European Network of Transmission System Operators for Electricity

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Nordic and Baltic Grid Disturbance Statistics 2020

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Nordic and Baltic Grid Disturbance Statistics 2020

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ENTSO-E Mission Statement

Who we are

ENTSO-E, the European Network of Transmission System Operators for Electricity, is the association for the cooperation of the European transmission system operators (TSOs). The 42 member TSOs, representing 35 countries, are responsible for the secure and coordinated operation of Europe's electricity system, the largest interconnected electrical grid in the world. In addition to its core, historical role in technical cooperation, ENTSO-E is also the common voice of TSOs.

ENTSO-E brings together the unique expertise of TSOs for the benefit of European citizens by keeping the lights on, enabling the energy transition, and promoting the completion and optimal functioning of the internal electricity market, including via the fulfilment of the mandates given to ENTSO-E based on EU legislation.

Our mission

ENTSO-E and its members, as the European TSO community, fulfil a common mission: Ensuring the security of the inter-connected power system in all time frames at pan-European level and the optimal functioning and development of the European interconnected electricity markets, while enabling the integration of electricity generated from renewable energy sources and of emerging technologies.

Our vision

ENTSO-E plays a central role in enabling Europe to become the first climate-neutral continent by 2050 by creating a system that is secure, sustainable and affordable, and that integrates the expected amount of renewable energy, thereby offering an essential contribution to the European Green Deal. This endeavour requires sector integration and close cooperation among all actors.

Europe is moving towards a sustainable, digitalised, integrated and electrified energy system with a combination of centralised and distributed resources. ENTSO-E acts to ensure that this energy system keeps consumers at its centre and is operated and developed with climate objectives and social welfare in mind.

ENTSO-E is committed to use its unique expertise and system-wide view – supported by a responsibility to maintain the system's security – to deliver a comprehensive roadmap of how a climate-neutral Europe looks.

Our values

ENTSO-E acts in solidarity as a community of TSOs united by a shared responsibility.

As the professional association of independent and neutral regulated entities acting under a clear legal mandate, ENTSO-E serves the interests of society by optimising social welfare in its dimensions of safety, economy, environment, and performance.

ENTSO-E is committed to working with the highest technical rigour as well as developing sustainable and innovative responses to prepare for the future and overcoming the challenges of keeping the power system secure in a climate-neutral Europe. In all its activities, ENTSO-E acts with transparency and in a trustworthy dialogue with legislative and regulatory decision makers and stakeholders.

Our contributions

ENTSO-E supports the cooperation among its members at European and regional levels. Over the past decades, TSOs have undertaken initiatives to increase their cooperation in network planning, operation and market integration, thereby successfully contributing to meeting EU climate and energy targets.

To carry out its legally mandated tasks, ENTSO-E's key responsibilities include the following:

› Development and implementation of standards, network codes, platforms and tools to ensure secure system and market operation as well as integration of renewable energy; › Assessment of the adequacy of the system in different timeframes;

› Coordination of the planning and development of infrastructures at the European level (Ten-Year Network Development Plans, TYNDPs);

› Coordination of research, development and innovation activities of TSOs;

› Development of platforms to enable the transparent sharing of data with market participants.

ENTSO-E supports its members in the implementation and monitoring of the agreed common rules.

ENTSO-E is the common voice of European TSOs and provides expert contributions and a constructive view to energy debates to support policymakers in making informed decisions.

Executive Summary

The Nordic and Baltic Grid Disturbance Statistics 2020 gives both an overview of the grid disturbances, faults, and energy not supplied (ENS) in the Nordic and Baltic 100–420 kV alternating current grids, as well as a deeper dive into the statistics of individual components used in the grids.

When it comes to the number of faults, the number of disturbances and the amount of ENS, the year 2020 was quite a good year. In 2020, the number of grid disturbances was clearly smaller in Estonia, Norway, Finland, and Sweden, roughly the same in Latvia, Lithuania and Denmark than the corresponding annual averages for 2011–2020.

In Iceland, the number of disturbances was 60 in 2020, 50 % more than the 10-year annual average. This larger number of disturbances did not cause more ENS than usually, rather the opposite: only about 50 % of the 10-year annual amount of ENS.

The total Baltic disturbance number was 83 % and the Nordic 84 % compared to the 10-year annual average. The number of disturbances that caused ENS was either clearly smaller or roughly the same than the 10-year annual averages in other countries except for Finland, where the number of disturbances that caused ENS was slightly larger compared to the 10-year annual average.

The amount of ENS caused by disturbances in 2020 was smaller than the annual 10-year average 2011–2020 for all other countries except for Latvia. In the Baltic countries, the total ENS was 213 MWh in 2020 (309 MWh on average per year in 2011–2020). In the Nordic countries, the situation was even better: the amount of ENS was roughly a third of the annual 10-year average (2044 MWh in 2020 and the annual average for 2011–2020 was 6369 MWh).

In Latvia, the ENS in 2020 was almost double the amount of the annual 10-year average (171 MWh in 2020 vs annual average 89 MWh). In Latvia, a disturbance (consisting of a single phase short-circuit fault of a cable) and a secondary fault of a control equipment caused 91 % of the annual ENS. The chain of events caused overload and the cascading disconnection of several 110 kV lines. The incident caused an hour-long outage in 28 substations and resulted in 155 MWh of ENS. This case shows that secondary faults, that is, the faults that extend or aggravate a grid disturbance can cause large amounts of ENS since the system is planned and operated to withstand a single fault. In Estonia, the amount of ENS was only 6 % and in Norway, only 19 % of the annual 10-year average.

Table ES.1 shows the key figures of this report for each participating country: the numbers of faults and disturbances, the fault to disturbance ratio in 2020, and ENS in 2020 and the corresponding annual averages for these.

Table ES.1: The number of faults, the number of disturbances, the fault to disturbance ratio, and ENS in 2020 and the corresponding annual averages for the 10-year period 2011–2020.

	Number of faults		No. of disturbances		Ratio		ENS (MWh)	
Country	2020	Annual avg. 2011–2020	2020	Annual avg. 2011–2020	2020	2011–2020	2020	Annual avg. 2011–2020
Estonia	142	192	127	186	1.12	1.03	10.5	179.8
Latvia[1]	132	151	123	137	1.07	1.10	170.5	88.9
Lithuania[1]	154	168	148	156	1.04	1.08	31.9	40.4
Baltic total	428	510.2	398	478.6	1.08	1.07	212.9	309.2
Denmark	63	65	58	57	1.09	1.13	26.9	28.3
Finland	363	447	345	426	1.05	1.05	149.1	297.5
Iceland	82	59	60	41	1.37	1.44	561.8	1073.9
Norway	257	349	229	304	1.12	1.14	639.9	3437.0
Sweden	396	472	387	456	1.02	1.03	666.6	1531.8
Nordic total	1161	1390.2	1079	1284.2	1.08	1.08	2044.3	6368.6
Baltic & Nordic total	1589	1900.4	1477	1762.8	1.08	1.08	2257.2	6677.7

[1] The data of Latvia and Lithuania cover 2012–2020.

The single grid component that had the largest share of faults in 2020 was overhead line for all other countries except for Iceland where the share of faults on adjoining grids was slightly higher.

For overhead line faults, the main cause of the overhead line faults was 'other environmental cause' in Estonia, Finland, Latvia, Iceland, and Norway. This fault cause contains causes such as wind, ice and snow. The most common fault cause was 'external influences' in Lithuania and Denmark. This fault cause includes for example tree felling, fire, and vandalism. In Sweden, lightnings caused most overhead line faults.

The major fault cause when looking at all the grid component varies between countries more than the causes of overhead line faults. The most common fault cause for all components together was

- 'technical equipment' for Estonia,
- 'other environmental causes' for Latvia and Norway,
- 'external influences' for Denmark and Lithuania,
- 'other causes' for Finland and Iceland, and
- 'unknown' for Sweden.

The fault cause 'other' contains for example faults at customers' grid, faults in other grids, problems in conjunction with faults in other components and system causes.

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Glossary

Disturbance See grid disturbance.

DSO Distribution System Operator.

End-user "Buyers of electrical energy who do not resell all the energy" [1, p. 11].

Energy not supplied "The estimated energy which would have been supplied to end-users if no interruption and no transmission restrictions had occurred" [1, p. 12].

ENS Energy not supplied.

ENTSO-E European Network of Transmission System Operators for Electricity.

Fault "The inability of a component to perform its required function" [1, p. 3–4].

Fault cause "Cause relating to design, production, installation, operation or maintenance which results in a fault" [1, p. 7].

Grid disturbance "Outages, forced or unintended disconnection or failed re-connection (of a component) as a result of faults in the power grid" [1, p. 5].

HVDC High-voltage direct current.

kV Kilovolt.

MWh Megawatt hour.

Nominal voltage "Value of the voltage by which the electrical installation or part of the electrical installation is designated and identified" [2].

ppm Parts per million.

Primary cause (of a fault) "Event or circumstance which leads to a fault" [1, p. 7].

Primary fault "A fault which initiates a grid disturbance" [1, p. 4].

RGN Regional Group Nordic.

Secondary fault A fault that aggravates a grid disturbance [1, p. 3–4].

SGU Significant Grid User.

Statistical area The area inside a country's borders. The statistical area is further limited to central components, as shown in Figure 1.2.

Statistical voltage level This report groups the voltage levels into three statistical voltage levels. The statistical voltage levels are 100–150 kV, 220–330 kV and 380–420 kV.

SVC Static var compensator.

TSO Transmission System Operator.

TWh Terawatt hour.

1 Introduction

1.1 Description of the report

The Nordic and Baltic Grid Disturbance Statistics 2020 gives an overview of the faults, disturbances, and energy not supplied (ENS) in the Nordic and Baltic 100–420 kV alternating current power grids for the year 2020. Transmission System Operators (TSOs) providing the statistical data are *Energinet* 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 are published on ENTSO-E's website, www.entsoe.eu. Figure 1.1 presents the grids of the statistics. Figure E.10 illustrates the differences between grid sizes, electricity consumption and ENS for the countries.

All of Denmark is included in the disturbance data of this report, although only the grid of eastern Denmark belongs to the Nordic synchronous system.

The report includes faults causing grid disturbances or ENS in the 100–420 kV grids, and it is made according to *Nordel's Guidelines for the Classification of Grid Disturbances* [1].

The report is organised into six chapters. Chapter 2 summarises the statistics, covering the consequences of disturbances in the form of ENS and covering the total number of disturbances in the Nordic and Baltic 100–420 kV grids. Besides, each TSO presents the key events of the year 2020.

Chapter 3 presents the grid disturbances and focuses on the allocation of their causes.

Chapter 4 presents the tables and figures of ENS for each country.

Chapter 5 presents secondary faults and their impact on the Nordic and Baltic transmission grids.

Chapter 6 presents an overview of faults causing grid disturbances in the Nordic and Baltic power grids and faults in the following components: cables, overhead lines, circuit breakers, control equipment, instrument transformers, power transformers, and compensation devices.

Appendices A–D describe how the TSO of each country calculates ENS, examines line fault causes, and contacts for TSOs as well as distribution network statistics.

Appendix E includes additional figures.

1.2 History

The disturbance statistics has a long history with mutual Nordic rules made already in 1964. In the beginning, the statistics covered Denmark, Finland, Norway and Sweden and was published by Nordel[1] in Swedish with the name "Driftstörningsstatistik" (Eng. Fault statistics) along with a summary in English. Iceland joined in 1994.

In 2007, the language of the statistics was changed to English, and the name became *Nordic Grid Disturbance Statistics*. In 2014, the Baltic countries joined the report, and the report changed its name to *Nordic and Baltic Grid Disturbance Statistics*, which is the name of the report today.

