European Network of
Transmission System Operators
for Electricity

NORDIC AND BALTIC GRID DISTURBANCE STATISTICS 2014

21.10.2015

REGIONAL GROUP NORDIC

1 INTRODUCTION

1.1 DESCRIPTION OF THE REPORT

This report is an overview of the Nordic and Baltic HVAC transmission grid disturbance statistics for the year 2014. Transmission System Operators providing the statistical data are *Energinet.dk* in Denmark, *Elering* in Estonia, *Fingrid Oyj* in Finland, *Landsnet* in Iceland, *Augstsprieguma tīkls* in Latvia, *Litgrid* in Lithuania, *Statnett SF* in Norway and *Svenska kraftnät* in Sweden. The statistics can be found at ENTSO-E website, www.entsoe.eu. 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. Figure 1.4.1 presents the grids of the statistics.

Although this summary originates from the Nordic and Baltic co-operation that aims to use the combined experience of the eight 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 report is made according to the Nordel Guidelines for Classification of Grid Disturbances [1] and includes the faults causing disturbances in the 100–420 kV grids. The guidelines for the Classification of Grid Disturbances were prepared by Nordel[1] during the years 1999–2000 and have been in use since 2000. Most charts include data for the ten-year period 2005–2014. In some cases where older data has been available, even longer periods have been used. 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.

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.

Despite common guidelines, there are slight differences in the 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.

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

The report is organised as follows. 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 and Baltic power system. In addition, each Transmission System Operator has presented the most important issues of the year 2014.

Chapter 3 discusses the disturbances and focuses on the analysis and allocation of the causes of disturbances. The distribution of disturbances during the year 2014 for each country is presented; for example, the consequences of the disturbances in the form of energy not supplied.

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

1.2 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 the ENTSO-E Nordic and Baltic disturbance statistics. The relevant contact information is given in Appendix 3.

There are no common Nordic and Baltic disturbance statistics for voltage levels lower than 100 kV. However, Appendix 4 presents the relevant contact persons for these statistics.

FIGURE 1.2.1 THE NORDIC AND BALTIC MAIN GRIDS [2]

1.3 VOLTAGE LEVELS IN THE NORDIC AND BALTIC NETWORKS

Table 1.3.1 presents the transmission system voltage levels of the networks in the Nordic and Baltic countries. In the statistics, voltage levels are grouped as statistical voltages according to the table.

TABLE 1.3.1 NOMINAL VOLTAGE LEVELS (U_N) IN THE NORDIC AND BALTIC NETWORKS, THE RESPECTIVE STATISTICAL VOLTAGES AND THE PERCENTAGE OF THE GRID AT THE RESPECTIVE NOMINAL VOLTAGE LEVEL (P)

Country			Statistical voltage range, kV				
			380–420 kV	220–330 kV	220–330 kV	100–150 kV	100–150 kV
Denmark	U_N		400	-	220	150	132
	P	%	100	-	100	62	38
Finland	U_N		400	-	220	110	-
	P	%	100	-	100	100	
Iceland	U_N		-	-	220	132	-
	P	%	-	-	100	100	-
Norway	U_N		420	300	220	132	110
	P	%	100	90	10	98	2
Sweden	U_N		400	-	220	130	-
	P	%	100	-	100	100	-
Estonia	U_N		-	330	220	110	-
	P	%	-	92	8	100	-
Latvia	U_N		-	330	-	110	-
	P	%	-	100	-	100	-
Lithuania	U_N		-	330	-	110	-
	P	%	-	100	-	100	-

1.4 THE 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 divided by the actual length of lines in the grid.

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	380–420 kV	220–330 kV	100–150 kV
Denmark	100 %	100 %	100 %
Estonia	-	100 %	100 %
Finland[1)]	100 %	100 %	96 %
Iceland	-	100 %	100 %
Latvia	-	100 %	100 %
Lithuania	-	100 %	100 %
Norway	100 %	100 %	100 %
Sweden	100 %	100 %	100 %

1) Percentage for Finland is reduced due to some small regional grids not delivering complete data.

The network statistics of each country 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.

Norway: A large part of the 110 and 132 kV network is resonant earthed. This category is combined with the 100–150 kV solid earthed network in these statistics.

The ten-year average values for the Baltic countries are not available in this report because they only have data from the year 2014. Hence, the Baltic countries are presented with statistics from the year 2014 and the average values are only calculated with the data from the Nordic countries.

2 SUMMARY

2.1 OVERVIEW OF THE NORDIC AND BALTIC COUNTRIES

In 2014, the energy not supplied (ENS) due to faults in the Nordic and Baltic main grids was 4.86 GWh. The ENS for the Nordic main grid totalled 4.76 GWh, which is below the ten-year average 6.66 GWh.

The energy not supplied and corresponding ten-year average values for the period 2005–2014 in each country are presented in the following sections. The sections also present the number of disturbances for each country as well as the number of disturbances that caused energy not supplied in 2014. In addition, the summaries present the most important issues in 2014 defined by each Transmission System Operator.

2.2 SUMMARY OF DENMARK

In Denmark, the energy not supplied in 2014 was 23.9 MWh (ten-year average 19.1 MWh). The number of grid disturbances was 77 (ten-year average 64) and 7 of them caused ENS. On average, 7 disturbances per year caused ENS in 2005–2014.

In 2014, 42 % of ENS was caused by faults during operation and maintenance and 48 % of ENS was caused by faults in adjoining statistical areas (statistical category 'Other').

2.3 SUMMARY OF FINLAND

In Finland, the energy not supplied in 2014 was 499 MWh (ten-year average 356 MWh). The number of grid disturbances was 513 (ten-year average 397) and 90 of them caused ENS. On average, 74 disturbances per year caused ENS in 2005–2014.

In 2014, 58 % of ENS was caused by overhead lines faults and 13 % by substation faults. The most significant reasons for ENS were ‘Other causes’ 54 % and ‘Technical equipment’ 23 %. Most of the disturbances were caused by ‘Lightning’ and occurred during the summer months.

2.4 SUMMARY OF ESTONIA

In Estonia, the energy not supplied in 2014 was 29.7 MWh (ten-year average 161 MWh). The number of grid disturbances was 225 (ten-year average 260) of which 11 caused ENS. On average, 20 disturbances per year caused ENS in 2005–2014.

In 2014, 65 % of ENS was caused by a fault in the adjoining network of a big customer connected to the 110 kV transmission grid. In the transmission grid, the most influential fault for customers occurred in June 6th: after line tripping the transformers automatic reserve switching failed to connect a replacement transformer after a transformer disconnected. This resulted in 5.5 MWh ENS for customers.

More than half of the disturbances were caused by environmental causes (stork contamination and lightning) on the 110 kV overhead lines and they occurred during the summer months. However, these were only insulator flashovers and did not cause any ENS.

2.5 SUMMARY OF ICELAND

In Iceland, the energy not supplied in 2014 was 834.9 MWh (ten-year average 1179 MWh). The total number of disturbances was 40 (ten-year average 31) of which 23 caused ENS. On average, 18 disturbances per year caused ENS in 2005–2014.

Registered grid disturbances increased in 2014 compared with the previous year. The weather played a central role in most cases. During the wintertime in January, February and October, the weather related disturbances caused some ENS. In May–August, three large disturbances resulted in the trip of power intensive industry causing the major part of ENS this year, total of 654 MWh.

On June 18th, an unusual disturbance in the transmission system occurred and it was the largest disturbance this year. It was caused by an upgrade of the EMS system in the control centre. The automatic generation control AGC received wrong parameters that resulted in units receiving wrong set points. This caused an under frequency and a trip of load. The total ENS of this event was 335 MWh

2.6 SUMMARY OF LATVIA

In Latvia the energy not supplied (ENS) in 2014 was 35.6 MWh. The number of grid disturbances was 151 of which 19 caused ENS.

There was one grid disturbance, caused by a fire in the overhead line corridor ('external influence') that caused 43 % of 2014 ENS. According to the overall disturbance origins, 78 % of the ENS was caused by faults in overhead lines and 22 % in substations. 73 (48 %) disturbances were cleared with a successful high-speed reclosing.

2.7 SUMMARY OF LITHUANIA

In Lithuania, the energy not supplied in 2014 was 39.2 MWh and originated from the 110 kV voltage grid. The total number of grid disturbances was 160 and 25 of them caused ENS.

In 2014, 77 % of ENS was caused by substation faults and 13 % by overhead line faults. 124 disturbances were cleared with a successful auto-reclosing.

On February 2nd, one of two power transformers was taken out of service at the 110/10/10kV substation Amaliai since the 110 kV inlet circuit breaker of the transformer needed maintenance. During the maintenance, incorrect protections of the active inlet circuit breaker by the telecommand disconnected the line circuit breaker at the supplying Kaunas substation. This fault resulted in 26 MWh ENS.

The largest number of the disturbances were caused by 'External influences and occurred during the summer months.

2.8 Summary of Norway

In Norway, the energy not supplied in 2014 was 2165 MWh (ten-year average 3316 MWh). The number of grid disturbances was 461 (ten-year average 293) and 146 of them caused ENS. On average, 95 disturbances per year caused ENS in 2009–2014.

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

In 2014 there were three major disturbances in the 420 kV network. They resulted all in outages of a gas pipeline terminal and it caused approximately 1/3 of the total ENS.

2.9 Summary of Sweden

In Sweden, the energy not supplied in 2014 was 1234.8 MWh (ten-year average 1832.1 MWh). There were 759 grid disturbances (ten-year average 546) of which 202 caused ENS. On average, 157 disturbances per year caused ENS in 2009–2014.

This year 279.7 MWh of ENS was caused by faults on the 400kV grid. 70 % of all disturbances during 2014 occurred during the summer months, from June to August. (Ten-year average 50 % for the same time period.)

In 2014, 41.7 % of ENS was caused by line faults and 54.5 % by substation faults. The main cause for ENS during 2014 was 'technical equipment' 51 %, followed by 'lightning' and 'unknown', 20 % and 23 % respectively. There were 134 faults with an unknown cause, many of those probably caused by lightning but not confirmed.

759 disturbances is an extremely high compared with a normal year. In 2014 there were 429 faults caused by lightning. This can be explained by an unusual number of thunderstorms during the summer.

Sweden had some very unusual events during one week of July when seven instrument transformers exploded. It was during an unusually long warm period, but still on a temperature below 40 ˚C.

3 DISTURBANCES

This chapter includes an overview of disturbances in the Nordic and Baltic countries. It also presents the connection between disturbances, energy not supplied, causes of faults, and distribution during the year 2014, together with the development of the number of disturbances over the ten-year period 2005–2014. 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.

Grid disturbances are defined as:

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 2005–2014

The number of disturbances during the year 2014 in the Nordic and Baltic main grids was 2386. The number for the Nordic main grids was 1850, which is above the ten-year average of 1331. 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 and Baltic countries.

Table 3.1.1 presents the sum of disturbances during the year 2014 for the Nordic and Baltic countries and the annual average for the period 2005–2014 for the Nordic countries for the complete 100–420 kV grids. Figure 3.1.1 shows the development of the number of disturbances in each Nordic country during the period 2005–2014.

TABLE 3.1.1 THE NUMBER OF GRID DISTURBANCES IN EACH NORDIC AND BALTIC COUNTRY IN 2014 AND THE ANNUAL AVERAGE FOR THE PERIOD 2005–2014

Country	Number of disturbances		Number of disturbances causing ENS[1)]	
	2014	2005–2014	2014	2009–2014
Denmark	77	64	7	7
Estonia	225	-	11	-
Finland	513	396.7	90	82
Iceland	40	32	23	16
Latvia	151	-	19	-
Lithuania	160	-	25	-
Norway	461	292.8	146	95
Sweden	759	546	202	158
Total	2386	1331	523	358

1) The time period is 2009–2014 because every country does not have complete data before 2009.

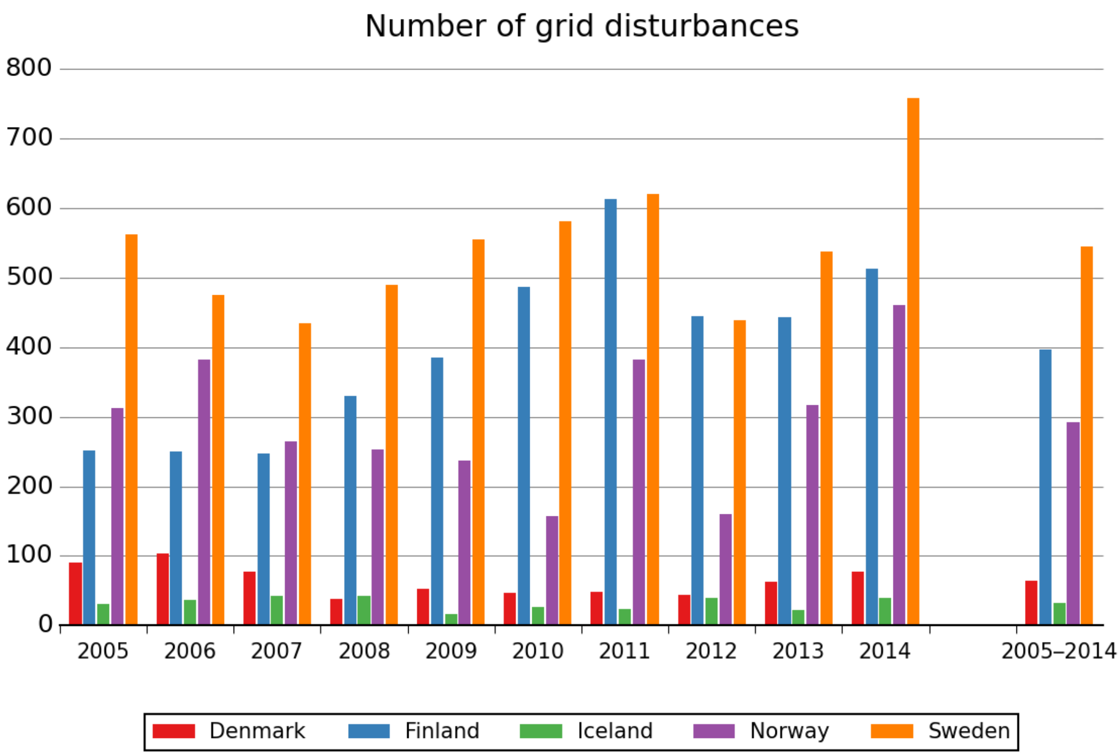

Figure 3.1.1 Number of grid disturbances in each Nordic country during the period 2005–2014

3.2 Disturbances distributed according to month

Figure 3.2.1 and 3.2.2 presents the percentage distribution of grid disturbances for all voltage levels according to month for the Nordic and Baltic countries, respectively. Figure 3.2.3 presents the respective ten-year average values for the Nordic countries.

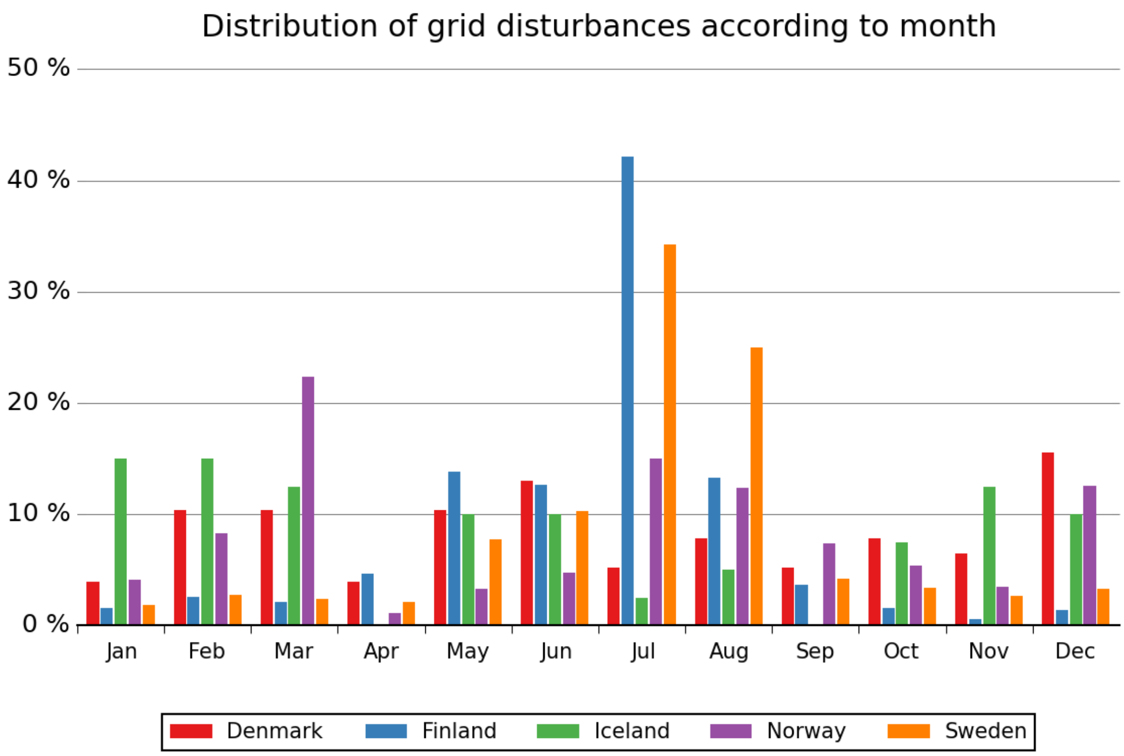

FIGURE 3.2.1 PERCENTAGE DISTRIBUTION OF GRID DISTURBANCES ACCORDING TO MONTH IN EACH NORDIC COUNTRY IN 2014

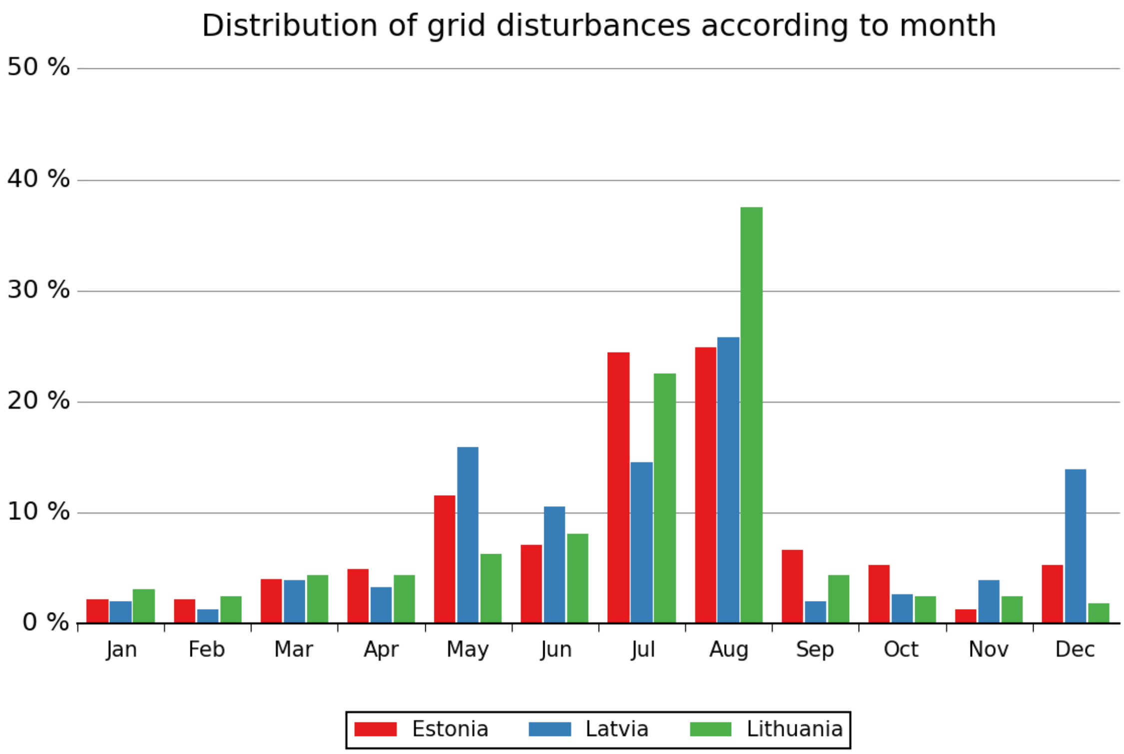

FIGURE 3.2.2 PERCENTAGE DISTRIBUTION OF GRID DISTURBANCES ACCORDING TO MONTH IN EACH BALTIC COUNTRY IN 2014

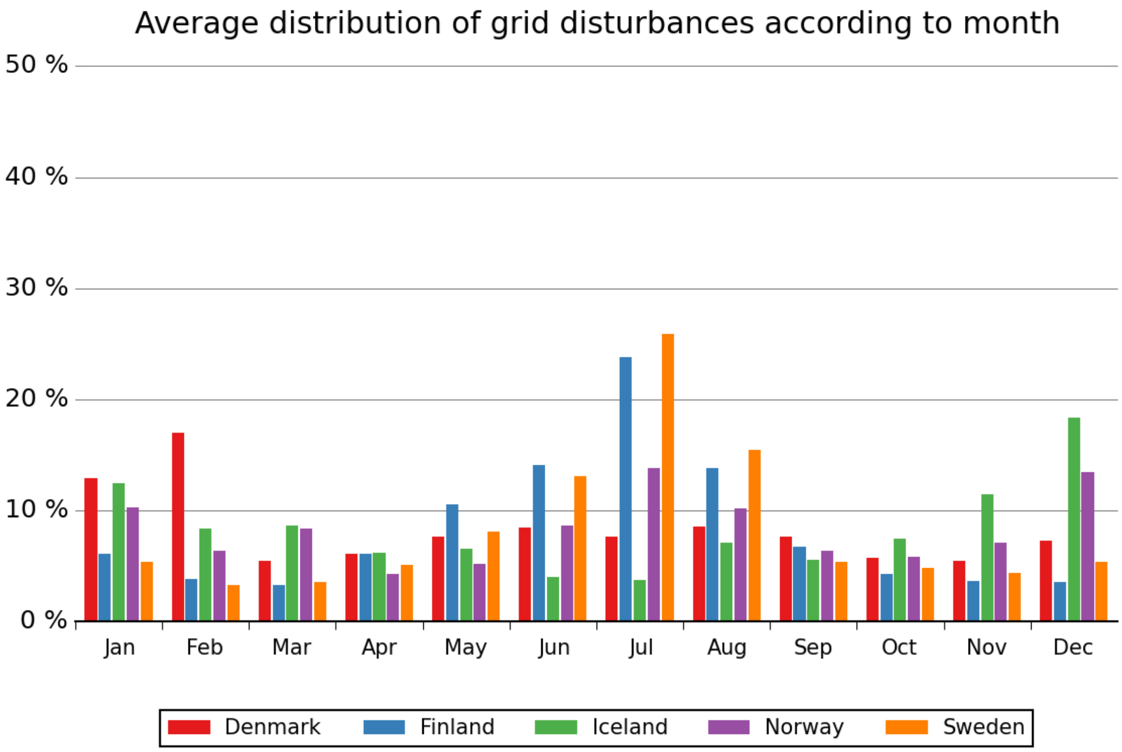

FIGURE 3.2.3 AVERAGE PERCENTAGE DISTRIBUTION OF GRID DISTURBANCES ACCORDING TO MONTH IN EACH NORDIC COUNTRY FOR THE PERIOD 2005–2014

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 100–420 kV networks. For all countries, except Iceland, the number of disturbances is usually largest during the summer period. This is caused by lightning strokes during the summer.

TABLE 3.2.1 NUMBER OF GRID DISTURBANCES PER MONTH IN EACH NORDIC AND BALTIC COUNTRY IN 2014

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Denmark	3	8	8	3	8	10	4	6	4	6	5	12
Estonia	5	5	9	11	26	16	55	56	15	12	3	12
Finland	8	13	11	24	71	65	216	68	19	8	3	7
Iceland	6	6	5	0	4	4	1	2	0	3	5	4
Latvia	3	2	6	5	24	16	22	39	3	4	6	21
Lithuania	5	4	7	7	10	13	36	60	7	4	4	3
Norway	19	38	103	5	15	22	69	57	34	25	16	58
Sweden	14	21	18	16	59	78	260	190	32	26	20	25
Total	63	97	167	71	217	224	663	478	114	88	62	142

TABLE 3.2.2 AVERAGE NUMBER OF GRID DISTURBANCES PER MONTH IN EACH NORDIC COUNTRY DURING THE YEARS 2005–2014.

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Denmark	8	11	4	4	5	5	5	6	5	4	4	5
Finland	24	15	13	24	42	56	94	55	27	17	15	14
Iceland	4	3	3	2	2	1	1	2	2	2	4	6
Norway	30	19	25	13	15	25	41	30	19	17	21	39
Sweden	29	18	20	28	44	72	141	85	29	26	24	30
Total	96	66	64	71	109	159	282	177	81	67	67	94

3.3 DISTURBANCES DISTRIBUTED 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 primary and underlying causes. The exact definitions are listed in section 5.2.9 in the Nordel Guidelines [1]. The Nordic and Baltic statistics use seven different options for fault causes and list the primary cause of the event as the starting point. Table 3.3.1 and Table 3.3.2 present an overview of the causes of grid disturbances and energy not supplied in each Nordic and Baltic country, respectively.

Each country in this statistics has its own detailed way of gathering data according to fault cause as is explained in Appendix 2. 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 IN EACH NORDIC COUNTRY

Cause	Country	Percentage distribution of disturbance		Percentual distribution of disturbances that caused ENS[1)]		Percentual distribution of ENS	
		2014	2005–2014	2014	2009–2014[2)]	2014	2005–2014
Lightning	Denmark	13	13	14	6	1	4
	Finland	39	27	32	22	14	6
	Iceland	5	3	4	4	6	2
	Norway	31	23	38	25	7	3
	Sweden	57	39	60	38	20	19
Other environmental causes	Denmark	12	23	0	6	0	14
	Finland	17	17	7	16	4	22
	Iceland	45	39	26	50	3	60
	Norway	35	25	27	27	37	66
	Sweden	2	5	0	3	0	7
External influence	Denmark	18	16	0	6	0	2
	Finland	1	2	2	4	2	10
	Iceland	3	2	0	1	0	0
	Norway	1	2	1	2	0	0
	Sweden	1	2	1	3	0	6
Operation and maintenance	Denmark	17	14	29	32	42	34
	Finland	4	7	11	10	1	15
	Iceland	5	10	9	9	42	18
	Norway	9	11	15	11	4	7
	Sweden	4	7	4	9	3	12
Technical equipment	Denmark	23	12	14	14	9	11
	Finland	3	5	7	7	23	25
	Iceland	18	23	22	11	28	12
	Norway	13	22	10	13	37	11
	Sweden	10	14	11	10	51	25
Other	Denmark	6	7	29	24	48	23
	Finland	32	10	29	9	54	15
	Iceland	23	21	35	23	21	8
	Norway	10	12	8	15	15	10
	Sweden	8	10	4	6	3	14
Unkown	Denmark	10	14	14	11	0	11
	Finland	4	32	12	32	2	7
	Iceland	3	2	4	1	0	1
	Norway	0	5	0	7	0	2
	Sweden	18	22	19	22	23	17

1) The way to calculate the ENS varies between the countries and is presented in Appendix 1.
2) The time span is 2009–2014 because there is not enough data available.

