2013	2013	2004–2013	2013	2004–2013
Overhead line	2,9	21,1	68,9	62,1	34,4	30,6	81,2	67,0	60,2	29,5	77,8	50,3
Cable	0,0	0,0	0,0	0,0	0,0	0,8	5,4	2,0	3,3	4,9	4,9	2,5
Line faults	**2,9**	**21,1**	**68,9**	**62,1**	**34,4**	**31,4**	**86,6**	**69,0**	**63,5**	**34,5**	**82,7**	**52,8**
Power transformers	0,0	17,5	0,1	1,9	0,0	0,5	2,2	3,5	5,2	7,5	2,4	4,1
Instrument transformers	14,3	3,5	7,9	3,4	0,0	0,0	0,0	0,8	0,3	5,4	0,2	2,1
Circuit breakers	19,6	4,5	0,5	2,2	14,8	26,9	0,9	1,4	0,0	2,8	1,1	5,9
Disconnectors and earth connectors	0,4	16,3	0,0	2,3	0,0	9,0	0,0	0,9	10,5	6,7	1,1	3,9
Surge arresters and spark gap	0,0	0,0	0,0	4,2	0,0	0,0	7,3	3,6	0,0	0,1	6,3	2,0
Busbar	7,6	7,5	0,0	2,1	0,0	4,0	0,1	1,6	13,5	3,5	1,5	2,6
Control equipment	54,8	12,2	1,9	14,6	31,3	12,2	2,2	9,5	2,1	4,0	2,8	8,6
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	0,4	20,5	2,9	0,0	0,0	0,7	4,7	0,0	29,1	1,0	10,7
Substation faults	**96,7**	**61,9**	**30,9**	**34,3**	**46,1**	**52,7**	**13,4**	**26,0**	**31,7**	**59,1**	**16,4**	**40,0**
Shunt capacitor	0,0	0,0	0,0	0,0	0,0	2,6	0,0	0,0	0,0	1,8	0,0	0,9
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	1,4	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
Compensation faults	**0,0**	**1,4**	**0,0**	**0,0**	**0,0**	**2,6**	**0,0**	**0,0**	**0,0**	**1,8**	**0,0**	**0,9**
System fault	0,0	13,4	0,0	0,0	19,5	12,4	0,0	3,7	0,0	0,9	0,4	4,2
Faults in adjoining statistical area	0,3	2,2	0,2	3,6	0,0	1,0	0,0	1,3	4,8	3,8	0,5	2,1
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
Other faults	**0,3**	**15,6**	**0,2**	**3,6**	**19,5**	**13,4**	**0,0**	**5,1**	**4,8**	**4,7**	**0,9**	**6,2**

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. Overhead lines, for example, 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 disturbance*

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.

5.2 Overview of the Faults Related to Disturbances

Table 5.2.1 presents the number of faults and disturbances during 2013.

Table 5.2.1 Number of faults and grid disturbances in 2013

	Denmark	Finland	Iceland	Norway	Sweden
Number of faults in 2013	83	458	25	376	558
Number of disturbances in 2013	63	444	22	317	538
Fault / disturbance ratio in 2013	1,32	1,03	1,14	1,19	1,04
Fault / disturbance ratio during 2004–2013	1,18	1,06	1,28	1,24	1,03

Table 5.2.2 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 on lines and in power transformers.

Table 5.2.2 Faults in different countries in terms of voltage level

Voltage	Country	Size of the grid		Number of faults		ENS (MWh)	
		Number of power transformers	Length of lines in km[1)]	2013	2004–2013	2013	2004–2013
400 kV	Denmark	30	1252	13	7,7	0,0	0,0
	Finland	56	4888	26	23,4	0,0	12,3
	Iceland	0	0	0	0,0	0,0	0,0
	Norway	64	2708	94	57,4	8547,7	1995,9
	Sweden	61	10984	110	114,7	0,3	7,2
220 kV	Denmark	7	140	1	0,4	0,0	0,0
	Finland	23	2398	22	23,4	0,8	9,5
	Iceland	33	858	4	12,3	121,3	695,4
	Norway	271	6165	92	94,2	380,1	329,2
	Sweden	92	4202	30	63,5	39,9	282,6
132 kV	Denmark	259	4478	59	62,9	14,8	16,6
	Finland	1121	16222	404	334,7	251,6	291,2
	Iceland	51	1355	21	26,3	117,6	382,7
	Norway	724	10677	190	175,0	1872,9	910,3
	Sweden	697	16158	380	335,5	1298,7	1591,3

[1)] Length of lines is the sum of the length of cables and overhead lines.

Table 5.2.3 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 5.2.3 PERCENTAGE DIVISION OF FAULTS ACCORDING TO COMPONENT TYPE

	Denmark		Finland		Iceland		Norway		Sweden		Nordic	
Component type	**2013**	**2004–2013**	**2013**	**2004–2013**	**2013**	**2004–2013**	**2013**	**2004–2013**	**2013**	**2004–2013**	**2013**	**2004–2013**
Overhead line	62,7	59,7	83,0	76,7	62,5	21,6	41,5	40,9	71,0	58,5	66,6	57,6
Cable	2,4	3,1	0,4	0,2	0,0	0,6	2,4	0,8	1,3	0,8	1,3	0,7
Sum of line faults	**65,1**	**62,9**	**83,4**	**76,8**	**62,5**	**22,2**	**43,9**	**41,7**	**72,3**	**59,3**	**67,9**	**58,3**
Power transformers	1,2	3,8	1,5	1,4	0,0	3,2	1,1	2,5	6,7	5,0	3,2	3,3
Instrument transformers	2,4	1,6	0,7	0,7	0,0	0,0	2,1	1,8	0,0	0,8	0,9	1,0
Circuit breakers	3,6	4,6	2,0	1,1	12,5	2,4	4,5	3,7	0,0	2,3	2,2	2,4
Disconnectors and earth connectors	1,2	1,5	0,0	0,4	0,0	0,1	0,5	1,8	0,7	0,7	0,5	0,9
Surge arresters and spark gap	0,0	0,5	0,0	0,3	0,0	0,0	2,1	1,5	0,0	0,2	0,5	0,5
Busbar	2,4	0,5	0,0	0,4	0,0	0,1	0,8	1,2	1,5	1,0	0,9	0,8
Control equipment[1)]	8,4	14,8	4,4	10,8	16,7	53,6	13,0	23,1	8,3	8,1	8,4	15,1
Common ancillary equipment	0,0	0,4	0,0	0,1	0,0	0,0	1,3	1,2	0,0	0,8	0,3	0,6
Other substation faults	1,2	2,0	4,6	2,2	0,0	2,9	20,7	11,9	0,7	8,1	7,0	6,8
Sum of substation faults	**20,5**	**29,9**	**13,1**	**17,3**	**29,2**	**62,3**	**46,3**	**48,6**	**17,9**	**27,2**	**24,0**	**31,5**
Shunt capacitor	1,2	0,3	1,3	0,6	0,0	1,6	1,1	1,1	0,2	0,6	0,8	0,8
Series capacitor	0,0	0,0	0,7	1,0	0,0	0,1	0,0	0,0	0,7	3,4	0,5	1,6
Reactor	0,0	1,8	0,0	0,2	0,0	0,0	0,3	0,4	1,3	1,5	0,5	0,8
SVC and statcom	0,0	0,1	0,2	0,1	0,0	0,0	8,2	2,7	0,6	1,7	2,4	1,3
Synchronous compensator	1,2	0,1	0,0	0,0	0,0	0,0	0,3	0,7	0,0	0,3	0,1	0,3
Sum of compensation faults	**2,4**	**2,3**	**2,2**	**1,9**	**0,0**	**1,7**	**9,8**	**5,0**	**2,8**	**7,6**	**4,3**	**4,8**
System fault	0,0	1,4	0,0	0,2	8,3	11,7	0,0	0,4	0,2	2,5	0,2	1,7
Faults in adjoining statistical area	12,0	3,5	1,3	3,8	0,0	1,6	0,0	4,2	6,8	3,5	3,6	3,7
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	**12,0**	**4,9**	**1,3**	**4,0**	**8,3**	**13,7**	**0,0**	**4,6**	**7,0**	**6,0**	**3,8**	**5,4**

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

5.3 FAULTS ON 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 2013 as well as the average values for the period 1996–2013. The tables also give the faults divided by cause during the period 1996–2013. Along with the tables, the annual division of faults and the number of permanent faults during the period 2004–2013 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 5.3.1 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 2013 and for the 18-year period 1996–2013. Figure 5.3.1 presents the annual line fault values per line length during the 10-year period 2004–2013 and the average value of period 1996–2013. Figure 5.3.1 presents the annual line permanent faults during the same period.

TABLE 5.3.1 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 400 KV OVERHEAD LINES

Country	Lines (km)	Number of faults	Number of faults per 100 km		Faults divided by cause (%) during the period 1996–2013								
					Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown	1-phase faults	Permanent faults
	2013	2013	2013	1996–2013									
Denmark	1173	11	0,94	0,34	19,2	63,0	6,8	4,1	4,1	1,4	1,4	45,2	4,1
Finland	4888	12	0,25	0,25	74,5	8,3	2,1	5,7	2,1	2,1	5,2	59,9	7,3
Norway	2683	25	0,93	1,03	24,1	69,0	0,2	0,2	1,7	2,0	2,8	67,7	7,8
Sweden	10976	50	0,46	0,36	49,7	18,4	2,0	3,0	3,3	1,4	22,0	82,1	6,5
Nordic	19720	98	0,50	0,42	43,2	35,8	1,7	2,5	2,7	1,7	12,5	72,5	6,9

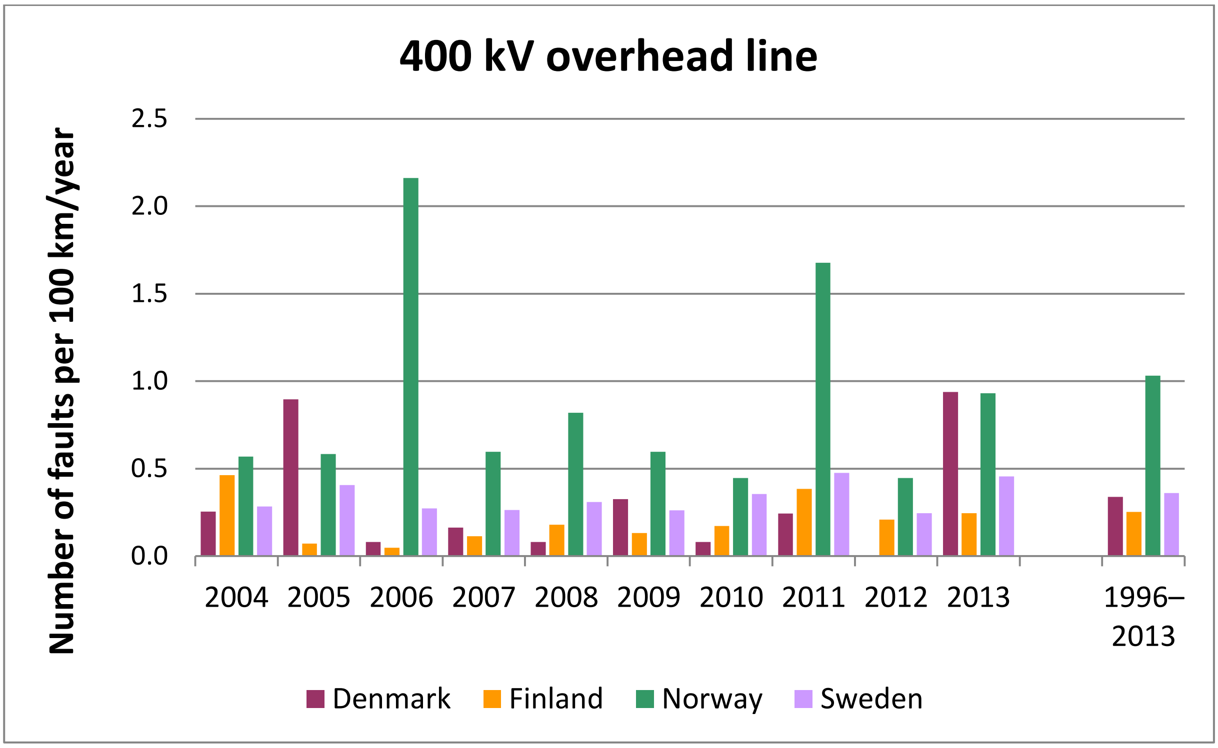

FIGURE 5.3.1 ANNUAL DIVISION OF FAULTS DURING THE PERIOD 2004–2013

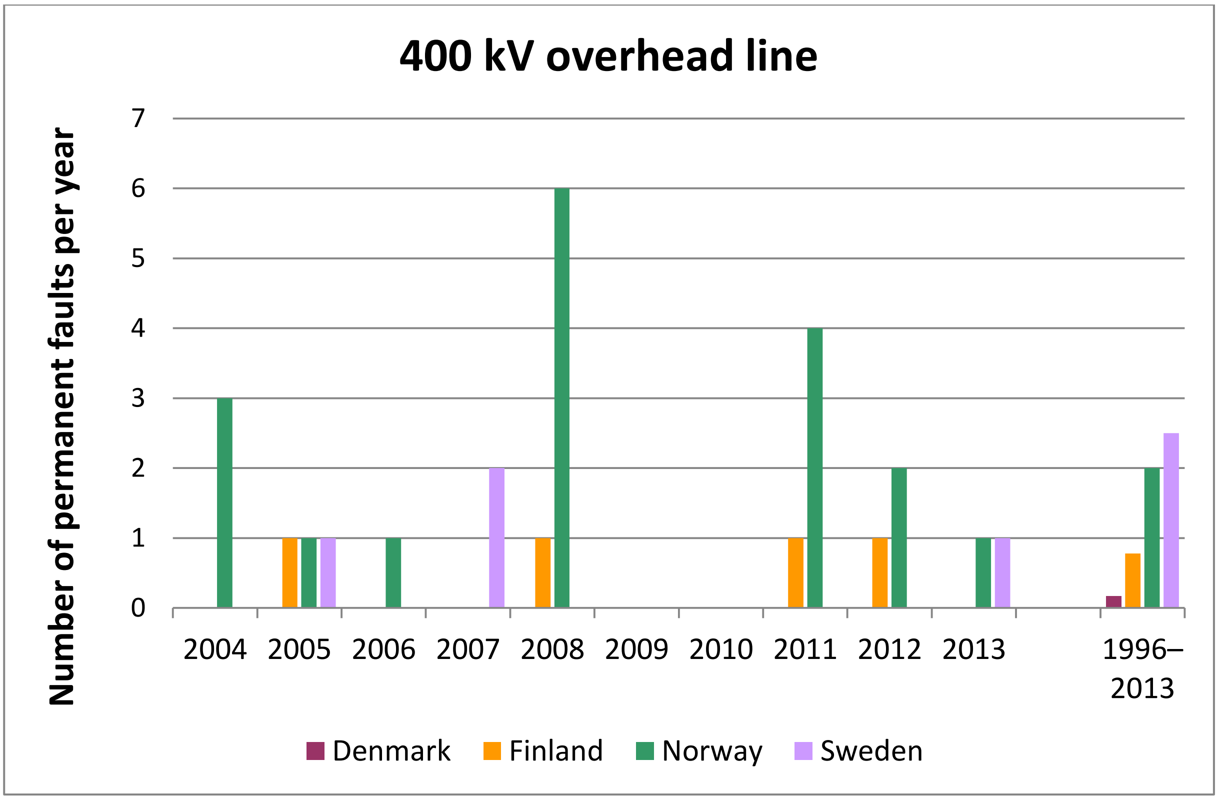

FIGURE 5.3.2 ANNUAL DIVISION OF PERMANENT FAULTS DURING THE PERIOD 2004–2013

5.3.2 220 KV OVERHEAD LINES

Table 5.3.2 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 2013 and for the 18-year period 1996–2013. Figure 5.3.3 presents the annual line fault values per line length during the 10-year period 2004–2013 and the average value of period 1996–2013. Figure 5.3.4 presents the annual line permanent faults during the same period.