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

Figure 1.1: The Nordic and Baltic main grids [3] in 2019. The map of 2019 is used because the interconnected network of Northern Europe map for 2020 was unavailable during the production of this report. All of Denmark is included in the disturbance data of this report, although only the grid of eastern Denmark belongs to the Nordic synchronous system.

1.3 The scope and limitations of the statistics

The statistics comprise grid disturbances, faults causing ENS, and the amounts of ENS in the Nordic and Baltic 100–420 kV grids.

When a table or figure in these statistics does not explicitly state voltages, all voltages 100–420 kV are included.

The statistics do not comprise:

- Faults in production units;
- Faults having nominal voltages below 100 kV;
- Faults detected during maintenance or testing;
- Planned outages operational interruptions in parts of the electricity system;
- The behaviour of circuit breakers and relay protection if they do not result in or extend a grid disturbance.
- High-voltage direct current (HVDC) units are not included in this report. ENTSO-E produces a separate report called *ENTSO-E HVDC Utilisation and Unavailability Statistics* [4].

Control equipment and installations for reactive compensation are included in the statistics if they control 100–420 kV systems. A graphical interpretation of the grid components included in the statistics is presented in Figure 1.2.

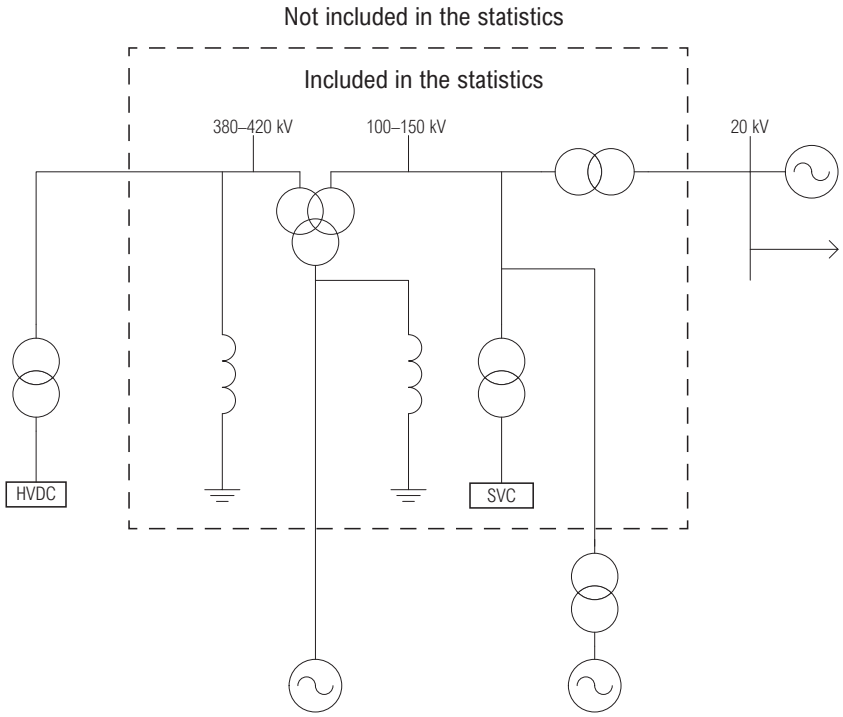

Figure 1.2: A graphical representation of the included grid components in the statistics.

Although the statistics are built upon common guidelines [1], there are slight differences in the interpretations between different countries and companies. These differences are considered to have a minor impact on the statistical material.

1.4 Available data in the report

Many figures and tables present data for 2020 or for 2011–2020. Some figures use data from longer periods. For example, moving average figures for component faults in Chapter 6 use data from 1995.

However, not all participating TSO's have data for the whole period 2011–2020. In these cases, the figures and tables show all the available data. In this report, Latvia and Lithuania have reported for 2012–2020.

Many of the reported values are presented in percentages. When the calculations are done, the percentage values are rounded to the nearest decimal and may result in the total sum deviating slightly from 100 %.

1.5 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 C.

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

1.6 Fault causes

Each grid disturbance and fault has a cause connected to it. The used causes in this report are detailed in Table 1.1.

There are minor differences in the fault cause groupings between countries. This report uses the fault causes presented in Table 1.1. Appendix B describes how each Nordic and Baltic TSO examines the cause of line faults.

Table 1.1: The fault causes used in these statistics, the explanations being similar as in the Nordel guidelines [1, Tab. 5.1]. 'Other natural causes' has been renamed to 'Other environmental causes'.

Fault cause	Explanation
Lightning	Lightning is separated from the environmental causes because it causes a large share of overhead line faults in some countries and is therefore insignificant from a maintenance perspective.
Other environmental causes	Environmental causes except for lightning, such as moisture, ice, low temperatures, earthquakes, pollution, rain, salt, snow, vegetation, wind, heat and forest fires.
External influences	Fire due to a third party, animals and birds, aircraft, excavation, collision, explosion, tree felling, vandalism.
Operation and maintenance	Lack of monitoring, fault in settings, fault in connection plan, fault in relay plan, incorrect operation, errors in documentation, human fault.
Technical equipment	Dimensioning, error in technical documentation (e.g., guidelines, manuals), design, corrosion, materials, installation, production, vibration, ageing.
Other causes	Operating problems, faults at customers', faults in other networks, issues in conjunction with faults in other components, system causes, other
Unknown	Unknown causes

1.7 Voltage levels in the Nordic and Baltic grids

Because slightly different voltage levels are used in each country, this report groups the voltage levels into three statistical voltage ranges. The statistical voltage in this report is the same as the nominal grid voltage at the fault.

When a table or figure in these statistics does not explicitly state voltages, all voltages 100–420 kV are included.

Table 1.2 presents the statistical voltage levels used in this report and their percentage allocation. Table 1.3 presents the coverage of the statistics in each country. The network statistics of each country cover data from several grid owners (TSOs and DSOs).

Table 1.2: Nominal voltage levels (U_N) included in this report and their percentage (p) allocation. Because slightly different voltage levels are used in each country, this report groups the voltage levels into the ranges below.

		Statistical voltage range, kV		
Country		100–150 kV	220–330 kV	380–420 kV
Denmark	U_N / p %	150 kV / 62 % 132 kV / 38 %	220 kV / 100 %	400 kV / 100 %
Estonia	U_N / p %	110 kV / 100 %	330 kV / 92 % 220 kV / 8 %	–
Finland	U_N / p %	110 kV / 100 %	220 kV / 100 %	400 kV / 100 %
Iceland	U_N / p %	132 kV / 100 %	220 kV / 100 %	–
Latvia	U_N / p %	110 kV / 100 %	330 kV / 100 %	–
Lithuania	U_N / p %	110 kV / 100 %	330 kV / 100 %	400 kV / 100 %
Norway[1]	U_N / p %	132 kV / 98 % 110 kV / 2 %	300 kV / 90 % 220 kV / 10 %	420 kV / 100 %
Sweden	U_N / p %	130 kV / 100 %	220 kV / 100 %	400 kV / 100 %

[1] A large part of Norway's 110 and 132 kV network is resonant earthed. This category is combined with the 100–150 kV solid-earthed network in these statistics.

Table 1.3: Percentage of networks included in the statistics per statistical voltage level. The percentage is estimated per line length.

	Voltage level		
Country	100–150 kV	220–330 kV	380–420 kV
Denmark	100 %	100 %	100 %
Estonia	100 %	100 %	–
Finland	87 %	100 %	100 %
Iceland	100 %	100 %	–
Latvia	100 %	100 %	–
Lithuania	100 %	100 %	100 %
Norway	100 %	100 %	100 %
Sweden	96 %	100 %	100 %

2 Summary

2.1 Nordic and Baltic Summary

In 2020, 1477 grid disturbances occurred in the Nordic and Baltic 100–420 kV grids, which is below the 10-year annual average of 1763 disturbances. The energy not supplied (ENS) due to faults in the Nordic grids amounted to 2044 MWh and 213 MWh in the Baltic. There were 2257 MWh of ENS in the Nordic and Baltic grids, which is also significantly below the 10-year annual average of 6678 MWh of ENS. Out of all disturbances, 311 caused ENS in 2020.

The following sections present the summaries for each Nordic and Baltic country including the most significant issues in 2020.

2.2 Summary of Denmark

In Denmark, the ENS caused by grid disturbances was 27 MWh in 2020 (10-year annual average 28 MWh). There were 58 grid disturbances (10-year annual average 57) and 2 of them caused ENS.

In 2020, all of the total ENS was caused by substation faults. All of the total ENS due to grid disturbances was caused by operation and maintenance. Disturbances were caused most by external influences (36 %) and operation and maintenance (22 %).

Secondary faults in Denmark accounted for 8 % of all faults in 2020 and caused no ENS. Secondary faults were primarily caused by operation and maintenance (80 %) and external influences (20 %).

The three most significant disturbances in 2020 were the following:

- A human error during testing on protection equipment disconnected the whole station due to insufficient insulation of the test signal. The resulting ENS was 10.5 MWh.
- During work in a station a human error caused a wrongful closing of a disconnector, which consequently disconnected the whole station. The disconnection caused 16.4 MWh of ENS.
- A row of trees had grown too close to an overhead line and resulted in a flashover due to wind. The flashover disconnected the line and set the nearby trees on fire. An additional flashover to a tree occurred on another overhead line on the same tower due to the air being ionized from the fire, resulting in a second overhead line disconnecting and a system split of the 400 kV grid. The fault did not cause any ENS.

2.3 Summary of Estonia

In Estonia, the ENS caused by grid disturbances was 11 MWh in 2020 (10-year annual average 180 MWh). There were 127 grid disturbances (10-year annual average 186) and 14 of them caused ENS.

In 2020, 99 % of the total ENS was caused by substation faults, and 1 % by overhead line faults. The most significant reasons for ENS caused by disturbances were operation and maintenance (85 %) and technical equipment (12 %). Disturbances were caused most by technical equipment (26 %) and other causes (19 %).

Secondary faults in Estonia accounted for 11 % of all faults in 2020 and caused approximately 1 % of the total ENS. Secondary faults were primarily caused by technical equipment (33 %) and operation and maintenance (27 %), and the ENS of the secondary faults was mainly due to technical equipment (56 %) and other causes (44 %).

The three most significant disturbances in 2020 were the following:

- On 17 January 2020 at 3.07, a portable grounding device was broken during a short-circuit test performed at the LVT substation. One phase on the portable grounding device was burned. The short-circuit caused the overhead lines L123 LVT-Püssi, L190 LVT-Püssi, L077 LVT-Põhja and L076 LVT-Põhja to be switched off from the LVT substation. The 6 kV consumers of the LVT and Põhja substations were interrupted for 9 minutes. The normal scheme of the substation was restored at 3.45. ENS was 7.2 MWh.

- On 8 June 2020 at 22.44 overhead line L116 Püssi-Oru-Allika-Balti switched off from permanent short-circuit that caused an interruption for consumers of Allika substation. Line L116 was put into operation at 22.46. The failure was caused by a thunderstorm with a strength of 62 kA. ENS was 0.1 MWh.
- On 2 July 2020 at 8.46 overhead lines L033 Sindi-Audru and L107B Audru-Lõpe were switched off. There was a temporary scheme in work, where the overhead lines were connected together through a sectioning switch. However, when the normal scheme was to be restored, the insulator of a disconnector broke. There were interruptions for consumers of Audru and Pärnu-Jaagupi substations. At 8.54 overhead lines L033 and L107B were in operation again and all consumers were fed. All protections worked correctly. ENS was 0.5 MWh.