TABLE 3.3.2 GROUPING OF GRID DISTURBANCES AND ENERGY NOT SUPPLIED (ENS) BY CAUSE IN EACH BALTIC COUNTRY

Cause	Country	Percentage distribution of disturbance	Percentual distribution of disturbances that caused ENS[1)]	Percentual distribution of ENS
		2014	2014	2014
Lightning	Estonia	13	0	0
	Latvia	17	5	2
	Lithuania	11	8	4
Other environmental causes	Estonia	37	0	0
	Latvia	23	47	28
	Lithuania	3	8	0
External influence	Estonia	4	45	7
	Latvia	25	32	51
	Lithuania	42	48	82
Operation and maintenance	Estonia	8	18	3
	Latvia	5	11	10
	Lithuania	12	28	10
Technical equipment	Estonia	27	9	19
	Latvia	6	5	4
	Lithuania	4	4	4
Other	Estonia	10	9	65
	Latvia	6	0	0
	Lithuania	0	0	0
Unkown	Estonia	2	18	7
	Latvia	19	0	5
	Lithuania	29	4	0

1) The way to calculate the ENS varies between the countries and is presented in Appendix 1.

Figure 3.3.1 and Figure 3.2.2 identify disturbances for all voltage levels in terms of the initial fault for the Nordic and Baltic countries, respectively. Figure 3.3.3 presents the respective ten-year average values for the Nordic countries.

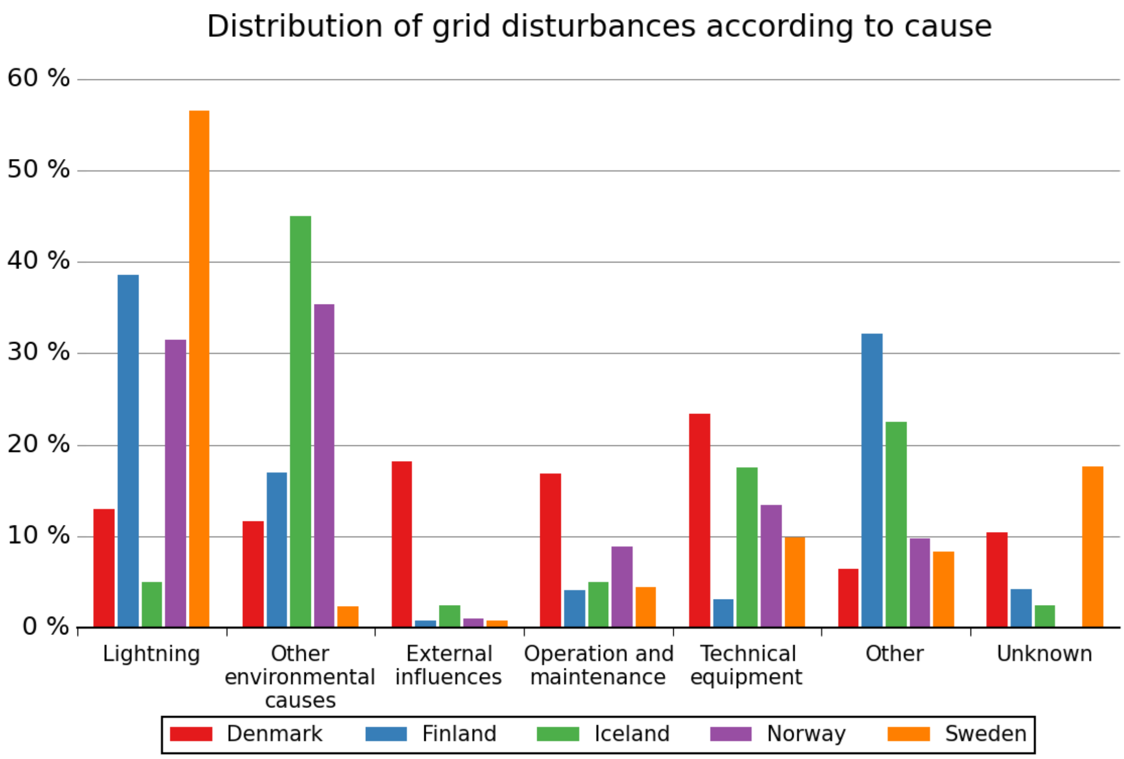

FIGURE 3.3.1 PERCENTAGE DISTRIBUTION OF GRID DISTURBANCES ACCORDING TO CAUSE IN EACH NORDIC COUNTRY IN 2014

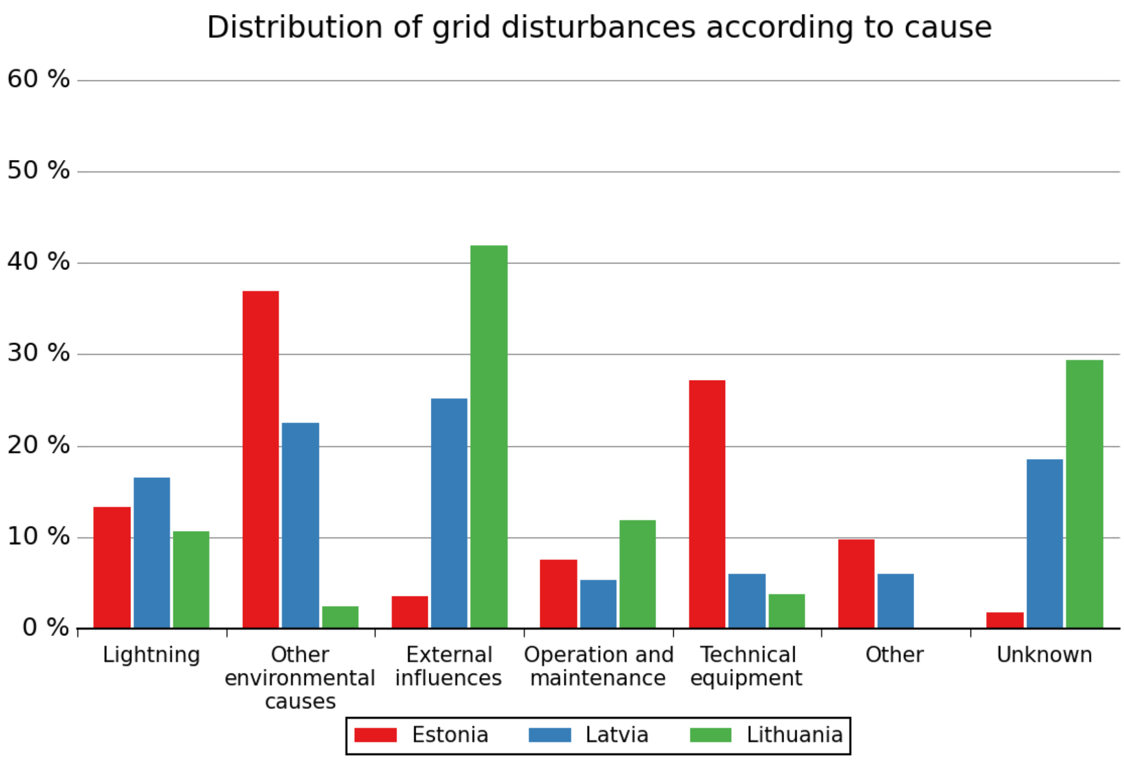

FIGURE 3.3.2 PERCENTAGE DISTRIBUTION OF GRID DISTURBANCES ACCORDING TO CAUSE IN EACH BALTIC COUNTRY IN 2014

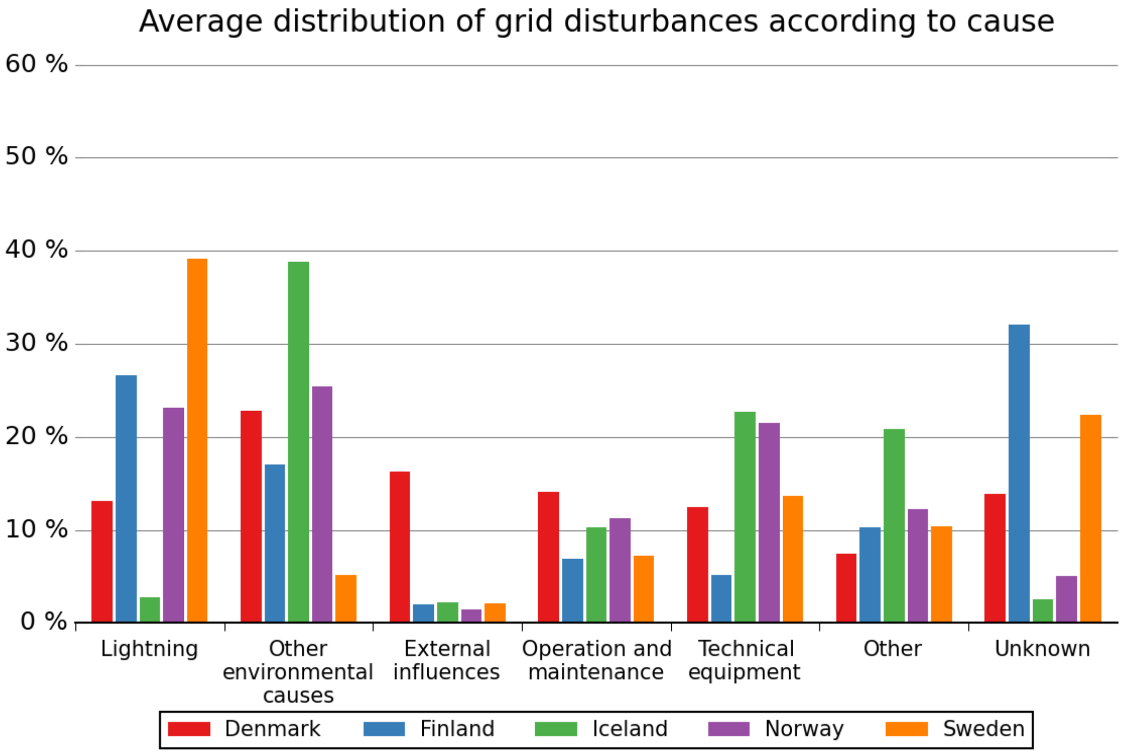

FIGURE 3.3.3 AVERAGE PERCENTAGE DISTRIBUTION OF GRID DISTURBANCES ACCORDING TO CAUSE IN EACH NORDIC COUNTRY DURING THE PERIOD 2005–2014

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 (ENS) in the Nordic and Baltic countries. One should remember that the amount of ENS 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.

Energy not supplied is defined as:

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 distributed according to voltage level

Table 4.1.1 shows the amount of energy not supplied in the five Nordic and three Baltic countries and its distribution according to voltage level.

Table 4.1.1 Energy not supplied (ENS) according to the voltage level of the primary fault in each Nordic and Baltic country

Country	Energy not supplied (MWh) 2014	Average ENS 2005–2014 (MWh)	ENS divided into different voltage levels, 2005–2014 (%)			
			100–150 kV	220–330 kV	380–420 kV	Other[1)]
Denmark	24	19	93.4	0.0	0.0	6.6
Finland	499	356	93.8	2.7	3.5	0.0
Iceland	835	1137	34.2	65.8	0.0	0.0
Norway	2165	3316	27.5	7.5	63.8	1.1
Sweden	1235	1832	82.0	15.2	1.9	0.8
			ENS (%) divided into different voltage levels, 2014			
Estonia	30	-	100.0	0.0	0.0	0.0
Latvia	36	-	96.7	3.3	0.0	0.0
Lithuania	39	-	100.0	0.0	0.0	0.0
Total	4758	6659	66.2	18.3	13.8	1.7

1) The category other contains energy not supplied from system faults, auxiliary equipment, lower voltage level networks and the connections to foreign countries, etc. This is described further in the guidelines [1].

Figure 4.1.1 presents the energy not supplied according to the different voltage levels for the year 2014 in the Nordic and Baltic countries and Figure 4.1.2 summarises the energy not supplied according to the different voltage levels for the period 2005–2014 for the Nordic countries. A voltage level refers to the primary fault of the respective disturbance.

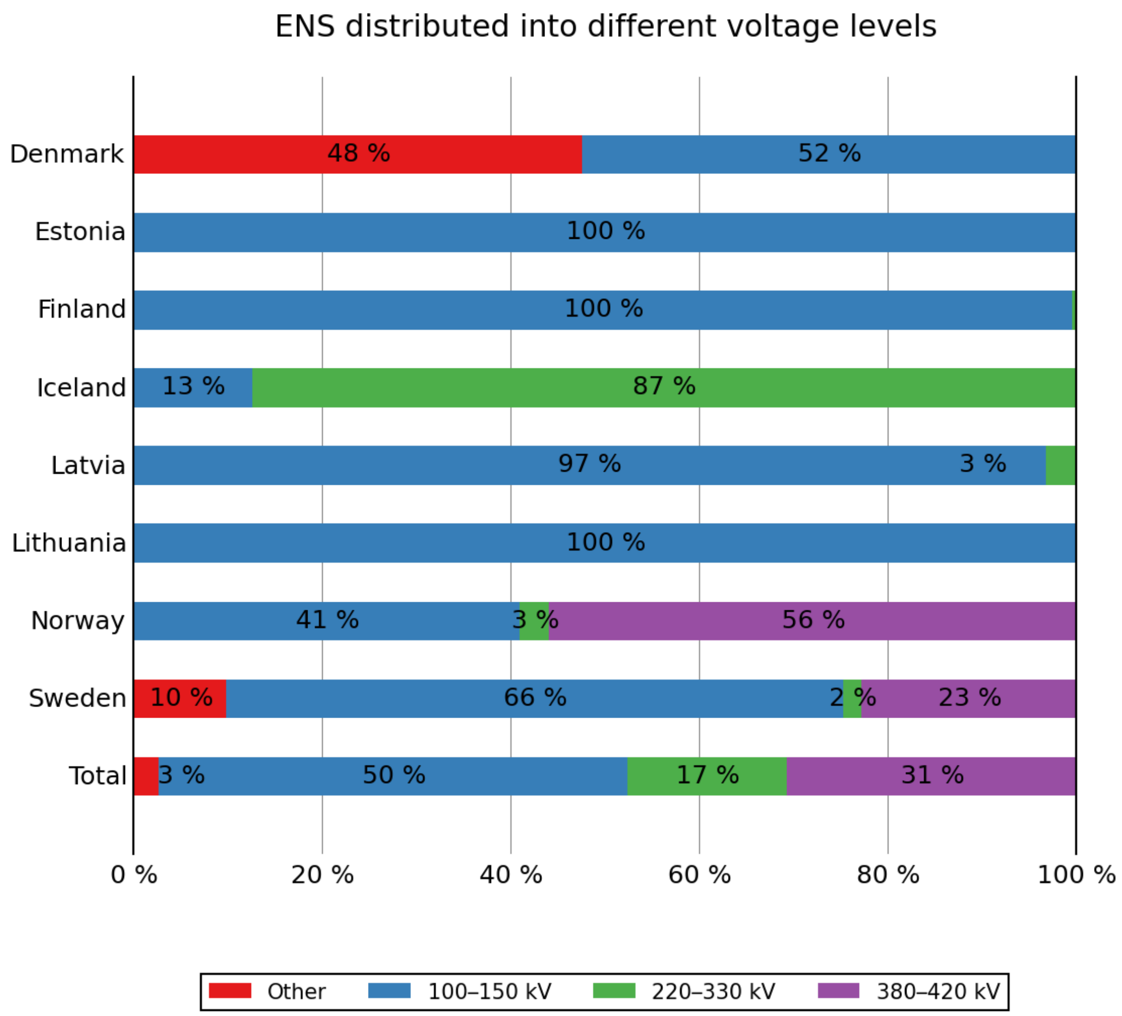

FIGURE 4.1.1 PERCENTAGE DISTRIBUTION OF ENERGY NOT SUPPLIED (ENS) IN TERMS OF THE VOLTAGE LEVEL OF THE PRIMARY FAULT IN EACH NORDIC AND BALTIC COUNTRY IN 2014

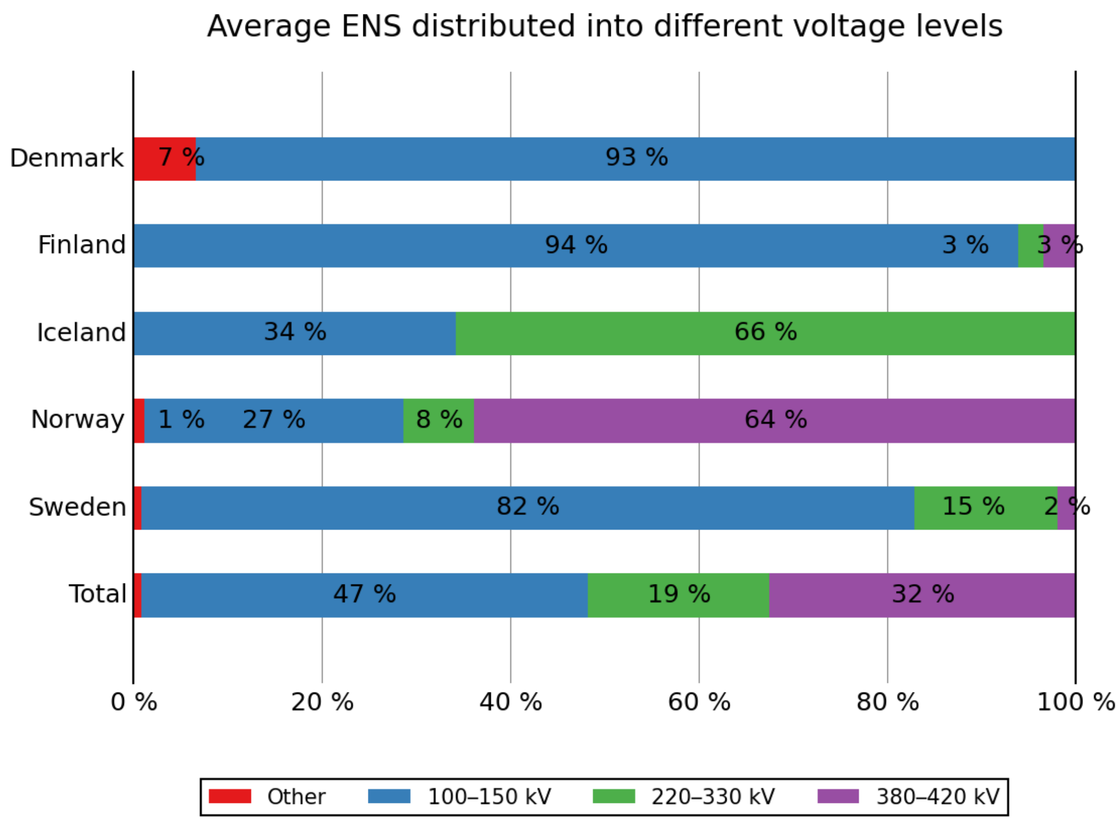

FIGURE 4.1.2 PERCENTAGE DISTRIBUTION OF ENERGY NOT SUPPLIED IN TERMS OF THE VOLTAGE LEVEL OF THE PRIMARY FAULT IN EACH NORDIC COUNTRY DURING THE PERIOD 2005–2014

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 distribution according to installation.

TABLE 4.2.1 ENERGY NOT SUPPLIED (ENS) AND ITS DISTRIBUTION ACCORDING TO INSTALLATION IN EACH NORDIC AND BALTIC COUNTRY

Country	Consumption GWh	ENS MWh	ENS / consumption ppm	ENS / consumption ppm	ENS divided according to installation: Overhead lines	Cable	Station	Other
	2014	2014	2014	2005–2014	during the period 2005–2014			
Denmark	32697	23.9	0.7	0.6	18.5	0.0	62.1	19.4
Finland	83300	499.2	6.0	4.2	62.5	0.3	30.3	10.1
Iceland	17592	835.0	47.5	75.3	29.4	0.7	52.7	18.1
Norway	125875	2164.9	17.2	25.6	70.3	1.8	25.2	0.7
Sweden	135200	1234.8	9.1	13.3	31.0	4.9	56.9	3.9
					during the year 2014			
Estonia	8120	29.7	3.7	-	4.7	0.0	30.6	64.6
Latvia	6029	35.6	5.9	-	78.5	0.0	21.5	0.0
Lithuania	9412	39.2	4.2	-	13.0	0.0	87.0	0.0
Total	394664	4758	16.1	23.8	42.3	1.5	45.5	10.4

Ppm (parts per million) represents ENS as a proportional value of the consumed energy, which is calculated: ENS (MWh) × 10^6 / consumption (MWh). The sum of the ENS divided according to installation may not be exactly 100 % because all the ENS is not always connected with a cause.

Figure 4.2.1 presents the progression of ENS during the period 2005–2014 for the Nordic countries. 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.

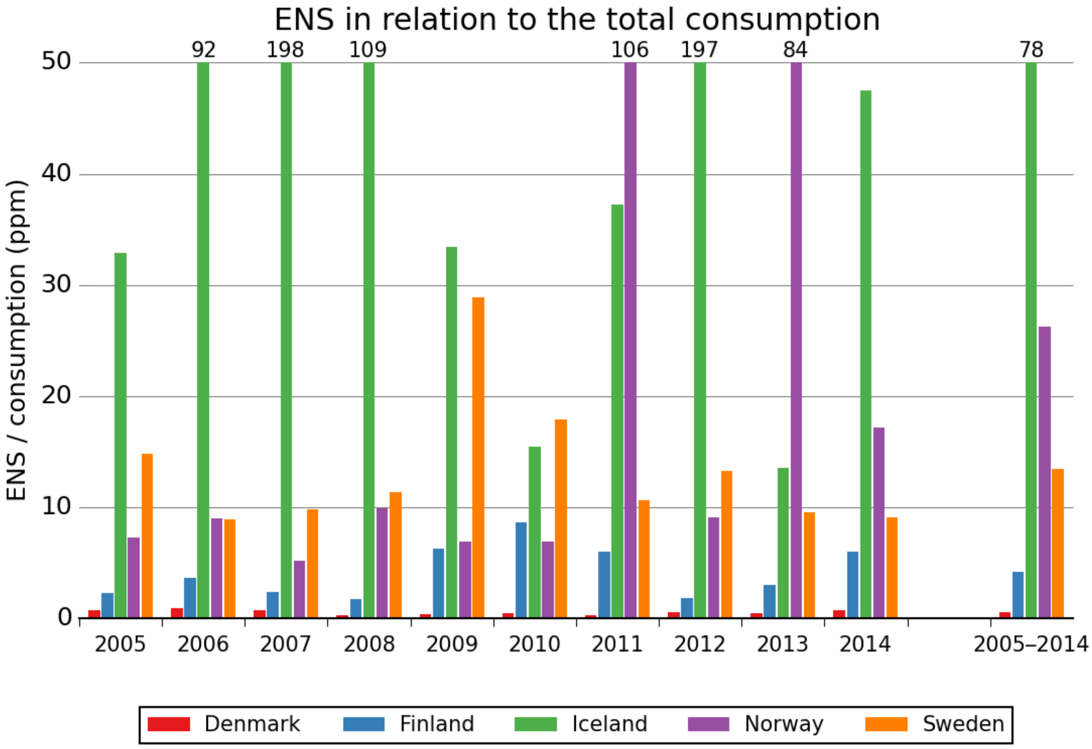

FIGURE 4.2.1 ENERGY NOT SUPPLIED (ENS) DIVIDED BY CONSUMPTION (PPM) IN EACH NORDIC COUNTRY

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 divided by the consumption in 2011 in Norway was caused by extreme weather conditions in December (aka the storm named Dagmar).

4.3 ENERGY NOT SUPPLIED (ENS) DISTRIBUTED ACCORDING TO MONTH

Figure 4.3.1 and Figure 4.3.2 present the distribution of energy not supplied according to month in the Nordic and Baltic countries, respectively. Figure 4.3.3 presents the percentage distribution of the energy not supplied in the Nordic countries according to month for the period 2005–2014.