TABLE 5.3.2 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 220 KV OVERHEAD LINES

Country	Lines (km)	Number of faults	Number of faults per 100 km		Faults divided by cause (%) during the period 1996–2013								
					Light-ning	Other environ-mental causes	Exter-nal influ-ences	Opera-tion and mainte-nance	Tech-nical equip-ment	Ot-her	Un-known	1-phase faults	Perma-nent faults
	2013	2013	2013	1996–2013									
Denmark	56	0	0.00	0.43	50.0	12.5	25.0	0.0	0.0	0.0	12.5	87.5	0.0
Finland	2398	20	0.83	0.77	44.3	11.0	1.7	1.4	0.6	1.2	39.7	73.0	3.5
Iceland	857	0	0.00	0.36	26.7	55.6	0.0	0.0	17.8	0.0	0.0	46.7	20.0
Norway	5715	45	0.79	0.70	53.4	35.0	1.0	0.6	2.0	2.6	5.4	62.6	11.0
Sweden	4099	18	0.44	0.87	67.3	4.6	3.8	4.4	3.4	1.0	15.5	56.3	6.6
Nordic	13125	83	0.63	0.75	56.2	19.3	2.3	2.2	2.6	1.7	15.7	62.0	8.1

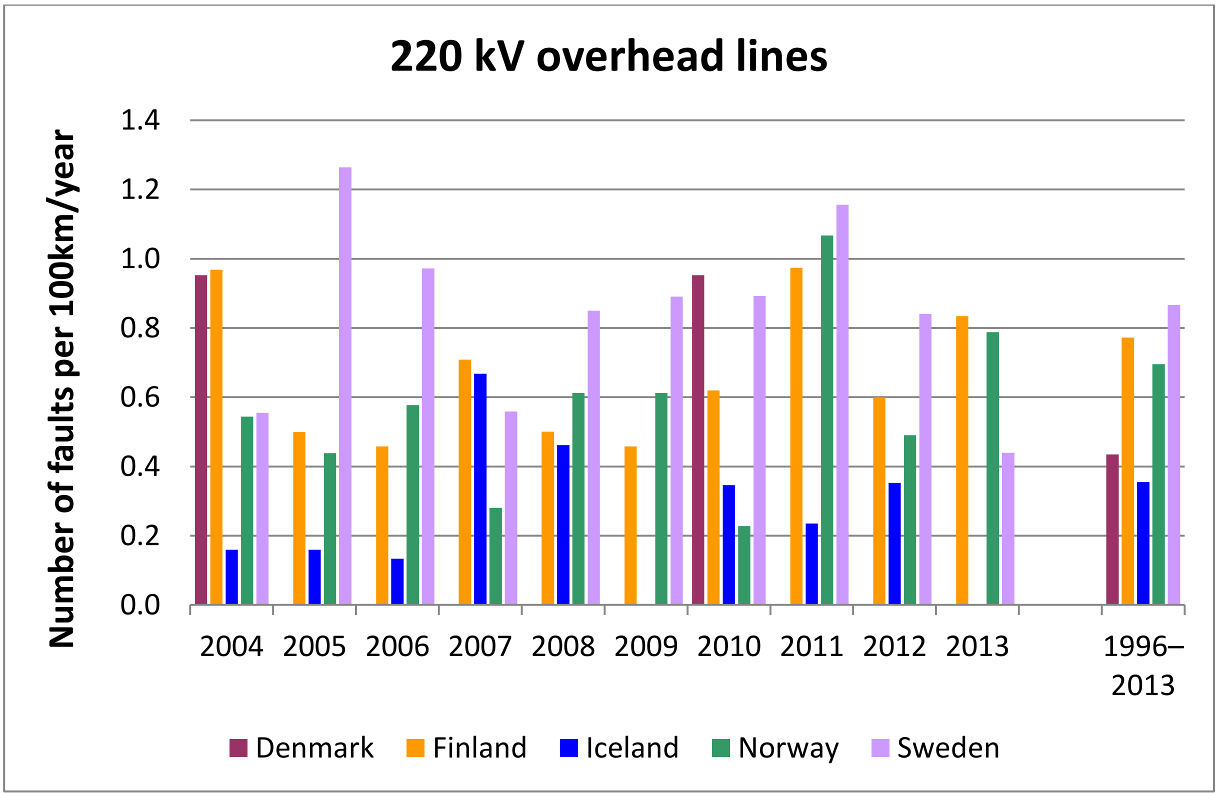

FIGURE 5.3.3 ANNUAL DIVISION OF FAULTS DURING THE PERIOD 2004–2013 AND THE AVERAGE FOR 1996–2013

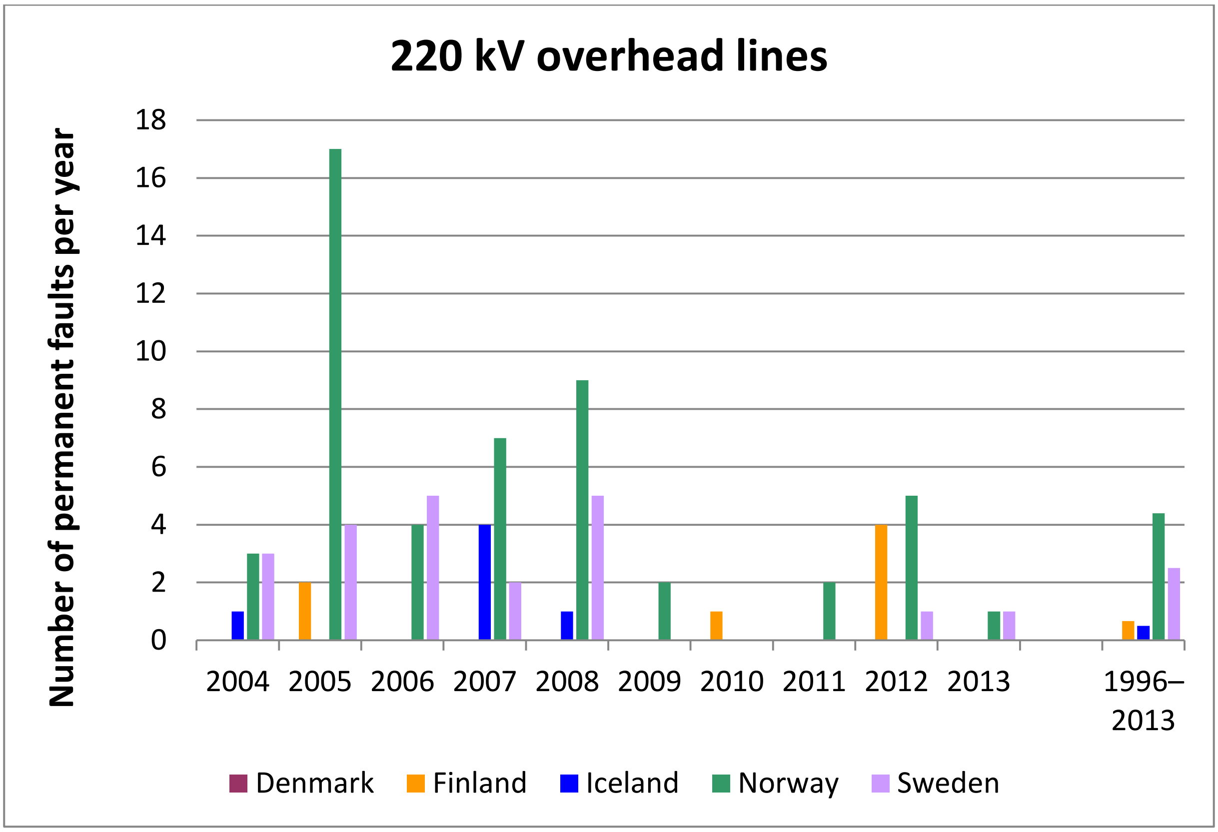

FIGURE 5.3.4 ANNUAL DIVISION OF PERMANENT FAULTS DURING THE PERIOD 2004–2013 AND THE AVERAGE FOR 1996–2013

5.3.3 132 KV OVERHEAD LINES

Table 5.3.3 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 2013 and for the 18-year period 1996–2013. Figure 5.3.5 presents the annual line fault values per line length during the 10-year period 2004–2013 and the average value of period 1996–2013. Figure 5.3.6 presents the annual line permanent faults during the same period.

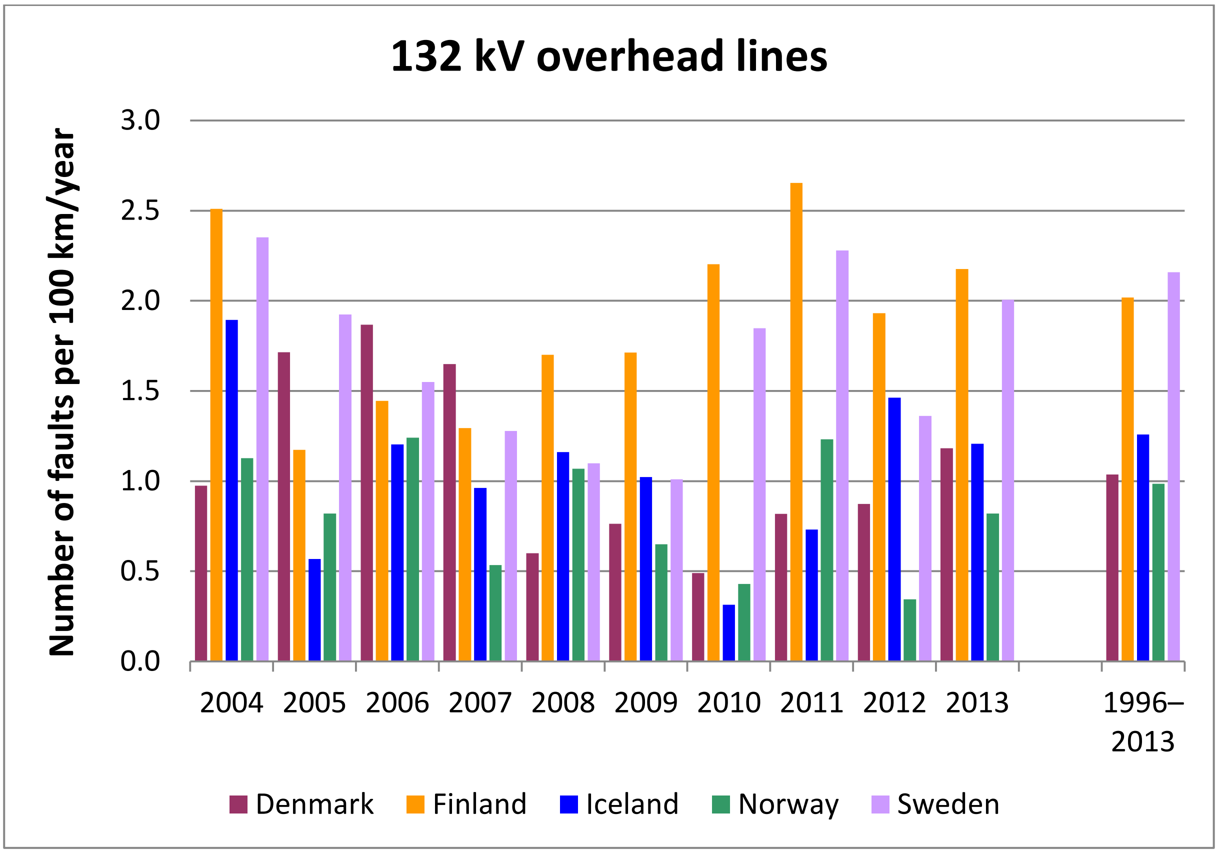

FIGURE 5.3.5 ANNUAL DIVISION OF FAULTS DURING THE PERIOD 2004–2013 AND THE AVERAGE FOR 1996–2013

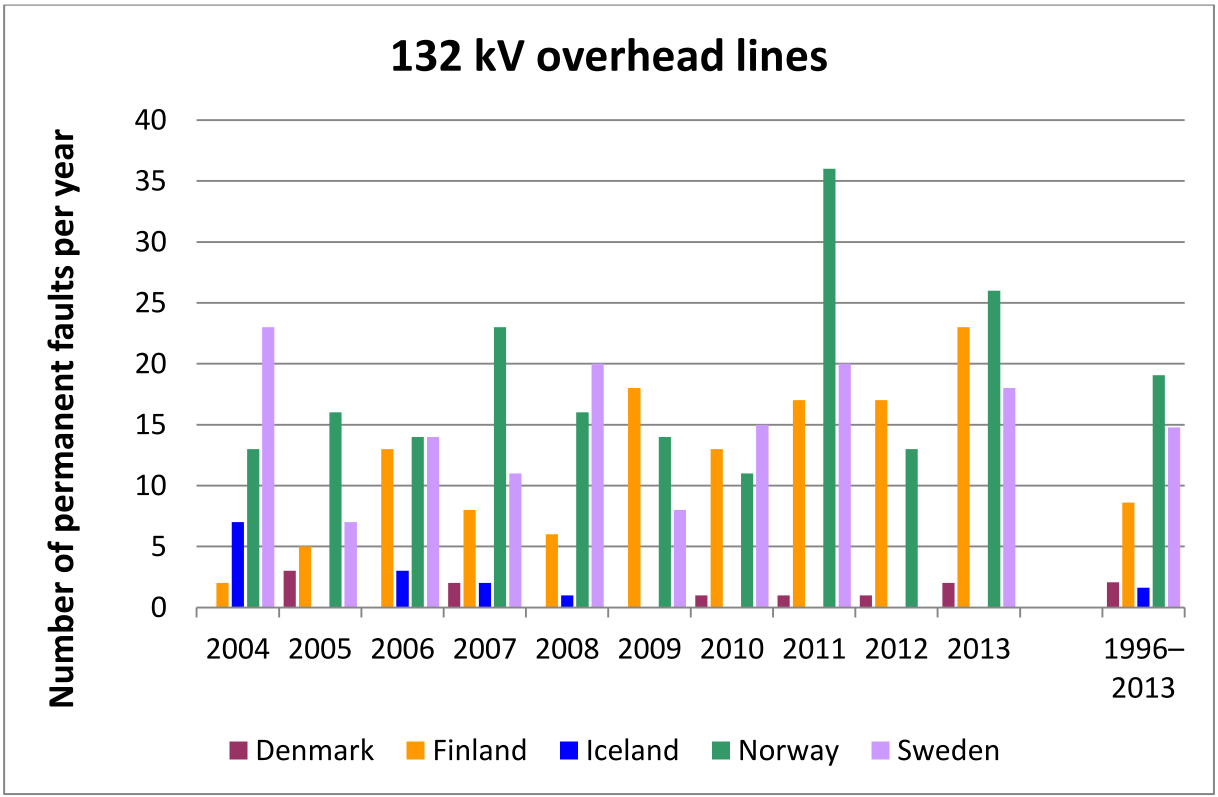

FIGURE 5.3.6 ANNUAL DIVISION OF PERMANENT FAULTS DURING THE PERIOD 2004–2013

TABLE 5.3.3 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 132 KV OVERHEAD LINES

Country	Lines (km)	Number of faults	Number of faults per 100 km		Faults divided by cause (%) during 1996–2013							1996–2013 (%)	
	2013	2013	2013	1996–2013	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown	1-phase faults	Permanent faults
Denmark	3470	41	1,18	1,04	23,4	40,2	20,1	2,3	1,1	2,4	10,6	49,9	4,9
Finland	15990	348	2,18	2,02	37,2	15,3	1,5	1,4	0,4	2,1	42,1	78,8	3,4
Iceland	1242	15	1,21	1,26	2,9	86,4	2,9	0,7	6,8	0,0	0,4	35,8	10,4
Norway	10475	86	0,82	0,99	53,1	32,0	2,5	1,0	5,9	4,2	1,6	28,2[1)]	18,7
Sweden	15761	316	2,00	2,16	60,9	5,3	2,3	2,8	2,8	1,8	24,1	37,3	5,2
Nordic	46938	806	1,72	1,69	47,6	16,7	3,1	1,9	2,4	2,2	26,0	51,8	6,6

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

5.3.4 LINE FAULT TRENDS

Figure 5.3.7, Figure 5.3.8 and

Figure 5.3.9 present faults divided by line length for 400 kV, 200 kV and 132 kV lines, respectively. The trend curve is proportioned to line length in order to get comparable results between countries.