2.4 Summary of Finland

In Finland, the ENS caused by disturbances was 149 MWh in 2020 (10-year annual average 298 MWh). There were 345 grid disturbances (10-year annual average 426) and 86 of them caused ENS (10-year annual average 73).

In 2020, 58 % of the total ENS was caused by overhead line faults, and 42 % by substation faults. The most significant reasons for ENS caused by disturbances were unknown causes (32 %) and external influences (19 %). Disturbances were caused most by other causes (28 %) and other environmental causes (25 %).

Secondary faults in Finland accounted for 5 % of all faults in 2020 and caused approximately 9 % of the total ENS. Secondary faults were primarily caused by lightning (28 %), and the ENS of the secondary faults was primarily due to lightning (63 %) and operation and maintenance (34 %).

The three most significant disturbances in the 110–400 kV grid in 2020 were:

- Earth fault on a 110 kV line. Unknown reason. ENS 25 MWh.
- Earth fault on a 110 kV line. Unknown reason. ENS 15 MWh.
- Earth fault on a 110 kV line. A tower had fallen. ENS 15 MWh.

Finland's data from 2020 covers approximately 87 % of the Finnish 110 kV grid and 100 % of the 220 kV and 400 kV grids.

2.5 Summary of Iceland

In Iceland, the ENS caused by grid disturbances was 562 MWh in 2020 (10-year annual average 1074 MWh). There were 60 grid disturbances (10-year annual average 40) and 22 of them caused ENS.

In 2020, 23 % of the total ENS was caused by substation faults, and 11 % by cable faults. The most significant reasons for ENS caused by disturbances were other causes (69 %) and other environmental causes (27 %). Disturbances were caused most by other causes (52 %) and other environmental causes (32 %).

Secondary faults in Iceland accounted for 27 % of all faults in 2020 and caused approximately 15 % of the total ENS. Secondary faults were primarily caused by other causes (91 %) and other environmental causes (5 %), and the ENS of the secondary faults was mainly due to other causes (99 %).

2020 was above average regarding number of disturbances in Iceland. Majority of ENS were due to 8 events with each having more than 22 MWh of ENS. The most significant disturbances in 2020 were the following:

- The biggest disturbances was when a 220 kV substation tripped due to salt and caused 225 MWh of ENS.
- The next biggest event was when a power intensive industry plant tripped causing a system split in the transmission system with 83.5 MWh of ENS.
- The third biggest event was due to human error during maintenance work, which resulted in 63.7 MWh of ENS.

2.6 Summary of Latvia

In Latvia, the ENS caused by grid disturbances was 171 MWh in 2020 (9-year annual average 89 MWh). There were 123 grid disturbances (9-year annual average 137) and 12 of them caused ENS.

In 2020, 99 % of the total ENS was caused by substation faults, and 0 % by overhead line faults. The most significant reasons for ENS caused by disturbances were technical equipment (98 %) and other causes (1 %). Disturbances were caused most by other environmental causes (40 %) and external influences (21 %).

Secondary faults in Latvia accounted for 7 % of all faults in 2020 and caused approximately 96 % of the total ENS. Secondary faults were primarily caused by technical equipment (67 %) and operation and maintenance (33 %), and the ENS of the secondary faults was mainly due to operation and maintenance (95 %).

The most significant disturbances in 2020 were the following:

- In a 10h period strong wind gusts felled trees, which disconnected 13 overhead lines and caused an outage in 4 regional substations. The resulting ENS was 13.5 MWh.
- Automatic disconnection of 330 kV power cable due to single phase short-circuit and secondary fault on control equipment, which disabled the power reduction function on a generating facility, caused overload and cascading disconnection of multiple 110 kV lines. The incident caused an outage in 28 substations for 1 hour, and resulted in 155 MWh of ENS.
- Disconnection of line due to fault in relay protection optical connection and secondary fault in automatic reconnection caused outage of feeding transformer for 42 min and 7 MWh of ENS.

2.7 Summary of Lithuania

In Lithuania, the ENS caused by grid disturbances was 32 MWh in 2020 (9-year annual average 40 MWh). There were 148 grid disturbances (9-year annual average 156) and 13 of them caused ENS.

In 2020, 95 % of the total ENS was caused by overhead line faults, and 5 % by substation faults. The most significant reasons for ENS caused by disturbances were external influences (82 %) and operation and maintenance (10 %). Disturbances were caused most by external influences (28 %) and other causes (27 %).

Secondary faults in Lithuania accounted for 4 % of all faults in 2020 and caused approximately 76 % of the total ENS. Secondary faults were primarily caused by unknown causes (50 %) and technical equipment (33 %), and all ENS of the secondary faults was due to technical equipment.

The most significant disturbances in 2020 were the following:

- During the 110 kV overhead line route cleaning works a tree fell on the line. ENS 2.7 MWh.
- A tree fell on the 110 kV overhead line phase L3. The short-circuit also broke the wire loop on the same phase on another location on the line and caused 24.1 MWh of ENS (75.7 % of total ENS).

2.8 Summary of Norway

In Norway, the ENS caused by grid disturbances was 640 MWh in 2020 (10-year annual average 3437 MWh). There were 229 grid disturbances (10-year annual average 304) and 37 of them caused ENS.

In 2020, 94 % of the total ENS was caused by substation faults, and 6 % by overhead line faults. The most significant reasons for ENS caused by disturbances were technical equipment (86 %) and operation and maintenance (9 %). Disturbances were caused most by other environmental causes (38 %) and technical equipment (17 %).

Secondary faults in Norway accounted for 11 % of all faults in 2020 and caused approximately 26 % of the total ENS. Secondary faults were primarily caused by technical equipment (50 %) and other environmental causes (11 %), and the ENS of the secondary faults was mainly due to external influences (99 %).

The most significant disturbances in 2020 were the following:

- A 300 kV line from Fana to Lille Sotra tripped unintendedly due to a fault on an older line differential protection relay. The auto-reclosing logic for the line was turned off as planned, the area had not full N-1 security due to maintenance work, and the system protection scheme was also offline due to human error. These factors resulted in an outage of 390 MW load for an oil/and gas facility, as well as 332 MWh of ENS.
- A 420 kV GIS Busbar A in Halden had a correct complete busbar trip due to a short-circuit in a breaker towards Sweden. At the same time, Busbar B in Halden was out due to maintenance. The exchange capacity between Norway and Sweden was also reduced due to this outage. The breaker failure disconnected 240 MW of load, including both paper industry and ordinary load, and resulted in 310 MWh of ENS.
- The Tegneby transformers T1 and T3 tripped due to a combo of high reactive load on the load side, software error on both transformers' voltage regulators and strict transformer relay settings. This incident disconnected 180 MW of load and resulted in 220 MWh of ENS.

2.9 Summary of Sweden

In Sweden, the ENS caused by grid disturbances was 667 MWh in 2020 (10-year annual average 1532 MWh). There were 387 grid disturbances (10-year annual average 456) and 125 of them caused ENS.

In 2020, 67 % of the total ENS was caused by overhead line faults, and 16 % by substation faults. The most significant reasons for ENS caused by disturbances were lightning (33 %) and technical equipment (26 %). Disturbances were caused most by unknown causes (38 %) and lightning (27 %).

Secondary faults in Sweden accounted for 2 % of all faults in 2020 and caused no ENS. Secondary faults were primarily caused by technical equipment (89 %) and lightning (11 %).

There were no significant grid disturbances causing ENS in Sweden in 2020. One interesting disturbance was the disconnection of approximately 5000 subscribers for approximately 2 hours at the end of February. It was caused by a single-phase earth fault that tripped one overhead line, and as it was a radial supply of a 220 kV busbar, it also disconnected local electrical power plants.

3 Disturbances

3.1 Overview

This chapter presents grid disturbances. The presentation includes an overview in Section 3.1, disturbances per month in Section 3.2, and disturbances per cause in Section 3.3.

Table 3.1 presents the number of grid disturbances in 2020 per country and the annual averages for 2011–2020, and Figure 3.1 shows the annual number of disturbances for 2011–2020, both in the 100–420 kV grids.

A grid disturbance is defined as:

> "Outages, forced or unintended disconnection or failed re-connection (of a component) as a result of faults in the power grid" [1, p. 5].

It is essential to note the difference between a grid disturbance and a fault. A grid disturbance is initiated by a fault, called the primary fault, and may be followed by consequential faults, called secondary faults. Only secondary faults that extend or aggravate a disturbance are included in this report.

The voltage level of a grid disturbance is determined by the voltage level of its primary fault.

Table 3.1: The number of disturbances and disturbances causing ENS in 2020, and their annual averages for 2011–2020 in the 100–420 kV grids.

	Disturbances		Disturbances causing ENS	
	Number	Annual average	Number	Annual average
Country	2020	2011–2020	2020	2011–2020
Estonia	127	185.6	14	29.4
Latvia[1]	123	137.1	12	16.1
Lithuania[1]	148	155.9	13	18.4
Baltic total	398	478.6	39	64.0
Denmark	58	57.0	2	6.6
Finland	345	425.9	86	72.6
Iceland	60	40.5	22	19.5
Norway	229	304.4	37	83.8
Sweden	387	456.4	125	148.1
Nordic total	1079	1284.2	272	330.6
Baltic & Nordic Total	1477	1762.8	311	394.6

[1] The data of Latvia and Lithuania cover 2012–2020.

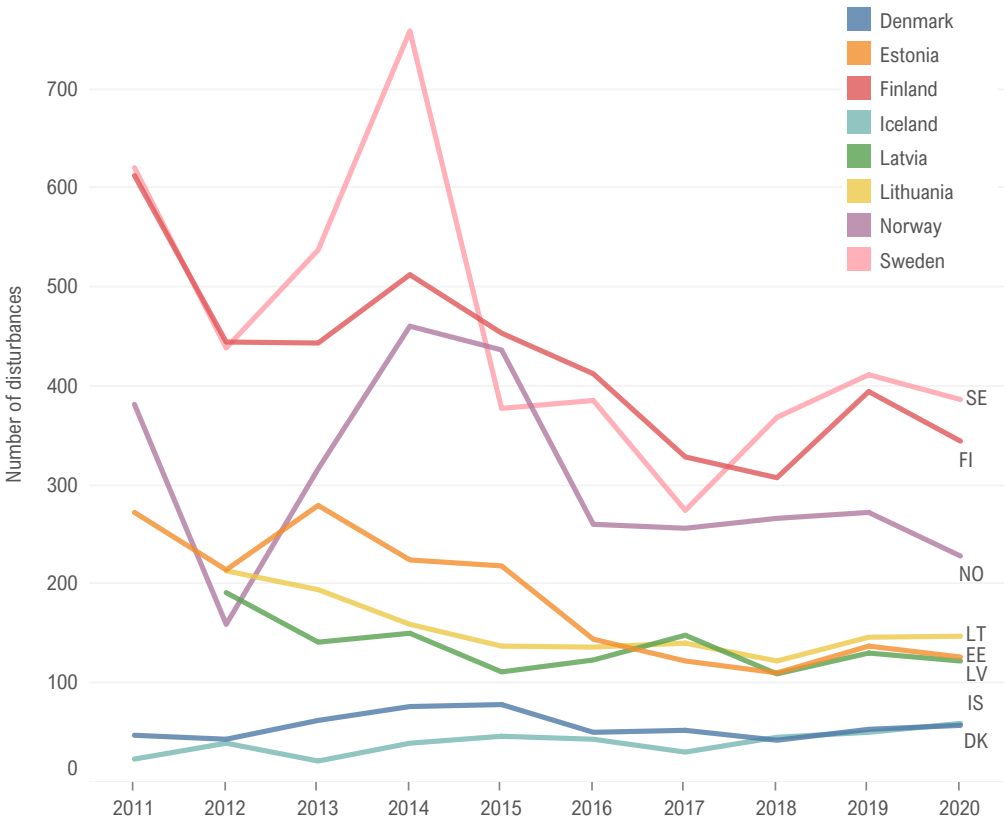

Figure 3.1: Annual number of grid disturbances in the 100–420 kV grids. Nordic and Estonian data as of 2011 and Latvian and Lithuanian data as of 2012.