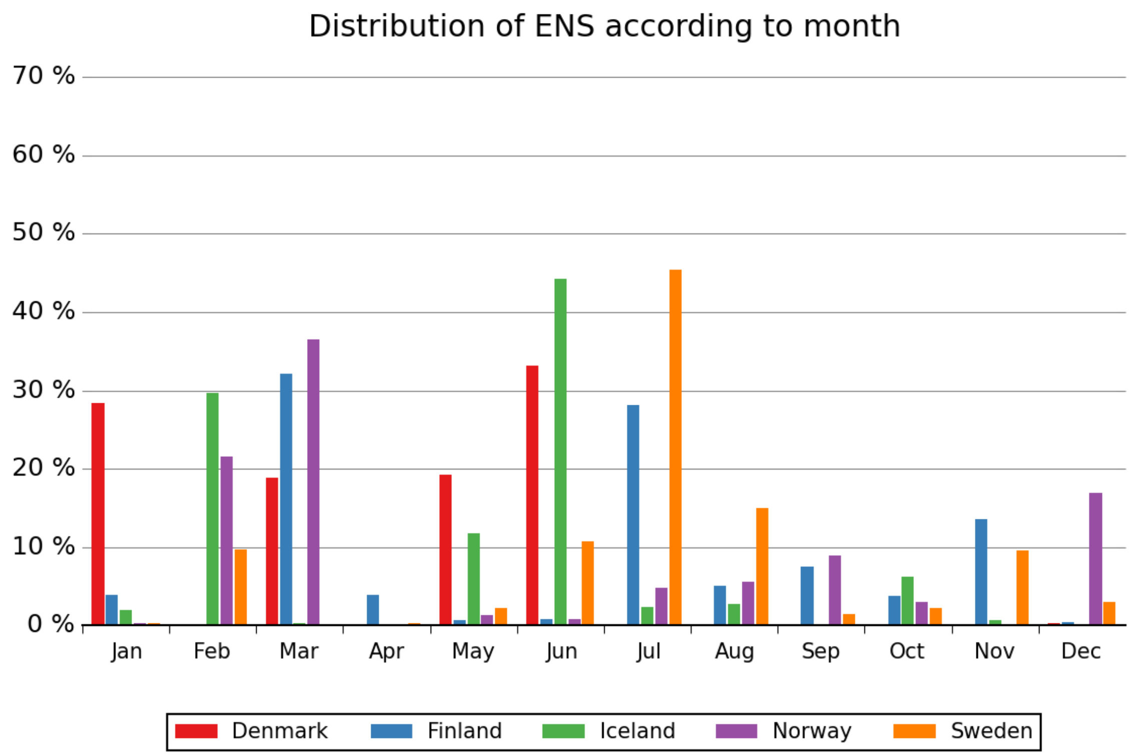

Figure 4.3.1 Percentage distribution of energy not supplied (ENS) according to month in each Nordic country in 2014

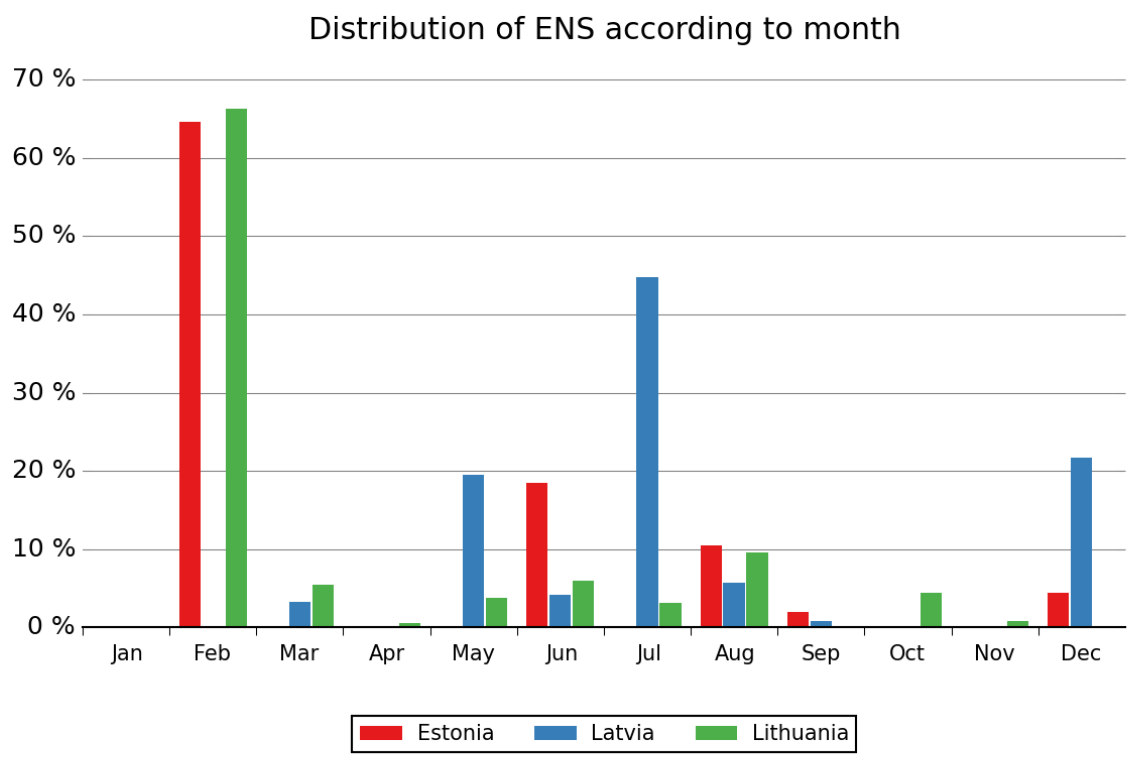

Figure 4.3.2 Percentage distribution of energy not supplied (ENS) according to month in each Baltic country in 2014

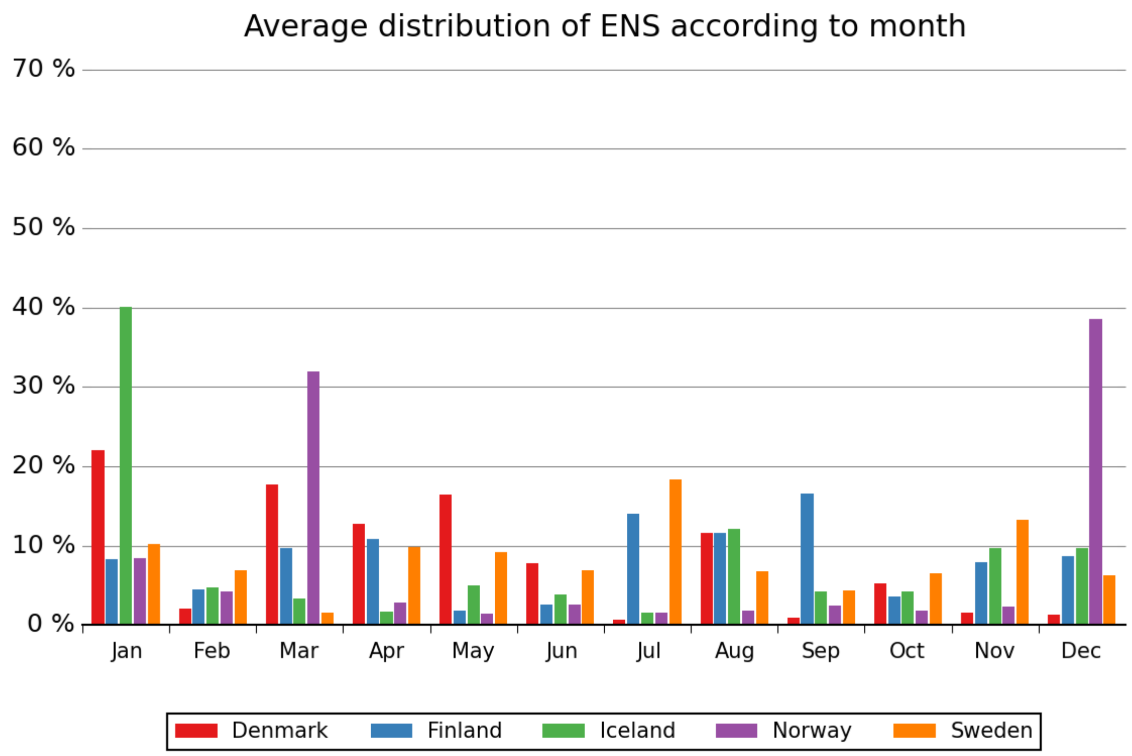

FIGURE 4.3.3 AVERAGE PERCENTAGE DISTRIBUTION OF GRID DISTURBANCES ACCORDING TO MONTH IN EACH NORDIC COUNTRY DURING THE PERIOD 2005–2014

4.4 ENERGY NOT SUPPLIED (ENS) DISTRIBUTED ACCORDING TO CAUSE

Figure 4.4.1 and Figure 4.4.2 present the distribution of energy not supplied in 2014 according to cause in the Nordic and Baltic countries, respectively. Figure 4.4.3 presents the percentage distribution of the energy not supplied in the Nordic countries according to cause for the period 2005–2014. Appendix 2 provides more details about how each country investigates line faults.

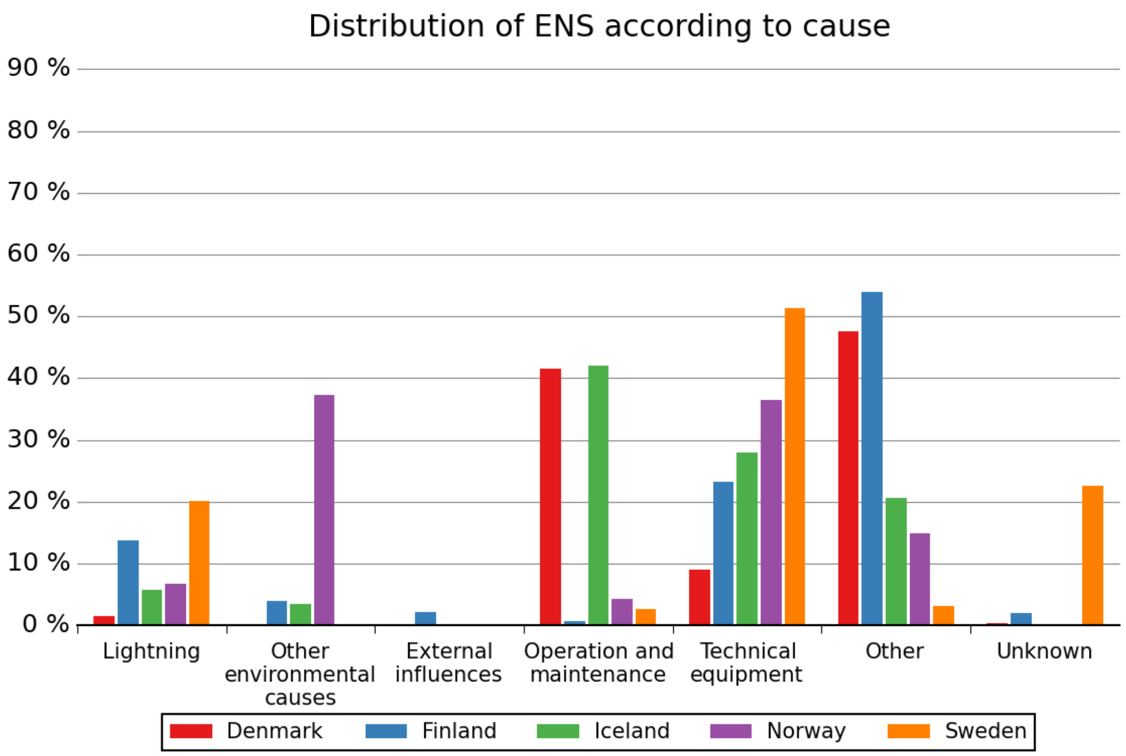

FIGURE 4.4.1 PERCENTAGE DISTRIBUTION OF ENERGY NOT SUPPLIED ACCORDING TO THE CAUSE OF THE PRIMARY FAULT IN EACH NORDIC COUNTRY IN 2014

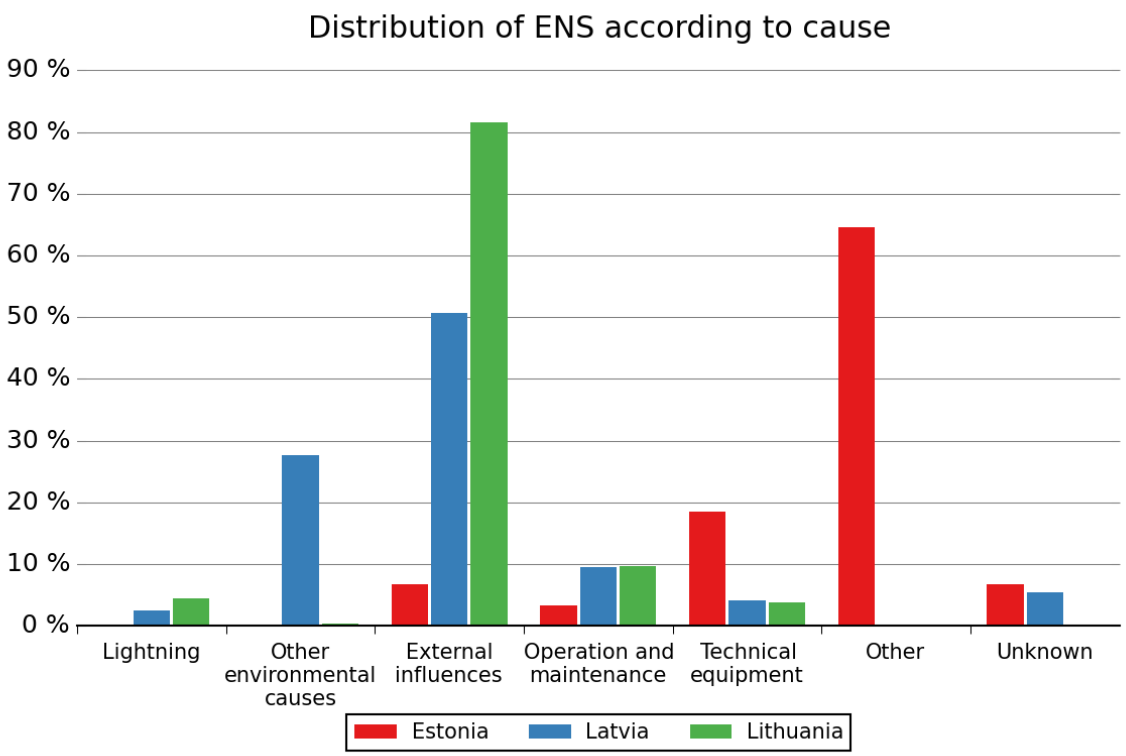

FIGURE 4.4.2 PERCENTAGE DISTRIBUTION OF ENERGY NOT SUPPLIED ACCORDING TO THE CAUSE OF THE PRIMARY FAULT IN EACH BALTIC COUNTRY IN 2014

In Lithuania, one disturbance caused 81 % ENS in the category ‘external influences’. More details are in Section 2.7.

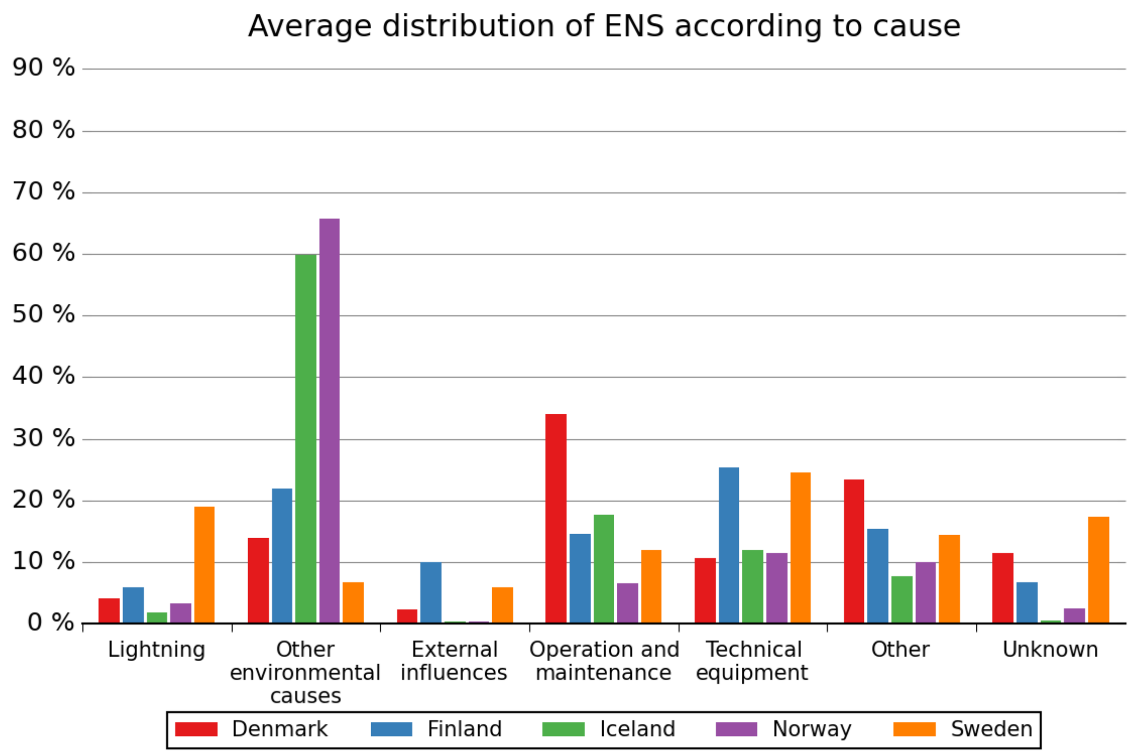

Figure 4.4.3 Average percentage distribution of ENS according to the cause of the primary fault in each Nordic country during period 2005–2014

4.5 Energy not supplied (ENS) distributed according to component

Table 4.5.1 shows the amount of energy not supplied in 2014 and the annual average for the period 2005–2014. Table 4.5.2 and Table 4.5.3 show the distribution of energy not supplied according to component in the Nordic and Baltic countries, respectively.

Table 4.5.1 Energy not supplied (ENS) in each Nordic and Baltic country in 2014 and the annual average for the period 2005–2014

Country	ENS (MWh)	
	2014	2005–2014
Denmark	24	19
Finland	499	356
Iceland	835	1137
Norway	2165	3316
Sweden	1235	1887
Estonia	30	-
Latvia	36	-
Lithuania	39	-
Total	4862	6714

1) One Swedish regional grid delivered incomplete data in 2012. The details of the origin of the fault were not reported and therefore 750 MWh of ENS is not included from that year.

TABLE 4.5.2 PERCENTAGE DISTRIBUTION OF ENERGY NOT SUPPLIED IN TERMS OF COMPONENT IN EACH NORDIC COUNTRY

	Denmark		Finland		Iceland		Norway		Sweden		Total	
Fault location	**2014**	**2005–2014**	**2014**	**2005–2014**	**2014**	**2005–2014**	**2014**	**2005–2014**	**2014**	**2005–2014**	**2014**	**2005–2014**
Overhead line	0.0	18.5	58.1	62.5	9.3	29.4	45.3	70.3	41.9	31.0	25.8	42.3
Cable	0.0	0.0	2.0	0.3	0.0	0.7	0.1	1.8	0.1	4.9	0.4	1.5
Line faults	**0.0**	**18.5**	**60.1**	**62.8**	**9.3**	**30.1**	**45.4**	**72.1**	**42.0**	**35.8**	**26.1**	**43.9**
Power transformers	0.0	15.4	0.3	1.8	0.0	0.4	2.0	3.7	21.1	8.1	3.9	5.9
Instrument transformers	9.1	4.2	5.0	3.6	0.0	0.0	11.5	1.5	24.6	4.8	8.4	2.8
Circuit breakers	41.5	9.2	1.1	2.1	0.0	23.8	0.2	1.3	8.0	3.3	8.5	7.9
Busbar	0.0	6.6	0.0	1.9	0.0	3.8	2.6	1.8	0.0	1.9	0.4	3.2
Control equipment	1.5	10.8	6.3	12.6	3.1	11.8	13.8	6.5	1.0	3.4	4.3	9.0
Disconnectors and earth connectors	0.0	14.3	0.0	2.0	0.0	8.5	5.9	1.0	0.1	6.6	1.0	6.5
Surge arresters and spark gap	0.0	0.0	0.2	3.8	0.0	0.0	0.1	3.5	0.0	0.1	0.0	1.5
Common ancillary equipment	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 substation faults	0.3	0.4	0.1	2.6	26.8	2.0	18.5	5.9	0.0	28.5	7.6	7.9
Substation faults	**52.4**	**60.9**	**13.0**	**30.3**	**29.9**	**50.3**	**54.6**	**25.2**	**54.9**	**56.8**	**34.1**	**44.7**
Shunt capacitor	0.0	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.5
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	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.3
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
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
Compensation faults	**0.0**	**1.2**	**0.0**	**0.0**	**0.0**	**2.4**	**0.0**	**0.0**	**0.0**	**0.2**	**0.0**	**0.8**
System fault	0.0	11.8	0.0	0.0	60.8	16.2	0.0	0.3	0.0	0.9	10.1	5.8
Faults in adjoining statistical area	47.6	7.6	49.7	10.1	12.8	1.9	0.0	0.5	3.8	3.0	19.0	4.6
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	**47.6**	**19.4**	**49.7**	**10.1**	**73.6**	**18.1**	**0.0**	**0.7**	**3.8**	**3.9**	**29.1**	**10.4**

TABLE 4.5.3 PERCENTAGE DISTRIBUTION OF ENERGY NOT SUPPLIED IN TERMS OF COMPONENT IN EACH BALTIC COUNTRY IN 2014

	Estonia	Latvia	Lithuania	Total
Fault location	**2014**	**2014**	**2014**	**2014**
Overhead line	4.7	78.5	13.0	4.7
Cable	0.0	0.0	0.0	0.0
Line faults	**4.7**	**78.5**	**13.0**	**4.7**
Power transformers	0.0	0.0	0.0	0.0
Instrument transformers	0.0	0.0	3.8	0.0
Circuit breakers	3.7	0.0	0.1	3.7
Busbar	2.0	6.7	2.5	2.0
Control equipment	18.9	14.8	76.3	18.9
Disconnectors and earth connectors	0.0	0.0	4.2	0.0
Surge arresters and spark gap	0.0	0.0	0.0	0.0
Common ancillary equipment	0.0	0.0	0.0	0.0
Other substation faults	6.1	0.0	0.0	6.1
Substation faults	**30.6**	**21.5**	**87.0**	**30.6**
Shunt capacitor	0.0	0.0	0.0	0.0
Series capacitor	0.0	0.0	0.0	0.0
Reactor	0.0	0.0	0.0	0.0
Synchronous compensator	0.0	0.0	0.0	0.0
SVC and statcom	0.0	0.0	0.0	0.0
Compensation faults	**0.0**	**0.0**	**0.0**	**0.0**
System fault	0.0	0.0	0.0	0.0
Faults in adjoining statistical area	64.6	0.0	0.0	64.6
Unknown	0.0	0.0	0.0	0.0
Other faults	**64.6**	**0.0**	**0.0**	**64.6**

It should be noted that some countries register the total amount of energy not supplied in a disturbance in terms of the primary fault. Therefore, the data is not necessarily comparable.

5 Faults in Power System Components

5.1 Definitions and Scope

A fault in a component implies that it is not able to perform its function properly. Faults can have many causes, for example manufacturing defects or insufficient maintenance. 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.

A component fault is defined as:

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 these 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 grouped into 100–150 kV, 220–330 kV and 380–420 kV voltage levels for most of the components. 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 2014.

Table 5.2.1 Number of faults and grid disturbances in each Nordic and Baltic country in 2014

2014	Number of faults in 2014	Number of disturbances in 2014	Fault / disturbance ratio in 2014	Fault / disturbance ratio during 2005–2014
Denmark	87	77	1.13	1.17
Estonia	225	225	1.00	-
Finland	544	513	1.06	1.06
Iceland	62	40	1.55	1.28
Latvia	165	151	1.09	-
Lithuania	160	160	1.00	-
Norway	539	461	1.17	1.10
Sweden	802	759	1.06	1.03

Table 5.2.2 presents the distribution of faults and energy not supplied in terms of voltage level and country. In addition, the table shows the overhead 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 in each Nordic and Baltic country

Voltage	Country	Size of the grid		Number of faults		ENS (MWh)	
		Number of power transformers	Length of lines in km[1)]	2014	2005–2014	2014	2005–2014
380–420 kV	Denmark	37	1302	14	8.0	0.0	0.0
	Estonia	0	0	0	-	0.0	-
	Finland	71	4964	28	24.9	0.0	12.3
	Iceland	0	0	0	0.0	0.0	0.0
	Latvia	0	0	0	-	0.0	-
	Lithuania	0	0	0	-	0.0	-
	Norway	64	2976	119	66.3	1210.8	2116.6
	Sweden	65	10991	116	113.5	281.3	35.3
220–330 kV	Denmark	5	140	2	0.6	0.0	0.0
	Estonia	22	1860	26	-	0.0	-
	Finland	28	2259	22	21.1	2.1	9.6
	Iceland	33	860	17	13.5	730.0	748.1
	Latvia	25	1395	18	-	1.2	-
	Lithuania	23	1761	11	-	0.0	-
	Norway	250	5207	114	95.7	67.1	250.3
	Sweden	105	4200	81	65.5	23.5	279.1
100–150 kV	Denmark	228	4295	64	63.3	12.5	17.8
	Estonia	216	3479	178	-	29.7	-
	Finland	1175	17384	442	355.9	497.1	333.6
	Iceland	51	1365	35	25.6	105.0	388.4
	Latvia	246	3891	137	-	34.5	-
	Lithuania	416	5032	146	-	39.2	-
	Norway	724	11199	306	180.0	887.1	911.3
	Sweden	739	16263	529	346.7	808.8	1502.5

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

Table 5.2.3 and Table 5.2.4 show the number of faults classified according to the component groups used in this statistics. One should note that not all countries have every type of equipment in their network. For example static var compensators (SVCs) or STATCOM installations do not exist in every country. 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 statistics (typically from networks with voltages lower than 100 kV) but still influence statistic area.

TABLE 5.2.3 PERCENTAGE DISTRIBUTION OF FAULTS ACCORDING TO COMPONENT TYPE IN EACH NORDIC COUNTRY

	Denmark		**Finland**		**Iceland**		**Norway**		**Sweden**		**Average**	
Component type	**2014**	**2005–2014**	**2014**	**2005–2014**	**2014**	**2005–2014**	**2014**	**2005–2014**	**2014**	**2005–2014**	**2014**	**2005–2014**
Overhead line	40.2	57.6	79.8	77.2	35.5	36.2	60.9	49.3	68.7	59.4	57.0	55.9
Cable	6.9	3.7	0.2	0.2	0.0	1.0	1.9	1.1	0.6	0.8	1.9	1.4
Line faults	**47.1**	**61.3**	**80.0**	**77.4**	**35.5**	**37.1**	**62.7**	**50.4**	**69.3**	**60.2**	**58.9**	**57.3**
Power transformers	4.6	3.9	1.7	1.6	0.0	4.4	1.7	2.6	9.2	5.7	3.4	3.6
Instrument transformers	3.4	2.0	0.6	0.7	0.0	0.0	1.5	2.0	1.4	1.0	1.4	1.1
Circuit breakers	3.4	4.3	1.3	1.1	1.6	3.9	3.2	3.8	1.6	2.4	2.2	3.1
Busbar	2.3	0.8	0.0	0.4	0.0	0.2	1.3	1.2	0.4	0.9	0.8	0.7
Control equipment	19.5	14.6	5.0	10.1	6.5	23.5	16.5	22.8	6.4	6.8	10.8	15.6
Disconnectors and earth connectors	1.1	1.6	0.0	0.3	0.0	0.2	0.9	1.7	0.4	0.5	0.5	0.9
Surge arresters and spark gap	0.0	0.3	0.2	0.3	0.0	0.0	0.4	1.1	0.0	0.2	0.1	0.4
Common ancillary equipment	0.0	0.1	0.0	0.0	0.0	0.0	0.7	0.9	0.4	0.5	0.2	0.3
Other substation faults	9.2	3.1	1.3	2.2	4.8	3.6	5.8	10.7	0.2	5.8	4.3	5.1
Substation faults	**43.7**	**30.6**	**9.9**	**16.5**	**12.9**	**35.9**	**31.9**	**47.0**	**20.0**	**23.8**	**23.7**	**30.8**
Shunt capacitor	0.0	0.3	0.2	0.5	0.0	2.4	0.4	0.9	0.1	0.4	0.1	0.9
Series capacitor	0.0	0.0	0.6	1.1	0.0	0.2	0.2	0.0	0.0	3.1	0.1	0.9
Reactor	2.3	1.9	0.0	0.1	0.0	0.0	0.4	0.5	1.6	1.5	0.9	0.8
Synchronous compensator	0.0	0.1	0.0	0.0	0.0	0.0	0.7	0.7	0.5	0.4	0.2	0.2
SVC and statcom	0.0	0.1	0.0	0.0	0.0	0.0	3.7	3.5	1.0	1.7	0.9	1.1
Compensation faults	**2.3**	**2.4**	**0.7**	**1.7**	**0.0**	**2.7**	**5.4**	**5.5**	**3.2**	**6.9**	**2.3**	**3.9**
System fault	0.0	1.2	0.0	0.1	35.5	22.1	0.0	0.3	0.0	1.7	7.1	5.1
Faults in adjoining statistical area	6.9	4.1	8.3	4.1	16.1	5.1	0.0	3.0	7.5	4.3	7.8	4.1
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	**6.9**	**5.3**	**8.3**	**4.2**	**51.6**	**27.2**	**0.0**	**3.4**	**7.5**	**6.0**	**14.9**	**9.2**

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

TABLE 5.2.4 PERCENTAGE DISTRIBUTION OF FAULTS ACCORDING TO COMPONENT TYPE IN EACH BALTIC COUNTRY

	Estonia	Latvia	Lithuania	Average
Component type	**2014**	**2014**	**2014**	**2014**
Overhead line	56.0	73.3	79.4	69.6
Cable	0.4	0.0	0.0	0.1
Line faults	**56.4**	**73.3**	**79.4**	**69.7**
Power transformers	6.7	4.8	1.9	4.5
Instrument transformers	0.4	0.6	0.6	0.6
Circuit breakers	3.6	1.8	1.3	2.2
Busbar	0.9	1.2	0.6	0.9
Control equipment	10.7	11.5	12.5	11.6
Disconnectors and earth connectors	4.4	0.0	1.9	2.1
Surge arresters and spark gap	0.0	0.0	0.0	0.0
Common ancillary equipment	0.0	0.0	1.9	0.6
Other substation faults	7.6	0.6	0.0	2.7
Substation faults	**34.2**	**20.6**	**20.6**	**25.2**
Shunt capacitor	0.0	0.0	0.0	0.0
Series capacitor	0.0	0.0	0.0	0.0
Reactor	0.0	0.6	0.0	0.2
Synchronous compensator	0.0	0.0	0.0	0.0
SVC and statcom	0.0	0.0	0.0	0.0
Compensation faults	**0.0**	**0.6**	**0.0**	**0.2**
System fault	0.0	0.0	0.0	0.0
Faults in adjoining statistical area	9.3	5.5	0.0	4.9
Unknown	0.0	0.0	0.0	0.0
Other faults	**9.3**	**5.5**	**0.0**	**4.9**

5.3 FAULTS ON OVERHEAD LINES

Overhead lines are a large part of the Nordic and Baltic transmission grids. Therefore, the tables in this section show the distribution of faults in 2014 as well as the average values for the period 1996–2014. The tables also give the faults distributed by cause during the period 1996–2014. Along with the tables, the annual distribution of faults and the number of permanent faults during the period 2005–2014 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.