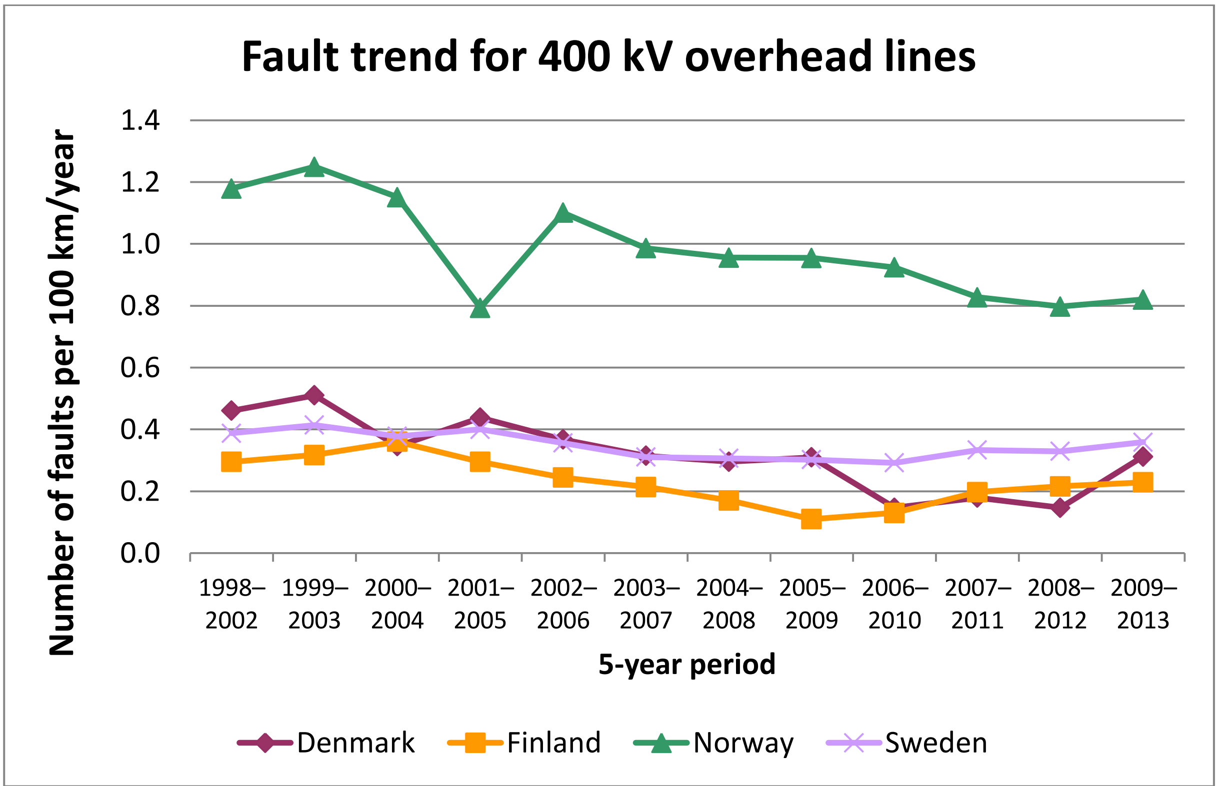

FIGURE 5.3.7 FAULT TREND FOR OVERHEAD LINES AT VOLTAGE LEVEL 400 KV

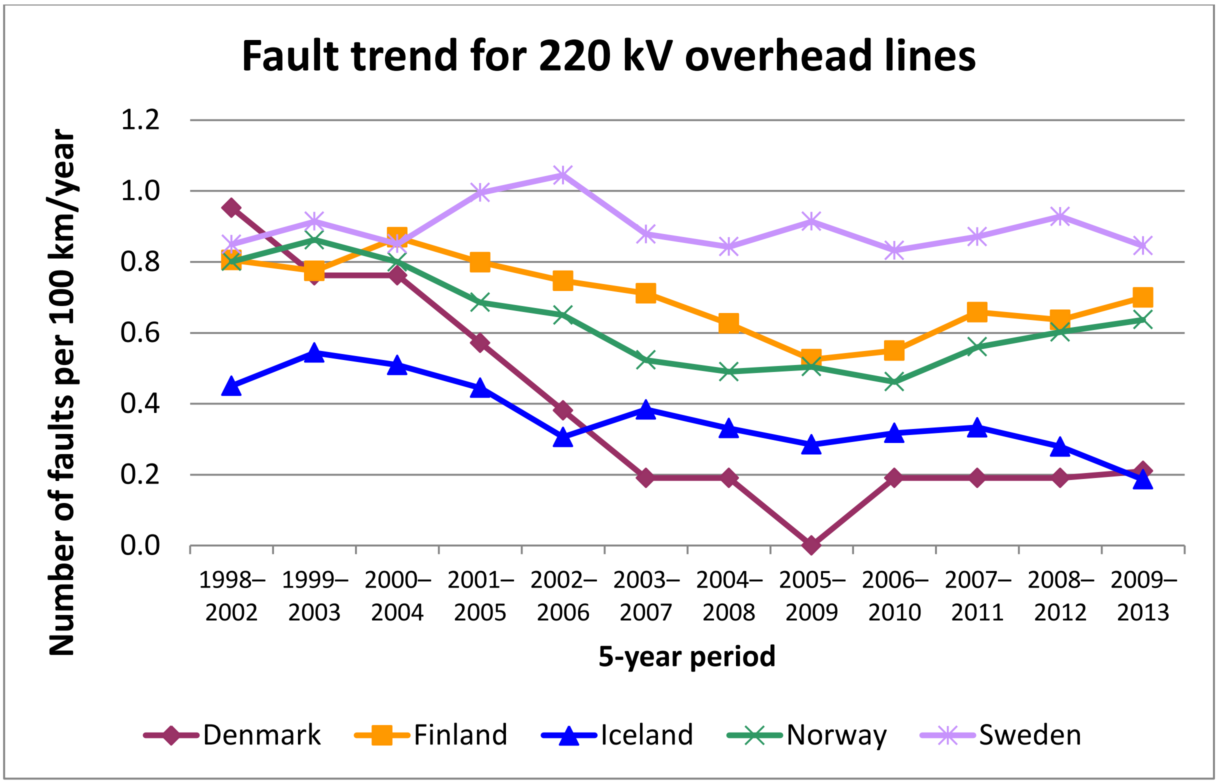

FIGURE 5.3.8 FAULT TREND FOR OVERHEAD LINES AT VOLTAGE LEVEL 220 KV

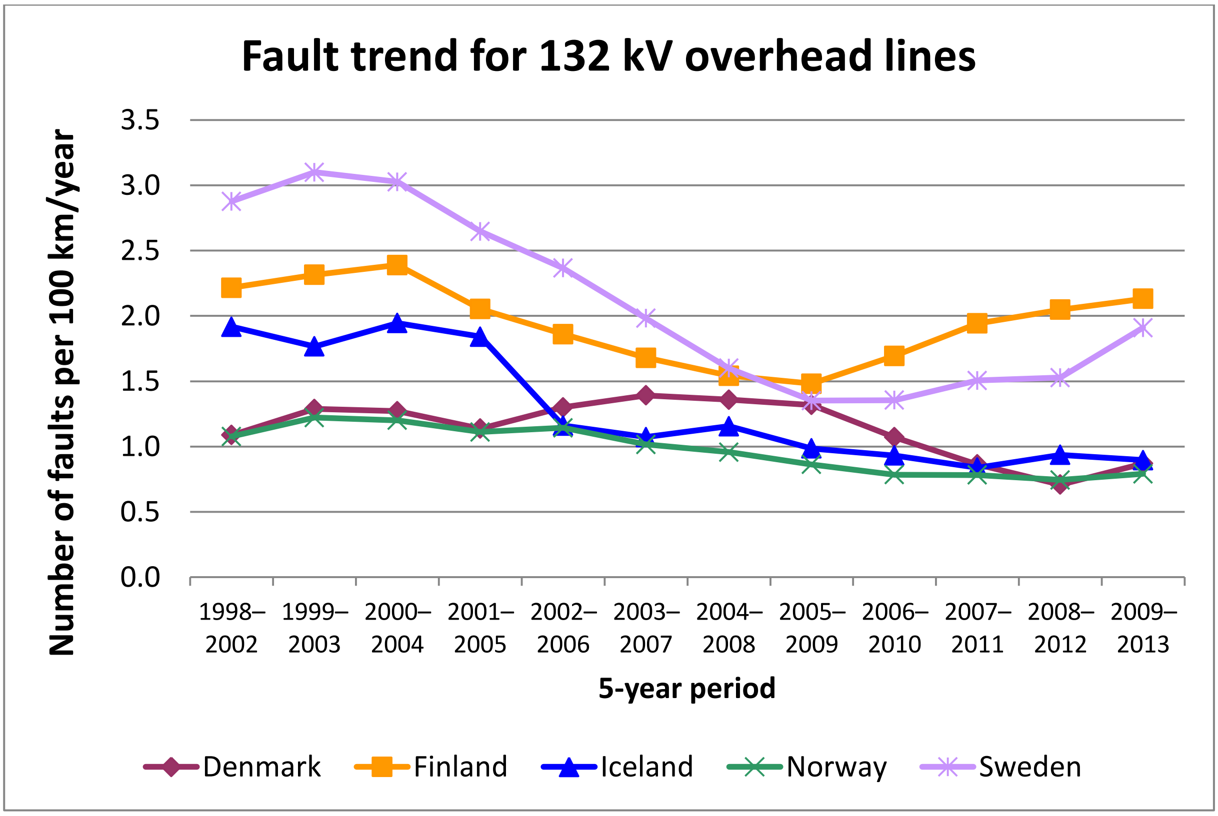

FIGURE 5.3.9 FAULT TREND FOR OVERHEAD LINES AT VOLTAGE LEVEL 132 KV

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 2013 and for the period 2004–2013. 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 2004–2013 is presented graphically for 132 kV cables only. Also fault trends are presented.

The Danish cable length data since 2004 has been corrected this year which means that the statistics is not directly comparable with older statistics.

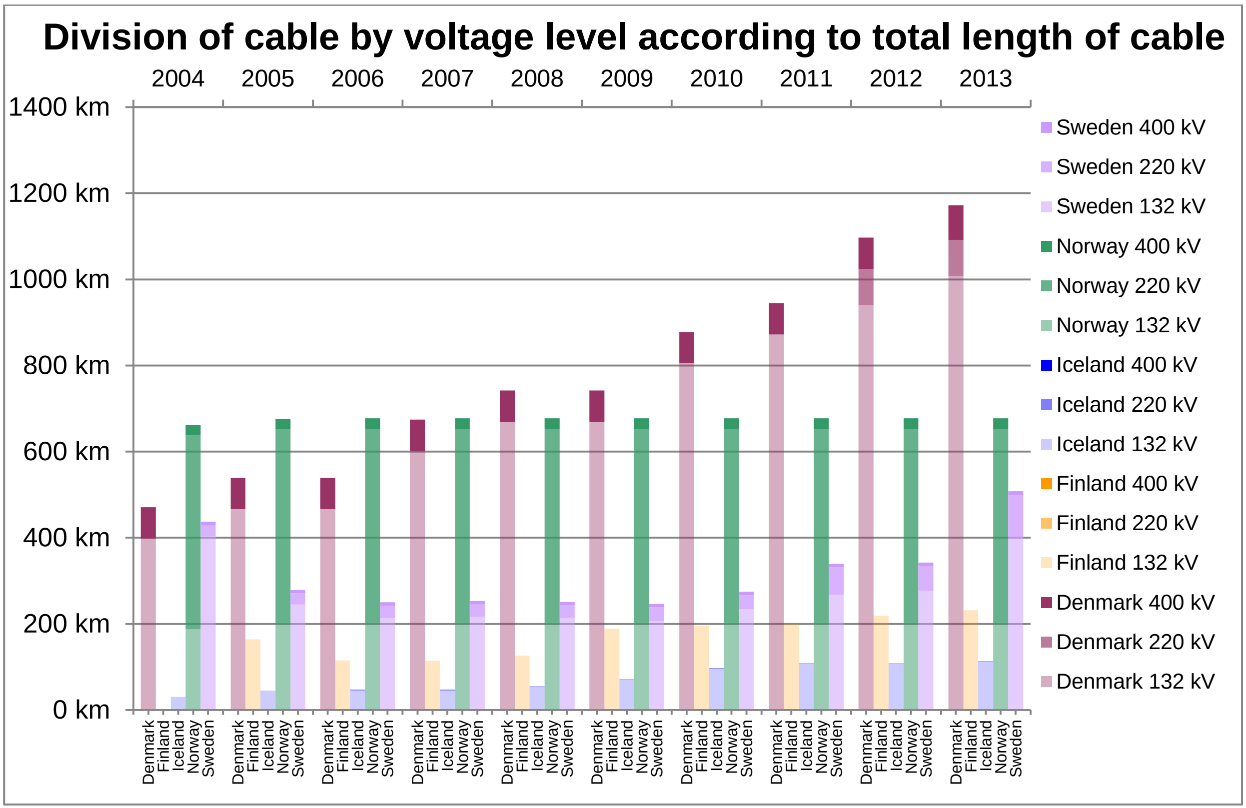

FIGURE 5.4.1 DIVISION OF CABLE BY VOLTAGE LEVEL ACCORDING TO TOTAL LENGTH OF CABLE DURING THE PERIOD 2004–2013

TABLE 5.4.1 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 400 KV CABLES

Country	Lines (km)	Number of faults	Number of faults per 100 km		Faults divided by cause (%) during the period 2004–2013						
	2013	2013	2013	2004–2013	Lightning	Other environmental causes	External influence	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	80	0	0,00	0,00	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Norway	25	0	0,00	1,61	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	113	0	0,00	0,47	0,0	0,0	0,0	0,0	60,0	20,0	20,0

TABLE 5.4.2 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 220 KV CABLES

Country	Lines (km) 2013	Number of faults 2013	Number of faults per 100 km 2013	Number of faults per 100 km 2004–2013	Faults divided by cause (%) during the period 2004–2013: Lightning	Other environmental causes	External influence	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	84	0	0,00	0,00	0,0	0,0	0,0	0,0	0,0	0,0	0,0
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	103	2	1,94	2,57	0,0	0,0	0,0	9,1	81,8	0,0	9,1
Nordic	554	2	0,36	0,24	0,0	0,0	0,0	8,3	75,0	0,0	16,7

TABLE 5.4.3 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 132 KV CABLES

Country	Lines (km) 2013	Number of faults 2013	Number of faults per 100 km 2013	Number of faults per 100 km 2004–2013	Faults divided by cause (%) during the period 2004–2013: Lightning	Other environmental causes	External influence	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	1008	2	0,20	0,33	0,0	0,0	17,4	8,7	60,9	8,7	4,3
Finland	232	1	0,43	0,32	0,0	0,0	0,0	0,0	40,0	20,0	40,0
Iceland	112	0	0,00	0,56	0,0	0,0	0,0	25,0	75,0	0,0	0,0
Norway	202	9	4,46	1,15	4,3	8,7	0,0	26,1	30,4	17,4	13,0
Sweden	397	5	1,26	1,05	0,0	0,0	14,3	7,1	53,6	3,6	21,4
Nordic	1951	17	0,87	0,60	1,2	2,4	9,6	13,3	49,4	9,6	14,5

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

Figure 5.4.2 presents the annual cable fault values per cable length faults during the 10-year period 2004–2013 for 132 kV cables.