3.2 Disturbances distributed per month

Table 3.2 presents the percentage allocation of grid disturbances in the 100–420 kV grids by month in 2020. Table 3.3 presents percentage allocation by month over 2011–2020, except for Latvia and Lithuania the data covers 2012–2020.

Table 3.2: Percentage allocation of grid disturbances in the 100–420 kV grids by month in 2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Estonia	5%	7%	4%	5%	6%	22%	18%	9%	5%	6%	12%	3%
Latvia	1%	5%	15%	11%	7%	17%	12%	14%	11%	3%	2%	2%
Lithuania	2%	2%	20%	4%	9%	15%	12%	16%	7%	3%	3%	6%
Denmark	5%	9%	2%	12%	5%	3%	7%	26%	9%	9%	9%	5%
Finland	4%	3%	4%	7%	11%	16%	24%	11%	9%	8%	2%	3%
Iceland	18%	23%	8%	2%	2%	8%	7%	3%	10%	3%	5%	10%
Norway	17%	15%	5%	5%	2%	12%	4%	7%	12%	3%	10%	7%
Sweden	4%	6%	4%	7%	8%	23%	11%	14%	10%	5%	4%	4%

Table 3.3: Percentage allocation of grid disturbances in the 100–420 kV grids by month over 2011–2020, except for Latvia and Lithuania the data covers 2012–2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Estonia	3%	3%	4%	5%	9%	13%	20%	20%	6%	7%	4%	6%
Latvia	3%	3%	6%	5%	9%	12%	14%	21%	8%	7%	5%	6%
Lithuania	2%	2%	7%	6%	9%	11%	18%	28%	5%	6%	3%	4%
Denmark	7%	6%	6%	7%	8%	9%	8%	11%	9%	9%	8%	11%
Finland	6%	4%	3%	6%	10%	14%	24%	13%	7%	4%	3%	5%
Iceland	11%	14%	13%	5%	4%	6%	6%	3%	6%	6%	8%	17%
Norway	14%	8%	8%	4%	4%	8%	12%	8%	6%	5%	8%	14%
Sweden	5%	4%	3%	5%	8%	14%	22%	17%	7%	5%	5%	6%

3.3 Disturbances distributed per cause

This section presents grid disturbances in the 100–420 kV grids per cause, the cause defined as the cause of the disturbance's primary fault. The used causes are lightning, other environmental causes, external influences, operation and maintenance, technical equipment, other causes and unknown. The causes are explained in more detail in Section 1.6.

Table 3.4 presents the percentage allocation of grid disturbances by cause in terms of the primary fault in 2020. Table 3.5 shows the respective percentages over 2011–2020.

Table 3.6 presents the percentage allocation of grid disturbances that caused ENS by cause in terms of the primary fault in 2020. Table 3.7 shows the respective percentages over 2011–2020.

Table 3.4: Grid disturbances (%) by cause for 2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	10%	17%	4%	7%	26%	19%	17%
Latvia	8%	40%	21%	2%	7%	7%	15%
Lithuania	5%	12%	28%	7%	5%	27%	15%
Denmark	3%	2%	36%	22%	21%	12%	3%
Finland	16%	25%	2%	8%	5%	28%	16%
Iceland	2%	32%	0%	8%	0%	52%	7%
Norway	14%	38%	0%	12%	17%	14%	5%
Sweden	27%	2%	2%	10%	13%	8%	38%

Table 3.5: Percentage allocation of grid disturbances by cause over 2011–2020, except for Latvia and Lithuania the data covers 2012–2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	11%	24%	7%	14%	22%	11%	11%
Latvia	10%	23%	23%	6%	9%	10%	19%
Lithuania	9%	5%	25%	7%	7%	14%	33%
Denmark	10%	8%	23%	18%	17%	11%	12%
Finland	22%	32%	1%	6%	5%	18%	17%
Iceland	3%	38%	2%	12%	13%	30%	3%
Norway	20%	34%	2%	13%	18%	9%	4%
Sweden	36%	4%	1%	8%	14%	10%	27%

Table 3.6: Percentage allocation of grid disturbances that caused ENS by cause in 2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	7%	0%	0%	14%	43%	21%	14%
Latvia	8%	33%	8%	8%	25%	17%	0%
Lithuania	8%	8%	38%	31%	8%	8%	0%
Denmark	0%	0%	0%	100%	0%	0%	0%
Finland	15%	7%	5%	8%	7%	14%	44%
Iceland	5%	55%	0%	5%	0%	36%	0%
Norway	27%	22%	0%	24%	27%	0%	0%
Sweden	32%	2%	2%	10%	14%	1%	38%

Table 3.7: Percentage allocation of grid disturbances that caused ENS by cause over 2011–2020, except for Latvia and Lithuania the data covers 2012–2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	3%	8%	10%	26%	22%	22%	8%
Latvia	1%	30%	26%	18%	16%	6%	3%
Lithuania	5%	9%	37%	22%	14%	4%	8%
Denmark	3%	6%	2%	47%	24%	12%	6%
Finland	17%	17%	2%	9%	8%	14%	33%
Iceland	4%	47%	2%	12%	13%	21%	1%
Norway	24%	28%	2%	18%	15%	11%	3%
Sweden	39%	2%	2%	10%	14%	6%	28%

4 Energy not supplied

This chapter presents energy not supplied (ENS) caused by grid disturbances. The presentation includes the amount of ENS in 2020 per country and the annual averages for 2011–2020. Furthermore, ENS is compared to consumption in Section 4.2, allocated by month in Section 4.3, allocated by cause in Section 4.4, allocated by voltage level in Section 4.5, and examined at component level in Section 4.6.

4.1 Overview

Table 4.1 shows the amount of ENS in 2020 per country and the annual averages for 2011–2020.

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].

One should remember that the amount of ENS is always an estimation and its accuracy, as well as calculation method, varies between companies, as described in Appendix A.

Table 4.1: ENS in 2020 and the annual averages for 2011–2020.

	ENS (MWh)	
		Annual average
Country	2020	2011–2020
Estonia	10.5	179.8
Latvia[1]	170.5	88.9
Lithuania[1]	31.9	40.4
Baltic total	212.9	309.2
Denmark	26.9	28.3
Finland	149.1	297.5
Iceland	561.8	1073.9
Norway	639.9	3437.0
Sweden[2]	666.6	1531.8
Nordic total	2044.3	6368.6
Baltic & Nordic Total	2257.2	6677.7

[1] The data of Latvia and Lithuania cover 2012–2020.
[2] The data from one Swedish regional grid company in 2012 was incomplete. The details of the origin of the fault were not reported, thus leaving 750 MWh of ENS missing from that year.

4.2 Energy not supplied and total consumption

This section presents ENS normalised by the total electricity consumption. Table 4.2 shows the consumption, ENS, and the ENS to consumption ratio.

Figure 4.1 presents the 5-year moving average of ENS scaled to consumption since 2000 in the Nordic countries, since 2007 in Estonia, and since 2012 in Latvia and Lithuania.

There is a considerable annual variance due to occasional events, such as storms. These events have a significant effect on each country's annual statistics.

More information on past events are available in the previous Nordic and Baltic statistics and from the contact persons in Appendix C. Iceland's high values, seen in Table 4.2 and Figure 4.1, are a result of power intensive industries that cause substantial amounts of ENS even during short interruptions.

Table 4.2: Electricity consumption, ENS, and their ratio in 2020 and the corresponding annual averages for 2011–2020. Ppm (parts per million) represents ENS (MWh) as a proportional value of the consumed energy (TWh).

	Consumption	ENS	ENS / consumption (ppm)	
	(TWh)	(MWh)		Annual average
Country	2020	2020	2020	2011–2020
Estonia	8.4	10.5	1.2	22.4
Latvia[1]	7.1	170.5	23.9	12.6
Lithuania[1]	13.1	31.9	2.4	3.7
Baltic total	28.6	212.9	7.4	11.9
Denmark	35.3	26.9	0.8	0.8
Finland	78.5	149.1	1.9	3.5
Iceland	17.9	561.8	31.4	59.8
Norway	132.9	639.9	4.8	26.4
Sweden	133.8	666.6	5.0	11.1
Nordic total	398.3	2044.3	5.1	15.8
Baltic & Nordic Total	427.0	2257.2	5.3	15.5

[1] The data of Latvia and Lithuania cover 2012–2020.

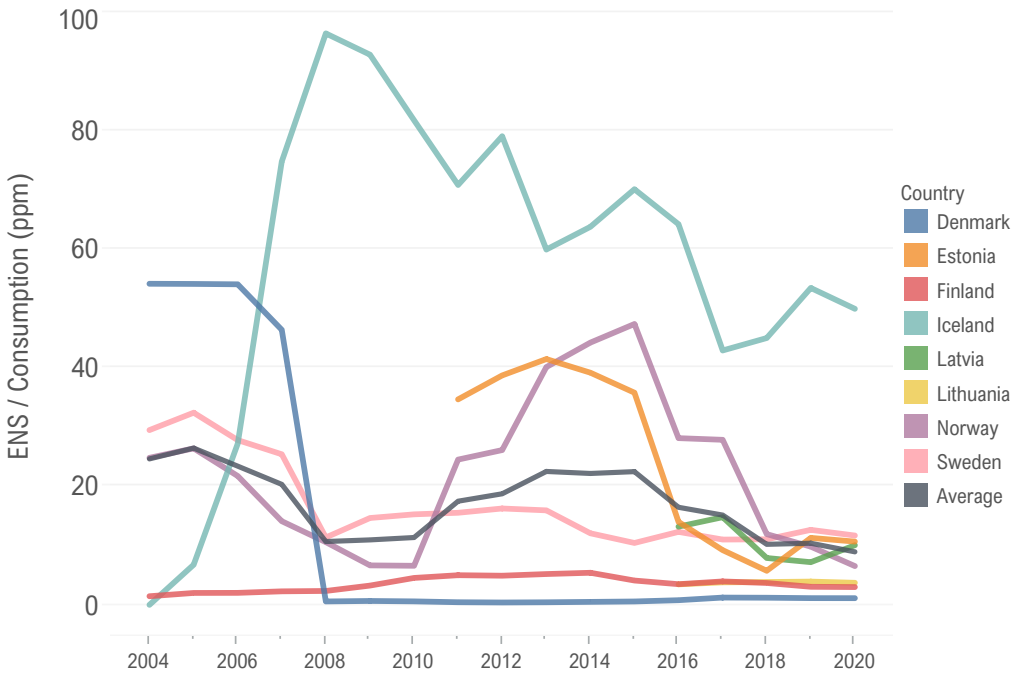

Figure 4.1: 5-year moving average for the amount of ENS divided per consumption (ppm) since 2000. Estonia has data since 2007 and since Latvia and Lithuania have data since 2012. Ppm (parts per million) represents ENS (MWh) as a proportional value of the consumed energy (TWh).

4.3 Energy not supplied per month

This section presents ENS due to disturbances that occurred in the 100–420 kV grids divided per month. Table 4.3 shows the percentage allocation of ENS by month in 2020 and Table 4.4 presents the respective percentage values over 2011–2020.