5.3.1 380–420 kV OVERHEAD LINES

Table 5.3.1 shows the line lengths, faults of 380–420 kV overhead lines, the causes of faults and the percentage values of 1-phase faults and permanent faults for the countries that have this voltage level. The data consists of the values for the year 2014 and for the 19-year period 1996–2014. Figure 5.3.1 presents the annual line fault values per line length during the ten-year period 2005–2014 and the average value of period 1996–2014. Figure 5.3.2 presents the annual distribution of permanent line faults during the same period.

TABLE 5.3.1 380–420 KV OVERHEAD LINES FAULTS AND THE DISTRIBUTION ACCORDING TO CAUSE IN NORDIC COUNTRIES

Country	Lines (km)	Number of faults	Number of faults per 100 km		Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown	1-phase faults	Permanent faults
	2014	2014	2014	1996–2014	Faults divided by cause (%) during the period 1996–2014								
Denmark	1192	0	0.00	0.32	19.2	63.0	6.8	4.1	4.1	1.4	1.4	49.3	5.5
Finland	4964	20	0.40	0.26	72.6	8.0	1.9	6.1	1.9	4.2	5.2	62.7	9.9
Norway	2951	61	2.07	1.10	23.0	70.5	0.2	0.2	1.7	1.9	2.5	66.7	6.1
Sweden	10983	49	0.45	0.37	51.1	17.5	2.0	2.8	3.2	1.3	21.9	82.0	7.0
Total	20090	130	0.65	0.44	43.1	36.2	1.6	2.5	2.6	1.9	12.1	72.6	7.0

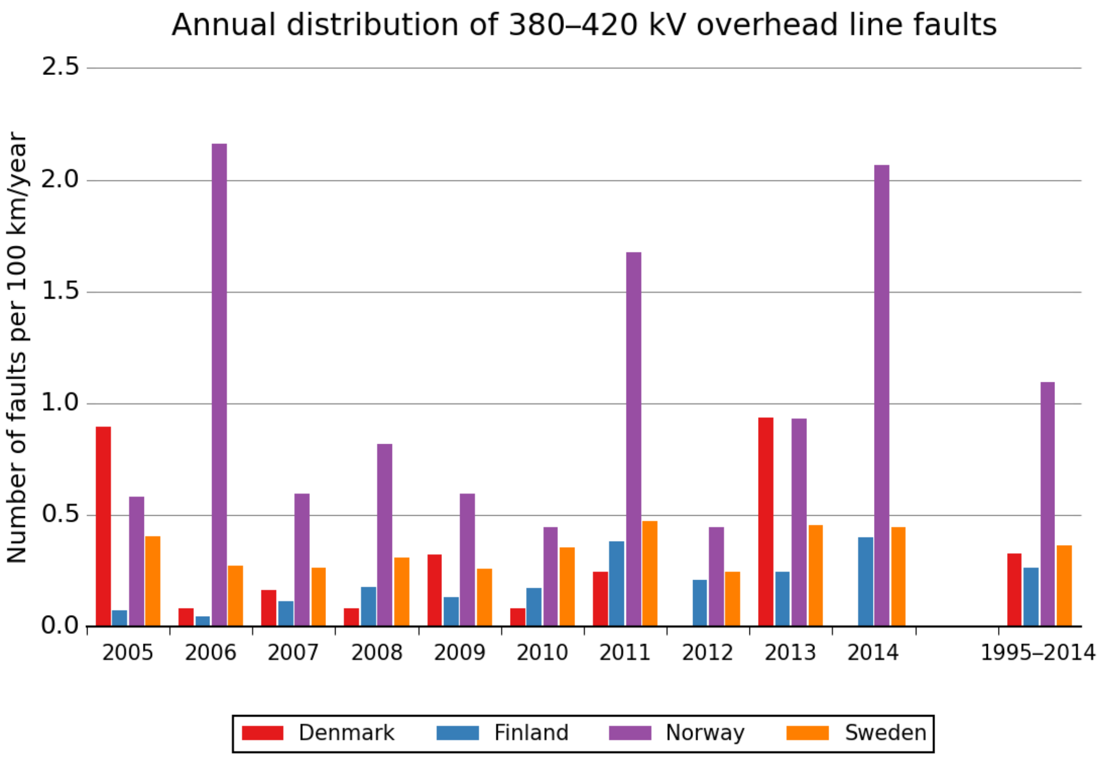

FIGURE 5.3.1 ANNUAL DISTRIBUTION OF FAULTS FOR 380–420 KV OVERHEAD LINES IN NORDIC COUNTRIES DURING THE PERIOD 2005–2014

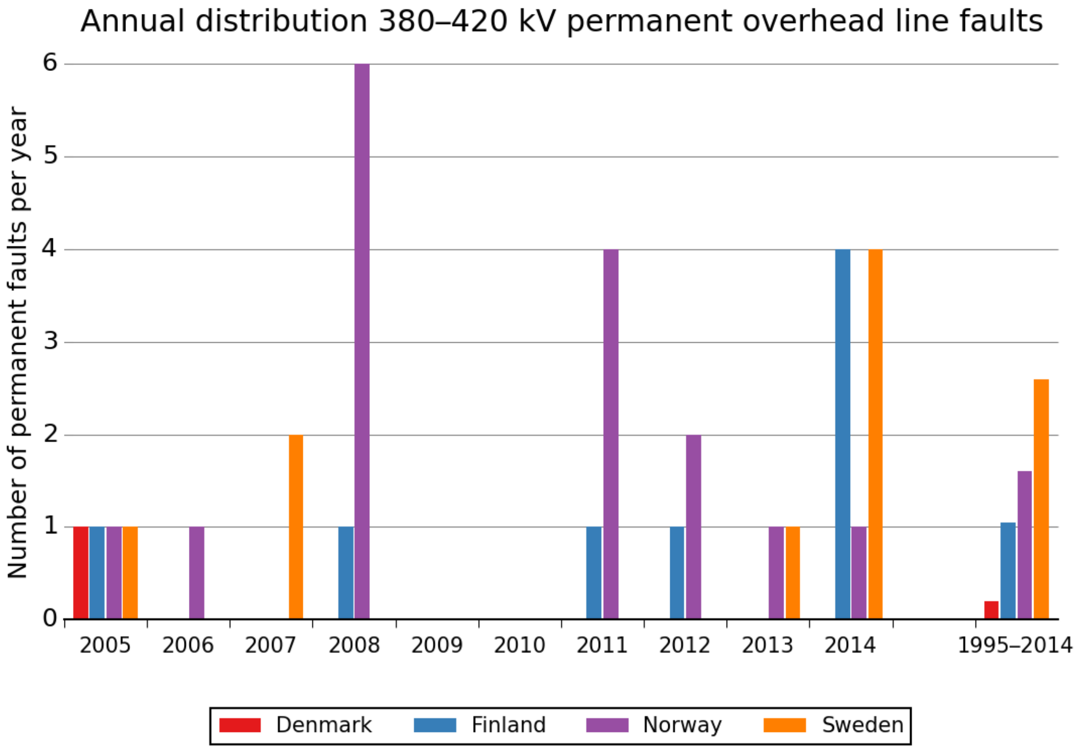

FIGURE 5.3.2 ANNUAL DISTRIBUTION OF PERMANENT FAULTS FOR 380–420 KV OVERHEAD LINES IN NORDIC COUNTRIES DURING THE PERIOD 1995–2014

5.3.2 220–330 KV OVERHEAD LINES

Table 5.3.2 shows the line lengths, faults of 220–330 kV overhead 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 2014 and for the 19-year period 1996–2014. Figure 5.3.3 presents the annual line fault values per line length during the ten-year period 2005–2014 and the average value of period 1996–2014. Figure 5.3.4 presents the annual distribution of permanent line faults during the same period.

TABLE 5.3.2 220–330 KV OVERHEAD LINES FAULTS AND THE DISTRIBUTION ACCORDING TO CAUSE IN EACH NORDIC AND BALTIC COUNTRY

Country	Lines (km)	Number of faults	Number of faults per 100 km		Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown	1-phase faults	Permanent faults
	2014	2014	2014	1996–2014	Faults divided by cause (%) during the period 1996–2014								
Denmark	56	1	1.79	0.47	44.4	11.1	22.2	0.0	0.0	11.1	11.1	88.9	0.0
Finland	2259	19	0.84	0.78	46.2	10.7	1.6	1.4	0.5	1.9	37.6	72.5	3.3
Iceland	859	1	0.12	0.34	26.1	56.5	0.0	0.0	17.4	0.0	0.0	47.8	21.7
Norway	5139	66	1.28	0.72	52.7	36.3	0.9	0.5	2.0	2.7	5.0	62.0	8.7
Sweden	4091	43	1.05	0.87	68.3	4.3	3.6	4.2	3.6	1.0	15.1	57.1	6.9
					Faults divided by cause (%) during year 2014								
Estonia	1860	7	0.38	-	28.6	57.1	0.0	14.3	0.0	0.0	0.0	85.7	14.3
Latvia	1381	12	0.87	-	25.0	16.7	8.3	8.3	0.0	0.0	41.7	58.3	8.3
Lithuania	1761	11	0.62	-	9.1	0.0	9.1	27.3	0.0	0.0	54.5	81.8	18.2
Total	17406	160	0.92	0.64	47.5	23.8	5.7	1.2	4.7	3.3	13.8	65.7	8.1

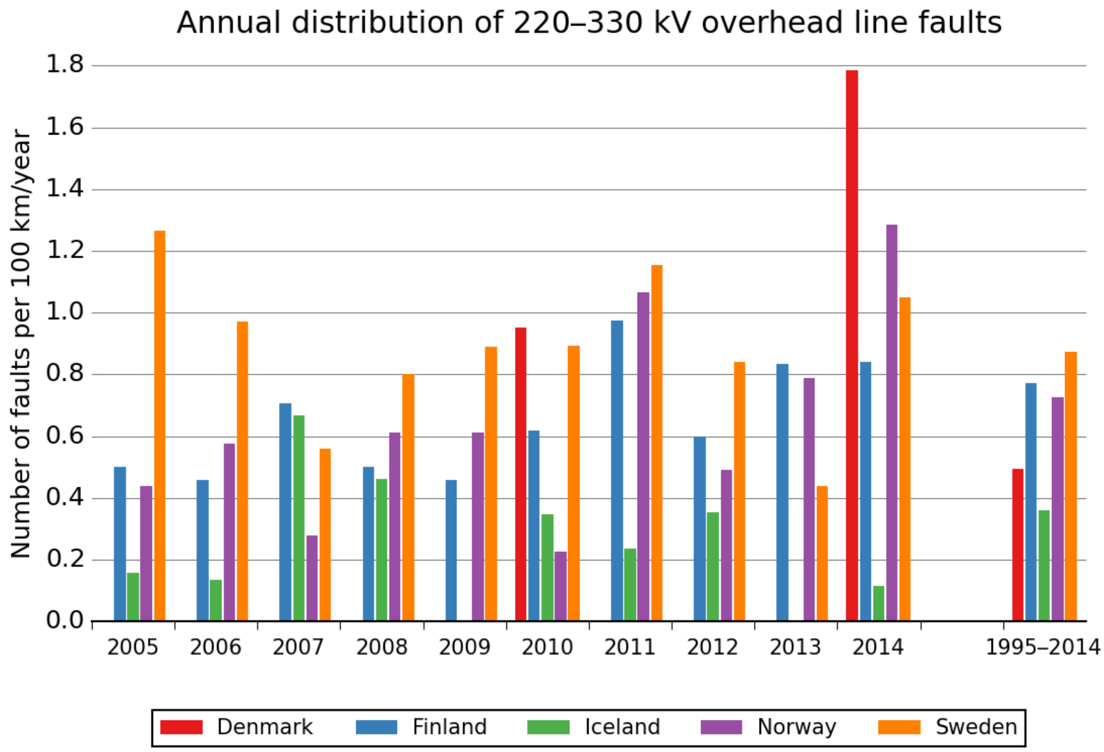

FIGURE 5.3.3 ANNUAL DISTRIBUTION OF FAULTS FOR 220–330 KV OVERHEAD LINES IN EACH NORDIC COUNTRY DURING THE PERIOD 2005–2014 AND THE AVERAGE FOR 1995–2014 IN EACH NORDIC COUNTRY

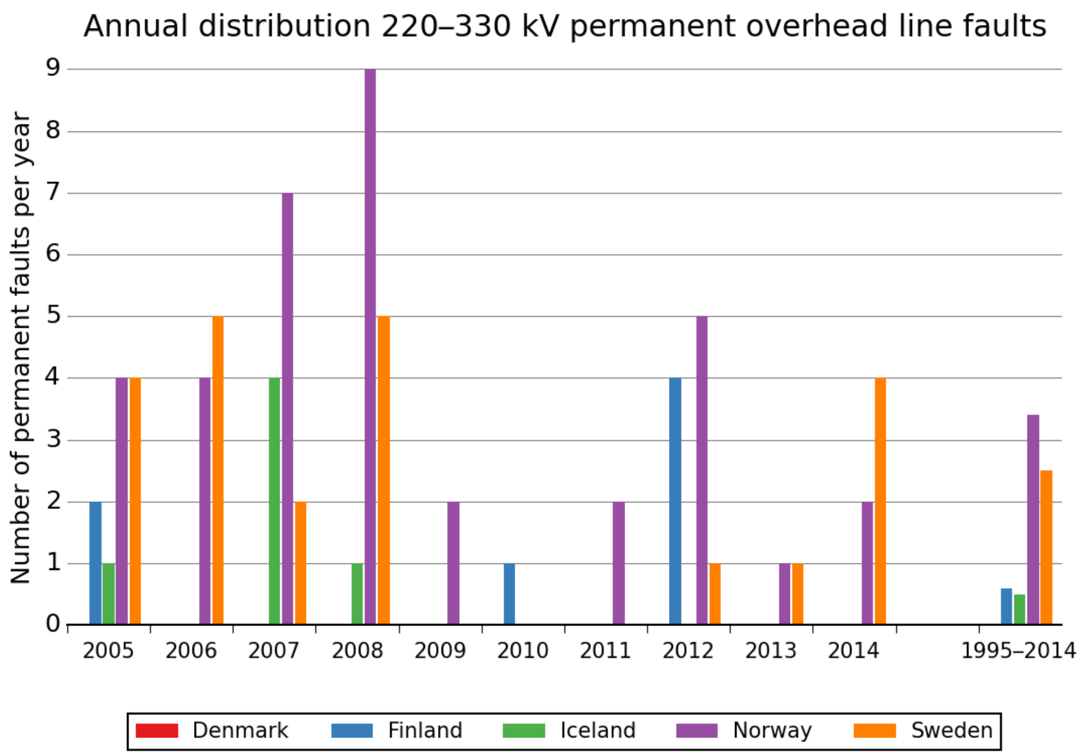

FIGURE 5.3.4 ANNUAL DISTRIBUTION OF PERMANENT FAULTS FOR 220–330 KV OVERHEAD LINES DURING THE PERIOD 2005–2014 AND THE AVERAGE FOR 1995–2014 IN EACH NORDIC COUNTRY

5.3.3 100–150 kV OVERHEAD LINES

Table 5.3.3 shows the line lengths, faults of 100–150 kV overhead 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 2014 and for the 19-year period 1996–2014. Figure 5.3.5 presents the annual line fault values per line length during the ten-year period 2005–2014 and the average value of period 1996–2014. Figure 5.3.6 presents the annual distribution of permanent line faults during the same period.

TABLE 5.3.3 100–150 KV OVERHEAD LINES FAULTS AND THE DISTRIBUTION ACCORDING TO CAUSE IN EACH NORDIC AND BALTIC COUNTRY

Country	Lines (km)	Number of faults	Number of faults per 100 km		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
	2014	2014	2014	1996–2014	Faults divided by cause (%) during the period 1996–2014								
Denmark	3220	34	1.06	1.04	23.5	39.4	20.6	2.3	1.0	2.3	10.9	52.0	5.1
Finland	17145	395	2.30	2.04	37.7	15.8	1.4	1.3	0.5	4.1	39.2	78.4	3.5
Iceland	1249	21	1.68	1.28	3.3	86.0	3.0	0.7	6.3	0.0	0.7	34.7	10.7
Norway	10997	201	1.83	1.03	53.4	32.7	2.4	1.0	5.4	4.0	1.4	25.8	17.8
Sweden	15860	459	2.89	2.20	61.4	4.9	2.2	2.8	3.0	1.8	24.0	35.5	4.8
					Faults divided by cause (%) during year 2014								
Estonia	3423	119	3.48	-	23.5	60.5	5.9	3.4	6.7	0.0	0.0	89.1	19.3
Latvia	3821	109	2.85	-	20.2	29.4	27.5	0.0	1.8	0.0	21.1	65.1	27.5
Lithuania	4968	116	2.34	-	13.8	2.6	46.6	2.6	0.9	0.0	33.6	84.5	12.1
Total	48471	1110	2.29	1.52	48.2	16.8	3.0	1.9	2.4	3.0	24.9	50.6	6.4

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

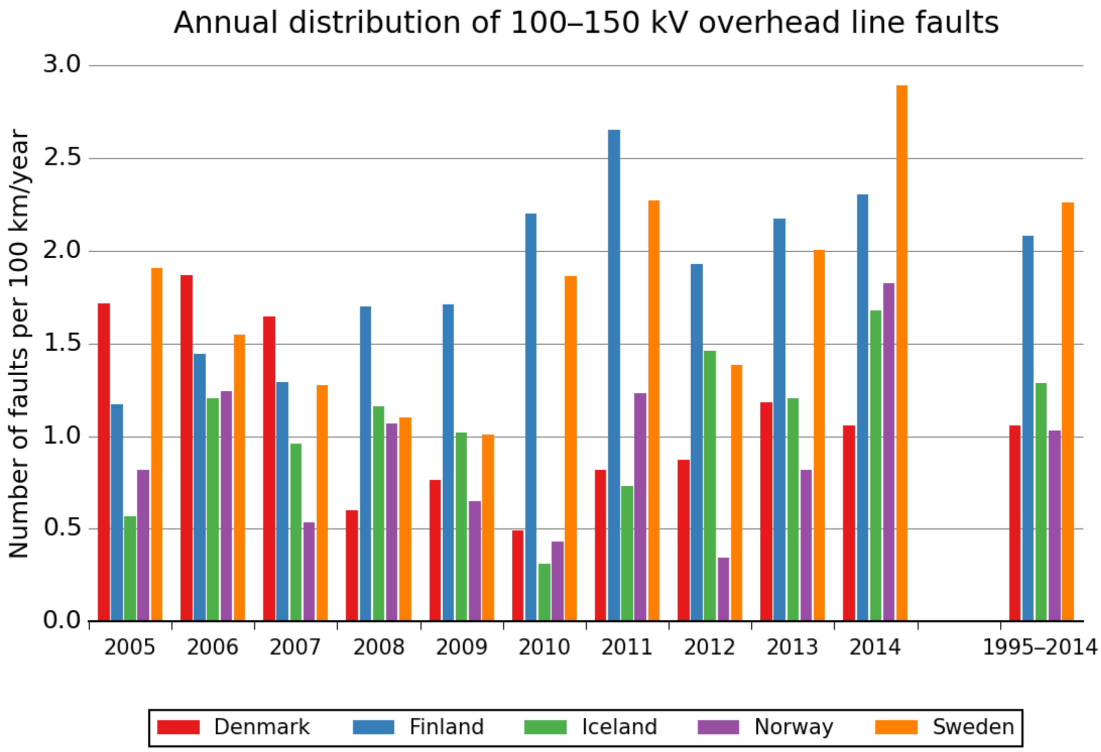

FIGURE 5.3.5 ANNUAL DISTRIBUTION OF LINE FAULTS FOR 100–150 KV OVERHEAD LINES DURING THE PERIOD 2005–2014 AND THE AVERAGE FOR 1995–2014 IN EACH NORDIC COUNTRY

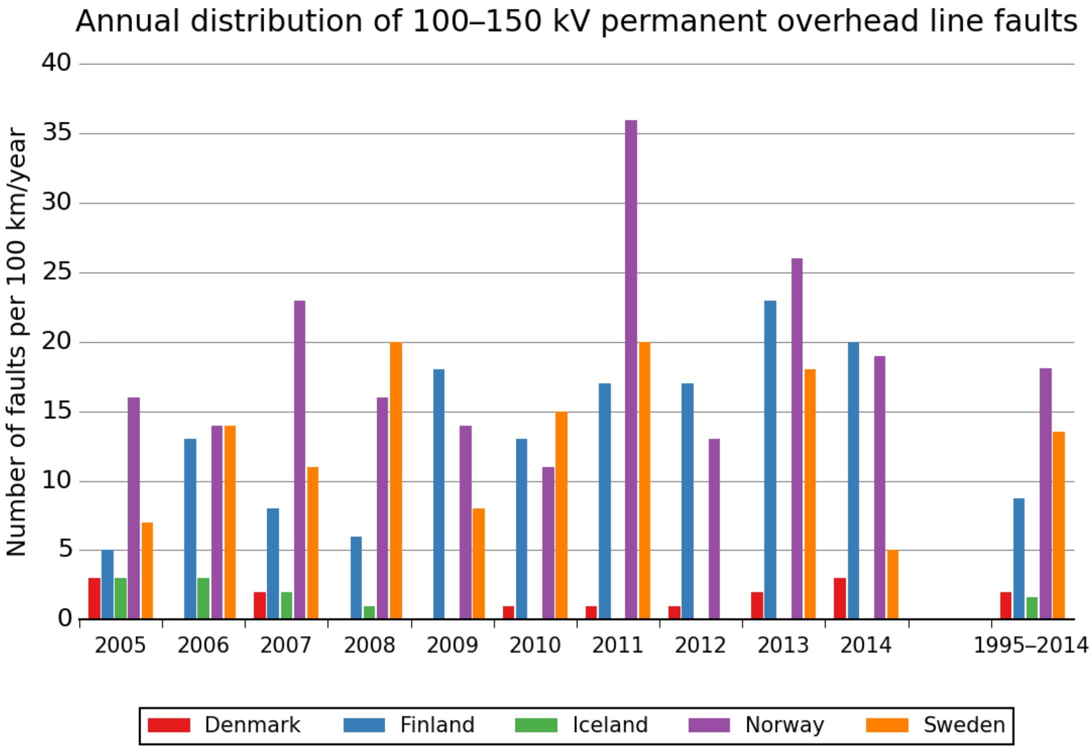

FIGURE 5.3.6 ANNUAL DISTRIBUTION OF PERMANENT LINE FAULTS FOR 100–150 KV OVERHEAD LINES DURING THE PERIOD 2005–2014 AND THE AVERAGE FOR 1995–2014 IN EACH NORDIC COUNTRY

5.3.4 OVERHEAD LINE FAULT TRENDS

Figure 5.3.7, Figure 5.3.8 and Figure 5.3.9 present trend curves of overhead line faults in the Nordic countries as of 1995 for 380–420 kV, 220–330 kV and 100–150 kV lines, respectively. The five-year average is calculated by dividing the sum of the faults by the total overhead line length for each five-year period. The trend curves are proportioned to overhead line length in order to get comparable results between countries.