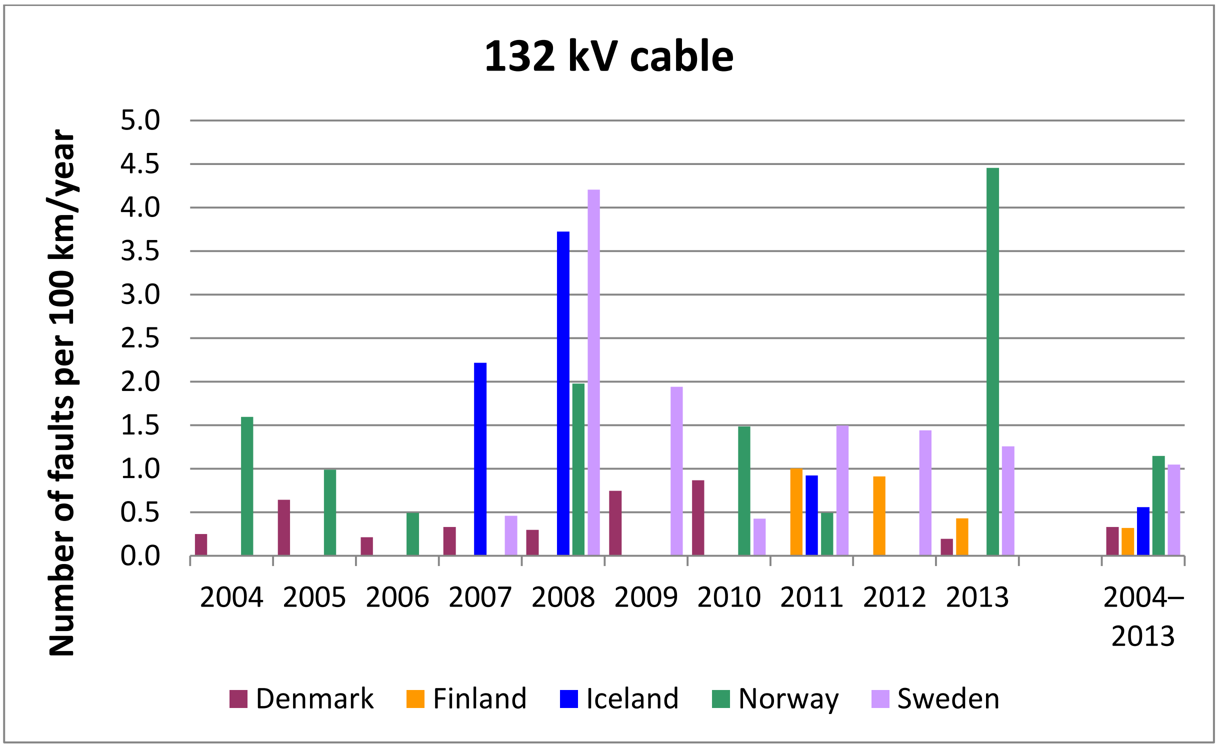

FIGURE 5.4.2 ANNUAL DIVISION OF FAULTS DURING THE PERIOD 2004–2013

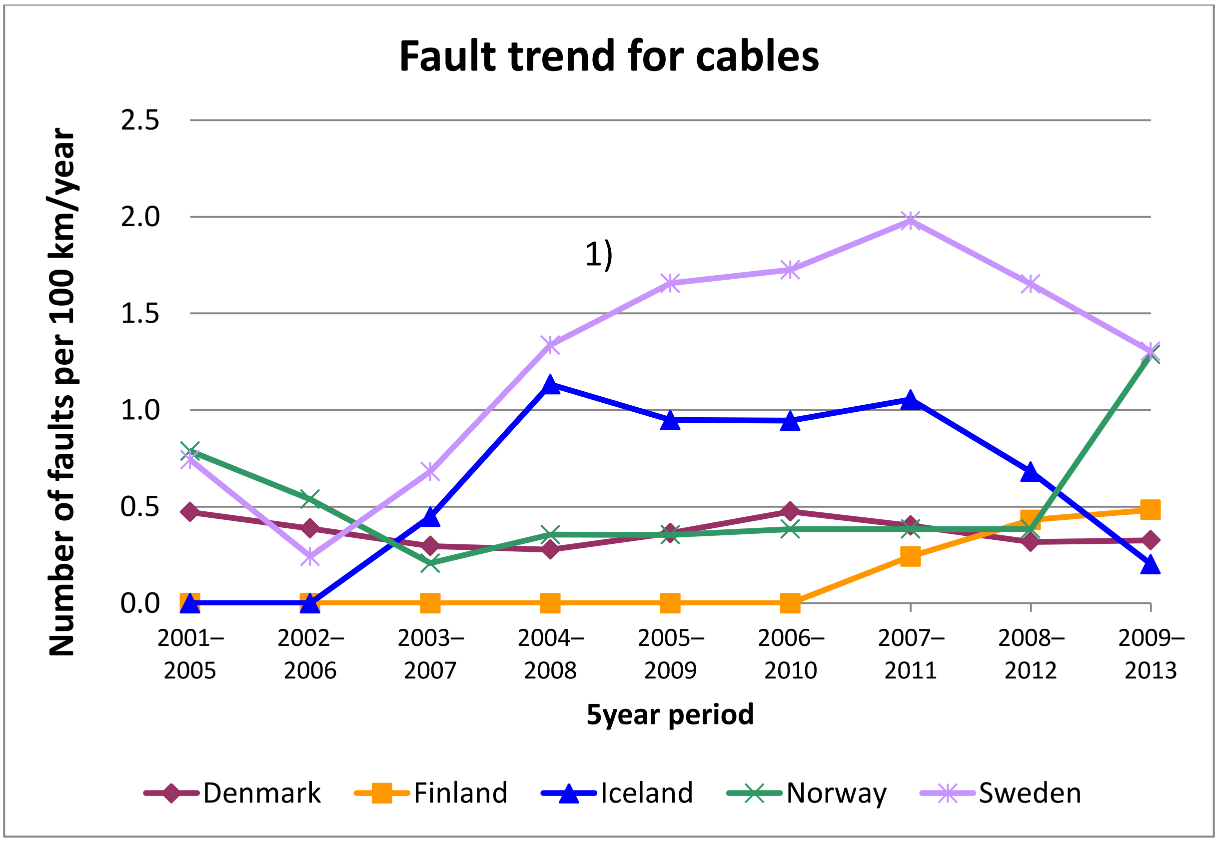

FIGURE 5.4.3 FAULT TREND FOR CABLES AT ALL VOLTAGE LEVELS

1) The main explanation for the high values in the fault trend for Sweden during the years 2008–2012 is that there were several cable faults in 2008, as seen in Figure 5.4.2.

5.5 Faults in power transformers

The tables in this section present the division of faults for the year 2013 and for the period 2004–2013 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 2004–2013. The annual division of faults during the period 2004–2013 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].

Table 5.5.1 Division of faults according to cause for 400 kV power transformers

Country	Number of devices	Number of faults	Number of faults per 100 devices		Faults divided by cause (%) during the period 2004–2013						
					Lightning	Other environmental causes	External influence	Operation and maintenance	Technical equipment	Other	Unknown
	2013	2013	2013	2004–2013							
Denmark	30	0	0,00	2,47	0,0	0,0	0,0	16,7	33,3	0,0	50,0
Finland	56	0	0,00	2,21	0,0	18,2	0,0	18,2	54,5	0,0	9,1
Norway	64	0	0,00	2,21	0,0	0,0	0,0	21,4	42,9	21,4	14,3
Sweden	61	3	4,92	2,07	0,0	0,0	0,0	42,9	7,1	42,9	7,1
Nordic	211	3	1,42	2,20	0,0	4,4	0,0	26,7	33,3	20,0	15,6

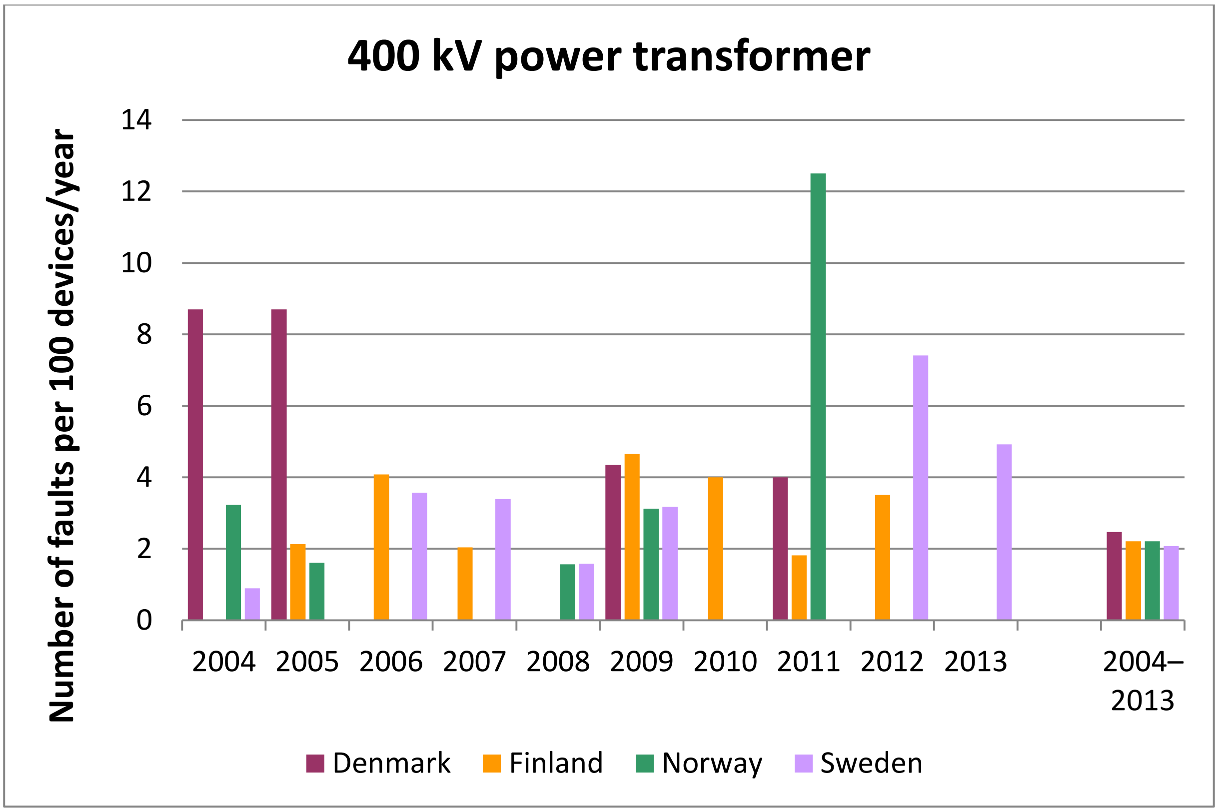

Figure 5.5.1 Annual division of faults during the period 2004–2013

TABLE 5.5.2 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 220 KV POWER TRANSFORMERS

Country	Number of devices 2013	Number of faults 2013	Number of faults per 100 devices 2013	Number of faults per 100 devices 2004–2013	Faults divided by cause (%) during the period 2004–2013: Lightning	Other environmental causes	External influence	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	7	0	0,00	0,00	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Finland	23	1	4,35	1,71	0,0	0,0	0,0	50,0	25,0	0,0	25,0
Iceland	33	1	3,03	3,65	0,0	9,1	0,0	0,0	81,8	0,0	9,1
Norway	271	1	0,37	1,10	3,3	3,3	0,0	16,7	43,3	26,7	6,7
Sweden	92	2	2,17	3,14	25,0	0,0	9,4	15,6	18,7	6,2	25,0
Nordic	426	5	1,17	1,79	11,7	2,6	3,9	15,6	37,7	13,0	15,6

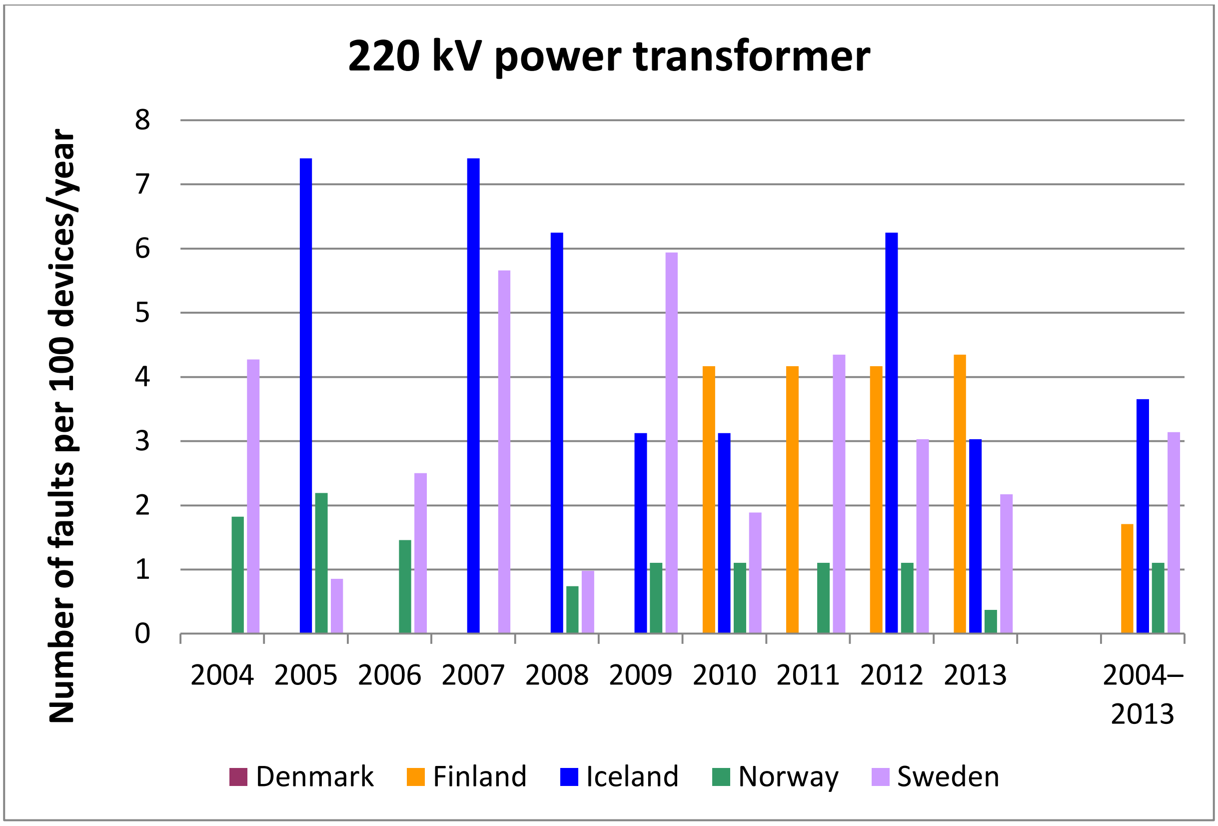

FIGURE 5.5.2 ANNUAL DIVISION OF FAULTS DURING THE PERIOD 2004–2013

TABLE 5.5.3 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 132 KV POWER TRANSFORMERS

Country	Number of devices	Number of faults	Number of faults per 100 devices		Faults divided by cause (%) during the period 2004–2013						
	2013	2013	2013	2004–2013	Lightning	Other environmental causes	External influence	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	259	1	0,39	0,93	9,1	9,1	4,5	31,8	22,7	4,5	18,2
Finland	1121	6	0,54	0,55	9,5	2,4	14,3	16,7	26,2	4,8	26,2
Iceland	51	0	0,00	1,19	0,0	33,3	0,0	33,3	33,3	0,0	0,0
Norway	724	3	0,41	0,58	4,8	33,3	4,8	14,3	21,4	16,7	4,8
Sweden	697	31	4,45	3,33	14,8	2,7	2,2	19,7	29,1	5,4	26,0
Nordic	2852	41	1,44	1,37	12,2	7,5	4,2	19,7	27,5	6,6	22,4