Table 4.3: ENS (%) by month in 2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Estonia	69%	0%	0%	0%	0%	1%	6%	0%	1%	2%	22%	0%
Latvia	0%	0%	0%	0%	0%	92%	1%	3%	1%	0%	0%	4%
Lithuania	0%	1%	85%	0%	0%	6%	0%	0%	5%	0%	1%	0%
Denmark	0%	0%	0%	39%	0%	0%	0%	0%	61%	0%	0%	0%
Finland	10%	2%	7%	22%	14%	12%	2%	1%	3%	28%	0%	0%
Iceland	16%	55%	16%	0%	2%	7%	0%	4%	0%	0%	0%	0%
Norway	2%	1%	2%	3%	0%	1%	0%	6%	53%	32%	0%	0%
Sweden	1%	14%	16%	5%	11%	27%	6%	7%	4%	6%	2%	0%

Table 4.4: Percentage allocation of ENS by month over 2011–2020, except for Latvia and Lithuania for which the data covers 2012–2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Estonia	5%	3%	2%	3%	5%	3%	7%	2%	4%	15%	12%	39%
Latvia	1%	0%	2%	0%	3%	23%	8%	10%	7%	36%	4%	6%
Lithuania	2%	8%	13%	6%	6%	24%	18%	7%	2%	10%	1%	3%
Denmark	5%	16%	6%	6%	8%	4%	1%	4%	6%	31%	4%	9%
Finland	6%	5%	9%	6%	3%	8%	14%	14%	3%	5%	10%	16%
Iceland	36%	12%	6%	2%	1%	5%	3%	1%	4%	4%	4%	23%
Norway	8%	7%	30%	3%	1%	4%	2%	2%	2%	1%	4%	35%
Sweden	5%	6%	3%	4%	6%	13%	22%	14%	5%	10%	5%	8%

4.4 Energy not supplied per cause

This section presents ENS per the cause of each fault. The used causes are lightning, other environmental causes, external influences, operation and maintenance, technical equipment, other causes and unknown. The causes are explained in more detail in Section 1.6.

Table 4.5 presents the percentage allocation of ENS by cause in 2020. Table 4.6 shows the respective percentages over 2011–2020.

Table 4.5: ENS (%) by cause in 2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	1%	0%	0%	85%	12%	0%	2%
Latvia	0%	0%	0%	92%	7%	1%	0%
Lithuania	2%	0%	6%	10%	77%	4%	0%
Denmark	0%	0%	0%	100%	0%	0%	0%
Finland	9%	1%	19%	14%	15%	10%	32%
Iceland	0%	27%	0%	4%	0%	69%	0%
Norway	3%	3%	26%	9%	60%	0%	0%
Sweden	32%	0%	7%	12%	19%	23%	7%

Table 4.6: Percentage allocation of ENS by cause over 2011–2020, except for Latvia and Lithuania the data covers 2012–2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	3%	1%	23%	7%	38%	26%	1%
Latvia	0%	40%	12%	38%	9%	0%	0%
Lithuania	1%	12%	32%	14%	35%	4%	2%
Denmark	1%	8%	0%	54%	29%	7%	1%
Finland	10%	17%	3%	8%	30%	22%	9%
Iceland	2%	52%	1%	14%	11%	21%	0%
Norway	4%	65%	1%	4%	13%	12%	1%
Sweden	27%	1%	4%	9%	33%	9%	18%

The reason behind Sweden having more disturbances and ENS due to unknown causes is that if the cause of a disturbance is not 100 % certain, which might be the case with lightning, it is reported as an unknown cause as explained in Appendix B.

4.5 Energy not supplied per voltage level

Table 4.7 and Table 4.8 show the amount of ENS and its allocation by voltage level in 2020 and for 2011–2020.

Table 4.7: ENS in 2020 and its annual average for 2011–2020, and the annual average amount of ENS by voltage level for 2011–2020.

	ENS (MWh)		Average annual ENS (MWh) by voltage level over 2011–2020			
Country	2020	Annual average 2011–2020	100–150 kV	220–330 kV	380–420 kV	Other[1]
Estonia	10.5	179.8	141.7	4.9	0.0	42.8
Latvia[3]	170.5	88.9	69.3	19.4	0.0	0.2
Lithuania[3]	31.9	40.4	38.9	1.0	0.0	0.6
Baltic total	212.9	309.2	250.0	25.3	0.0	43.6
Denmark	26.9	28.3	27.0	0.0	0.0	1.4
Finland	149.1	297.5	263.4	2.7	11.7	37.0
Iceland	561.8	1073.9	395.7	551.1	0.0	208.3
Norway	639.9	3437.0	1081.1	304.1	2030.6	12.6
Sweden	666.6	1531.8	1224.3	110.5	52.0	111.1
Nordic total	2044.3	6368.6	2991.7	968.5	2094.3	370.4
Baltic & Nordic total	2257.2	6677.7	3241.6	993.7	2094.3	414.0

[1] The category *Other* contains ENS from, for example, system faults, lower voltage level networks and connections to foreign countries.
[2] The data of Latvia and Lithuania cover 2012–2020.

Table 4.8: ENS (MWh) per statistical voltage level in 2020.

Country	100–150 kV	220–330 kV	380–420 kV	Other
Estonia	10.5	0.0	0.0	0.0
Latvia	13.7	155.9	0.0	0.9
Lithuania	31.9	0.0	0.0	0.0
Denmark	26.9	0.0	0.0	0.0
Finland	147.4	1.6	0.0	0.1
Iceland	206.6	38.2	0.0	317.1
Norway	38.7	390.0	211.2	0.0
Sweden	564.7	21.0	1.3	79.6
Baltic & Nordic	1040.4	606.6	212.5	397.7

4.6 Energy not supplied per component

Table 4.9 presents the percentage allocation of ENS per component in 2020, and Table 4.10 shows the respective percentages over 2011–2020. The ENS is allocated to the component where each fault occurred. The total amount of ENS in 2020 and the annual average values for 2011–2020 are in Table 4.7.

Table 4.9: ENS (%) per component in 2020. The ENS is allocated to the component where each fault occurred. Proportionately higher percentage values are highlighted in yellow and red.

Lines
- Cables
- Overhead lines

Substation components
- Busbars
- Circuit breakers
- Common ancillary equipment
- Control equipment
- Disconnectors
- Instrument transformers
- Power transformers
- Surge arresters and spark gaps
- Other high voltage appliances

Compensation devices
- Reactors
- Series capacitors
- Shunt capacitors
- SVC and statcom
- Synchronous compensators

Other
- Adjoining grid
- System faults

	Lines			Substation components										Compensation devices						Other		
			Total										Total				SVC		Total			Total
Estonia	0%	1%	1%	2%	0%	1%	23%	73%	0%	0%	0%	0%	99%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Latvia	0%	0%	0%	0%	1%	0%	96%	0%	3%	0%	0%	0%	99%	0%	0%	0%	0%	0%	0%	1%	0%	1%
Lithuania	0%	95%	95%	0%	0%	0%	0%	0%	4%	0%	1%	0%	5%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Denmark	0%	0%	0%	0%	61%	0%	39%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Finland	0%	58%	58%	12%	12%	0%	16%	0%	0%	0%	1%	0%	42%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Iceland	11%	10%	21%	0%	0%	0%	7%	0%	0%	11%	0%	4%	23%	0%	0%	0%	0%	0%	0%	56%	0%	56%
Norway	1%	6%	6%	1%	32%	1%	54%	0%	6%	0%	0%	0%	94%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Sweden	5%	67%	72%	0%	0%	0%	13%	0%	1%	0%	0%	0%	16%	0%	0%	0%	0%	0%	0%	12%	0%	12%

Table 4.10: Percentage allocation of ENS per component over 2011–2020, except for Latvia and Lithuania the data covers 2012–2020. The ENS is allocated to the component where each fault occurred. Proportionately higher percentage values are highlighted in yellow and red. The symbols are presented in Table 4.9.

	Lines			Substation components										Compensation devices						Other		
			Total										Total				SVC		Total			Total
Estonia	1%	49%	49%	1%	1%	0%	7%	0%	0%	12%	4%	0%	25%	0%	0%	2%	0%	0%	2%	24%	0%	24%
Latvia	0%	51%	51%	3%	0%	0%	38%	3%	1%	0%	3%	0%	48%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Lithuania	1%	52%	53%	1%	7%	0%	25%	8%	1%	0%	1%	1%	46%	0%	0%	0%	0%	0%	0%	2%	0%	2%
Denmark	0%	2%	2%	48%	12%	0%	10%	8%	7%	0%	8%	0%	92%	1%	0%	0%	0%	0%	1%	5%	0%	5%
Finland	0%	55%	56%	2%	4%	0%	10%	1%	5%	3%	4%	3%	31%	0%	1%	0%	0%	0%	1%	12%	1%	12%
Iceland	1%	16%	17%	0%	29%	0%	14%	0%	0%	7%	13%	0%	64%	0%	0%	0%	0%	0%	0%	12%	8%	19%
Norway	3%	68%	71%	3%	1%	1%	8%	3%	2%	5%	3%	3%	29%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Sweden	5%	46%	51%	5%	3%	1%	7%	3%	7%	5%	7%	2%	39%	1%	0%	1%	0%	0%	2%	7%	0%	8%

5 Secondary faults

5.1 Overview

This chapter presents statistics about secondary faults, that is, faults that extend or aggravate a grid disturbance.

The number of disturbances with secondary faults is significantly smaller than the number of disturbances with only one fault. However, these disturbances may cause more ENS.

Table 5.1 presents an overview of faults connected to grid disturbances as well as the secondary faults.

Table 5.1: The number of faults (including secondary faults), the number of faults that caused ENS, total ENS, the number of secondary faults, and the amount of ENS caused by secondary faults in 2020.

	Faults in 2020			Secondary faults in 2020	
Country	Number	causing ENS	ENS (MWh)	Number	ENS (MWh)
Estonia	142	14	10.5	15	0.1
Latvia	132	12	170.5	9	163.3
Lithuania	154	13	31.9	6	24.1
Baltic total	428	39	212.9	30	187.6
Denmark	63	2	26.9	5	0.0
Finland	363	88	149.1	18	12.9
Iceland	82	24	561.8	22	84.1
Norway	257	41	639.9	28	167.2
Sweden	396	130	666.6	9	0.0
Nordic total	1161	285	2044.3	82	264.1
Baltic & Nordic Total	1589	324	2257.2	112	451.7

5.2 Statistics of secondary faults

Table 5.2 presents the percentage allocation of secondary faults by cause in 2020, and Table 5.3 shows the respective values over 2017–2020. Table 5.4 presents the annual number of secondary faults for 2017–2020.

Table 5.5 presents the percentage allocation of ENS due to secondary faults in 2020, and Table 5.6 shows the respective values over 2017–2020. Table 5.7 presents the annual amounts of ENS caused by the secondary faults for 2017–2020.

Data about secondary faults have been collected since 2017.

Table 5.2: Percentage allocation of secondary faults by cause in 2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	0%	0%	0%	27%	33%	27%	13%
Latvia	0%	0%	0%	33%	67%	0%	0%
Lithuania	0%	0%	0%	17%	33%	0%	50%
Denmark	0%	0%	20%	80%	0%	0%	0%
Finland	28%	11%	6%	17%	6%	22%	11%
Iceland	0%	5%	0%	5%	0%	91%	0%
Norway	4%	11%	4%	11%	50%	11%	11%
Sweden	11%	0%	0%	0%	89%	0%	0%

Table 5.3: Percentage allocation of secondary faults by cause over 2017–2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	0%	8%	8%	28%	28%	23%	5%
Latvia	0%	0%	0%	32%	54%	8%	6%
Lithuania	2%	0%	0%	27%	21%	13%	38%
Denmark	0%	0%	4%	87%	0%	9%	0%
Finland	13%	9%	4%	30%	4%	24%	15%
Iceland	0%	12%	0%	5%	11%	72%	0%
Norway	14%	8%	2%	25%	36%	9%	8%
Sweden	10%	0%	0%	8%	58%	10%	15%

Table 5.4: Annual number of secondary faults for 2017–2020.