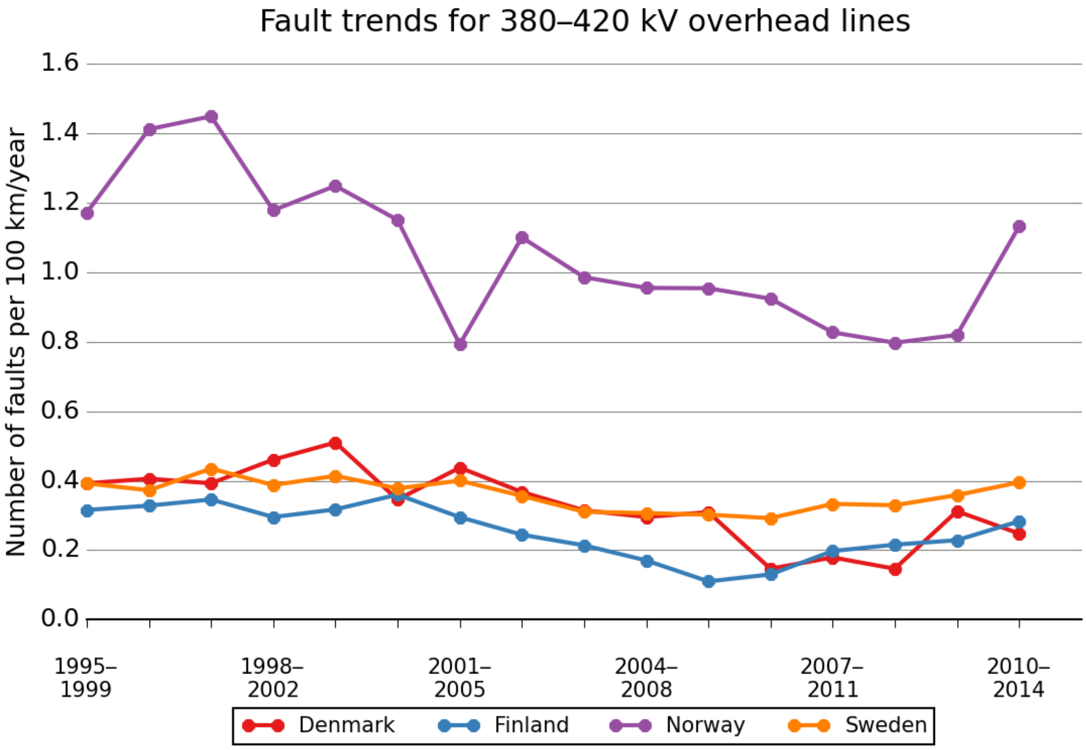

Figure 5.3.7 Fault trends as five-year averages for overhead lines at the voltage level 380–420 kV in Nordic countries

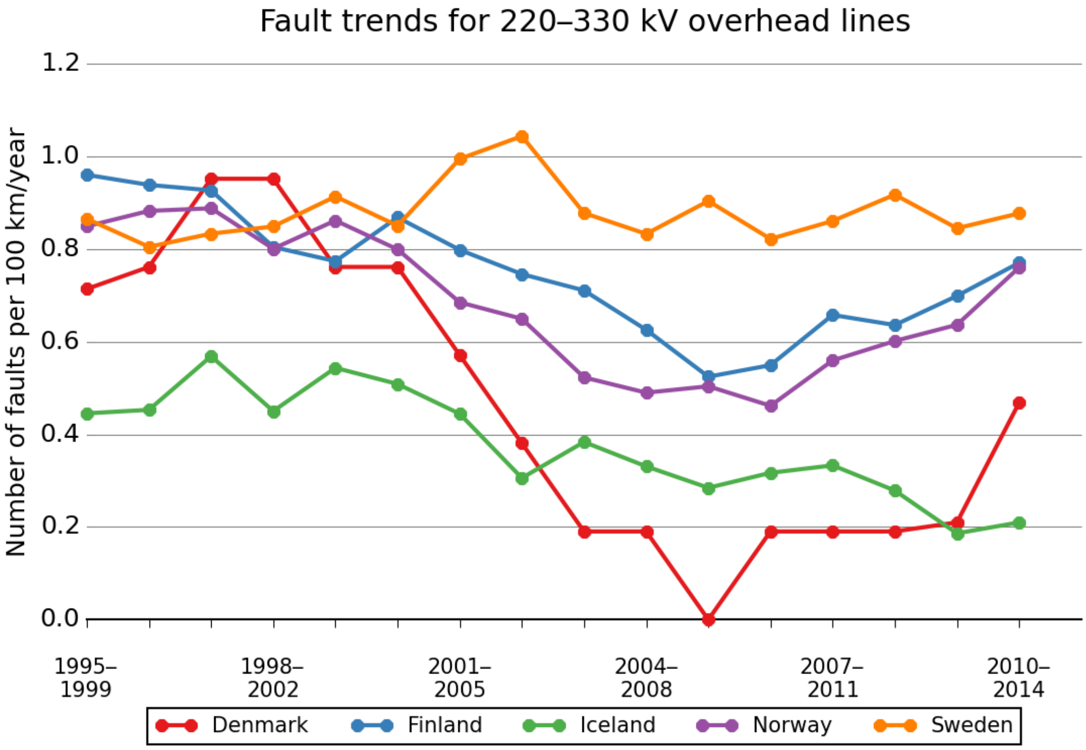

Figure 5.3.8 Fault trends as five-year averages for overhead lines at the voltage level 220–330 kV in each Nordic country

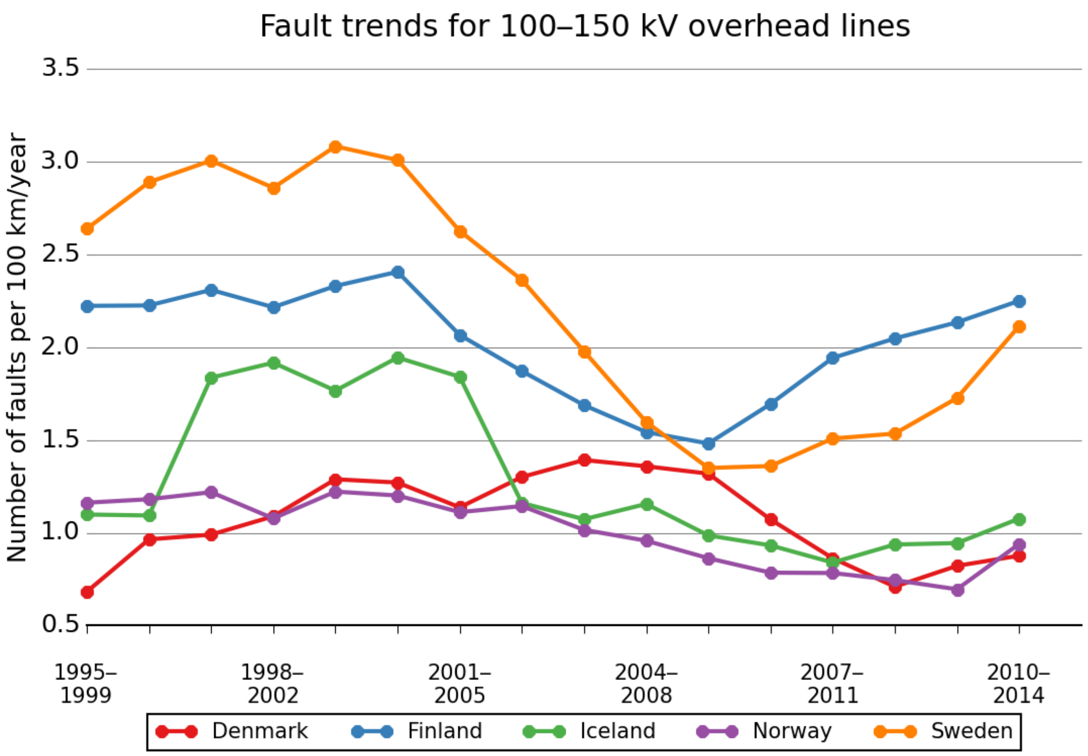

FIGURE 5.3.9 FAULT TRENDS AS FIVE-YEAR AVERAGES FOR OVERHEAD LINES AT THE VOLTAGE LEVEL 100–150 KV IN EACH NORDIC COUNTRY

5.4 FAULTS IN CABLES

Figure 5.4.1 presents the cable distributions in the Nordic countries to voltage levels in each year from 2005 to 2015.

Table 5.4.1, Table 5.4.2, and Table 5.4.3 present cable faults and fault distribution at each statistical voltage level for the year 2014 and for the period 2005–2014. In addition, the distribution of faults according to cause is given for the whole ten-year period. The annual distribution of faults during the period 2005–2014 is presented graphically for 100–150 kV cables only in the Nordic countries in Figure 5.4.2.

Fault trends for all the voltage levels in the Nordic countries are presented in Figure 5.4.3.

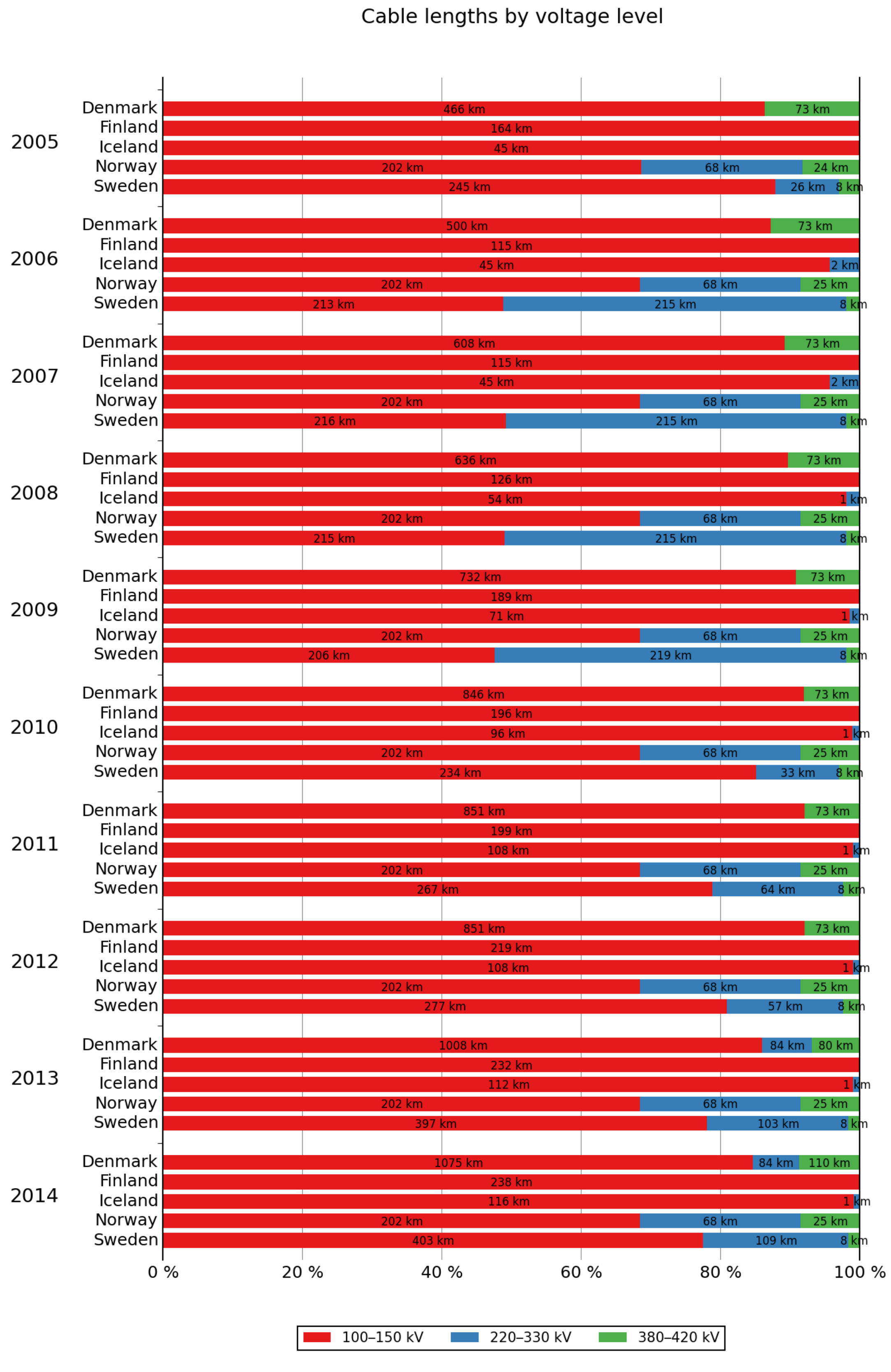

FIGURE 5.4.1 DISTRIBUTION OF CABLES LENGTHS ACCORDING TO VOLTAGE LEVEL IN EACH NORDIC COUNTRY FROM 2005 TO 2014

TABLE 5.4.1 380–420 KV CABLES FAULTS AND THE DISTRIBUTION ACCORDING TO CAUSE IN NORDIC COUNTRIES

Country	Lines (km)	Number of faults	Number of faults per 100 km		Light-ning	Other environ-mental causes	External influence	Operation and mainte-nance	Technical equipment	Other	Unknown
	2014	2014	2014	2005–2014	Faults divided by cause (%) during the period 2005–2014						
Denmark	110	1	0.91	0.13	0.0	0.0	0.0	0.0	100.0	0.0	0.0
Norway	25	1	4.00	2.01	0.0	0.0	0.0	0.0	60.0	20.0	20.0
Sweden	8	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	143	2	1.40	0.55	0.0	0.0	0.0	0.0	66.7	16.7	16.7

TABLE 5.4.2 DISTRIBUTION OF FAULTS ACCORDING TO CAUSE FOR 220–330 KV CABLES IN NORDIC AND BALTIC COUNTRIES

Country	Lines (km)	Number of faults	Number of faults per 100 km		Light-ning	Other environ-mental causes	External influence	Operation and mainte-nance	Technical equipment	Other	Unknown
	2014	2014	2014	2005–2014	Faults divided by cause (%) during the period 2005–2014						
Denmark	84	1	1.19	0.60	0.0	0.0	0.0	0.0	100.0	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	68	0	0.00	0.15	0.0	0.0	0.0	0.0	0.0	0.0	100.0
Sweden	109	2	1.83	1.20	6.7	0.0	0.0	13.3	73.3	0.0	6.7
					Faults divided by cause (%) during year 2014						
Latvia	14	0	0.00	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	262	3	1.15	0.80	5.9	0.0	0.0	11.8	70.6	0.0	11.8

TABLE 5.4.3 100–150 KV CABLES FAULTS AND THE DISTRIBUTION ACCORDING TO CAUSE IN EACH NORDIC AND BALTIC COUNTRY

Country	Lines (km)	Number of faults	Number of faults per 100 km		Light-ning	Other environ-mental causes	External influence	Operation and mainte-nance	Technical equipment	Other	Unknown
	2014	2014	2014	2005–2014	Faults divided by cause (%) during the period 2005–2014						
Denmark	1075	4	0.37	0.39	0.0	7.7	11.5	7.7	61.5	7.7	3.8
Finland	238	1	0.42	0.33	0.0	0.0	0.0	0.0	50.0	16.7	33.3
Iceland	116	0	0.00	0.50	0.0	0.0	0.0	25.0	75.0	0.0	0.0
Norway	50	1	2.00	0.44	0.0	0.0	0.0	0.0	50.0	50.0	0.0
Sweden	403	3	0.74	1.16	0.0	0.0	12.9	6.5	54.8	3.2	22.6
					Faults divided by cause (%) during year 2014						
Estonia	56	1	1.79	-	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Latvia	70	0	0.00	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lithuania	65	0	0.00	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	1882	9	0.48	0.55	0.0	2.9	10.1	7.2	58.0	7.2	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 ten-year period 2005–2014 for 100–150 kV cables.

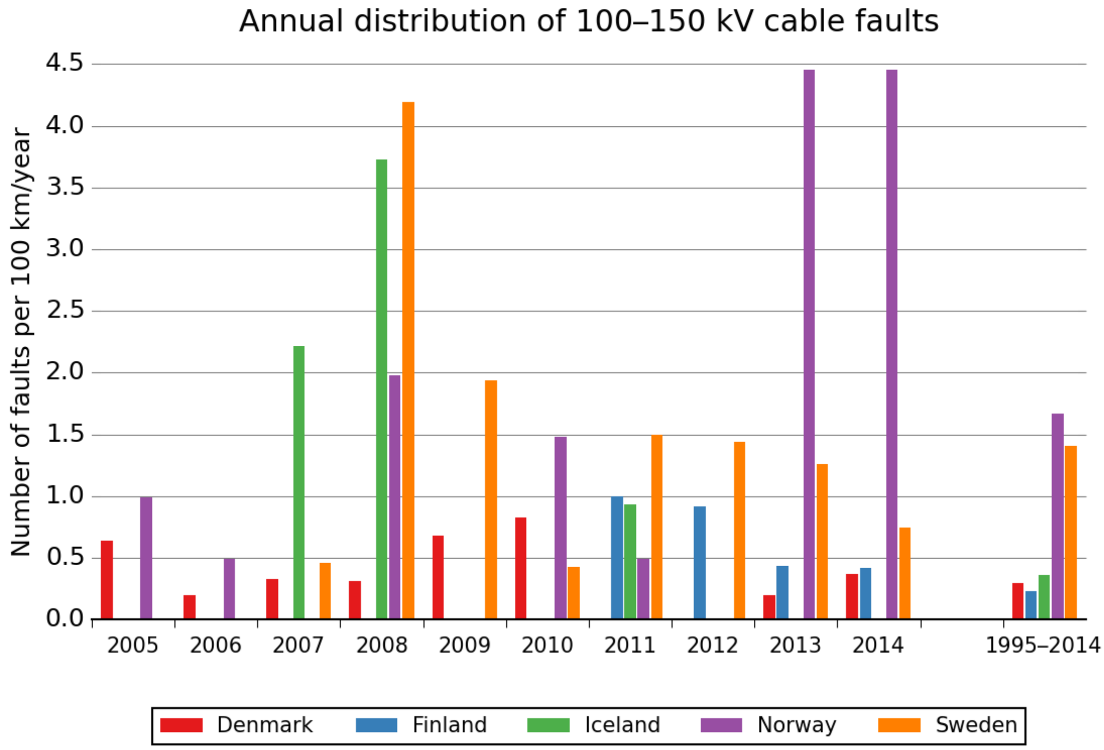

FIGURE 5.4.2 ANNUAL DISTRIBUTION OF CABLE FAULTS DURING THE PERIOD 2005–2014 AND THE AVERAGE FOR THE PERIOD 1995–2014 IN EACH NORDIC COUNTRY FOR 100–150 KV CABLES

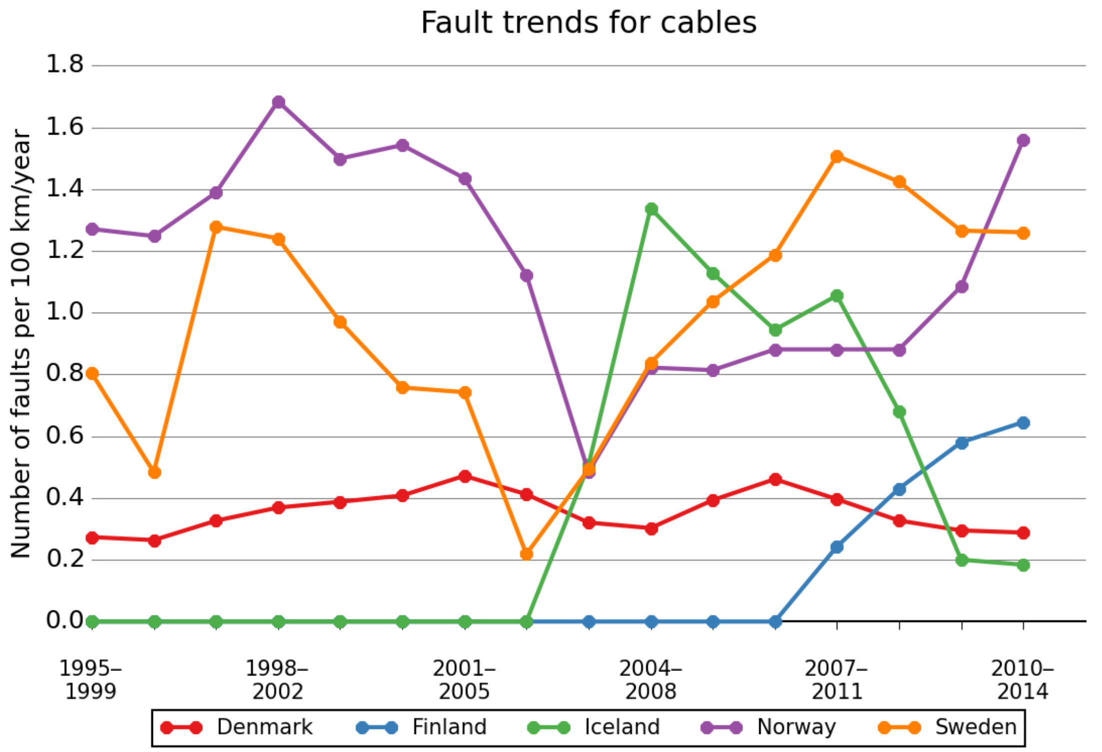

FIGURE 5.4.3 FAULT TRENDS AS FIVE-YEAR AVERAGES FOR CABLES AT ALL VOLTAGE LEVELS IN EACH NORDIC COUNTRY

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 distribution of faults for the year 2014 and for the period 2005–2014 in power transformers at each respective voltage level. In addition, the tables present the distribution of faults according to cause during the ten-year period 2005–2014. The annual distribution of faults during the period 2005–2014 is presented graphically for all voltage levels. Fault trends for the Nordic power transformers are presented in Figure 5.5.4, Figure 5.5.5 and Figure 5.5.6. 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 5.5.1 380–420 kV power transformers faults and the distribution according to cause in Nordic countries

Country	Number of devices	Number of faults	Number of faults per 100 devices		Light-ning	Other environ-mental causes	External influence	Operation and mainte-nance	Technical equipment	Other	Unknown
	2014	2014	2014	2005–2014	Faults divided by cause (%) during the period 2005–2014						
Denmark	37	1	2.70	1.95	0.0	20.0	0.0	20.0	40.0	0.0	20.0
Finland	71	1	1.41	2.27	0.0	16.7	0.0	16.7	50.0	8.3	8.3
Norway	64	1	1.56	2.04	0.0	0.0	0.0	23.1	30.8	30.8	15.4
Sweden	65	2	3.08	2.76	13.3	0.0	0.0	40.0	6.7	33.3	6.7
Total	237	1	0.42	2.29	4.4	6.7	0.0	26.7	28.9	22.2	11.1

Table 5.5.2 220–330 kV power transformers faults and the distribution according to cause in each Nordic and Baltic country

Country	Number of devices	Number of faults	Number of faults per 100 devices		Light-ning	Other environ-mental causes	External influence	Operation and mainte-nance	Technical equipment	Other	Unknown
	2014	2014	2014	2005–2014	Faults divided by cause (%) during the period 2005–2014						
Denmark	5	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Finland	28	2	7.14	2.50	0.0	0.0	0.0	50.0	16.7	16.7	16.7
Iceland	33	0	0.00	3.91	0.0	8.3	0.0	0.0	91.7	0.0	8.3
Norway	250	0	0.00	0.93	4.0	4.0	0.0	12.0	44.0	28.0	8.0
Sweden	105	17	16.19	4.47	26.7	0.0	8.9	13.3	15.6	11.1	22.2
					Faults divided by cause (%) during year 2014						
Estonia	22	6	27.27	-	0.0	0.0	0.0	16.7	83.3	0.0	0.0
Latvia	25	2	8.00	-	0.0	0.0	0.0	50.0	50.0	0.0	0.0
Lithuania	23	1	4.35	-	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Total	421	19	4.51	2.06	14.8	2.3	4.5	13.6	34.1	14.8	15.9

TABLE 5.5.3 100–150 KV POWER TRANSFORMERS FAULTS AND THE DISTRIBUTION ACCORDING TO CAUSE IN EACH NORDIC AND BALTIC COUNTRY

Country	Number of devices	Number of faults	Number of faults per 100 devices		Light-ning	Other environ-mental causes	External influence	Operation and mainte-nance	Technical equipment	Other	Unknown
	2014	2014	2014	2005–2014	Faults divided by cause (%) during the period 2005–2014						
Denmark	228	3	1.32	1.03	8.3	12.5	4.2	29.2	25.0	4.2	16.7
Finland	1175	6	0.51	0.54	8.3	2.1	12.5	18.7	25.0	10.4	22.9
Iceland	51	0	0.00	1.17	0.0	33.3	0.0	33.3	33.3	0.0	0.0
Norway	724	8	1.10	0.65	8.5	31.9	4.3	12.8	21.3	17.0	4.3
Sweden	739	55	7.44	3.77	20.4	1.9	1.9	19.2	26.2	4.6	25.4
					Faults divided by cause (%) during year 2014						
Estonia	216	9	4.17	-	0.0	0.0	0.0	0.0	100.0	0.0	0.0
Latvia	246	6	2.44	-	0.0	0.0	66.7	0.0	33.3	0.0	0.0
Lithuania	416	2	0.48	-	0.0	0.0	0.0	0.0	100.0	0.0	0.0
Total	2917	72	2.47	1.49	16.4	6.8	3.6	19.2	25.5	6.8	21.6

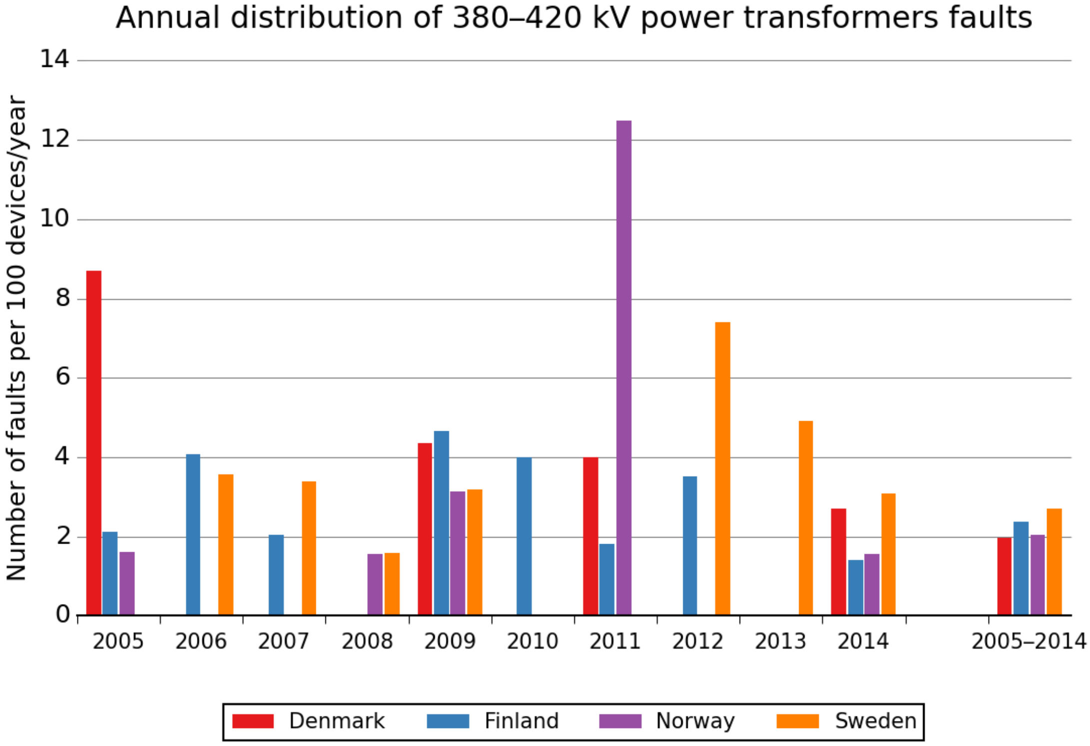

FIGURE 5.5.1 ANNUAL DISTRIBUTION OF FAULTS FOR 380–420 KV POWER TRANSFORMERS IN NORDIC COUNTRIES DURING THE PERIOD 2005–2014