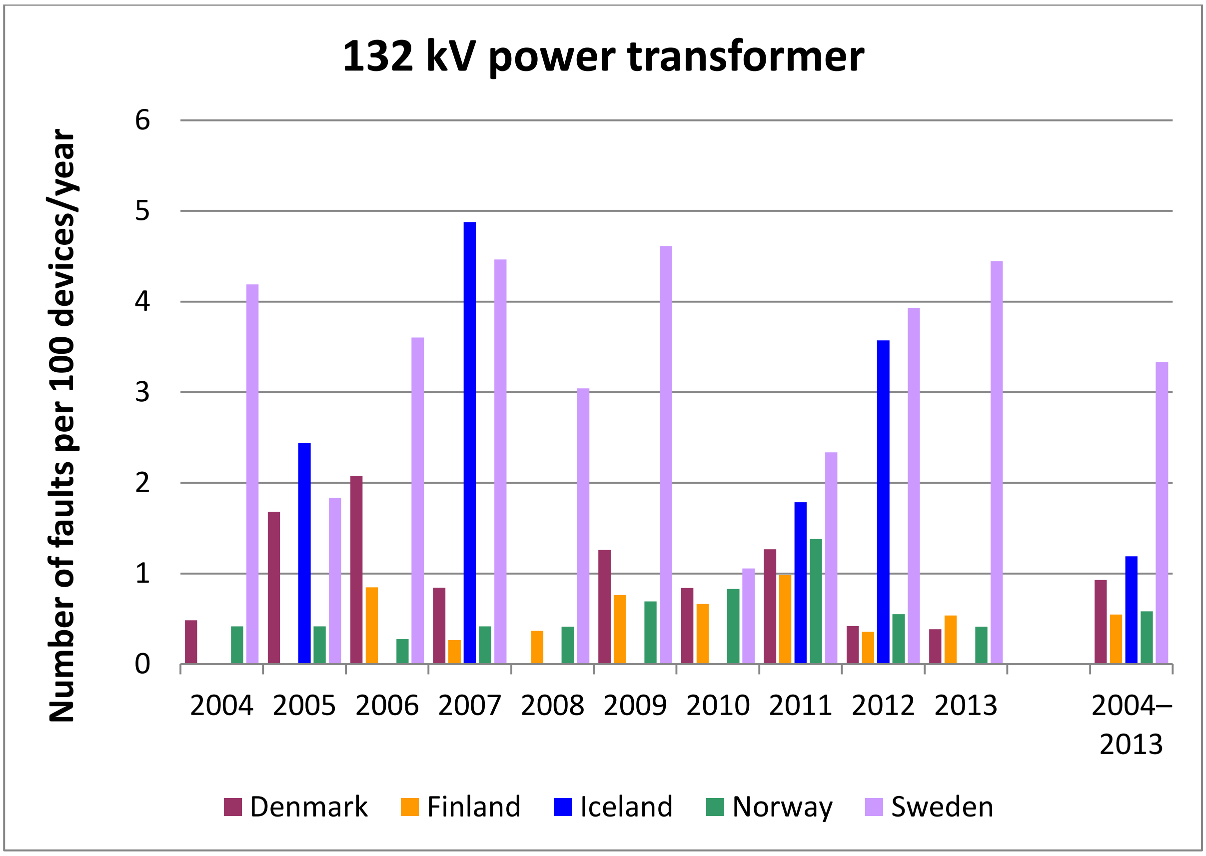

FIGURE 5.5.3 ANNUAL DIVISION OF FAULTS DURING THE PERIOD 2004–2013

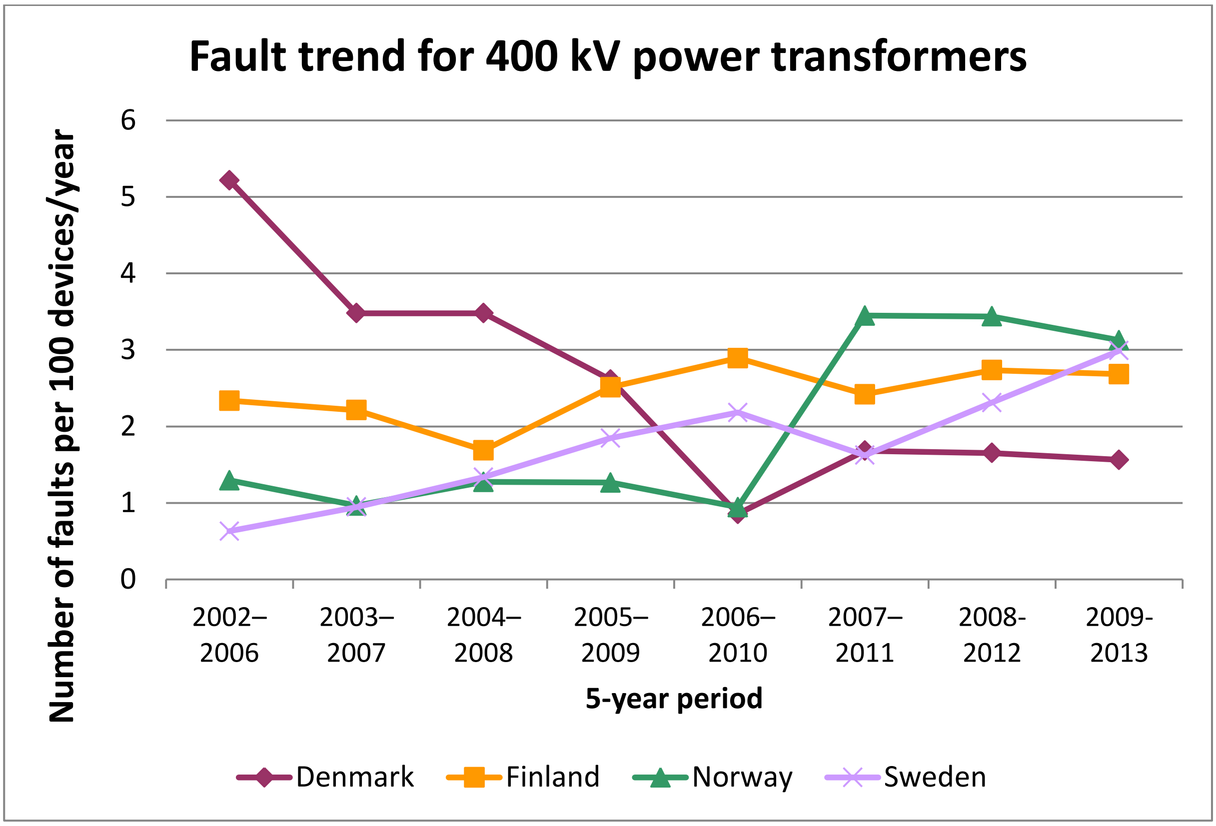

FIGURE 5.5.4 FAULT TREND FOR POWER TRANSFORMERS AT VOLTAGE LEVEL 400 KV

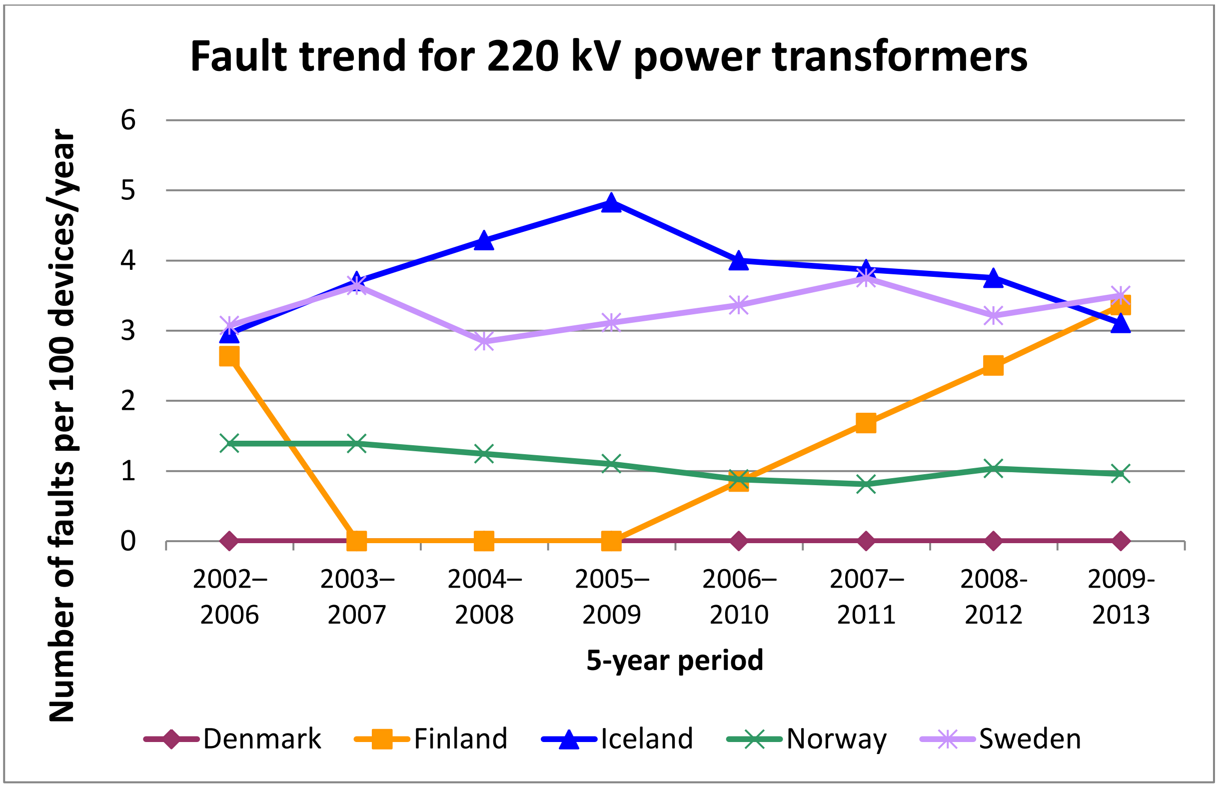

FIGURE 5.5.5 FAULT TREND FOR POWER TRANSFORMERS AT VOLTAGE LEVEL 220 KV

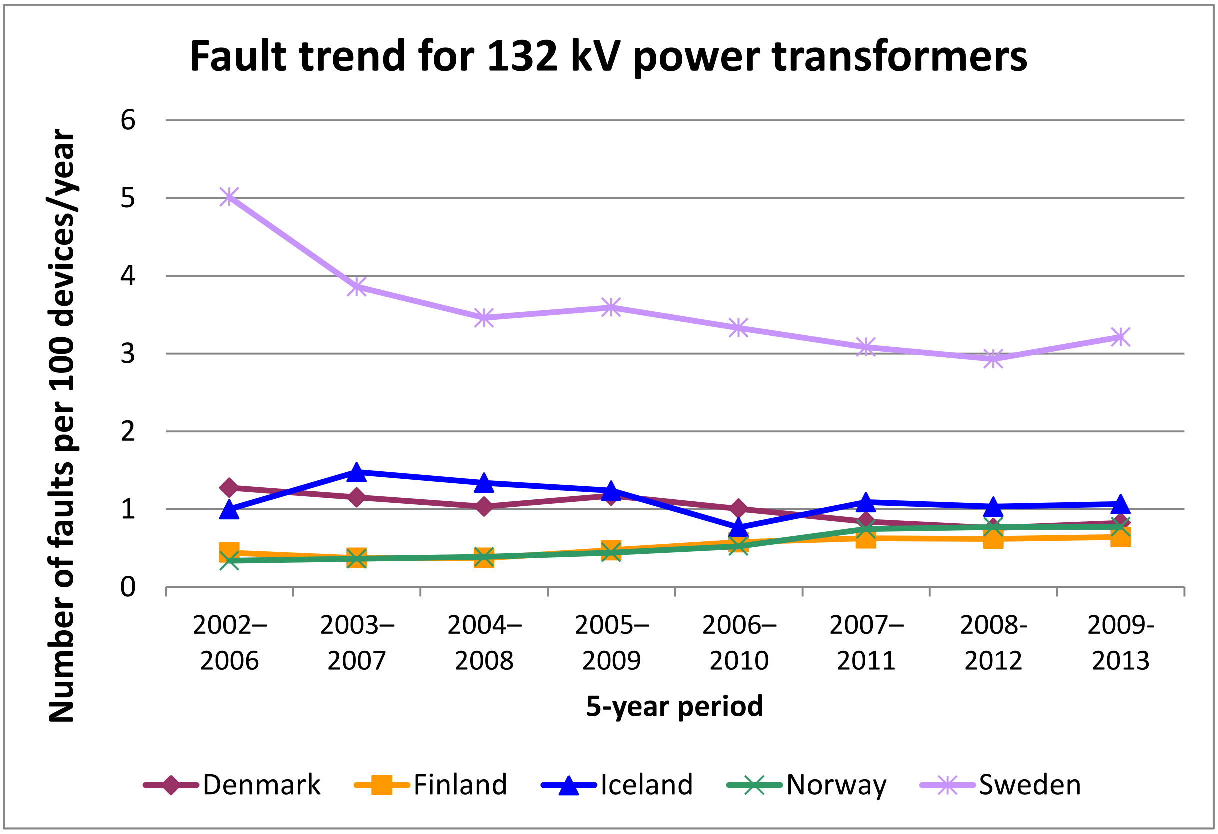

FIGURE 5.5.6 FAULT TREND FOR POWER TRANSFORMERS AT VOLTAGE LEVEL 132 KV

Due to a misinterpretation of the guidelines there were a high number of faults for Sweden during 1999–2003. The old data has not been corrected in the tables and figures affected.

5.6 Faults in Instrument Transformers

This section presents the faults in instrument transformers for the year 2013 and for the period 2004–2013 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 5.6.1 Division of faults according to cause for 400 kV instrument transformers

Country	Number of devices	Number of faults	Number of faults per 100 devices		Faults divided by cause (%) during the period 2004–2013						
					Lightning	Other environmental causes	External influence	Operation and maintenance	Technical equipment	Other	Unknown
	2013	2013	2013	2004–2013							
Denmark	118	0	0,00	0,00	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Finland	477	0	0,00	0,03	0,0	0,0	0,0	0,0	100,0	0,0	0,0
Norway	930	3	0,32	0,11	0,0	10,0	0,0	20,0	70,0	0,0	0,0
Sweden	1107	4	0,36	0,11	0,0	0,0	0,0	9,1	81,8	0,0	9,1
Nordic	2632	7	0,27	0,08	0,0	4,5	0,0	13,6	77,3	0,0	4,5

Table 5.6.2 Division of faults according to cause for 220 kV instrument transformers

Country	Number of devices	Number of faults	Number of faults per 100 devices		Faults divided by cause (%) during the period 2004–2013						
					Lightning	Other environmental causes	External influence	Operation and maintenance	Technical equipment	Other	Unknown
	2013	2013	2013	2004–2013							
Denmark	10	0	0,00	0,85	0,0	0,0	0,0	0,0	0,0	0,0	100,0
Finland	146	0	0,00	0,00	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Iceland	80	0	0,00	0,00	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Norway	2805	3	0,11	0,07	10,5	0,0	0,0	15,8	47,4	15,8	10,5
Sweden	639	0	0,00	0,09	12,5	0,0	0,0	0,0	87,5	0,0	0,0
Nordic	3680	3	0,08	0,07	10,7	0,0	0,0	10,7	57,1	10,7	10,7

Table 5.6.3 Division of faults according to cause for 132 kV instrument transformers

Country	Number of devices	Number of faults	Number of faults per 100 devices		Faults divided by cause (%) during the period 2004–2013						
					Lightning	Other environmental causes	External influence	Operation and maintenance	Technical equipment	Other	Unknown
	2013	2013	2013	2004–2013							
Denmark	619	2	0,32	0,03	0,0	0,0	0,0	9,1	72,7	0,0	18,2
Finland	3523	3	0,09	0,10	9,1	0,0	4,5	0,0	54,5	13,6	18,2
Iceland	176	0	0,00	0,00	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Norway	7768	2	0,03	0,05	11,4	0,0	0,0	11,4	37,1	28,6	11,4
Sweden	3838	2	0,05	0,06	9,1	0,0	3,0	12,1	66,7	0,0	9,1
Nordic	15924	9	0,06	0,05	8,9	0,0	2,0	8,9	54,5	12,9	12,9

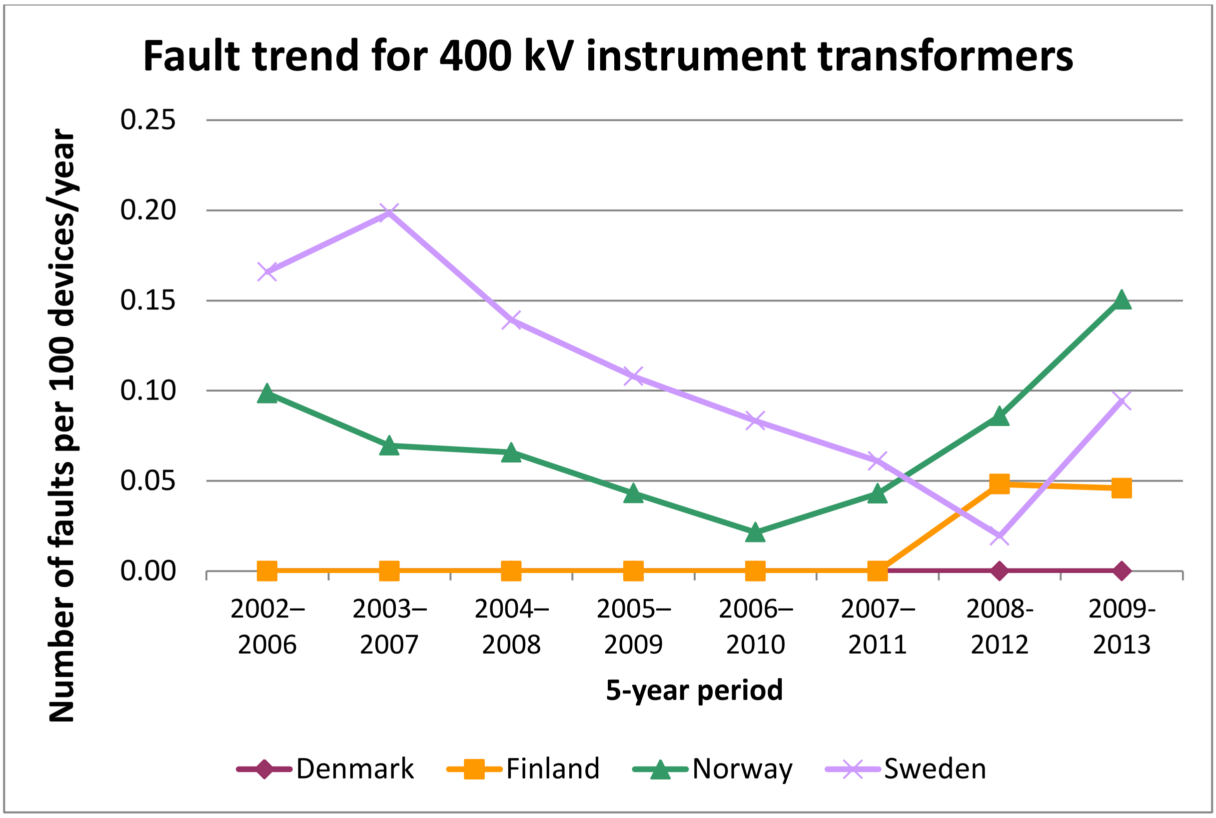

Figure 5.6.1 Fault trend for instrument transformers at voltage level 400 kV

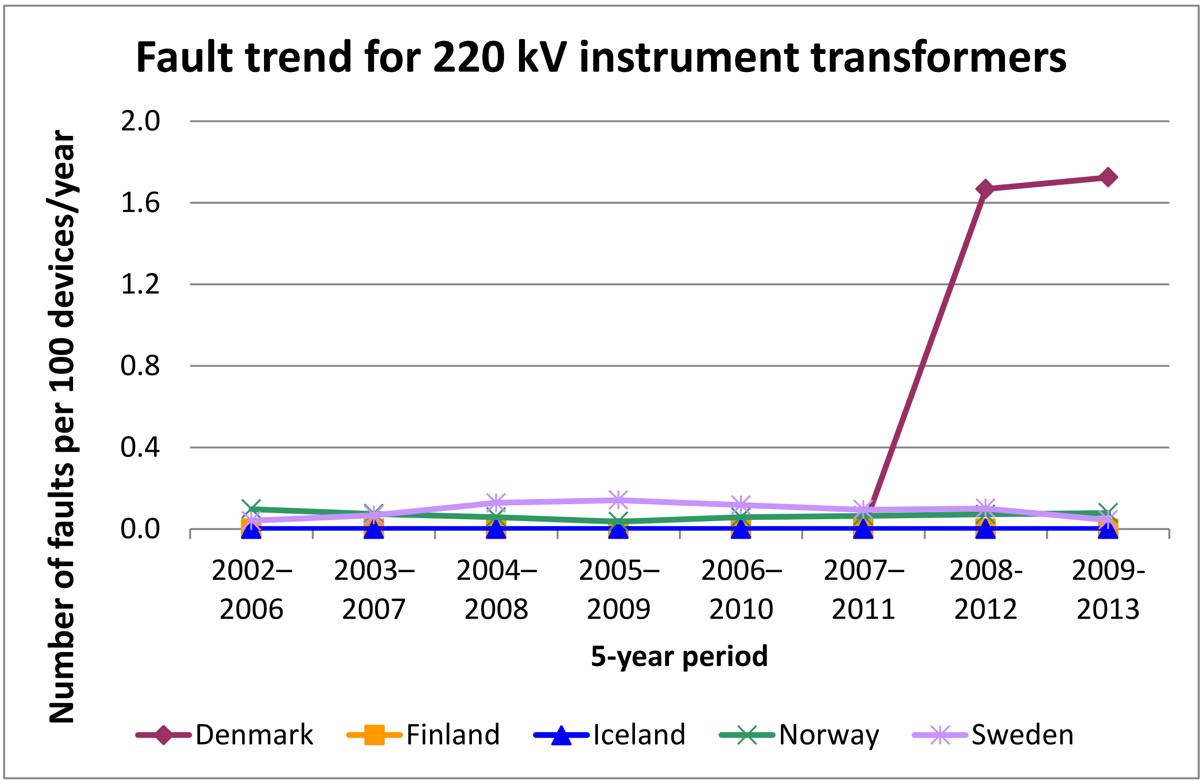

Figure 5.6.2 Fault trend for instrument transformers at voltage level 220 kV.