Country	2017	2018	2019	2020	Annual average
Estonia	9	8	7	15	9.8
Latvia	20	20	23	9	14.0
Lithuania	13	19	18	6	18.0
Denmark	9	3	6	5	5.8
Finland	13	9	6	18	11.5
Iceland	8	18	26	22	18.5
Norway	30	34	26	28	29.5
Sweden	10	7	14	9	10.0
Baltic & Nordic	112	118	126	112	117.0

Table 5.5: Percentage allocation of ENS due to secondary faults by cause in 2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	0%	0%	0%	0%	56%	44%	0%
Latvia	0%	0%	0%	95%	5%	0%	0%
Lithuania	0%	0%	0%	0%	100%	0%	0%
Denmark	0%	0%	0%	0%	0%	0%	0%
Finland	63%	0%	2%	34%	0%	1%	0%
Iceland	0%	1%	0%	0%	0%	99%	0%
Norway	0%	0%	99%	0%	1%	0%	0%
Sweden	0%	0%	0%	0%	0%	0%	0%

Table 5.6: Percentage allocation of ENS due to secondary faults by cause over 2017–2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	0%	1%	4%	60%	28%	7%	0%
Latvia	0%	0%	0%	94%	5%	0%	0%
Lithuania	0%	0%	0%	1%	95%	4%	0%
Denmark	0%	0%	0%	76%	0%	24%	0%
Finland	10%	7%	0%	11%	9%	61%	2%
Iceland	0%	1%	0%	0%	0%	99%	0%
Norway	0%	3%	39%	11%	0%	46%	0%
Sweden	0%	0%	0%	0%	0%	79%	20%

Table 5.7: Annual amount of ENS (MWh) due to secondary faults for 2017–2020.

Country	2017	2018	2019	2020	Annual average
Estonia	0.1	0.3	0.1	0.1	0.1
Latvia	16.0	34.1	2.2	163.3	53.9
Lithuania	50.0	25.2	0.5	24.1	25.0
Denmark	4.0	0.3	4.7	0.0	2.2
Finland	6.0	48.2	12.6	12.9	19.9
Iceland	0.0	0.0	0.2	84.1	21.1
Norway	58.8	131.3	71.3	167.2	107.2
Sweden	32.0	0.0	8.4	0.0	10.1
Baltic & Nordic	166.9	239.3	100.0	451.7	239.5

6 Faults in power system components

This chapter presents an overview of all faults related to grid disturbances. Furthermore, faults for each type of power system component are shown. Some figures and tables show values normalised by the length of overhead line or cable, or the number of installed components in each country to allow comparable results.

Section 6.1 gives an overview of all faults, and Section 6.2 shows faults per cause. Sections 6.3–6.8 present a more detailed view, along with fault trends, of cables, overhead lines, circuit breakers, control equipment, and instrument and power transformers. Finally, short statistics of compensation devices are shown in Section 6.9.

6.1 Overview of faults

This section presents an overview of faults. A fault is defined as:

> "The inability of a component to perform its required function" [1, p. 3–4].

This report includes only faults that caused, aggravated or extended a grid disturbance. The causes are presented in more detail in Section 1.6.

Table 6.1 presents the number of faults and the energy not supplied (ENS) caused by them in 2020 and for 2011–2020. Table 6.2 shows the number of faults and number of grid disturbances in 2020, their annual averages for 2011–2020, and the faults to disturbance ratio over 2011–2020.

Table 6.3 shows the percentage allocation of faults per component in 2020, and Table 6.4 shows the respective percentages over 2011–2020. The component groups used in these statistics are further described in the guidelines [1, Section 5.4.10].

Table 6.1: The number of faults, the number of faults that caused ENS and amount of ENS in 2020 and their annual averages for 2011–2020.

	Number of faults		No. of faults with ENS		ENS (MWh)	
Country	2020	Annual avg. 2011–2020	2020	Annual avg. 2011–2020	2020	Annual avg. 2011–2020
Estonia	142	192.0	14	29.4	10.5	179.8
Latvia[1]	132	150.7	12	18.1	170.5	88.9
Lithuania[1]	154	167.6	13	18.6	31.9	40.4
Baltic total	428	510.2	39	66.1	212.9	309.2
Denmark	63	64.5	2	7.4	26.9	28.3
Finland	363	446.7	88	81.5	149.1	297.5
Iceland	82	58.5	24	21.5	561.8	1073.9
Norway	257	348.5	41	95.4	639.9	3437.0
Sweden	396	472.0	130	173.2	666.6	1531.8
Nordic total	1161	1390.2	285	379.0	2044.3	6368.6
Baltic & Nordic Total	1589	1900.4	324.0	445.1	2257.2	6677.7

[1] The data of Latvia and Lithuania cover 2012–2020.

Table 6.2: The number of faults and the number of grid disturbances in 2020, their annual averages for 2011–2020, and the fault to disturbance ratio in 2020 and over 2011–2020.

	Number of faults		No. of disturbances		Ratio	
Country	2020	Annual avg. 2011–2020	2020	Annual avg. 2011–2020	2020	Annual avg. 2011–2020
Estonia	142	192.0	127	185.6	1.12	1.03
Latvia[1]	132	150.7	123	137.1	1.07	1.10
Lithuania[1]	154	167.6	148	155.9	1.04	1.07
Baltic total	428	510.2	398	478.6	1.08	1.07
Denmark	63	64.5	58	57.0	1.09	1.13
Finland	363	446.7	345	425.9	1.05	1.05
Iceland	82	58.5	60	40.5	1.37	1.44
Norway	257	348.5	229	304.4	1.12	1.14
Sweden	396	472.0	387	456.4	1.02	1.03
Nordic total	1161	1390.2	1079	1284.2	1.08	1.08
Baltic & Nordic total	1589	1900.4	1477	1762.8	1.08	1.08

[1] The data of Latvia and Lithuania cover 2012–2020.

Table 6.3: Percentage allocation of faults per component in 2020. Proportionately higher percentage values are highlighted in yellow and red.

Lines
- Cables
- Overhead lines

Substation components
- Busbars
- Circuit breakers
- Common ancillary equipment
- Control equipment
- Disconnectors
- Instrument transformers
- Power transformers
- Surge arresters and spark gaps
- Other high voltage appliances

Compensation devices
- Reactors
- Series capacitors
- Shunt capacitors
- SVC and statcom
- Synchronous compensators

Other
- Adjoining grid
- System faults

	Lines			Substation components										Compensation devices						Other		
			Total										Total				SVC		Total			Total
Estonia	0%	37%	37%	6%	4%	1%	23%	6%	2%	1%	4%	0%	47%	1%	0%	1%	0%	0%	3%	13%	0%	13%
Latvia	1%	78%	79%	0%	2%	0%	9%	0%	2%	0%	1%	1%	14%	0%	0%	0%	0%	0%	0%	7%	0%	7%
Lithuania	0%	63%	63%	3%	3%	0%	7%	0%	1%	1%	2%	1%	17%	0%	0%	0%	0%	0%	0%	20%	0%	20%
Denmark	6%	41%	48%	0%	5%	0%	21%	0%	0%	3%	2%	2%	32%	3%	0%	0%	0%	8%	11%	10%	0%	10%
Finland	0%	80%	80%	1%	2%	0%	8%	0%	0%	0%	1%	2%	14%	0%	1%	1%	0%	0%	2%	4%	0%	4%
Iceland	2%	22%	24%	0%	5%	1%	10%	1%	0%	5%	6%	1%	29%	0%	0%	0%	0%	0%	0%	30%	16%	46%
Norway	1%	46%	47%	2%	2%	5%	16%	0%	2%	1%	2%	0%	32%	0%	0%	0%	6%	2%	9%	0%	13%	13%
Sweden	2%	61%	63%	0%	5%	1%	11%	0%	2%	0%	1%	0%	19%	1%	1%	0%	1%	0%	2%	13%	3%	16%

Table 6.4: Percentage allocation of faults per component over 2011–2020, except for Latvia and Lithuania the data covers 2012–2020. Proportionately higher percentage values are highlighted in yellow and red. The symbols are presented in Table 6.3.

	Lines			Substation components										Compensation devices						Other		
			Total										Total				SVC		Total			Total
Estonia	0%	58%	58%	2%	4%	1%	6%	3%	1%	7%	5%	0%	30%	1%	0%	1%	0%	0%	2%	10%	0%	10%
Latvia	0%	67%	67%	1%	2%	0%	14%	1%	1%	0%	4%	1%	23%	1%	0%	0%	0%	0%	1%	9%	0%	9%
Lithuania	0%	67%	67%	2%	5%	1%	10%	1%	1%	0%	1%	1%	20%	0%	0%	0%	0%	0%	0%	12%	0%	12%
Denmark	5%	45%	50%	4%	5%	0%	14%	2%	3%	3%	7%	0%	37%	2%	0%	0%	1%	2%	5%	8%	0%	8%
Finland	0%	81%	81%	0%	1%	0%	7%	0%	1%	1%	2%	0%	13%	0%	1%	1%	0%	0%	2%	4%	0%	4%
Iceland	1%	33%	34%	0%	6%	0%	14%	1%	0%	4%	5%	0%	29%	0%	0%	1%	0%	0%	2%	19%	17%	36%
Norway	1%	49%	50%	1%	4%	1%	18%	1%	2%	9%	2%	1%	41%	0%	0%	1%	5%	1%	7%	0%	1%	1%
Sweden	1%	61%	62%	1%	2%	1%	10%	2%	1%	2%	5%	0%	25%	2%	2%	0%	2%	0%	6%	7%	1%	8%

6.2 Faults per cause

This section presents faults according to cause, with the cause of a fault defined as the primary cause of the fault. The used causes are lightning, other environmental causes, external influences, operation and maintenance, technical equipment, other causes and unknown. The causes are explained in more detail in Section 1.6.

There are minor differences in the fault cause groupings between countries. This report uses the fault causes presented in Table 1.1. Appendix B describes how each Nordic and Baltic TSO examines the cause of line faults.

Table 6.5 presents the percentage allocation of faults by cause in 2020. Table 6.6 shows the respective percentages over 2011–2020.

Table 6.7 presents the percentage allocation of faults that caused ENS by cause in 2020. Table 6.8 shows the respective percentages over 2011–2020.