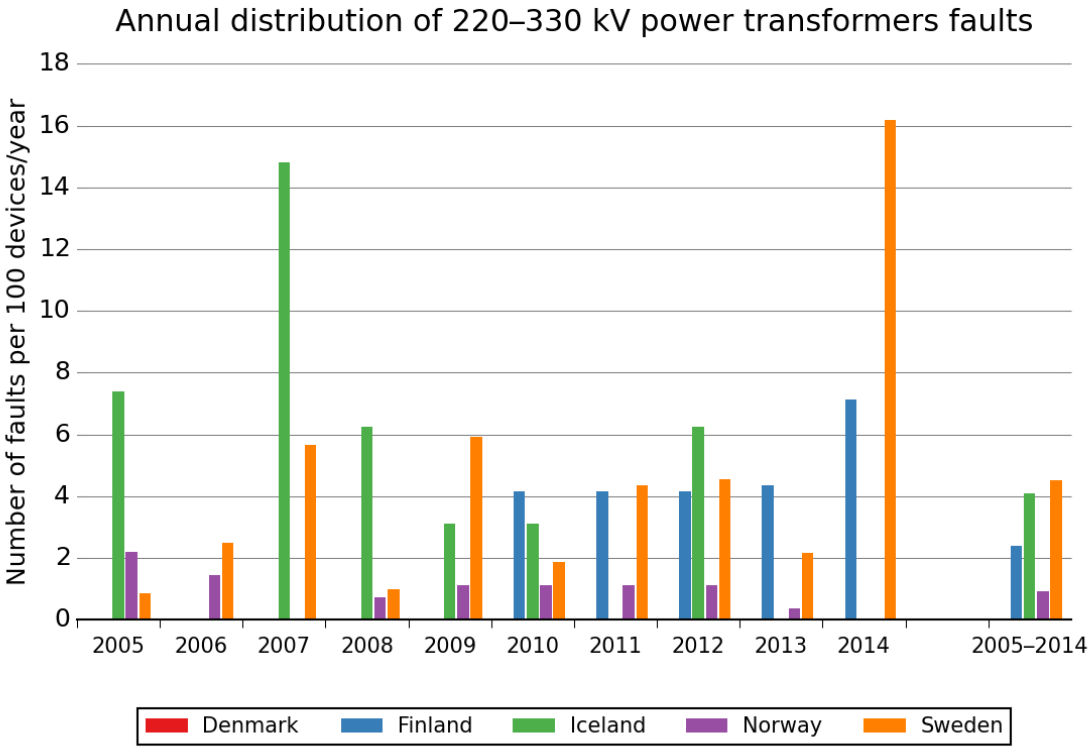

FIGURE 5.5.2 ANNUAL DISTRIBUTION OF FAULTS FOR 220–330 KV POWER TRANSFORMERS IN EACH NORDIC COUNTRY DURING THE PERIOD 2005–2014

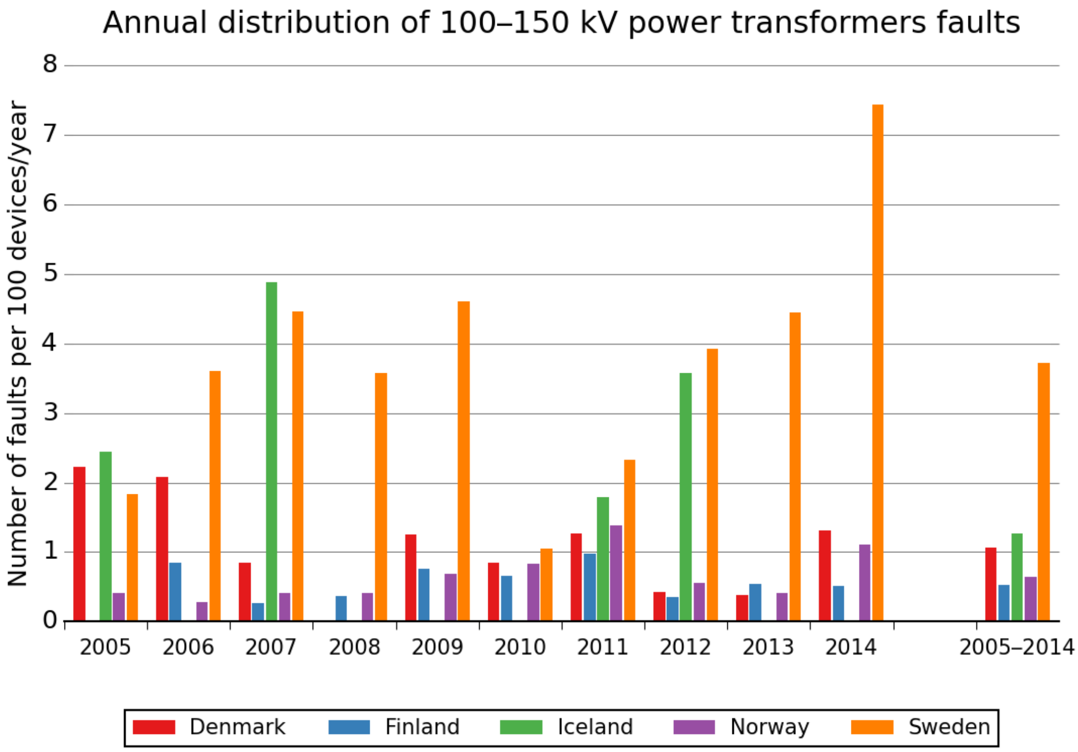

FIGURE 5.5.3 ANNUAL DISTRIBUTION OF FAULTS FOR 100–150 KV POWER TRANSFORMERS IN EACH NORDIC COUNTRY DURING THE PERIOD 2005–2014

Due to a misinterpretation of the guidelines Sweden reported a high number of faults since 1999. This has been noted and Sweden will change this from 2015 and onward.

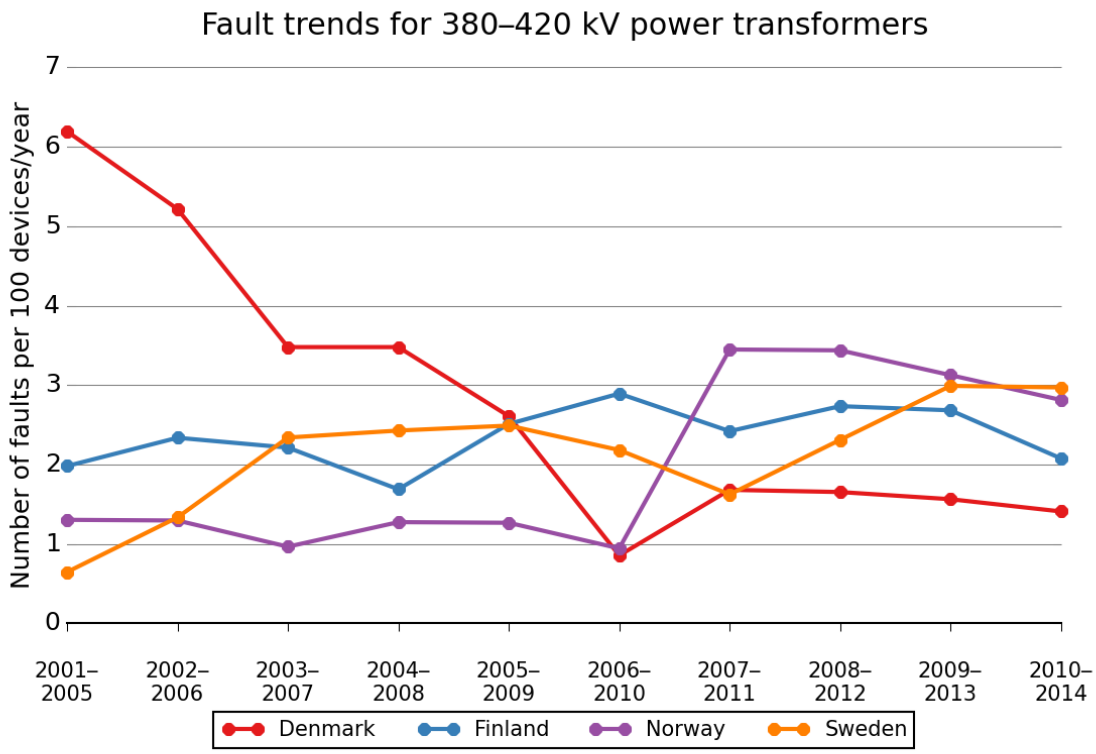

FIGURE 5.5.4 FAULT TRENDS AS FIVE-YEAR AVERAGES FOR 380–420 KV POWER TRANSFORMERS IN NORDIC COUNTRIES

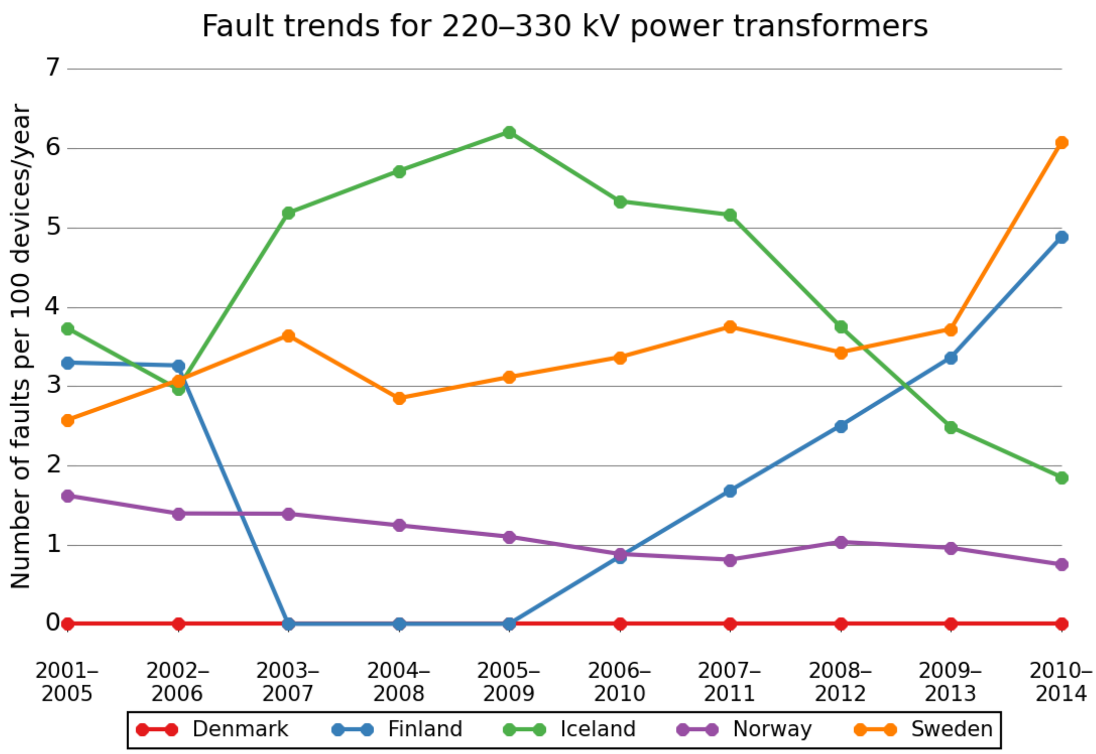

FIGURE 5.5.5 FAULT TRENDS AS FIVE-YEAR AVERAGES FOR 220–330 KV POWER TRANSFORMERS IN EACH NORDIC COUNTRY

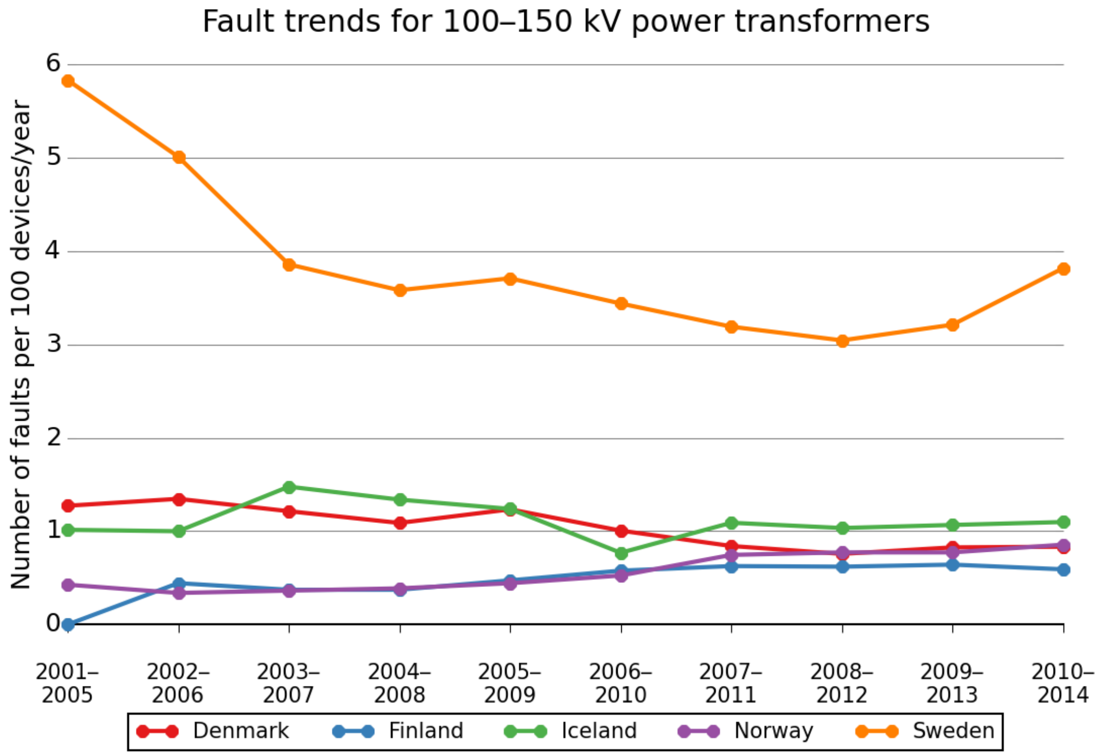

FIGURE 5.5.6 FAULT TRENDS AS FIVE-YEAR AVERAGES FOR 100–150 KV POWER TRANSFORMERS IN EACH NORDIC COUNTRY

Due to a misinterpretation of the guidelines Sweden reported a high number of faults since 1999. This has been noted and Sweden will change this from 2015 and onward.

5.6 FAULTS IN INSTRUMENT TRANSFORMERS

Tables in this section present the faults in instrument transformers for the year 2014 and for the period 2005–2014 at each respective voltage level. In addition, the tables present the distribution 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. The figures in this section present the fault trends for instrument transformers at each statistical voltage level in the Nordic countries.

TABLE 5.6.1 380–420 KV INSTRUMENT TRANSFORMERS FAULTS AND THE DISTRIBUTION ACCORDING TO CAUSE IN NORDIC COUNTRIES

Country	Number of devices	Number of faults	Number of faults per 100 devices		Light-ning	Other environ-mental causes	External influence	Operation and mainte-nance	Technical equipment	Other	Unknown
	2014	2014	2014	2005–2014	Faults divided by cause (%) during the period 2005–2014						
Denmark	139	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Finland	465	0	0.00	0.02	0.0	0.0	0.0	0.0	100.0	0.0	0.0
Norway	930	1	0.11	0.11	0.0	10.0	0.0	10.0	80.0	0.0	0.0
Sweden	1098	8	0.73	0.18	0.0	0.0	0.0	5.6	88.9	0.0	5.6
Total	2632	9	0.34	0.10	0.0	3.4	0.0	6.9	86.2	0.0	3.4

TABLE 5.6.2 220–330 KV INSTRUMENT TRANSFORMERS FAULTS AND THE DISTRIBUTION ACCORDING TO CAUSE IN EACH NORDIC AND BALTIC COUNTRY

Country	Number of devices	Number of faults	Number of faults per 100 devices		Light-ning	Other environ-mental causes	External influence	Operation and mainte-nance	Technical equipment	Other	Unknown
	2014	2014	2014	2005–2014	Faults divided by cause (%) during the period 2005–2014						
Denmark	11	0	0.00	0.95	0.0	0.0	0.0	0.0	0.0	0.0	100.0
Finland	140	1	0.71	0.07	0.0	0.0	0.0	0.0	100.0	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	0	0.00	0.05	13.3	0.0	0.0	20.0	40.0	13.3	13.3
Sweden	611	0	0.00	0.09	12.5	0.0	0.0	0.0	87.5	0.0	0.0
					Faults divided by cause (%) during year 2014						
Estonia	212	0	0.00	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Latvia	200	0	0.00	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lithuania	195	0	0.00	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	4011	1	0.02	0.06	12.0	0.0	0.0	12.0	56.0	8.0	12.0

TABLE 5.6.3 100–150 KV INSTRUMENT TRANSFORMERS FAULTS AND THE DISTRIBUTION ACCORDING TO CAUSE IN EACH NORDIC AND BALTIC COUNTRY

Country	Number of devices	Number of faults	Number of faults per 100 devices		Lightning	Other environmental causes	External influence	Operation and maintenance	Technical equipment	Other	Unknown
	2014	2014	2014	2005–2014	Faults divided by cause (%) during the period 2005–2014						
Denmark	509	3	0.59	0.04	0.0	0.0	0.0	7.1	71.4	7.1	14.3
Finland	3574	2	0.06	0.11	7.7	0.0	3.8	7.7	53.8	11.5	15.4
Iceland	611	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Norway	7768	7	0.09	0.05	17.5	0.0	0.0	10.0	35.0	30.0	7.5
Sweden	4083	3	0.07	0.06	6.2	0.0	3.1	12.5	65.6	0.0	9.4
					Faults divided by cause (%) during year 2014						
Estonia	920	1	0.11	-	0.0	0.0	0.0	0.0	100.0	0.0	0.0
Latvia	930	1	0.11	-	0.0	0.0	0.0	0.0	100.0	0.0	0.0
Lithuania	809	1	0.12	-	0.0	0.0	0.0	0.0	100.0	0.0	0.0
Total	16545	15	0.09	0.06	9.8	0.0	1.8	9.8	52.7	14.3	10.7

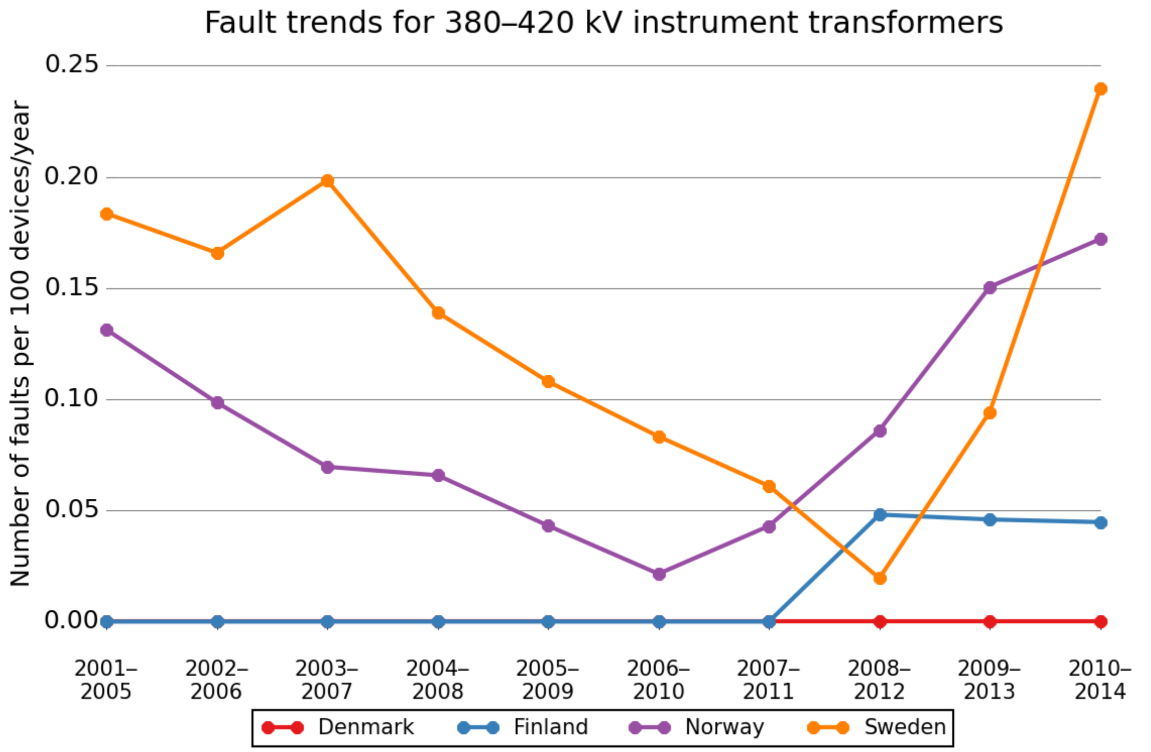

FIGURE 5.6.1 FAULT TRENDS AS FIVE-YEAR AVERAGES FOR 380–420 KV INSTRUMENT TRANSFORMERS IN NORDIC COUNTRIES

The change in the Swedish trend curve in Figure 5.6.1 is because in 2014, seven instrument transformers exploded in Sweden. All of the transformers that exploded were from the same manufacturer, of the same type and were manufactured the same year and they exploded during the same week after a long and warm summer period.

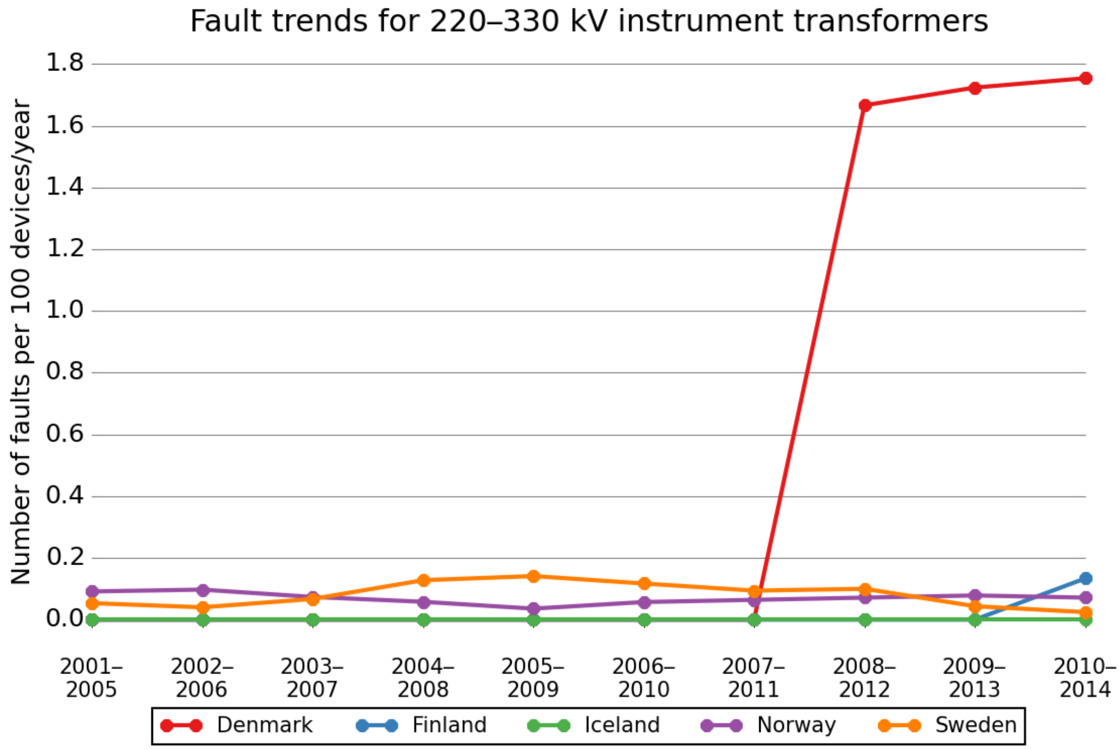

FIGURE 5.6.2 FAULT TRENDS AS FIVE-YEAR AVERAGES FOR INSTRUMENT TRANSFORMERS AT THE VOLTAGE LEVEL 220–330 KV IN EACH NORDIC COUNTRY

The high value for the Danish fault trend during 2007–2011 is caused by the transformer failures during years 2008 and 2009. Another reason is due to the fact that the number of instrument transformers is significantly smaller in Denmark than the other countries.

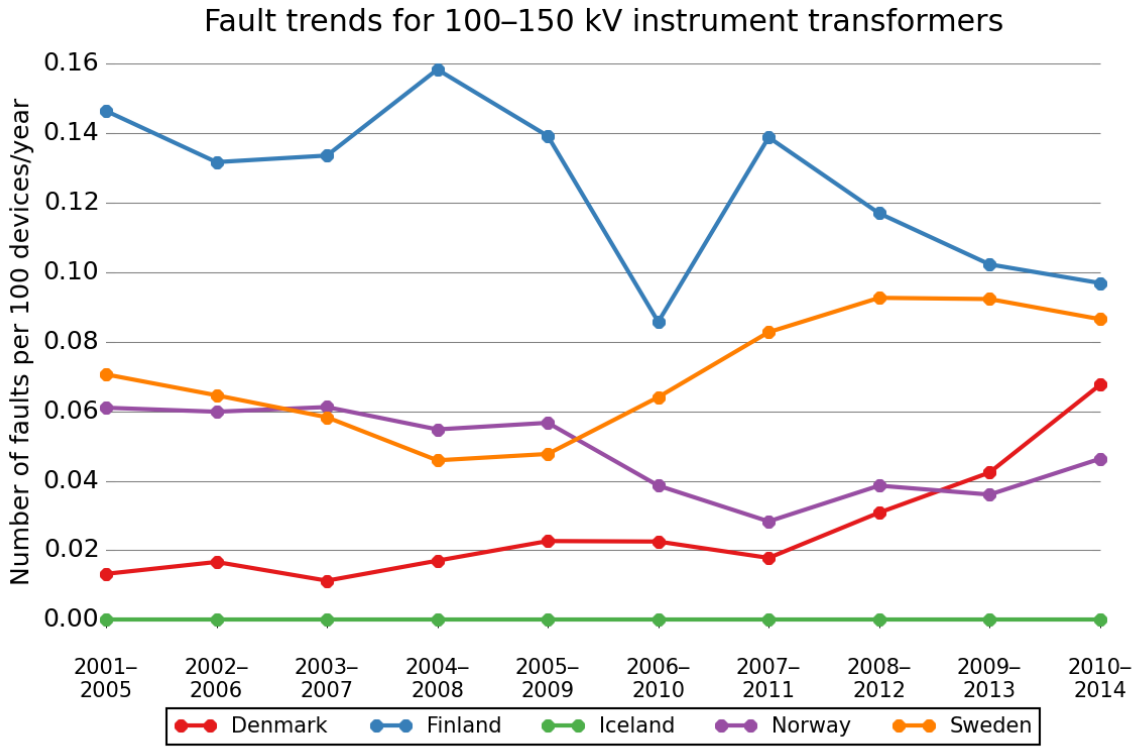

FIGURE 5.6.3 FAULT TRENDS AS FIVE-YEAR AVERAGES FOR INSTRUMENT TRANSFORMERS AT THE VOLTAGE LEVEL 100–150 KV IN EACH NORDIC COUNTRY

5.7 FAULTS IN CIRCUIT BREAKERS

The tables in this section present circuit breaker faults at each respective voltage level for the year 2014 and for the ten-year period 2005–2014. The tables also present the distribution of faults according to cause during the ten-year period.