[1)] The value for Denmark during years 2008 and 2009 is high compared to the other countries because they have a significantly smaller amount of instrument transformers than the other countries.

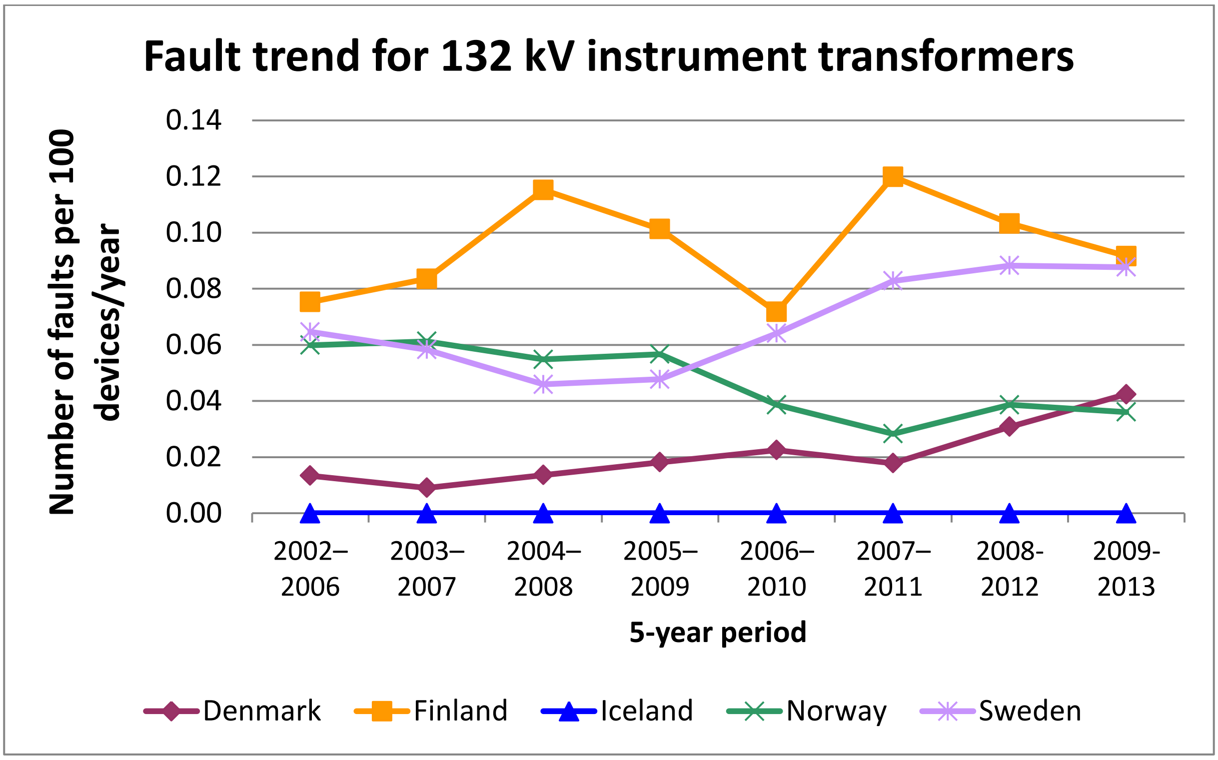

FIGURE 5.6.3 FAULT TREND FOR INSTRUMENT TRANSFORMERS AT VOLTAGE LEVEL 132 KV.

5.7 FAULTS IN CIRCUIT BREAKERS

The tables in this section present circuit breaker faults at each respective voltage level for the year 2013 and for the ten-year period 2004–2013. The tables also present the division of faults according to cause during the ten-year period.

TABLE 5.7.1 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 400 KV CIRCUIT BREAKERS

Country	Number of devices	Number of faults	Number of faults per 100 devices		Faults divided by cause (%) during the period 2004–2013						
					Light-ning	Other environ-mental causes	External influence	Ope-ration and mainte-nance[2)]	Technical equipment	Ot-her	Un-known
	2013	2013	2013	2004–2013							
Denmark	118	0	0,00	0,67	0,0	0,0	10,0	20,0	60,0	10,0	0,0
Finland	276	1	0,36	0,39	0,0	0,0	11,1	0,0	77,8	11,1	0,0
Norway	262	3	1,15	0,85	0,0	0,0	0,0	40,9	50,0	4,5	4,5
Sweden[1)]	558	8	1,43	1,65	0,0	1,3	0,0	3,9	87,0	1,3	6,5
Nordic	1214	12	0,99	1,07	0,0	0,8	1,7	11,9	77,1	3,4	5,1

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.

2) One should note that a high number of operation and maintenance is because erroneous circuit breaker operations are registered as faults with operation and maintenance as the cause. These are caused by 400 kV shunt reactor circuit breakers, which usually operate very often compared to other circuit breakers.

TABLE 5.7.2 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 220 KV CIRCUIT BREAKERS

Country	Number of devices	Number of faults	Number of faults per 100 devices		Faults divided by cause (%) during the period 2004–2013						
					Lightning	Other environmental causes	External influence	Operation and maintenance	Technical equipment	Other	Unknown
	2013	2013	2013	2004–2013							
Denmark	10	0	0,00	0,00	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Finland	92	0	0,00	0,42	0,0	0,0	0,0	0,0	100,0	0,0	0,0
Iceland	80	1	1,25	0,81	0,0	33,3	0,0	16,7	50,0	0,0	0,0
Norway	724	5	0,69	0,61	0,0	0,0	0,0	29,5	59,1	2,3	9,1
Sweden	310	1	0,32	0,38	7,1	0,0	0,0	14,3	57,1	0,0	21,4
Nordic	1216	7	0,58	0,54	1,5	2,9	0,0	23,5	60,3	1,5	10,3

TABLE 5.7.3 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 132 KV CIRCUIT BREAKERS

Country	Number of devices	Number of faults	Number of faults per 100 devices		Faults divided by cause (%) during the period 2004–2013						
					Lightning	Other environmental causes	External influence	Operation and maintenance	Technical equipment	Other	Unknown
	2013	2013	2013	2004–2013							
Denmark	619	3	0,48	0,34	0,0	0,0	0,0	29,6	63,0	3,7	3,7
Finland	2300	8	0,35	0,16	3,2	6,5	3,2	35,5	35,5	6,5	9,7
Iceland	176	2	1,14	0,87	0,0	8,3	8,3	16,7	66,7	0,0	0,0
Norway	2119	9	0,42	0,29	4,8	0,0	0,0	61,3	27,4	4,8	1,6
Sweden	1852	2	0,11	0,31	20,4	1,9	5,6	20,4	42,6	3,7	5,6
Nordic	7066	24	0,34	0,28	8,1	2,2	2,7	37,6	40,9	4,3	4,3

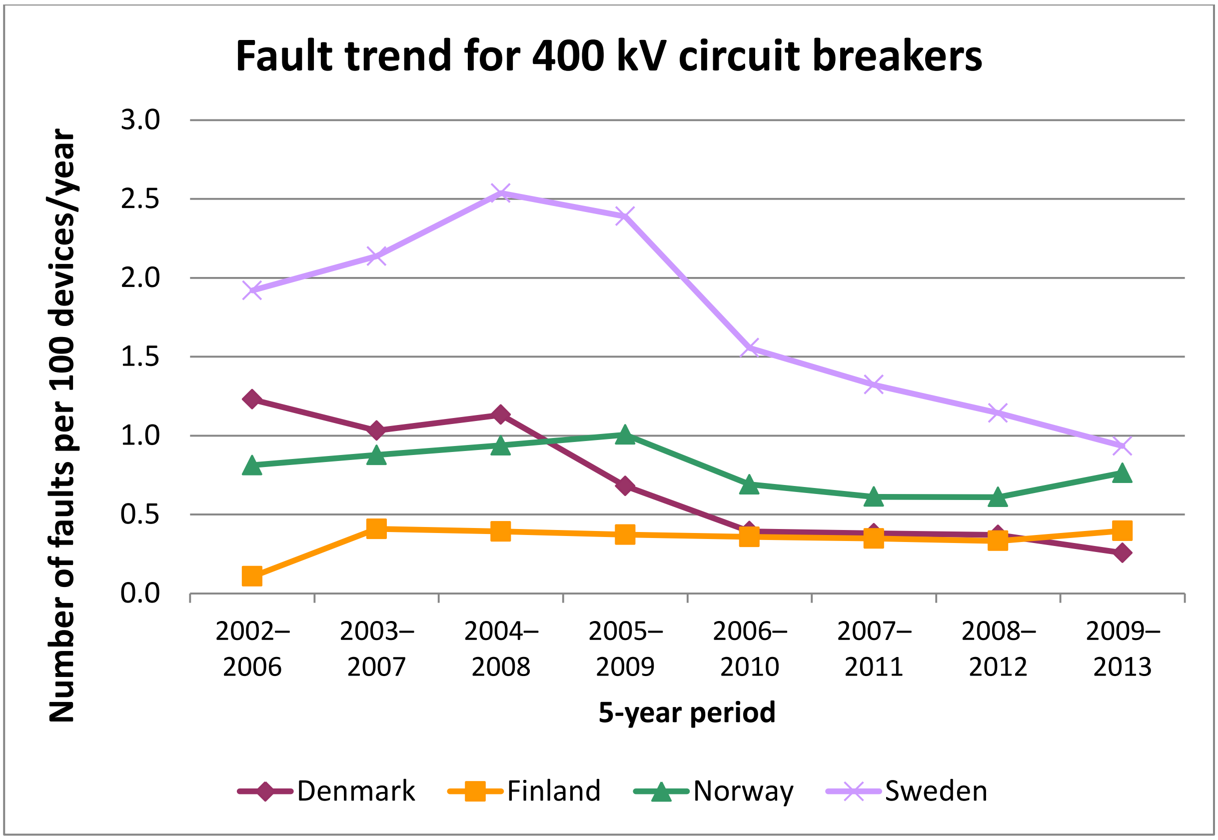

FIGURE 5.7.1 FAULT TREND FOR CIRCUIT BREAKERS AT VOLTAGE LEVEL 400 KV

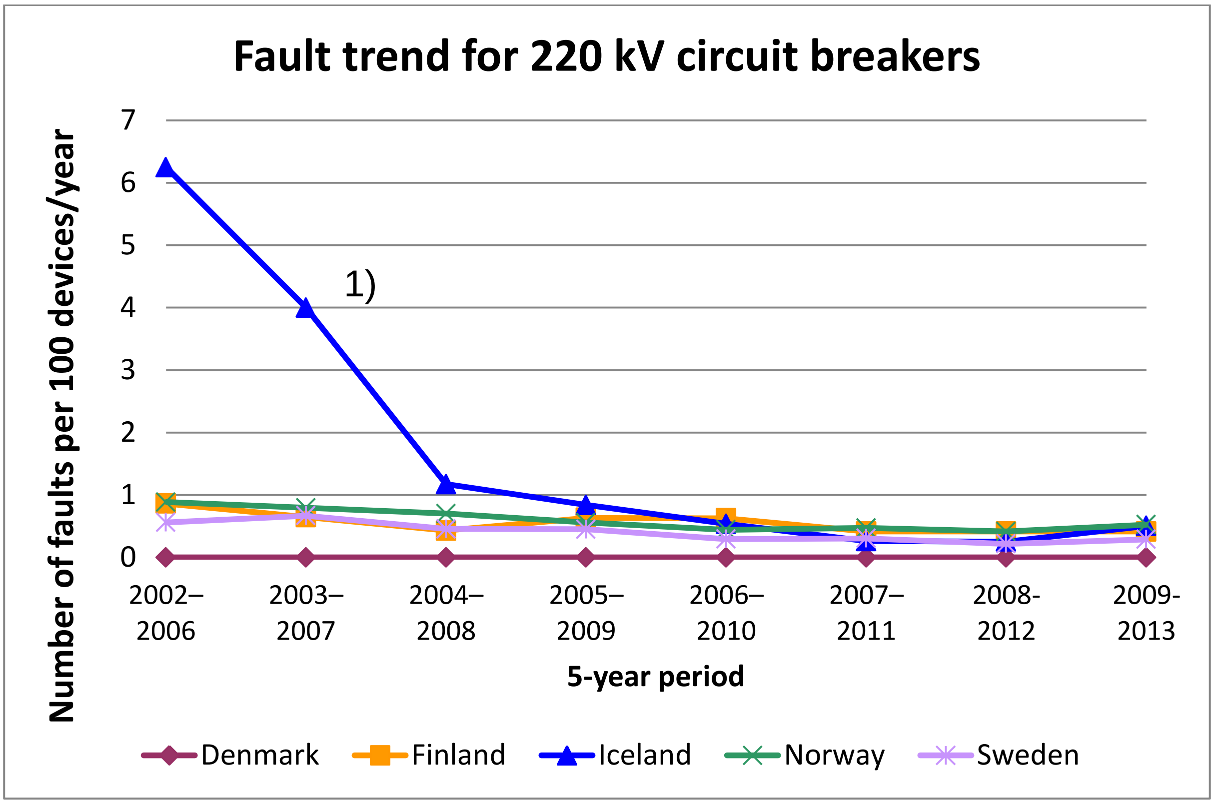

FIGURE 5.7.2 FAULT TREND FOR CIRCUIT BREAKERS AT VOLTAGE LEVEL 220 KV

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.