Table 6.5: Percentage allocation of the number of faults by cause in 2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	9%	15%	4%	9%	27%	20%	17%
Latvia	8%	37%	20%	4%	11%	7%	14%
Lithuania	5%	12%	27%	8%	6%	26%	16%
Denmark	3%	2%	35%	27%	19%	11%	3%
Finland	16%	25%	2%	8%	5%	28%	16%
Iceland	1%	24%	0%	5%	0%	68%	1%
Norway	11%	35%	1%	11%	20%	18%	4%
Sweden	25%	2%	2%	9%	14%	17%	32%

Table 6.6: Percentage allocation of the number of faults by cause over 2011–2020, except for Latvia and Lithuania the data covers 2012–2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	11%	23%	7%	15%	23%	11%	11%
Latvia	9%	21%	21%	9%	12%	9%	17%
Lithuania	8%	4%	23%	9%	8%	14%	33%
Denmark	10%	8%	21%	21%	17%	12%	12%
Finland	21%	31%	1%	7%	5%	18%	17%
Iceland	2%	31%	1%	8%	13%	44%	1%
Norway	19%	31%	2%	15%	19%	11%	4%
Sweden	35%	4%	1%	8%	15%	12%	25%

Table 6.7: Percentage allocation of the number of faults that caused ENS by cause in 2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	7%	0%	0%	14%	43%	21%	14%
Latvia	8%	8%	8%	25%	42%	8%	0%
Lithuania	8%	8%	31%	31%	15%	8%	0%
Denmark	0%	0%	0%	100%	0%	0%	0%
Finland	17%	7%	6%	11%	6%	11%	42%
Iceland	4%	54%	0%	4%	0%	38%	0%
Norway	24%	20%	2%	22%	29%	2%	0%
Sweden	30%	2%	2%	8%	12%	14%	31%

Table 6.8: Percentage allocation of the number of faults that caused ENS by cause over 2011–2020, except for Latvia and Lithuania the data covers 2012–2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	3%	8%	10%	27%	22%	22%	8%
Latvia	1%	21%	15%	29%	27%	2%	4%
Lithuania	4%	9%	35%	23%	16%	6%	7%
Denmark	3%	5%	1%	45%	24%	16%	5%
Finland	16%	15%	3%	11%	8%	15%	32%
Iceland	3%	45%	1%	11%	14%	25%	0%
Norway	23%	26%	2%	19%	15%	12%	2%
Sweden	35%	2%	2%	10%	15%	11%	26%

6.3 Faults in cables

This section presents cable faults in 2020 and for 2011–2020.

Table 6.9 presents the length of cables and the number of faults in 2020, and the 10-year annual average of the number of faults for 2011–2020. Table 6.10 presents the number of faults per 100 km of cable in 2020 and the annual averages for 2011–2020.

Table 6.11 shows the percentage allocation of cable faults by cause in 2020. Table 6.12 presents the respective percentages over 2011–2020.

Figure 6.1 presents the 5-year moving average of cable faults per 100 km.

Table 6.9: Length of cable (km) and the number of cable faults in 2020, and the annual average number of faults for 2011–2020, grouped by voltage level. The data of Latvia and Lithuania cover 2012–2020.

Country	100–150 kV			220–330 kV			380–420 kV		
	km in 2020	Number of faults in 2020	10-year ann. avg of faults	km in 2020	Number of faults in 2020	10-year ann. avg of faults	km in 2020	Number of faults in 2020	10-year ann. avg of faults
Estonia	103.0	0	0.4	0.0	0	0.0	0.0	0	0.0
Latvia	82.0	0	0.1	22.4	1	0.2	0.0	0	0.0
Lithuania	112.0	0	0.2	0.3	0	0.0	0.0	0	0.0
Denmark	1 708.4	4	2.7	366.0	0	0.3	214.5	0	0.1
Finland	10.0	1	1.3	0.0	0	0.0	0.0	0	0.0
Iceland	89.6	2	0.3	0.0	0	0.0	0.0	0	0.0
Norway	422.0	1	3.4	98.0	0	0.0	25.0	1	0.8
Sweden	485.5	5	2.6	140.2	1	1.4	27.2	0	0.4
Baltic & Nordic	3 012.4	13	11.0	626.8	2	1.9	266.7	1	1.3

Table 6.10: Number of cable faults per 100 km in 2020 and the annual average for 2011–2020, grouped by voltage level. The data of Latvia and Lithuania cover 2012–2020.

Country	100–150 kV		220–330 kV		380–420 kV	
	Number of faults / 100 km in 2020	10-year ann. avg no. of faults / 100 km	Number of faults / 100 km in 2020	10-year ann. avg no. of faults / 100 km	Number of faults / 100 km in 2020	10-year ann. avg no. of faults / 100 km
Estonia	0.00	0.63	0.00	0.00	0.00	0.00
Latvia	0.00	0.15	4.47	1.48	0.00	0.00
Lithuania	0.00	0.27	0.00	0.00	0.00	0.00
Denmark	0.23	0.22	0.00	0.21	0.00	0.07
Finland	10.00	0.68	0.00	0.00	0.00	0.00
Iceland	2.23	0.27	0.00	0.00	0.00	0.00
Norway	0.24	1.09	0.00	0.00	4.00	3.20
Sweden	1.03	0.63	0.71	1.15	0.00	3.18
Baltic & Nordic	0.43	0.44	0.32	0.53	0.37	0.74

Table 6.11: Percentage allocation of cable faults by cause in 2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	0%	0%	0%	0%	0%	0%	0%
Latvia	0%	0%	0%	0%	100%	0%	0%
Lithuania	0%	0%	0%	0%	0%	0%	0%
Denmark	0%	0%	0%	25%	50%	0%	25%
Finland	0%	100%	0%	0%	0%	0%	0%
Iceland	0%	50%	0%	0%	0%	50%	0%
Norway	0%	50%	50%	0%	0%	0%	0%
Sweden	0%	0%	0%	67%	33%	0%	0%

Table 6.12: Percentage allocation of cable faults by cause over 2011–2020, except for Latvia and Lithuania the data covers 2012–2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	0%	0%	50%	0%	50%	0%	0%
Latvia	0%	0%	0%	0%	100%	0%	0%
Lithuania	0%	0%	50%	0%	50%	0%	0%
Denmark	0%	0%	10%	16%	68%	0%	6%
Finland	0%	8%	8%	23%	23%	23%	15%
Iceland	0%	33%	0%	33%	0%	33%	0%
Norway	0%	26%	7%	5%	36%	19%	7%
Sweden	4%	0%	2%	11%	64%	2%	17%

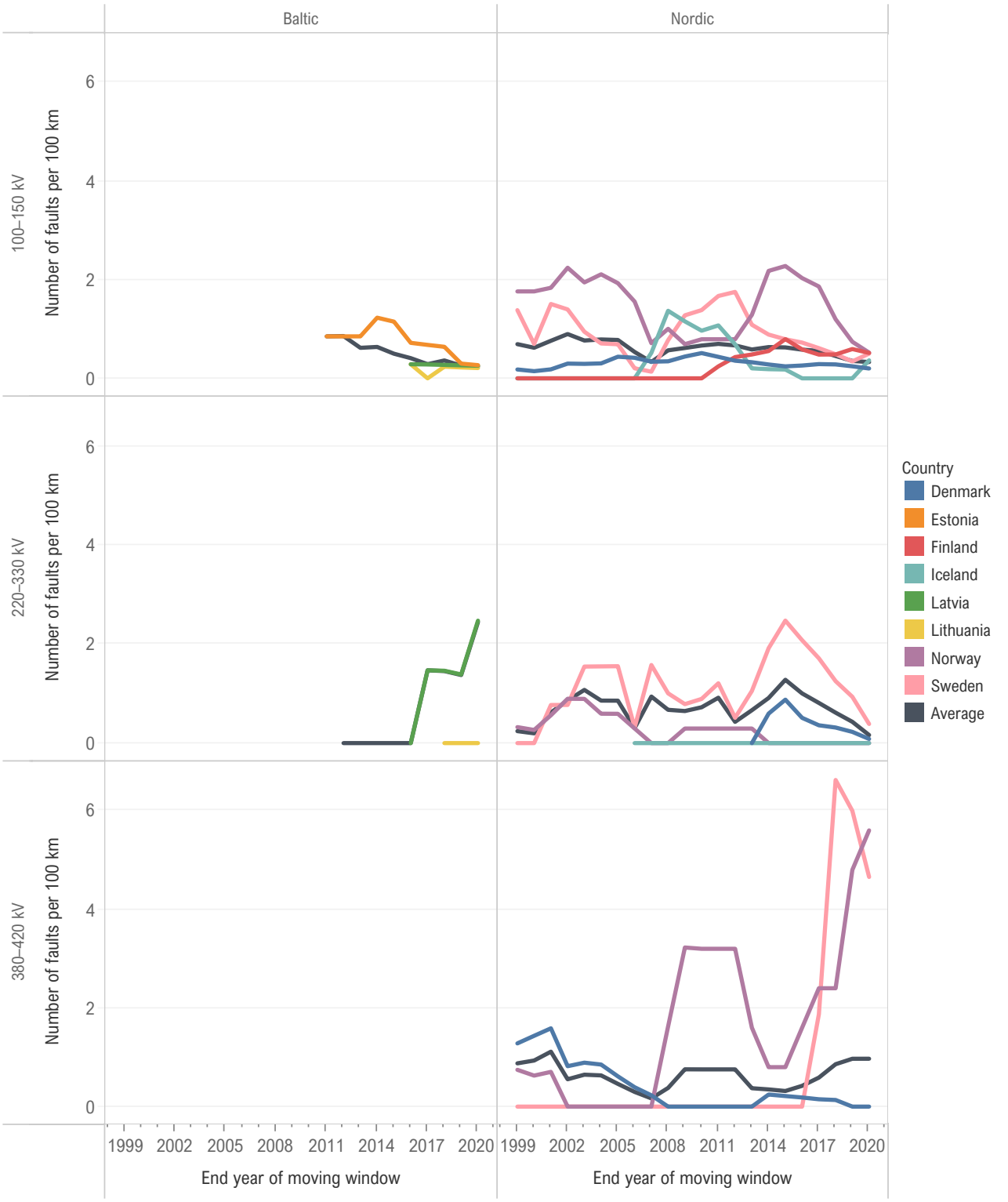

Figure 6.1: 5-year moving average of cable faults per 100 km. Estonia has data since 2007, and Latvia and Lithuania have data since 2012. Estonia, Finland and Lithuania do not own 220–330 kV cables. Estonia, Finland, Iceland, Latvia and Lithuania do not own 380–420 kV cables.

6.4 Faults on overhead lines

This section presents overhead line faults in 2020 and for 2011–2020.

Table 6.13 presents the length of overhead lines and the number of faults in 2020, and the 10-year annual average of the number of faults for 2011–2020. Table 6.14 presents the number of faults per 100 km of overhead line in 2020 and the annual averages for 2011–2020.

Table 6.15 presents the number of faults and the number of permanent faults for 2020 and their 10-year respective average values for 2011–2020.

Table 6.16 shows the percentage allocation of overhead line faults by cause in 2020. Table 6.17 presents the respective percentages over 2011–2020.

Figure 6.2 presents the 5-year moving average of overhead line faults per 100 km.

Table 6.13: Length of overhead line (km) and number faults in 2020, and the annual average number of faults for 2011–2020, grouped by voltage level. The data of Latvia and Lithuania cover 2012–2020.

Country	100–150 kV			220–330 kV			380–420 kV		
	km in 2020	Number of faults in 2020	10-year ann. avg of faults	km in 2020	Number of faults in 2020	10-year ann. avg of faults	km in 2020	Number of faults in 2020	10-year ann. avg of faults
Estonia	3 389.0	45	98.0	2 065.0	8	13.2	0.0	0	0.0
Latvia	3 870.8	93	91.0	1 742.0	10	10.3	0.0	0	0.0
Lithuania	5 016.0	92	100.6	1 984.0	5	11.3	102.7	0	0.6
Denmark	2 796.4	19	25.0	25.4	0	0.3	1 369.3	7	3.5
Finland	16 385.0	271	335.1	1 408.7	13	14.7	5 601.2	5	9.9
Iceland	1 246.8	15	16.0	919.3	3	3.4	0.0	0	0.0
Norway	10 736.0	44	92.9	5 355.0	18	38.6	3 266.0	56	40.2
Sweden	14 962.8	196	216.8	3 466.2	21	30.1	9 360.5	26	36.2
Baltic & Nordic	58 402.8	775	956.2	16 965.6	78	119.8	19 699.7	94	90.3

Table 6.14: Number of overhead line faults per 100 km in 2020 and the annual average for 2011–2020, grouped by voltage level. The data of Latvia and Lithuania cover 2012–2020.