The figures in this section present the fault trends for circuit breakers at each statistical voltage level in the Nordic countries.

TABLE 5.7.1 380–420 KV CIRCUIT BREAKER FAULTS AND THE DISTRIBUTION ACCORDING TO CAUSE IN NORDIC COUNTRIES

Country	Number of devices	Number of faults	Number of faults per 100 devices		Light-ning	Other environ-mental causes	External influence	Operation and mainte-nance[2)]	Technical equipment	Other	Unknown
	2014	2014	2014	2005–2014	Faults divided by cause (%) during the period 2005–2014						
Denmark	139	0	0.00	0.40	0.0	0.0	16.7	33.3	33.3	16.7	0.0
Finland	290	0	0.00	0.38	0.0	0.0	11.1	0.0	77.8	11.1	0.0
Norway	287	3	1.05	0.88	0.0	0.0	0.0	43.5	43.5	8.7	4.3
Sweden[1)]	560	1	0.18	1.48	0.0	0.0	0.0	4.2	87.3	1.4	7.0
Total	1276	4	0.31	0.96	0.0	0.0	1.8	13.8	74.3	4.6	5.5

1) For Sweden, the breaker failures at the 380–420 kV level most often occurred in breakers that are 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 380–420 kV shunt reactor circuit breakers, which usually operate very often compared to other circuit breakers.

TABLE 5.7.2 220–330 KV CIRCUIT BREAKER FAULTS AND THE DISTRIBUTION ACCORDING TO CAUSE IN EACH NORDIC AND BALTIC COUNTRY

Country	Number of devices	Number of faults	Number of faults per 100 devices		Light-ning	Other environ-mental causes	External influence	Operation and mainte-nance	Technical equipment	Other	Unknown
	2014	2014	2014	2005–2014	Faults divided by cause (%) during the period 2005–2014						
Denmark	11	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Finland	88	0	0.00	0.32	0.0	0.0	0.0	0.0	100.0	0.0	0.0
Iceland	80	1	1.25	0.80	0.0	16.7	0.0	16.7	66.7	0.0	0.0
Norway	734	5	0.68	0.57	0.0	2.4	0.0	26.8	53.7	7.3	9.8
Sweden	321	1	0.31	0.36	7.7	0.0	0.0	0.0	69.2	0.0	23.1
					Faults divided by cause (%) during year 2014						
Estonia	121	2	1.65	-	0.0	0.0	0.0	50.0	50.0	0.0	0.0
Latvia	103	0	0.00	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lithuania	104	0	0.00	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	1234	7	0.57	0.50	1.6	3.2	0.0	19.0	60.3	4.8	11.1

TABLE 5.7.3 100–150 KV CIRCUIT BREAKER FAULTS AND THE DISTRIBUTION ACCORDING TO CAUSE IN EACH NORDIC AND BALTIC COUNTRY

Country	Number of devices	Number of faults	Number of faults per 100 devices		Lightning	Other environmental causes	External influence	Operation and maintenance	Technical equipment	Other	Unknown
	2014	2014	2014	2005–2014	Faults divided by cause (%) during the period 2005–2014						
Denmark	509	3	0.59	0.35	0.0	0.0	0.0	38.5	53.8	3.8	3.8
Finland	2395	7	0.29	0.16	5.9	2.9	2.9	35.3	23.5	5.9	23.5
Iceland	176	0	0.00	0.70	0.0	10.0	10.0	20.0	60.0	0.0	10.0
Norway	2058	9	0.44	0.28	8.5	0.0	0.0	59.3	23.7	6.8	0.0
Sweden	1965	11	0.56	0.28	29.4	2.0	5.9	29.4	31.4	0.0	3.9
					Faults divided by cause (%) during year 2014						
Estonia	555	6	1.08	-	0.0	0.0	0.0	16.7	83.3	0.0	0.0
Latvia	606	3	0.50	-	0.0	0.0	0.0	0.0	100.0	0.0	0.0
Lithuania	720	2	0.28	-	0.0	0.0	0.0	50.0	50.0	0.0	0.0
Total	7103	30	0.42	0.26	12.2	1.7	2.8	41.1	32.2	3.9	6.7

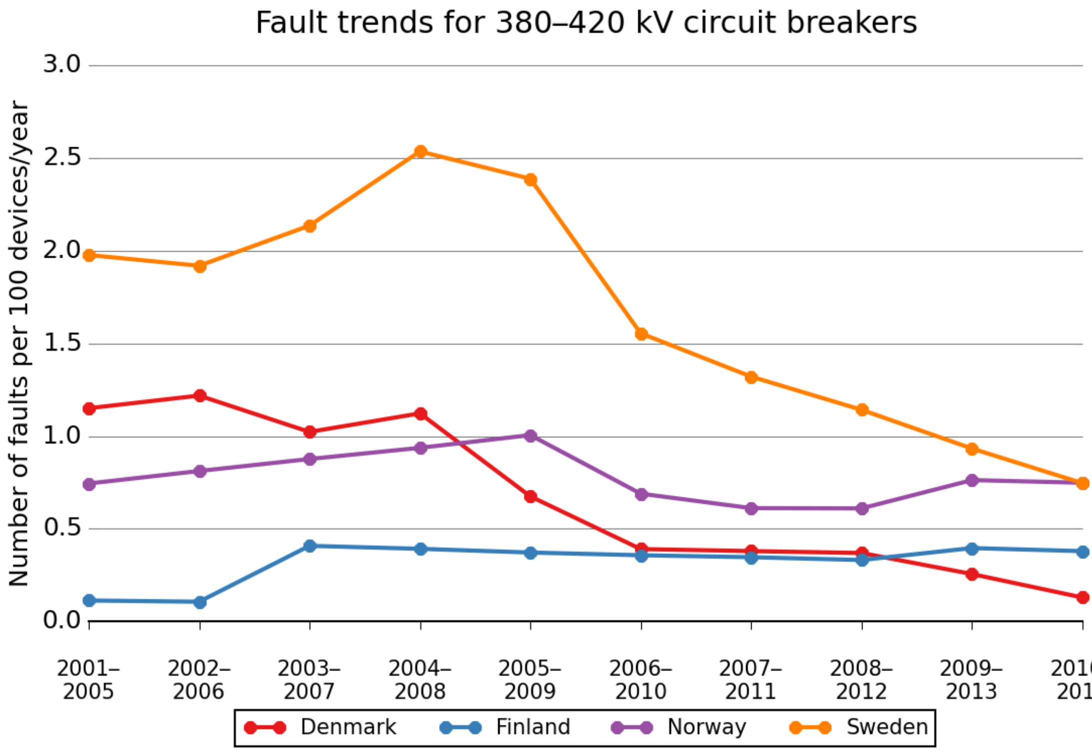

FIGURE 5.7.1 FAULT TRENDS AS FIVE-YEAR AVERAGES FOR CIRCUIT BREAKERS AT THE VOLTAGE LEVEL 380–420 KV IN NORDIC COUNTRIES

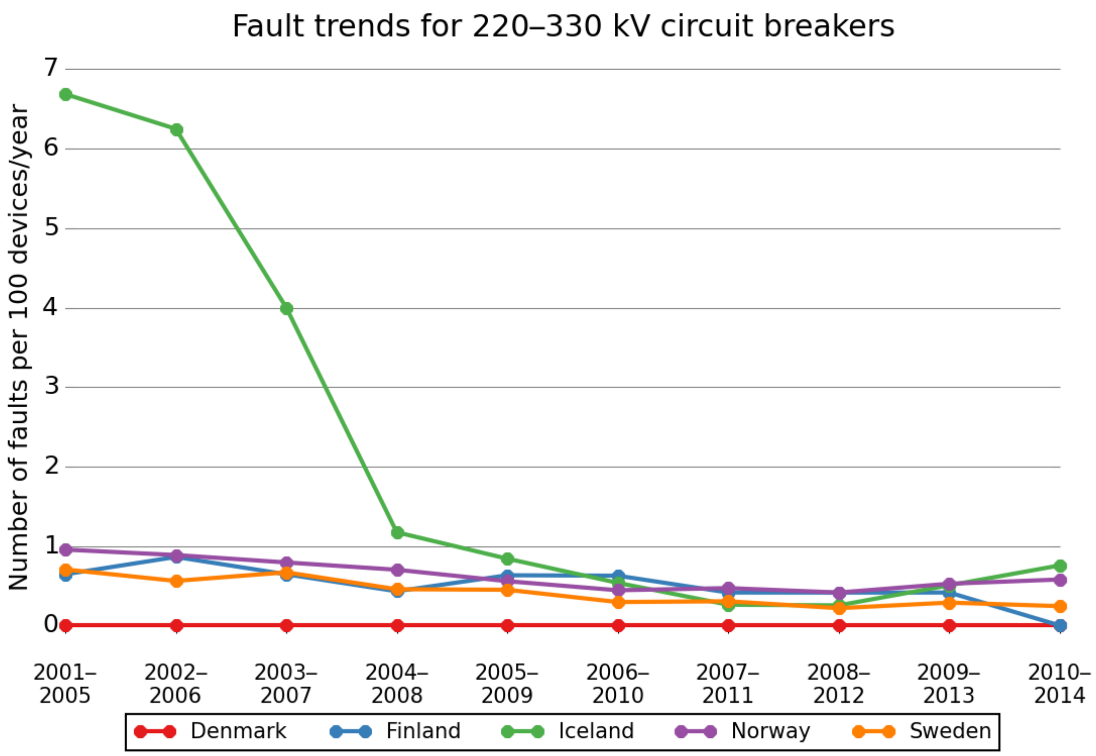

Figure 5.7.2 Fault trends as five-year averages for circuit breakers at the voltage level 220–330 kV in Nordic countries

The explanation for the remarkable improvement on the fault trend of Iceland is that most of the faults on circuit breakers up to 2003 in the 220 kV network occurred at one substation. These breakers caused problems due to gas leaks and were repaired in 2003.

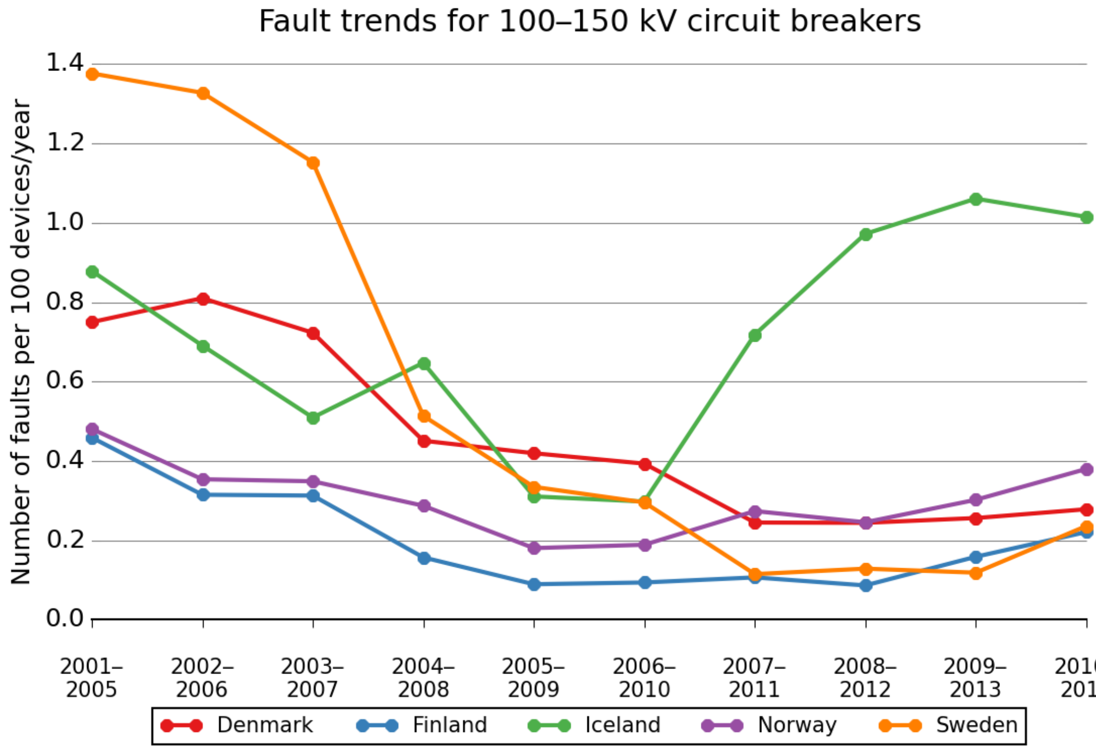

FIGURE 5.7.3 FAULT TRENDS AS FIVE-YEAR AVERAGES FOR CIRCUIT BREAKERS IN EACH NORDIC COUNTRY AT THE VOLTAGE LEVEL 100–150 KV

5.8 FAULTS IN CONTROL EQUIPMENT

The tables in this section present faults in control equipment at each respective voltage level for the year 2014 and for the period 2005–2014. In addition, the tables present the distribution of faults according to cause during the ten-year period.

Figure 5.8.1, Figure 5.8.2 and Figure 5.8.3 present the annual distribution of control equipment faults in the Nordic countries during the period 2005–2014 at each statistical voltage level.

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 5.8.1 380–420 KV CONTROL EQUIPMENT FAULTS AND THE DISTRIBUTION ACCORDING TO CAUSE IN NORDIC COUNTRIES

Country	Number of devices	Number of faults	Number of faults per 100 devices		Light-ning	Other environ-mental causes	External influence	Operation and mainte-nance	Technical equipment	Other	Unknown
	2014	2014	2014	2005–2014	Faults divided by cause (%) during the period 2005–2014						
Denmark	139	7	5.04	0.88	0.0	9.1	0.0	27.3	54.5	9.1	0.0
Finland	290	3	1.03	3.31	0.0	0.0	0.0	68.4	20.3	1.3	10.1
Norway	287	21	7.32	4.58	0.0	1.7	0.0	42.5	40.8	5.8	9.2
Sweden	560	37	6.61	5.07	0.0	2.5	0.0	13.7	80.9	1.7	1.2
Total	1276	68	5.33	4.09	0.0	2.0	0.0	31.3	59.0	2.9	4.9

TABLE 5.8.2 220–330 KV CONTROL EQUIPMENT FAULTS AND THE DISTRIBUTION ACCORDING TO CAUSE IN EACH NORDIC AND BALTIC COUNTRY

Country	Number of devices	Number of faults	Number of faults per 100 devices		Light-ning	Other environ-mental causes	External influence	Operation and mainte-nance	Technical equipment	Other	Unknown
	2014	2014	2014	2005–2014	Faults divided by cause (%) during the period 2005–2014						
Denmark	11	0	0.00	2.86	0.0	0.0	0.0	100.0	0.0	0.0	0.0
Finland	88	0	0.00	3.61	0.0	0.0	0.0	55.9	29.4	5.9	8.8
Iceland	80	1	1.25	5.31	0.0	2.5	0.0	32.5	52.5	2.5	0.0
Norway	734	27	3.68	3.71	1.1	0.4	1.1	35.2	43.8	7.1	11.2
Sweden	321	11	3.43	2.07	0.0	0.0	1.3	37.3	45.3	10.7	5.3
					Faults divided by cause (%) during year 2014						
Estonia	107	4	3.74	-	0.0	0.0	0.0	0.0	100.0	0.0	0.0
Latvia	103	5	4.85	-	0.0	0.0	0.0	80.0	20.0	0.0	0.0
Lithuania	104	0	0.00	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	1234	39	3.16	3.32	0.7	0.5	1.0	37.2	43.6	7.2	8.9

TABLE 5.8.3 100–150 KV CONTROL EQUIPMENT FAULTS AND THE DISTRIBUTION ACCORDING TO CAUSE IN EACH NORDIC AND BALTIC COUNTRY

Country	Number of devices	Number of faults	Number of faults per 100 devices		Light-ning	Other environ-mental causes	External influence	Operation and mainte-nance	Technical equipment	Other	Unknown
	2014	2014	2014	2005–2014	Faults divided by cause (%) during the period 2005–2014						
Denmark	509	10	1.96	1.33	6.1	7.1	2.0	40.8	26.5	8.2	9.2
Finland	2395	24	1.00	1.46	2.6	0.0	2.2	47.8	25.3	6.1	16.0
Iceland	176	3	1.70	4.01	0.0	0.0	0.0	21.1	68.4	1.8	3.5
Norway	2058	41	1.99	1.68	2.0	3.7	0.6	36.3	30.8	9.8	16.7
Sweden	1965	3	0.15	0.38	6.1	0.0	0.0	48.5	30.3	6.1	10.6
					Faults divided by cause (%) during year 2014						
Estonia	543	20	3.68	-	0.0	0.0	0.0	35.0	50.0	0.0	15.0
Latvia	606	14	2.31	-	0.0	0.0	0.0	50.0	35.7	14.3	0.0
Lithuania	720	20	2.78	-	0.0	0.0	45.0	45.0	0.0	0.0	10.0
Total	7103	81	1.14	1.29	2.8	2.3	1.3	40.8	30.8	7.5	14.3

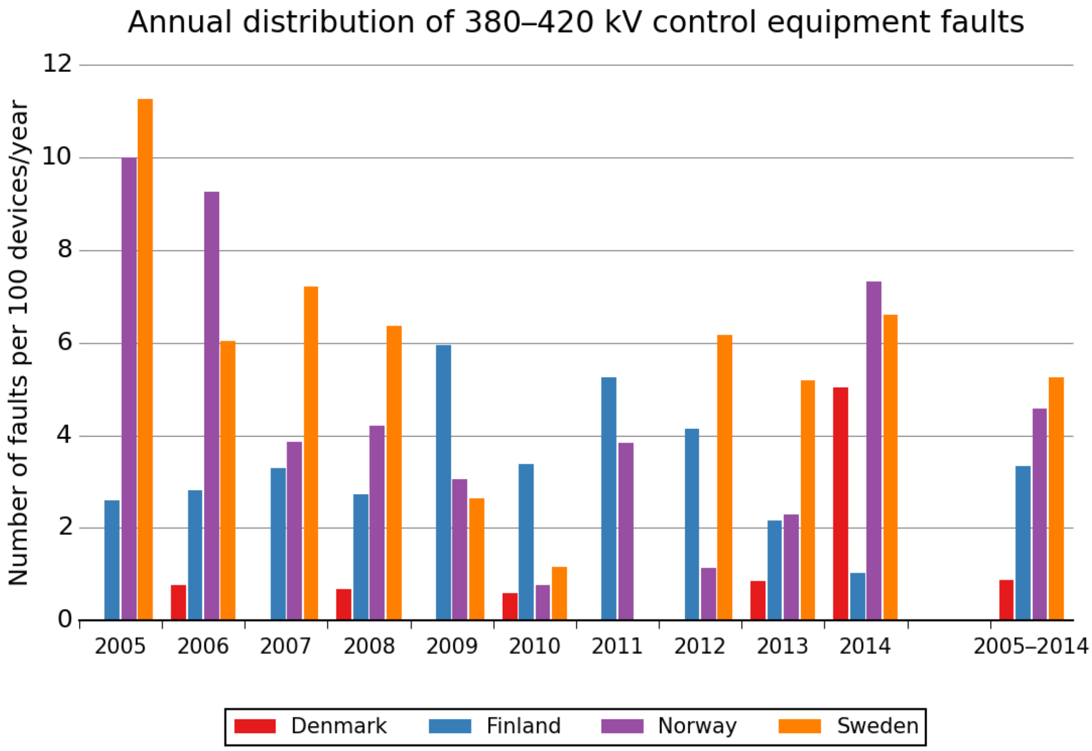

FIGURE 5.8.1 ANNUAL DISTRIBUTION OF 380–420 KV CONTROL EQUIPMENT FAULTS IN NORDIC COUNTRIES DURING THE PERIOD 2005–2014

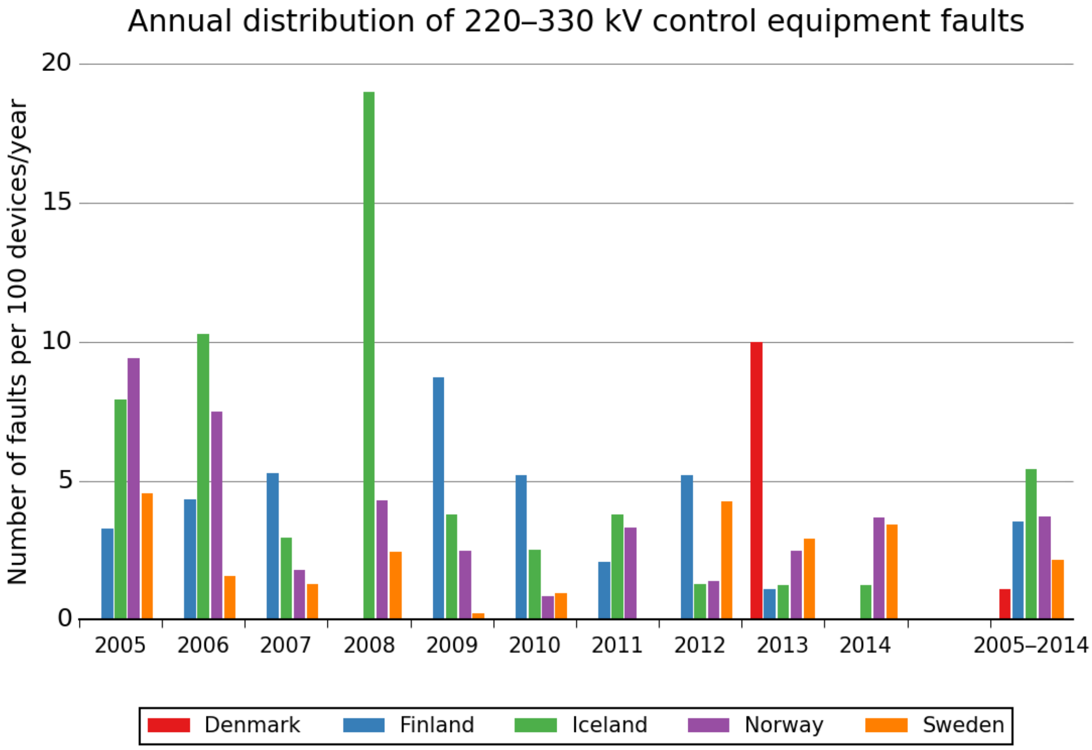

Figure 5.8.2 Annual distribution of 220–330 kV control equipment faults during the period 2005–2014 in each Nordic country

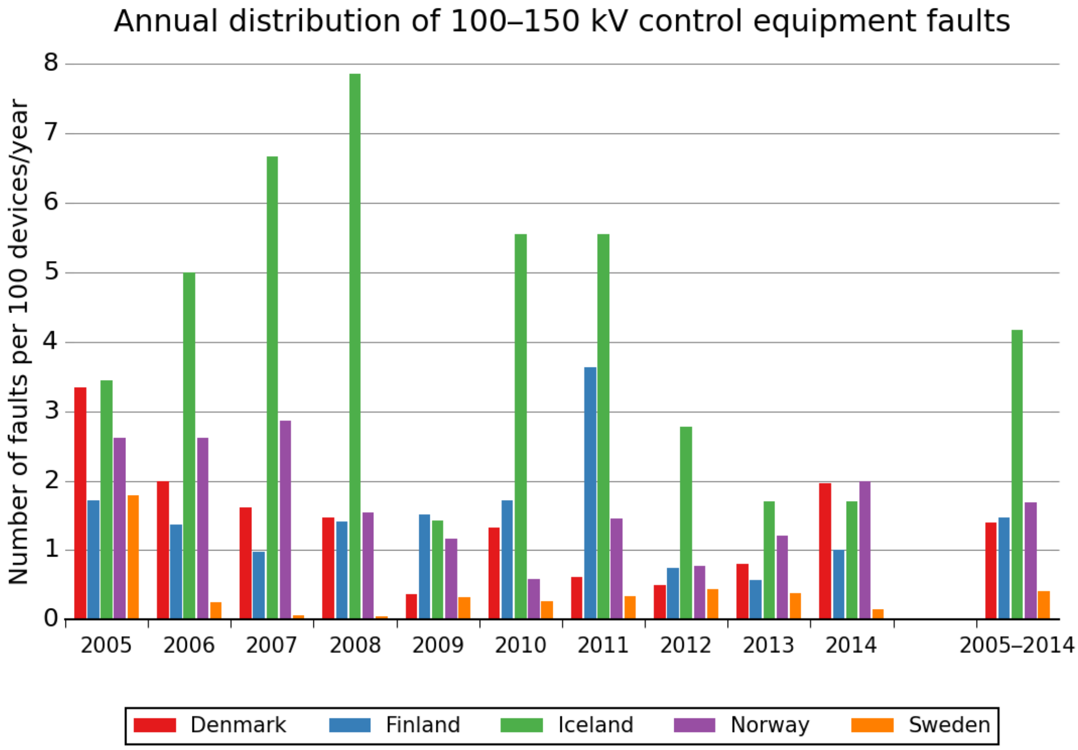

Figure 5.8.3 Annual distribution of 100–150 kV control equipment faults in each Nordic country during the period 2005–2014

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 2014 and for the period 2005–2014. In addition, the tables present the distribution of faults according to cause during the ten-year period 2005–2014.

All Swedish reactor faults were because of problems with the cooling system. Half of the faults were due to loss of local power, some due to weather conditions and some due to technical faults in the stations.

Table 5.9.1 Reactor faults and the distribution according to cause in Nordic and Baltic countries

Country	Number of devices	Number of faults	Number of faults per 100 devices		Light-ning	Other environ-mental causes	External influence	Operation and mainte-nance	Technical equipment	Other	Unknown
	2014	2014	2014	2005–2014	Faults divided by cause (%) during the period 2005–2014						
Denmark	80	2	2.50	4.58	0.0	0.0	0.0	28.6	57.1	0.0	14.3
Finland	70	0	0.00	0.95	0.0	0.0	0.0	0.0	83.3	0.0	16.7
Norway	36	2	5.56	4.17	0.0	6.7	0.0	33.3	46.7	13.3	0.0
Sweden	77	13	16.88	12.39	0.0	29.3	1.2	11.0	29.3	25.6	4.9
					Faults divided by cause (%) during year 2014						
Estonia	21	0	0.00	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Latvia	16	1	6.25	-	0.0	0.0	0.0	0.0	100.0	0.0	0.0
Lithuania	11	0	0.00	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	263	17	6.46	5.97	0.0	21.4	0.9	15.4	37.6	19.7	6.0

In Finland, reactors compensating the reactive power of 380–420 kV lines are connected to the 20 kV tertiary winding of the 380–420/100–150/20 kV power transformers.