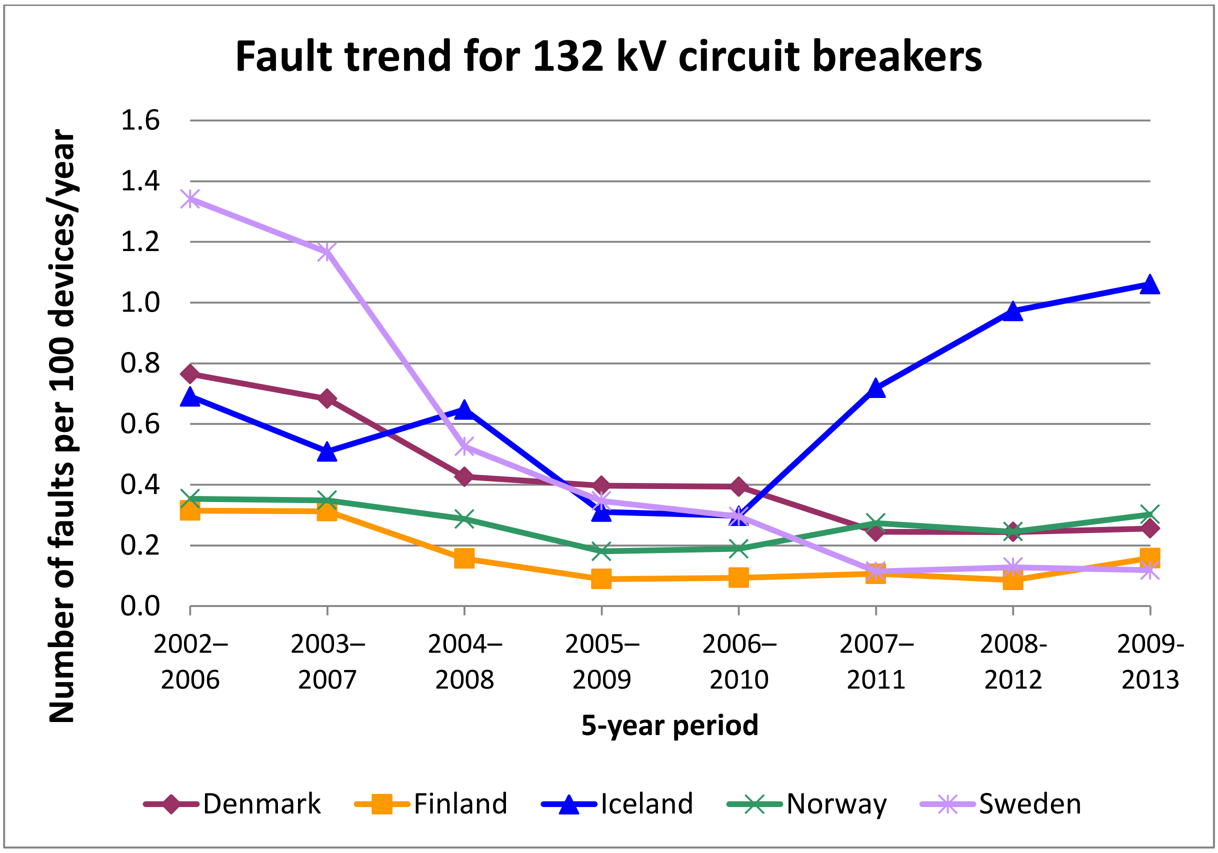

FIGURE 5.7.3 FAULT TREND FOR CIRCUIT BREAKERS AT VOLTAGE LEVEL 132 KV

5.8 FAULTS IN CONTROL EQUIPMENT

The tables, in this section, present faults in control equipment at each respective voltage level for the year 2013 and for the period 2004–2013. In addition, the tables present the division of faults according to cause during the ten-year period.

For control equipment it is important to distinguish between faults in technical equipment and faults made by human errors. Human errors include for example erroneous settings in an IED. In the statistics human errors is registered under operation and maintenance, separated from the category technical equipment.

In apparatus where the control equipment is integrated, (typical for SVC's) there is an uncertainty whether faults are registered in the control equipment or in the actual apparatus. When the control equipment is integrated in another installation it shall normally be categorized as faults in the installation and not in the control equipment. However, this definition is not yet fully applied in all countries.

TABLE 5.8.1 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 400 KV CONTROL EQUIPMENT

Country	Number of devices	Number of faults	Number of faults per 100 devices		Faults divided by cause (%) during the period 2004–2013						
					Lightning	Other environmental causes	External influence	Operation and maintenance	Technical equipment	Other	Unknown
	2013	2013	2013	2004–2013							
Denmark	118	1	0,85	0,61	0,0	0,0	0,0	37,5	62,5	0,0	0,0
Finland	276	6	2,17	3,38	0,0	0,0	0,0	67,5	20,8	1,3	10,4
Norway	261	6	2,30	4,76	0,0	1,6	0,0	38,2	45,5	3,3	11,4
Sweden	558	29	5,20	5,47	0,0	1,2	0,0	11,6	82,0	4,0	1,2
Nordic	1213	42	3,46	4,26	0,0	1,1	0,0	28,6	61,6	3,3	5,5

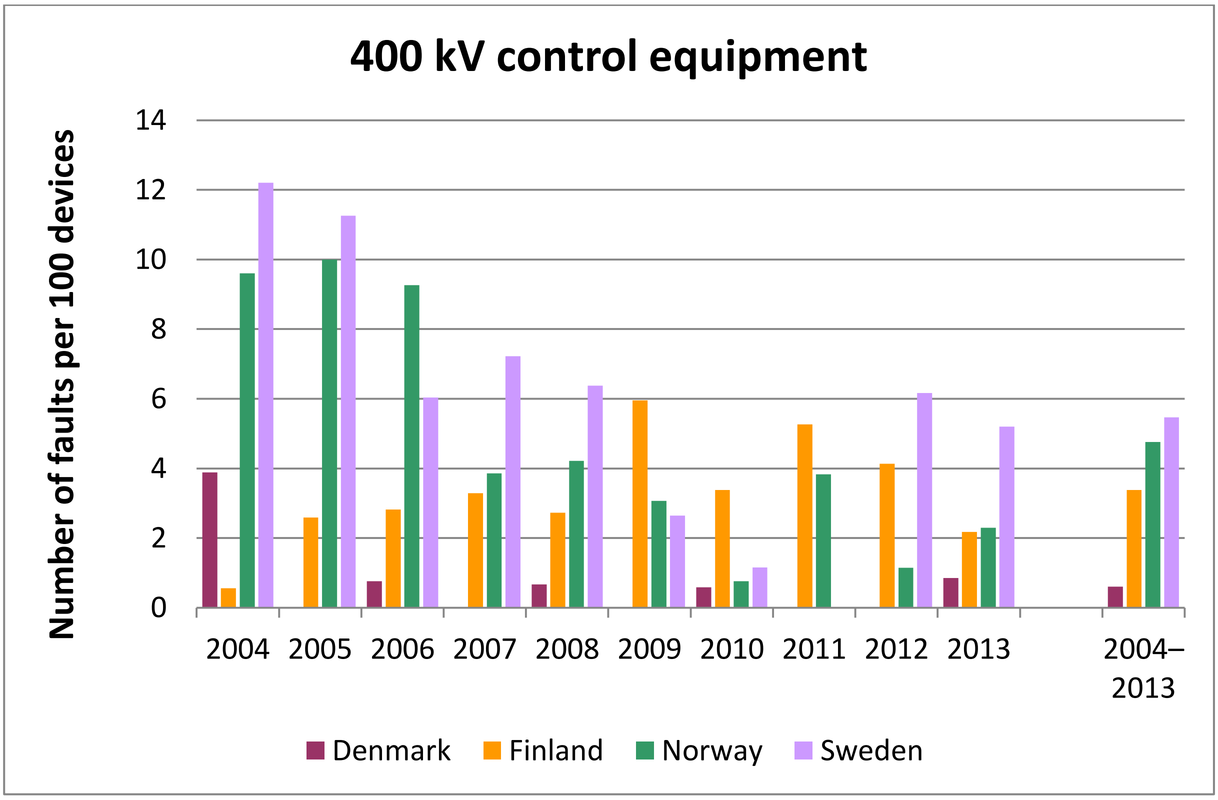

FIGURE 5.8.1 ANNUAL DIVISION OF FAULTS DURING THE PERIOD 2004–2013

TABLE 5.8.2 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 220 KV CONTROL EQUIPMENT

Country	Number of devices	Number of faults	Number of faults per 100 devices		Faults divided by cause (%) during the period 2004–2013						
	2013	2013	2013	2004–2013	Lightning	Other environmental causes	External influence	Operation and maintenance	Technical equipment	Other	Unknown
Denmark	10	1	10.00	3.57	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Finland	92	1	1.09	4.32	0.0	0.0	0.0	53.7	34.1	4.9	7.3
Iceland	80	1	1.25	5.02	0.0	2.7	0.0	29.7	56.8	10.8	0.0
Norway	721	18	2.50	4.21	0.7	1.0	0.7	33.1	45.4	6.0	13.2
Sweden	310	9	2.90	2.20	0.0	0.0	3.7	34.6	42.0	14.8	4.9
Nordic	1213	30	2.47	3.68	0.4	0.9	1.1	35.1	44.6	7.8	10.2

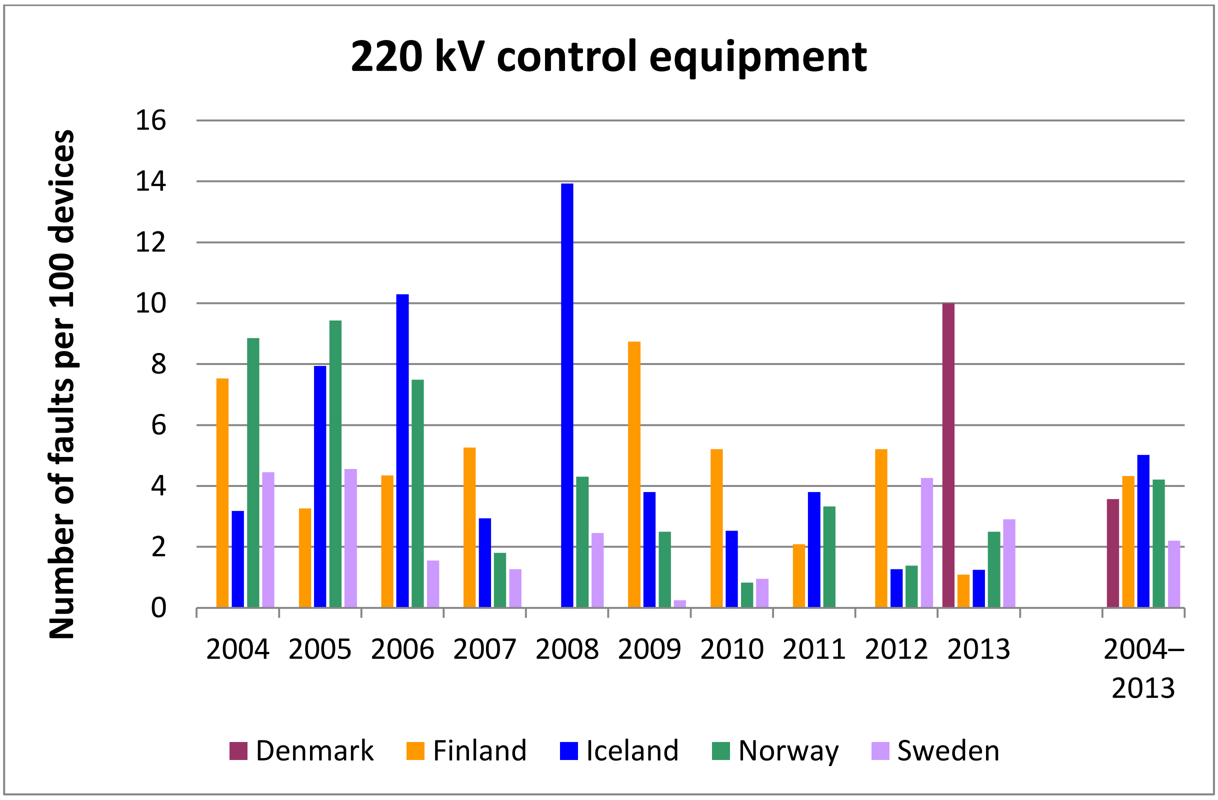

FIGURE 5.8.2 ANNUAL DIVISION OF FAULTS DURING THE PERIOD 2004–2013

TABLE 5.8.3 DIVISION OF FAULTS ACCORDING TO CAUSE FOR 132 KV CONTROL EQUIPMENT

Country	Number of devices	Number of faults	Number of faults per 100 devices		Faults divided by cause (%) during the period 2004–2013						
	2013	2013	2013	2004–2013	Light-ning	Other environ-mental causes	External influence	Operation and mainte-nance	Technical equipment	Ot-her	Un-known
Denmark	619	5	0,81	1,05	6,2	7,4	2,5	42,0	25,9	8,6	7,4
Finland	2300	13	0,57	1,59	2,6	0,0	1,9	43,5	28,8	5,8	17,6
Iceland	176	3	1,70	3,97	0,0	0,0	1,9	20,4	74,1	1,9	1,9
Norway	2064	25	1,21	1,82	1,6	2,7	0,3	34,0	33,0	8,2	20,2
Sweden	1852	7	0,38	0,44	4,1	0,0	0,0	48,6	29,7	6,8	10,8
Nordic	7011	53	0,76	1,35	2,4	1,8	1,1	38,4	33,1	6,9	16,3

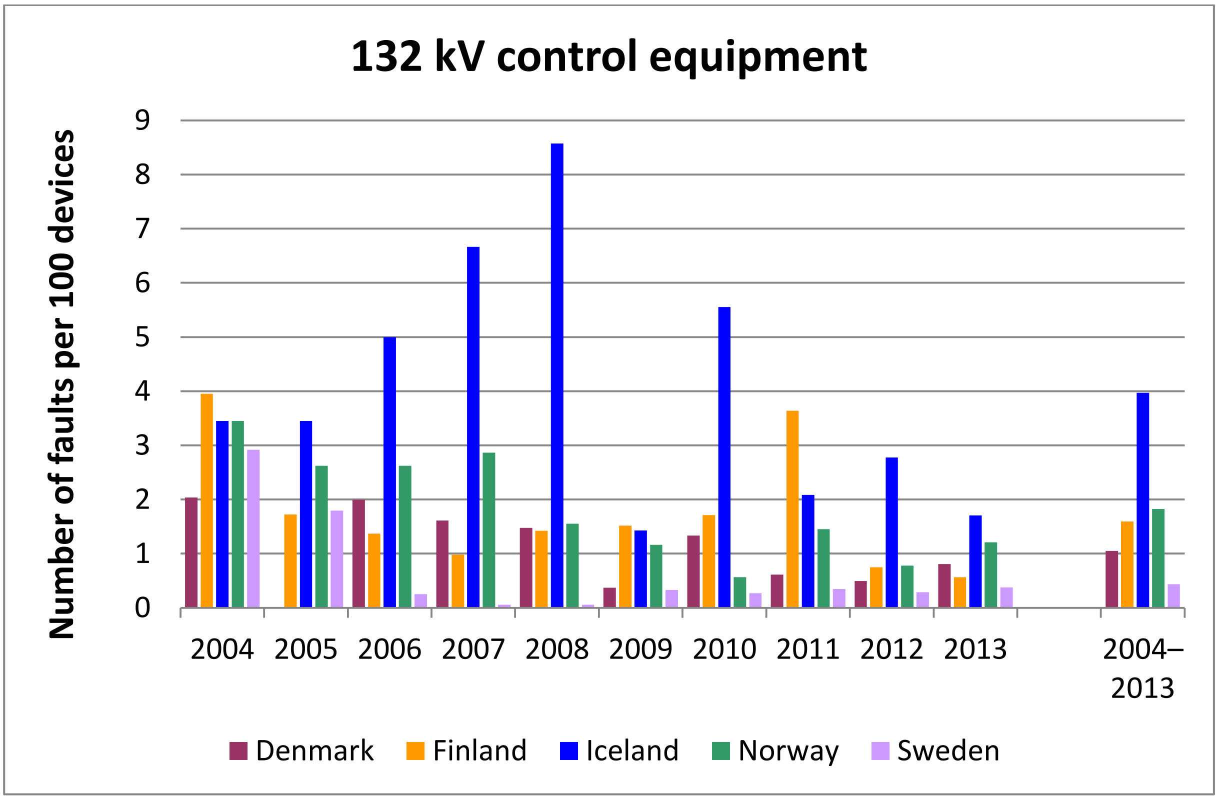

FIGURE 5.8.3 ANNUAL DIVISION OF FAULTS DURING THE PERIOD 2004–2013

5.9 FAULTS IN COMPENSATION DEVICES

For compensation devices, 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 2013 and for the period 2004–2013. In addition, the tables present the division of faults according to cause during the ten-year period 2004–2013.