Table 5.9.2 Series capacitor faults and the distribution according to cause in Nordic countries

Country	Number of devices	Number of faults	Number of faults per 100 devices		Light-ning	Other environ-mental causes	External influence	Operation and mainte-nance	Technical equipment	Other	Unknown
	2014	2014	2014	2005–2014	Faults divided by cause (%) during the period 2005–2014						
Finland	9	3	33.33	54.88	0.0	2.2	6.7	8.9	46.7	0.0	35.6
Iceland	1	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Norway	3	1	33.33	3.33	0.0	100.0	0.0	0.0	0.0	0.0	0.0
Sweden	12	0	0.00	144.17	0.6	0.6	0.0	0.6	15.0	79.2	6.4
Total	25	4	16.00	90.50	0.5	1.4	1.4	2.3	21.5	62.6	12.3

TABLE 5.9.3 SHUNT CAPACITOR FAULTS AND THE DISTRIBUTION ACCORDING TO CAUSE IN EACH NORDIC AND BALTIC COUNTRY

Country	Number of devices	Number of faults	Number of faults per 100 devices		Light-ning	Other environ-mental causes	External influence	Operation and mainte-nance	Technical equipment	Other	Unknown
	2014	2014	2014	2005–2014	Faults divided by cause (%) during the period 2005–2014						
Denmark	26	0	0.00	1.42	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Finland	42	1	2.38	4.36	0.0	5.0	65.0	0.0	25.0	0.0	5.0
Iceland	13	0	0.00	9.71	0.0	20.0	10.0	0.0	70.0	0.0	0.0
Norway	194	2	1.03	1.49	3.4	3.4	0.0	13.8	62.1	13.8	3.4
Sweden	186	1	0.54	1.37	4.8	14.3	9.5	0.0	52.4	0.0	19.0
					Faults divided by cause (%) during year 2014						
Estonia	14	0	0.00	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Latvia	2	0	0.00	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lithuania	2	0	0.00	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	461	4	0.87	1.96	2.4	8.5	22.0	4.9	50.0	4.9	7.3

TABLE 5.9.4 SVC FAULTS AND THE DISTRIBUTION ACCORDING TO CAUSE IN EACH NORDIC COUNTRY

Country	Number of devices	Number of faults	Number of faults per 100 devices		Light-ning	Other environ-mental causes	External influence	Operation and mainte-nance	Technical equipment	Other	Unknown
	2014	2014	2014	2005–2014	Faults divided by cause (%) during the period 2005–2014						
Denmark	1	0	0.00	11.11	0.0	100.0	0.0	0.0	0.0	0.0	0.0
Finland	5	0	0.00	20.00	0.0	0.0	0.0	50.0	50.0	0.0	0.0
Iceland	2	0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Norway	15	20	133.33	74.67	1.8	0.9	0.0	2.7	70.5	19.6	4.5
Sweden	3	8	266.67	290.63	1.1	8.6	1.1	15.1	61.3	3.2	9.7
Total	26	28	107.69	101.46	1.4	4.8	0.5	8.7	65.9	12.0	6.7

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 2014. 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. The system components in this chapter cover all the voltage levels.

A system unit is defined as:

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

An outage state is defined as:

"the component or unit is not in the in-service state; that is, it is partially or fully isolated from the system" [1, pp. 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 overhead lines according to the number of outages per line in each Nordic and Baltic country in 2014

Overhead line		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	193	150	34	6	3	0	0	0
Estonia	214	140	52	6	7	4	2	3
Finland	315	179	85	26	13	8	4	0
Iceland	61	52	4	1	2	1	0	1
Latvia	220	141	46	19	10	2	0	2
Lithuania	374	292	58	14	5	3	0	2
Norway	1233	1023	123	67	7	5	6	2
Sweden	550	310	131	45	18	21	12	13

TABLE 6.1.2 GROUPING OF CABLES ACCORDING TO THE NUMBER OF OUTAGES PER LINE IN EACH NORDIC AND BALTIC COUNTRY IN 2014

Cable		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	70	54	14	1	0	1	0	0
Estonia	20	19	1	0	0	0	0	0
Finland	32	31	1	0	0	0	0	0
Iceland	0	0	0	0	0	0	0	0
Latvia	17	17	0	0	0	0	0	0
Lithuania	37	37	0	0	0	0	0	0
Norway	5	5	0	0	0	0	0	0
Sweden	37	34	3	0	0	0	0	0

TABLE 6.1.3 GROUPING OF TRANSFORMERS ACCORDING TO THE NUMBER OF OUTAGES PER UNIT IN EACH NORDIC AND BALTIC COUNTRY IN 2014

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	270	244	24	0	1	1	0	0
Estonia	238	223	15	0	0	0	0	0
Finland	1274	1264	7	3	0	0	0	0
Iceland	56	54	2	0	0	0	0	0
Latvia	271	217	46	7	1	0	0	0
Lithuania	439	436	3	0	0	0	0	0
Norway	1038	1031	7	0	0	0	0	0
Sweden	528	489	27	5	6	0	1	0

TABLE 6.1.4 GROUPING OF BUSBARS ACCORDING TO THE NUMBER OF OUTAGES PER UNIT IN EACH NORDIC AND BALTIC COUNTRY IN 2014

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	185	173	11	0	1	0	0	0
Estonia	140	137	3	0	0	0	0	0
Finland	991	991	0	0	0	0	0	0
Iceland	56	56	0	0	0	0	0	0
Latvia	137	135	2	0	0	0	0	0
Lithuania	237	236	1	0	0	0	0	0
Norway	435	428	7	0	0	0	0	0
Sweden	383	372	11	0	0	0	0	0

TABLE 6.1.5 GROUPING OF REACTORS ACCORDING TO THE NUMBER OF OUTAGES PER UNIT EACH NORDIC AND BALTIC COUNTRY IN 2014

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	80	75	5	0	0	0	0	0
Estonia	21	21	0	0	0	0	0	0
Finland	70	70	0	0	0	0	0	0
Iceland	0	0	0	0	0	0	0	0
Latvia	16	15	1	0	0	0	0	0
Lithuania	11	11	0	0	0	0	0	0
Norway	36	34	2	0	0	0	0	0
Sweden	51	38	11	2	0	0	0	0

TABLE 6.1.6 GROUPING OF SHUNT CAPACITORS ACCORDING TO THE NUMBER OF OUTAGES PER UNIT EACH NORDIC AND BALTIC COUNTRY IN 2014

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	26	24	2	0	0	0	0	0
Estonia	10	10	0	0	0	0	0	0
Finland	42	41	1	0	0	0	0	0
Iceland	13	13	0	0	0	0	0	0
Latvia	2	2	0	0	0	0	0	0
Lithuania	2	2	0	0	0	0	0	0
Norway	194	192	2	0	0	0	0	0
Sweden	54	54	0	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 OVERHEAD LINES WITH DIFFERENT OUTAGE DURATIONS EACH NORDIC AND BALTIC IN 2014.

Overhead line		Number of system units grouped by total outage duration time								
Country	Number of system units	No outages	<3 min	3-10 min	10-30 min	30-60 min	60-120 min	120-240 min	240-480 min	>480 min
Denmark	193	150	26	5	0	0	1	1	1	9
Estonia	214	140	58	0	0	1	2	2	7	4
Finland	315	179	89	15	13	2	6	1	4	6
Iceland	61	52	0	1	1	1	2	0	1	3
Latvia	220	141	17	6	7	5	0	8	15	21
Lithuania	374	292	66	4	2	4	0	1	0	5
Norway	1233	1023	123	24	12	10	13	9	7	12
Sweden	550	310	171	26	11	9	6	1	2	14

TABLE 6.2.2 NUMBER OF CABLES WITH DIFFERENT OUTAGE DURATIONS IN EACH NORDIC AND BALTIC COUNTRY IN 2014.

Cable		Number of system units grouped by total outage duration time								
Country	Number of system units	No outages	<3 min	3-10 min	10-30 min	30-60 min	60-120 min	120-240 min	240-480 min	>480 min
Denmark	70	54	0	1	0	0	0	7	0	8
Estonia	20	19	0	0	0	0	0	0	0	1
Finland	32	31	0	0	0	0	0	0	0	1
Iceland	0	0	0	0	0	0	0	0	0	0
Latvia	17	17	0	0	0	0	0	0	0	0
Lithuania	37	37	0	0	0	0	0	0	0	0
Norway	5	5	0	0	0	0	0	0	0	0
Sweden	37	34	3	0	0	0	0	0	0	0

TABLE 6.2.3 NUMBER OF TRANSFORMERS WITH DIFFERENT OUTAGE DURATIONS IN EACH NORDIC AND BALTIC COUNTRY IN 2014

Transformer		Number of system units grouped by total outage duration time								
Country	Number of system units	No outages	<3 min	3-10 min	10-30 min	30-60 min	60-120 min	120-240 min	240-480 min	>480 min
Denmark	270	244	1	7	3	1	0	3	2	9
Estonia	238	223	1	0	1	0	0	1	0	12
Finland	1274	1264	4	2	2	0	1	0	0	1
Iceland	56	54	0	0	2	0	0	0	0	0
Latvia	271	217	2	4	9	6	3	8	7	15
Lithuania	439	436	0	0	0	1	0	0	0	2
Norway	1038	1031	0	0	0	0	0	0	0	7
Sweden	528	489	12	10	5	2	2	2	3	3

TABLE 6.2.4 NUMBER OF BUSBARS WITH DIFFERENT OUTAGE DURATIONS IN EACH NORDIC AND BALTIC COUNTRY IN 2014

Busbar		Number of system units grouped by total outage duration time								
Country	Number of system units	No outages	<3 min	3-10 min	10-30 min	30-60 min	60-120 min	120-240 min	240-480 min	>480 min
Denmark	185	173	1	3	0	0	0	2	1	5
Estonia	140	137	0	1	0	0	0	0	0	2
Finland	991	991	0	0	0	0	0	0	0	0
Iceland	56	56	0	0	0	0	0	0	0	0
Latvia	137	135	0	0	1	0	0	0	0	1
Lithuania	237	236	0	0	0	0	0	0	0	1
Norway	435	428	2	5	0	0	0	0	0	0
Sweden	383	372	0	0	5	0	1	0	1	4

TABLE 6.2.5 NUMBER OF REACTORS WITH DIFFERENT OUTAGE DURATIONS IN EACH NORDIC AND BALTIC COUNTRY IN 2014

Reactor		Number of system units grouped by total outage duration time								
Country	Number of system units	No outages	<3 min	3-10 min	10-30 min	30-60 min	60-120 min	120-240 min	240-480 min	>480 min
Denmark	80	75	0	2	0	0	0	0	0	3
Estonia	21	21	0	0	0	0	0	0	0	0
Finland	70	70	0	0	0	0	0	0	0	0
Iceland	0	0	0	0	0	0	0	0	0	0
Latvia	16	15	0	0	0	0	0	0	0	1
Lithuania	11	11	0	0	0	0	0	0	0	0
Norway	36	34	0	0	0	0	0	0	0	2
Sweden	51	38	0	0	1	1	3	1	2	5

TABLE 6.2.6 NUMBER OF SHUNT CAPACITORS WITH DIFFERENT OUTAGE DURATIONS IN EACH NORDIC AND BALTIC COUNTRY IN 2014

Shunt capacitor		Number of system units grouped by total outage duration time								
Country	Number of system units	No outages	<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	0	0	0	0	0	1	0	1
Estonia	10	10	0	0	0	0	0	0	0	0
Finland	42	41	0	0	0	0	0	0	0	1
Iceland	13	13	0	0	0	0	0	0	0	0
Latvia	2	2	0	0	0	0	0	0	0	0
Lithuania	2	2	0	0	0	0	0	0	0	0
Norway	194	192	0	0	0	0	0	0	0	2
Sweden	54	54	0	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. Every country in this report is included in the data.

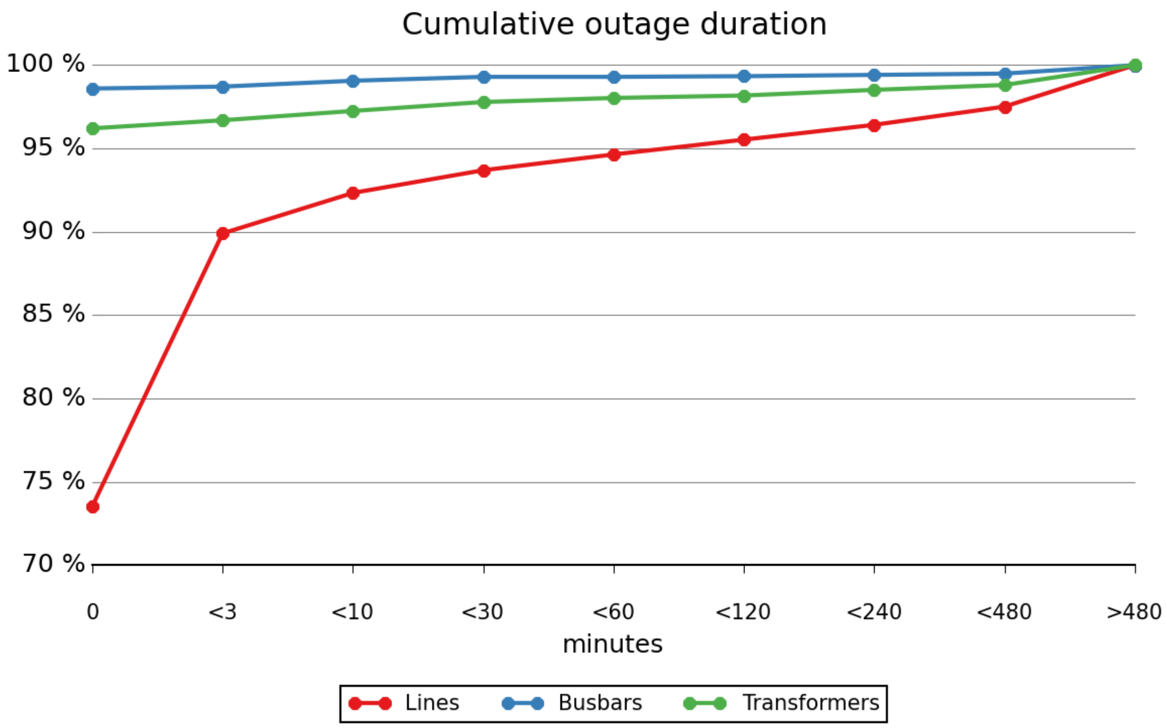

FIGURE 6.3.1 PERCENTAGE OF COMPONENTS WITH DIFFERENT OUTAGE DURATION IN EVERY NORDIC AND BALTIC COUNTRY IN 2014

Figure 6.3.1 shows that approximately 62 % of the lines, 95 % of the transformers and 98 % of the busbars had no outages in 2014.

6.4 RELIABILITY TRENDS FOR SOME POWER SYSTEM UNITS

Figure 6.4.1 presents reliability trends for lines, busbars and transformers during the ten-year period 2005–2014 in the Nordic countries.

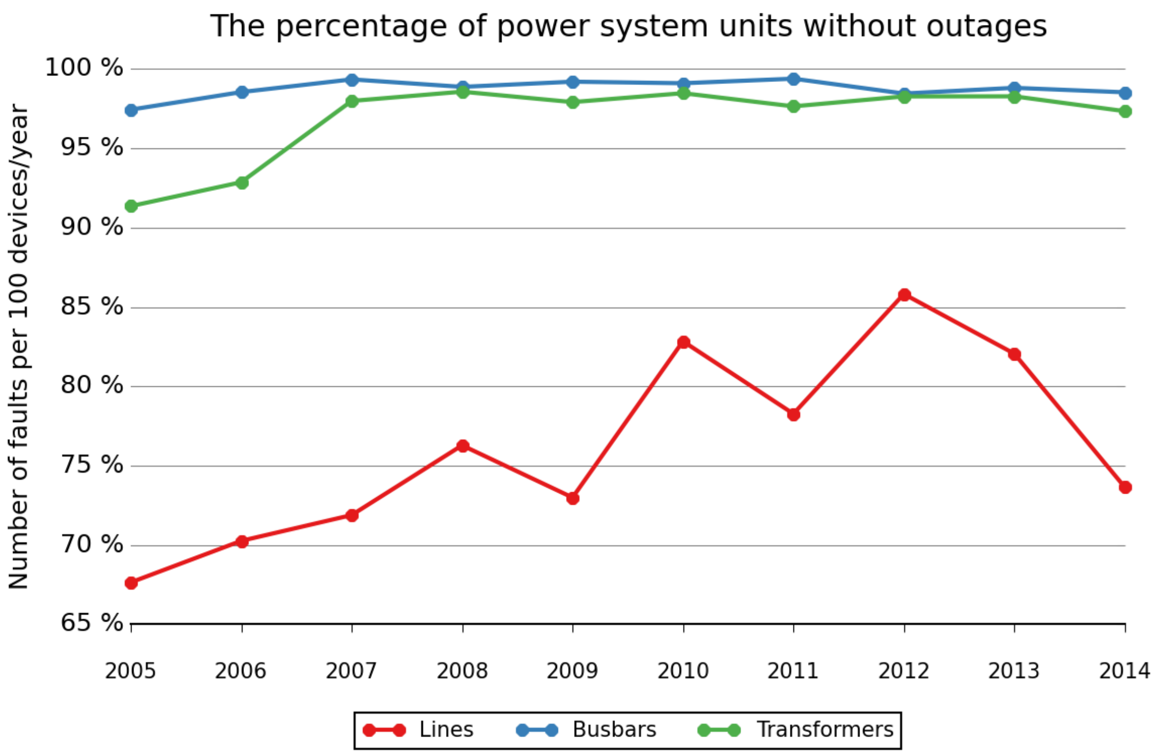

FIGURE 6.4.1 THE YEARLY PERCENTAGE OF THE POWER SYSTEM UNITS THAT HAD NO OUTAGES IN THE NORDIC COUNTRIES DURING THE PERIOD 2005–2014

7 References

[1] Nordel, “Guidelines for the Classification of Grid Disturbances,” 2009. [Online]. Available: http://www.entsoe.eu/index.php?id=63. [Accessed 19 October 2015].

[2] ENTSO-E, ”The ENTSO-E Interconnected System Grid Map,” [Online]. Available: https://www.entsoe.eu/publications/order-maps-and-publications/electronic-grid-maps/Pages/default.aspx. [Haettu 19 October 2015].

[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),” 2001. [Online]. Available: https://www.sintef.no/globalassets/project/kile/definisjoner.pdf. [Accessed 19 October 2015].

[4] IEC 50(191-05-01), *International Electrotechnical Vocabulary, Dependability and Quality of Service. Note that the IEC standard 50-191 Dependability and quatlity of service is canceled on 27 April 2015. Since the statistics have been prepared by using this defintion,* it is used as a reference.

[5] IEEE, *Standard Terms for Reporting and Analyzing Outage Occurrence and Outage States of Electrical Transmission Facilities,* IEEE Std 859-1987, 1988. DOI: 10.1109/IEEESTD.1988.86288, p. 11.

Appendix 1 The calculation of energy not supplied

Every country calculates their energy not supplied (ENS) is various ways. This chapter describes how the calculations are done.

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 connection points 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 Estonia, ENS calculation is based on interruption time for the end user. When the outage duration is less than two hours, ENS is calculated by cut-off power (measured straight before the outage) multiplied by the interruption time. When the outage duration is more than two hours, the load data of previous or next day shall be taken into account and ENS is calculated according to these load profiles.

In Iceland, ENS is computed according to the delivery from the transmission grid. It 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 and Baltic 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 Latvia, the ENS is linked to the end user. This means that ENS is not counted as long as the end user receives energy through the distribution grid. Note that the distribution grid is 100 % dependent of the TSO supply due to undeveloped energy generation. The amount of ENS is calculated by multiplying the load before the outage occurred with the duration of the outage.

In Lithuania energy not delivered (END) is treated as the ENS. The END of the transmission grid is calculated at the point of supply of the end customer. The point of supply means the low voltage side of the 110/35/10 kV or 110/10 kV transformer at the low voltage customer connection point. If an outage is in a radial 110 kV connection, END is calculated by the distribution system operator (DSO), who considers the possibility to supply energy from the other 35 kV or 10 kV voltage substations. The DSO then uses the average load before the outage and its duration in the calculations. All events with the energy not supplied shall be investigated together with the DSO or Significant User directly connected to 110 kV network. Both parties shall agree and confirm the amounts of not supplied energy.

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 power 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 100–150 kV network. It is also a fact that every line fault is not inspected, which may lead to a cause stated as unknown.

In Finland, Fingrid Oyj 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 Estonia, the causes of line faults are found by inspections or by some identifying or highly probable signs. Fault location is usually categorised as it is measured by disturbance recorders although the accuracy may vary a lot. The 110 kV lines have many trips with a successful automatic reclosing at nights during summer months. The reasons were examined and it was found out that stork contamination on insulators causes these flashovers. In these cases, the fault sites are not always inspected. Elering has an access to lightning detection system, which allows identifying the line faults caused by lightning. If there are no signs referring to a certain cause, the reason for a fault is unknown.

In Iceland, disturbances in Landsnet‘s transmission system are classified into two categories: sudden disturbances in the transmission network and sudden disturbances in other systems. Every month the listings for interference are analysed by the staff of system operation and corrections are made to the data if needed. In 2014, Landsnet started to hold meetings three times a year, with representatives from the asset management and maintenance department to review the registration of interference and corrections made if the cause was something else than what was originally reported. This also leads to a better understanding how disturbances are listed in the disturbance database for these parties.

In Latvia, disturbance recorders, relay protection systems, on-sight inspections and information from witnesses are used to find the cause of a disturbance. If there is enough evidence for a fault cause, a disturbance will be counted as known. Unfortunately there are many cases (for example lightning, other environmental causes or external influences), where it is difficult to find the right cause. In those cases, we use our experience to pinpoint the most probable cause and mark it as such.

In Lithuania, disturbances in the transmission system are mainly classified into two categories: disturbances that affected the consumers (Significant users and the DSO) connected to the transmission network and disturbances that did not. All disturbances are investigated according to the internal investigation procedures of Litgrid. To detect line faults, TSO analyses the data from disturbance recorders, relay protection terminals and the post-inspection of the line. Litgrid does not have access to the data of the lightning detection system.

In Norway, primarily for these statistics, the reporting TSO needs to distinguish between six fault categories and unknown. Norway has at least a single sided distance to a fault on most lines on this reporting level and all line faults are inspected. 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. To distinguish between the remaining two categories lightning and other environmental faults, Statnett uses waveform analysis on fault records, the lightning detection system and weather information to sort out the lightning. If the weather was good and no other category is suitable, unknown is used.

In Sweden, data from disturbance recorders and other gathered information is not enough to pinpoint the cause of the disturbance in many cases. Svenska kraftnät does not have full access to raw data from the lightning detection system and if a successful reclosing has taken place Svenska kraftnät prefers to declare the cause unknown instead of lightning, which may be the most probable cause.

Appendix 3 Contact persons in the Nordic and Baltic countries

Denmark: Energinet.dk
Tonne Kjærsvej 65, DK-7000 Fredericia, Denmark
Anders Bratløv
Tel. +45 51 38 01 31
E-mail: anv@energinet.dk

Finland: Fingrid Oyj
P.O. Box 530, FI-00101 Helsinki, Finland
Markku Piironen
Tel. +358 30 395 4172, Mobile +358 40 351 1718
E-mail: markku.piironen@fingrid.fi

Estonia: Elering AS
Kadaka tee 42, Tallinn
Kaur Krusell
Tel. +372 56486011
E-mail: kaur.krusell@elering.ee
Raul Uuring
Tel. +372 5296214
E-mail: raul.uuring@elering.ee

Iceland: Landsnet
Gylfaflöt 9, IS-112 Reykjavik
Ragnar Stefánsson
Tel. +354 863 7181 or +354 825 2395
E-mail: ragnars@landsnet.is

Latvia: AS "Augstsprieguma tīkls"
86 Darzciema Str., Riga, LV-1073, Latvia
Anrijs Maklakovs
Tel. +371 293 352 216
E-mail: anrijs.maklakovs@ast.lv

Lithuania: Litgrid AB
A.Juozapavičiaus g. 13, LT-09311, Vilnius
Valdas Tarvydas
Tel. +370 5 278 2471
E-mail: valdas.tarvydas@litgrid.eu
Romas Pangonis
Tel. +370 5 278 2245
E-mail: romas.pangonis@litgrid.eu
Rimas Savukas
Tel. +370 5 278 2850
E-mail: rimas.savukas@litgrid.eu

Norway: Statnett SF
Postboks 4904 Nydalen, NO-0423 Oslo
Jørn Schaug-Pettersen
Tel. +47 23 90 35 55
E-mail: jsp@statnett.no
Christian Melaaen
Tel. +47 23 90 41 53, Mobile +47 91 31 40 58
E-mail: christian.melaaen@statnett.no

Sweden: Svenska kraftnät
Sturegatan 1, P.O. Box 1200, SE-172 24 Sundbyberg
Hampus Bergquist
Tel. +46 10 475 84 48, Mobile: +46 72 515 90 70
E-mail: hampus.bergquist@svk.se
Tarek Tallberg
Tel. +46 10 475 86 79, Mobile: +46 72 244 96 97
E-mail: tarek.tallberg@svk.se

Production of the report:
Aalto University, School of Electrical Engineering
P.O. BOX 13000, 00076 Aalto, Finland
Liisa Haarla and Henrik Hillner
Tel. +358 40 550 2033
E-mail: liisa.haarla@aalto.fi or henrik.hillner@aalto.fi

Appendix 4 Contact persons for the distribution network statistics

ENTSO-E Regional Group Nordic provides no statistics for distribution networks (voltage voltages lower than 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 and Baltic countries, which are listed below:

Denmark: Peter Hansen
Danish Energy Association R&D
Rosenørns Allé 9, DK-1970 Frederiksberg
Tel. +45 300 380–420
E-mail: pha@danskenergi.dk

Finland: Taina Wilhelms
Energiateollisuus ry, Finnish Energy Industries
Fredrikinkatu 51–53 B, P.O. Box 100, FI-00101 Helsinki
Tel. +358 9 5305 2114
E-mail: taina.wilhelms@energia.fi

Estonia: Taivo Tonne
OÜ Elektrilevi
Kadaka tee 63, Tallinn
Tel. +372 5078921
E-mail: Taivo.Tonne@elektrilevi.ee

Iceland: Sigurdur Ágústsson
Samorka
Sudurlandsbraut 48, IS-108 Reykjavík
Tel. +354 588 4430
E-mail: sa@samorka.is

Latvia: Anrijs Maklakovs
AS "Augstsprieguma tīkls"
86 Darzciema Str., Riga, LV-1073, Latvia
Tel. +371 293 352 216
E-mail: anrijs.maklakovs@ast.lv

Lithuania: Šarūnas Kirlys
AB LESTO
Aguonų g. 26, LT-03212 Vilnius
Tel. +370 5 251 4781
E-mail: sarunas.kirlys@lesto.lt

Norway: Jørn Schaug-Pettersen
Statnett SF
Postboks 4904 Nydalen, NO-0423 Oslo
Tel. +47 23 90 35 55
E-mail: jsp@statnett.no

Sweden: Matz Tapper
Svensk Energi
SE-101 53 Stockholm
Tel. +46 8 677 27 26
E-mail: matz.tapper@svenskenergi.se