TABLE 5.9.1 DIVISION OF FAULTS ACCORDING TO CAUSE FOR REACTORS

Country	Number of devices	Number of faults	Number of faults per 100 devices		Faults divided by cause (%) during the period 2004–2013						
					Light-ning	Other environ-mental causes	External influence	Ope-ration and mainte-nance	Technical equipment	Ot-her	Un-known
	2013	2013	2013	2004–2013							
Denmark	62	0	0.00	4.55	0.0	0.0	0.0	30.8	53.8	0.0	15.4
Finland[1)]	70	0	0.00	1.13	0.0	0.0	0.0	0.0	85.7	0.0	14.3
Norway	36	1	2.78	4.17	0.0	6.7	0.0	26.7	60.0	6.7	0.0
Sweden	73	7	9.59	13.02	0.0	30.5	2.4	7.3	35.4	19.5	4.9
Nordic	241	8	3.32	6.17	0.0	22.2	1.7	12.0	43.6	14.5	6.0

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 5.9.2 DIVISION OF FAULTS ACCORDING TO CAUSE FOR SERIES CAPACITORS

Country	Number of devices	Number of faults	Number of faults per 100 devices		Faults divided by cause (%) during the period 2004–2013						
					Light-ning	Other environ-mental causes	External influence	Ope-ration and mainte-nance	Technical equipment	Ot-her	Un-known
	2013	2013	2013	2004–2013							
Finland	9	3	33.33	50.00	0.0	2.5	5.0	7.5	47.5	0.0	37.5
Iceland	1	0	0.00	10.00	0.0	100.0	0.0	0.0	0.0	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	4	33.33	150.00	0.6	0.6	0.0	1.1	15.6	76.1	6.1
Nordic	25	7	28.00	92.08	0.5	1.4	0.9	2.3	21.3	62.0	11.8

TABLE 5.9.3 DIVISION OF FAULTS ACCORDING TO CAUSE FOR SHUNT CAPACITORS

Country	Number of devices	Number of faults	Number of faults per 100 devices		Faults divided by cause (%) during the period 2004–2013						
					Light-ning	Other environ-mental causes	External influence	Ope-ration and mainte-nance	Technical equipment	Ot-her	Un-known
	2013	2013	2013	2004–2013							
Denmark	26	1	3,85	1,86	0,0	0,0	100,0	0,0	0,0	0,0	0,0
Finland	68	6	8,82	5,29	0,0	20,0	52,0	0,0	20,0	0,0	8,0
Iceland	13	0	0,00	11,11	0,0	18,2	9,1	0,0	72,7	0,0	0,0
Norway	194	4	2,06	2,01	2,6	0,0	2,6	10,3	53,8	28,2	2,6
Sweden	122	1	0,82	2,33	6,1	9,1	12,1	3,0	45,5	0,0	24,2
Nordic	423	12	2,84	2,72	2,7	9,0	19,8	4,5	44,1	9,9	9,9

TABLE 5.9.4 DIVISION OF FAULTS ACCORDING TO CAUSE FOR SVC DEVICES

Country	Number of devices	Number of faults	Number of faults per 100 devices		Faults divided by cause (%) during the period 2004–2013						
					Light-ning	Other environ-mental causes	External influence	Ope-ration and mainte-nance	Technical equipment	Ot-her	Un-known
	2013	2013	2013	2004–2013							
Denmark	1	0	0	0,00	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Finland	1	1	100	40,00	0,0	0,0	0,0	50,0	50,0	0,0	0,0
Norway	15	31	206,67	63,33	2,1	1,1	0,0	3,2	68,4	20,0	5,3
Sweden	3	3	100,00	281,82	1,1	4,3	3,2	15,1	64,5	3,2	8,6
Nordic	20	35	175,00	96,94	1,6	2,6	1,6	9,5	66,3	11,6	6,8

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 CAUSED BY DISTURBANCES

For the most part, this chapter covers statistics only for the year 2013. However, a ten-year trend line for the reliability of some power system components is presented at the end of the chapter. More information can be found in the Nordel guidelines [1] in Section 5.3.

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].

6.1 OUTAGES IN POWER SYSTEM UNITS

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

TABLE 6.1.1 GROUPING OF LINES ACCORDING TO THE NUMBER OF OUTAGES PER LINE IN 2013

Line[1)]		Number of system units grouped by number of outages						
Country	Number of system units	No outages	1 outages	2 outages	3 outages	4 outages	5 outages	>5 outages
Denmark	264	199	49	12	3	1	0	0
Finland	621	433	107	39	15	9	6	12
Iceland	58	47	5	2	0	2	1	1
Norway	1233	1151	45	12	7	4	8	6
Sweden	399	283	55	33	11	9	2	6

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

TABLE 6.1.2 GROUPING OF TRANSFORMERS ACCORDING TO THE NUMBER OF OUTAGES PER UNIT IN 2013

Transformer		Number of system units grouped by number of outages						
Country	Number of system units	No outages	1 outages	2 outages	3 outages	4 outages	5 outages	>5 outages
Denmark	296	271	25	0	0	0	0	0
Finland	1200	1191	9	0	0	0	0	0
Iceland	89	88	1	0	0	0	0	0
Norway	1059	1055	4	0	0	0	0	0
Sweden	267	256	7	4	0	0	0	0

TABLE 6.1.3 GROUPING OF BUSBARS ACCORDING TO THE NUMBER OF OUTAGES PER UNIT IN 2013

Busbar		Number of system units grouped by number of outages						
Country	Number of system units	No outages	1 outages	2 outages	3 outages	4 outages	5 outages	>5 outages
Denmark	183	178	5	0	0	0	0	0
Finland	1019	1018	1	0	0	0	0	0
Iceland	52	51	1	0	0	0	0	0
Norway	435	432	3	0	0	0	0	0
Sweden	257	244	13	0	0	0	0	0

TABLE 6.1.4 GROUPING OF REACTORS ACCORDING TO THE NUMBER OF OUTAGES PER UNIT IN 2013

Reactor		Number of system units grouped by number of outages						
Country	Number of system units	No outages	1 outages	2 outages	3 outages	4 outages	5 outages	>5 outages
Denmark	62	62	0	0	0	0	0	0
Finland	70	68	2	0	0	0	0	0
Norway	36	35	1	0	0	0	0	0
Sweden	47	37	8	0	2	0	0	0

TABLE 6.1.5 GROUPING OF SHUNT CAPACITORS ACCORDING TO THE NUMBER OF OUTAGES PER UNIT IN 2013

Shunt capacitor		Number of system units grouped by number of outages						
Country	Number of system units	No outages	1 outages	2 outages	3 outages	4 outages	5 outages	>5 outages
Denmark	26	24	2	0	0	0	0	0
Finland	68	65	2	0	0	1	0	0
Iceland	10	10	0	0	0	0	0	0
Norway	194	190	0	4	0	0	0	0
Sweden	49	48	1	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 6.2.1 NUMBER OF LINES WITH DIFFERENT OUTAGE DURATIONS IN 2013

Line[1)]		Number of system units grouped by total outage duration time								
Country	Total number of lines	No outage	<3 min	3-10 min	10-30 min	30-60 min	60-120 min	120-240 min	240-480 min	>480 min
Denmark	264	199	29	11	6	0	3	4	6	6
Finland	621	433	137	14	13	3	4	4	4	9
Iceland	58	47	0	3	2	2	0	0	1	3
Norway	1233	1151	45	13	12	3	2	2	3	2
Sweden	399	283	75	9	3	7	6	4	4	8

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

TABLE 6.2.2 NUMBER OF TRANSFORMERS WITH DIFFERENT OUTAGE DURATIONS IN 2013

Transformer		Number of system units grouped by total outage duration time								
Country	Total number of transformers	No outage	<3 min	3-10 min	10-30 min	30-60 min	60-120 min	120-240 min	240-480 min	>480 min
Denmark	296	271	4	9	3	3	3	1	1	1
Finland	1200	1191	1	1	1	0	1	3	0	2
Iceland	89	88	0	0	0	0	0	0	0	1
Norway	1059	1055	0	1	0	0	0	0	0	3
Sweden	267	256	1	2	1	1	1	2	3	0

TABLE 6.2.3 NUMBER OF BUSBARS WITH DIFFERENT OUTAGE DURATIONS IN 2013

Busbar		Number of system units grouped by total outage duration time								
Country	Total number of busbars	No outage	<3 min	3-10 min	10-30 min	30-60 min	60-120 min	120-240 min	240-480 min	>480 min
Denmark	183	178	4	1	0	0	0	0	0	0
Finland	1019	1018	0	0	0	0	0	1	0	0
Iceland	52	51	0	1	0	0	0	0	0	0
Norway	435	432	0	0	0	3	0	0	0	0
Sweden	257	244	0	1	1	5	3	2	0	1

TABLE 6.2.4 NUMBER OF REACTORS WITH DIFFERENT OUTAGE DURATIONS IN 2013

Reactor		Number of system units grouped by total outage duration time								
Country	Total number of reactors	No outage	<3 min	3-10 min	10-30 min	30-60 min	60-120 min	120-240 min	240-480 min	>480 min
Denmark	62	62	0	0	0	0	0	0	0	0
Finland	70	68	0	0	0	0	0	0	0	2
Norway	36	35	0	0	0	0	0	1	0	0
Sweden	47	37	0	1	0	0	0	3	0	6

TABLE 6.2.5 NUMBER OF SHUNT CAPACITORS WITH DIFFERENT OUTAGE DURATIONS IN 2013

Shunt capasitor		Number of system units grouped by total outage duration time								
Country	Total number of shunt capasitors	No outage	<3 min	3-10 min	10-30 min	30-60 min	60-120 min	120-240 min	240-480 min	>480 min
Denmark	26	24	1	0	0	0	0	0	1	0
Finland	68	65	0	0	0	0	0	1	0	2
Iceland	10	10	0	0	0	0	0	0	0	0
Norway	194	190	0	2	0	2	0	0	0	0
Sweden	49	48	1	0	0	0	0	0	0	0

6.3 CUMULATIVE DURATION OF OUTAGES IN SOME POWER SYSTEM UNITS

Figure 6.3.1 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.

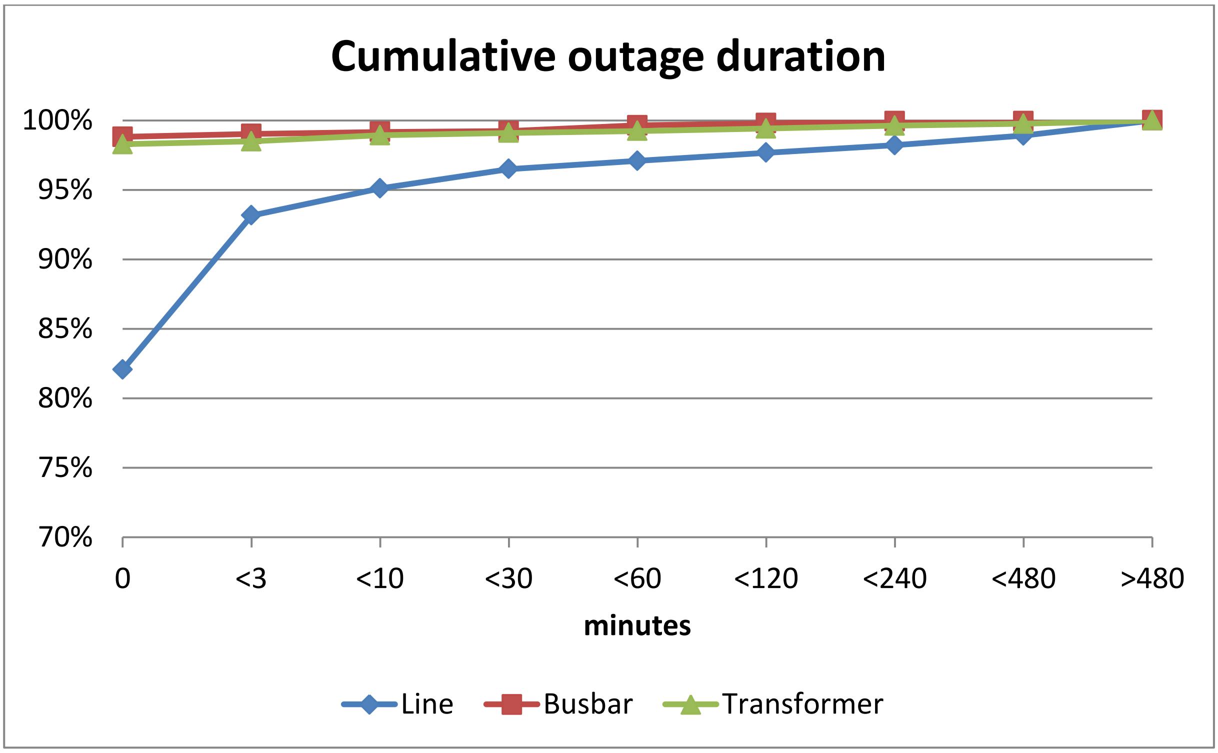

FIGURE 6.3.1 PERCENTAGE OF COMPONENTS WITH DIFFERENT OUTAGE DURATION IN 2013

Figure 6.3.1 shows that approximately 82% of lines, 98% of transformers and 99% of busbars had no outages in 2013.

6.4 RELIABILITY TRENDS FOR SOME POWER SYSTEM UNITS

Figure 6.4.1 presents a reliability trend for lines, busbars and transformers during the ten-year period 2004–2013. All five countries are included in the data of Figure 6.4.1.

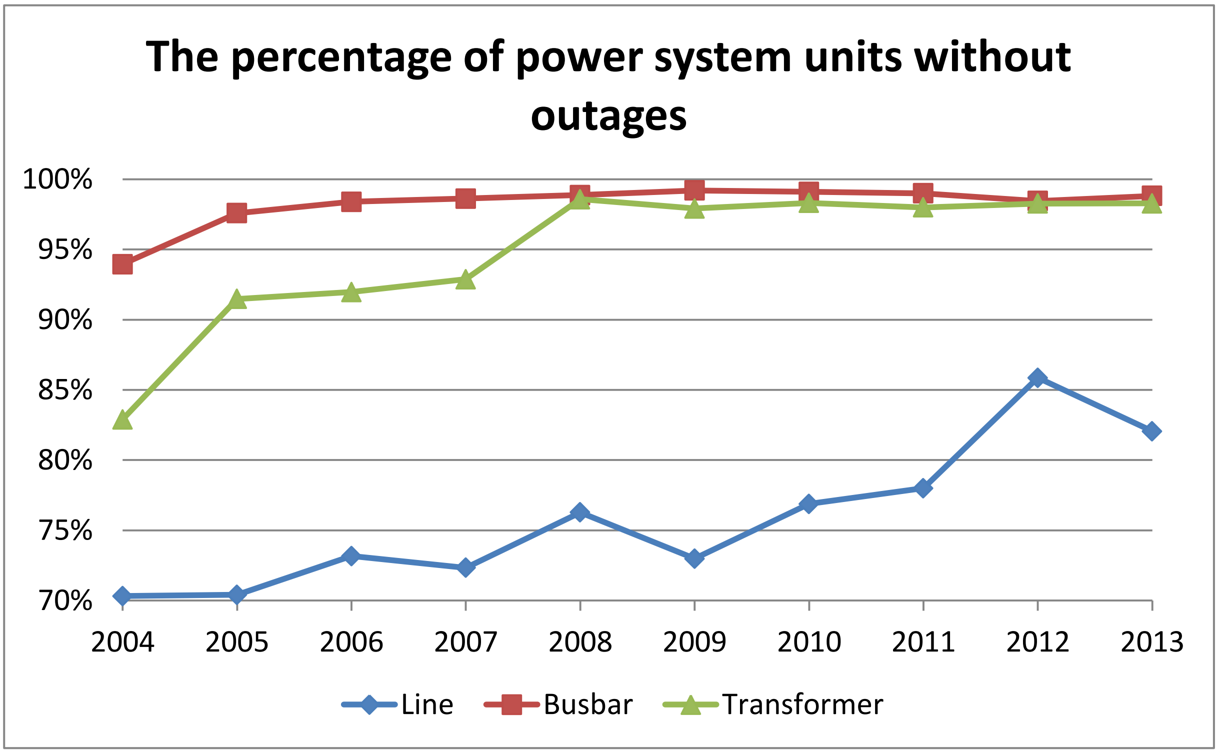

FIGURE 6.4.1 THE YEARLY PERCENTAGE OF THE POWER SYSTEM UNITS THAT HAD NO OUTAGES DURING THE PERIOD 2004–2013

7 REFERENCES

1. **Nordel.** Nordel's Guidelines for the Classification of Grid Disturbances. [Online] 2009.

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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/project/KILE/definisjoner.pdf

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.

   http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=35063

Appendix 1 The calculation of energy not supplied

Energy not supplied (ENS) is calculated in various ways in different countries. The differences are depending on the calculation method.

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.

Appendix 2 Policies for examining the cause for line faults

This appendix is added in order to explain the effort put into finding the most probable cause of each disturbance.

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 these statistics, the reporting TSO needs to distinguish between six 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.

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 Incident classification scale (ICS) reporting to ENTSO-E during 2013

Nordic Transmission System Operators (TSO) report disturbances also according to ENTSO-E methodology Incidents Classification Scale (ICS). ICS has to be used by each TSO of the ENTSO-E area.

Disturbances are reported following four degrees scale (0 to 3) corresponding to incidents of growing seriousness up to a general Europe-wide incident.

- Scale 0 (anomaly) is assigned to local events with low effect on reliability.
- Scale 1 is assigned to noteworthy events and wide area disturbances which are affecting more than one TSO and could lead to emergency state.
- Scale 2 (extensive incidents) is assigned to wide area regional events (beyond both responsibility and national areas) due to extensive incidents.
- Scale 3 is assigned to major wide area events. After the incident occurs, the system is in blackout State.

Nordic TSOs reported 66 scale 0 incidents. Of these 88% were disturbances on transmission network equipment and 8% violation of standards on voltage. There were 20 incidents which belonged to scale 1. Half of these were disturbances on transmission network equipment and every one led to a reduction of exchange capacity, many times from Sweden to Finland via HVDC connection Fenno-Skan. Nine incidents were N-1 violation situations due to unexpected load and one incident due to violation of standards on voltage.

Appendix 4 Contact persons in the Nordic countries

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Appendix 5 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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