Country	100–150 kV		220–330 kV		380–420 kV	
	Number of faults / 100 km in 2020	10-year ann. avg no. of faults / 100 km	Number of faults / 100 km in 2020	10-year ann. avg no. of faults / 100 km	Number of faults / 100 km in 2020	10-year ann. avg no. of faults / 100 km
Estonia	1.33	2.86	0.39	0.72	0.00	0.00
Latvia	2.40	2.38	0.57	0.72	0.00	0.00
Lithuania	1.83	2.02	0.25	0.64	0.00	0.98
Denmark	0.68	0.79	0.00	0.46	0.51	0.27
Finland	1.65	2.01	0.92	0.71	0.09	0.19
Iceland	1.20	1.29	0.33	0.39	0.00	0.00
Norway	0.41	0.87	0.34	0.71	1.71	1.33
Sweden	1.31	1.43	0.61	0.76	0.28	0.34
Baltic & Nordic	1.33	1.64	0.46	0.70	0.48	0.44

Table 6.15: Number of overhead lines faults and permanent faults in 2020 and their 10-year annual average values for 2011–2020, grouped by voltage level. The data of Latvia and Lithuania cover 2012–2020.

	100–150 kV				220–330 kV				380–420 kV			
	Faults		Permanent faults		Faults		Permanent faults		Faults		Permanent faults	
Country	Number in 2020	10-year ann. avg	Number in 2020	10-year ann. avg	Number in 2020	10-year ann. avg	Number in 2020	10-year ann. avg	Number in 2020	10-year ann. avg	Number in 2020	10-year ann. avg
Estonia	45	98.0	9	16.5	8	13.2	3	4.7	0	0.0	0	0.0
Latvia	93	91.0	43	34.7	10	10.3	1	1.8	0	0.0	0	0.0
Lithuania	92	100.6	23	16.8	5	11.3	1	2.3	0	0.6	0	0.3
Denmark	19	25.0	2	1.3	0	0.3	0	0.0	7	3.5	4	0.5
Finland	271	335.1	28	21.8	13	14.7	0	1.4	5	9.9	2	1.1
Iceland	15	16.0	6	1.0	3	3.4	2	0.8	0	0.0	0	0.0
Norway	44	92.9	12	20.6	18	38.6	1	2.7	56	40.2	5	2.0
Sweden	196	216.8	13	8.5	21	30.1	1	1.3	26	36.2	0	1.1
Baltic & Nordic	775	975.4	136	121.1	78	122.0	9	15.0	94	90.4	11	5.0

Table 6.16: Percentage allocation of overhead line faults by cause in 2020.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	23%	40%	9%	4%	0%	0%	25%
Latvia	10%	48%	24%	1%	0%	0%	17%
Lithuania	6%	19%	42%	4%	4%	3%	22%
Denmark	8%	0%	81%	0%	8%	0%	4%
Finland	17%	26%	2%	6%	4%	25%	19%
Iceland	6%	89%	0%	0%	0%	6%	0%
Norway	21%	66%	0%	5%	5%	0%	3%
Sweden	40%	2%	1%	3%	3%	2%	49%

Table 6.17: Percentage allocation of overhead line faults by cause over 2011–2020, except for Latvia and Lithuania the data covers 2012–2020.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	18%	38%	11%	13%	6%	0%	14%
Latvia	14%	31%	28%	1%	1%	0%	24%
Lithuania	12%	6%	32%	2%	3%	1%	44%
Denmark	20%	12%	41%	4%	1%	1%	21%
Finland	25%	37%	1%	2%	1%	15%	18%
Iceland	6%	82%	3%	1%	4%	4%	1%
Norway	34%	57%	1%	1%	3%	2%	2%
Sweden	52%	5%	2%	3%	3%	2%	34%

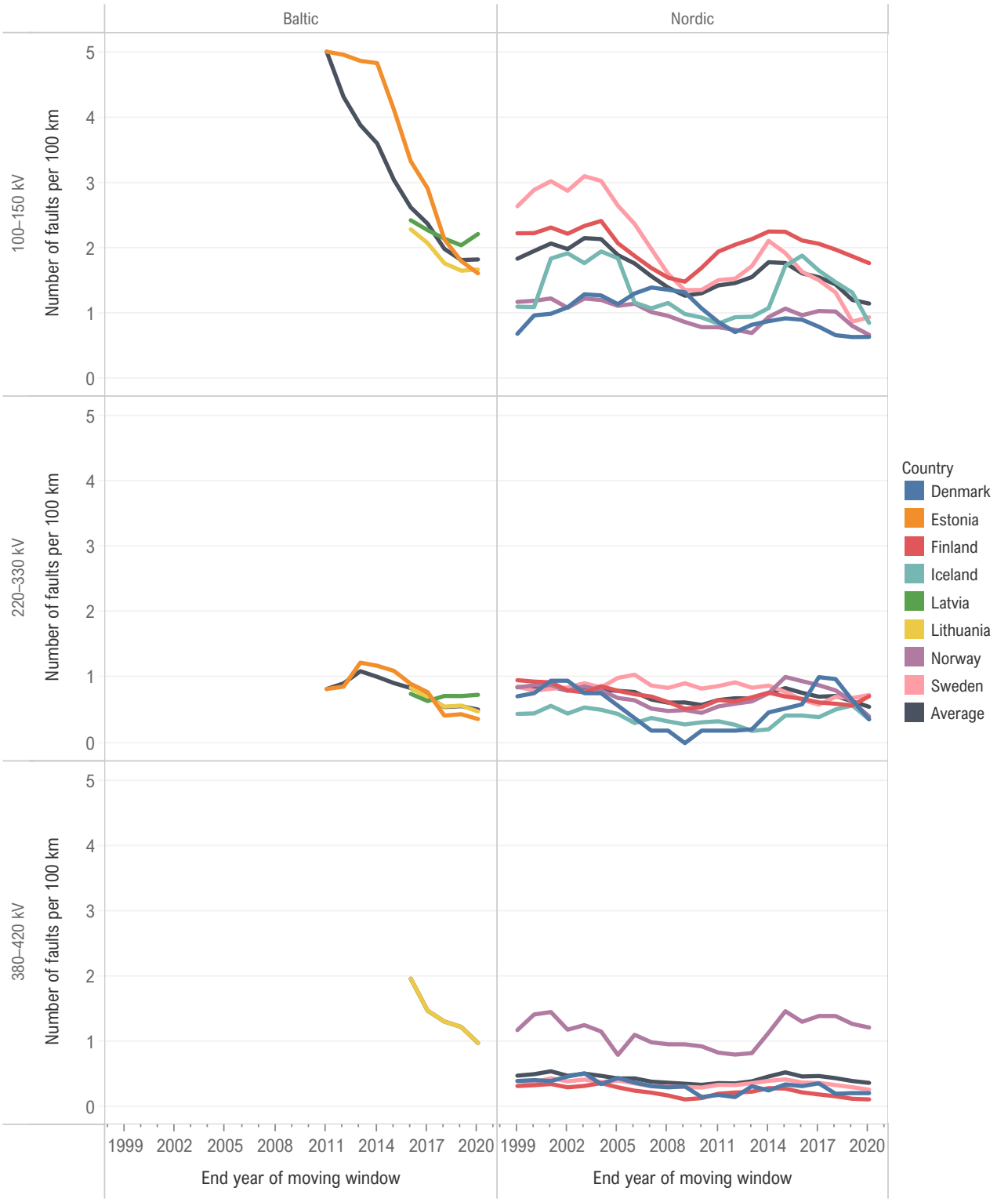

Figure 6.2: 5-year moving average of overhead line faults per 100 km. Estonia has data since 2007, and Latvia and Lithuania have data since 2012. Estonia, Iceland and Latvia do not own 380–420 kV transmission grids.

6.5 Faults in circuit breakers

This section presents circuit breaker faults in 2020 and for 2011–2020.

Table 6.18 presents the number of circuit breakers and the number of faults in 2020, and the 10-year annual average of the number of faults for 2011–2020. Table 6.19 presents the number of faults per 100 devices in 2020 and the annual averages for 2011–2020.

Table 6.20 presents the percentage allocation of circuit breaker faults by cause in 2020. Table 6.21 presents the respective percentages over 2011–2020.

Figure 6.3 presents the 5-year moving average of circuit breaker faults per 100 devices.

Table 6.18: Number of circuit breakers and their faults in 2020, and the annual average number of faults for 2011–2020, grouped by voltage level. The data of Latvia and Lithuania cover 2012–2020.

Country	100–150 kV			220–330 kV			380–420 kV		
	Number of devices in 2020	Number of faults in 2020	10-year ann. avg of faults	Number of devices in 2020	Number of faults in 2020	10-year ann. avg of faults	Number of devices in 2020	Number of faults in 2020	10-year ann. avg of faults
Estonia	660	6	5.2	137	0	2.2	0	0	0.0
Latvia	602	3	2.7	100	0	0.1	0	0	0.0
Lithuania	890	3	6.7	115	1	0.8	6	0	0.1
Denmark	946	3	2.4	36	0	0.0	226	0	0.5
Finland	2 800	7	4.5	77	0	0.0	365	0	0.6
Iceland	125	3	2.5	87	1	0.8	0	0	0.0
Norway	2 491	0	8.2	730	5	4.6	453	1	2.2
Sweden	2 717	3	3.7	341	1	1.1	661	14	4.9
Baltic & Nordic	11 231	28	35.8	1 623	8	9.6	1 711	15	8.3

Table 6.19: Number of circuit breaker faults per 100 devices in 2020 and the annual average for 2011–2020, grouped by voltage level. The data of Latvia and Lithuania cover 2012–2020.

Country	100–150 kV		220–330 kV		380–420 kV	
	Number of faults / 100 devices in 2020	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2020	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2020	10-year ann. avg no. of faults / 100 devices
Estonia	0.91	0.88	0.00	1.80	0.00	0.00
Latvia	0.50	0.44	0.00	0.11	0.00	0.00
Lithuania	0.34	0.78	0.87	0.73	0.00	3.85
Denmark	0.32	0.29	0.00	0.00	0.00	0.26
Finland	0.25	0.18	0.00	0.00	0.00	0.20
Iceland	2.40	1.56	1.15	0.99	0.00	0.00
Norway	0.00	0.36	0.68	0.63	0.22	0.61
Sweden	0.11	0.16	0.29	0.34	2.12	0.83
Baltic & Nordic	0.25	0.35	0.49	0.62	0.88	0.57

Table 6.20: Percentage allocation of circuit breakers faults by cause in 2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	0%	0%	0%	17%	67%	17%	0%
Latvia	0%	0%	0%	33%	67%	0%	0%
Lithuania	0%	0%	0%	50%	50%	0%	0%
Denmark	0%	0%	0%	100%	0%	0%	0%
Finland	14%	0%	0%	57%	29%	0%	0%
Iceland	0%	0%	0%	0%	0%	100%	0%
Norway	0%	0%	0%	0%	67%	17%	17%
Sweden	0%	0%	0%	11%	78%	6%	6%

Table 6.21: Percentage allocation of circuit breaker faults over 2011–2020, except for Latvia and Lithuania the data covers 2012–2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	1%	0%	0%	11%	78%	1%	8%
Latvia	0%	0%	4%	12%	84%	0%	0%
Lithuania	1%	0%	3%	32%	43%	4%	16%
Denmark	0%	0%	0%	79%	17%	0%	3%
Finland	6%	2%	4%	24%	31%	10%	24%
Iceland	0%	12%	3%	12%	42%	30%	0%
Norway	3%	2%	2%	41%	30%	8%	15%
Sweden	11%	0%	0%	11%	69%	1%	7%

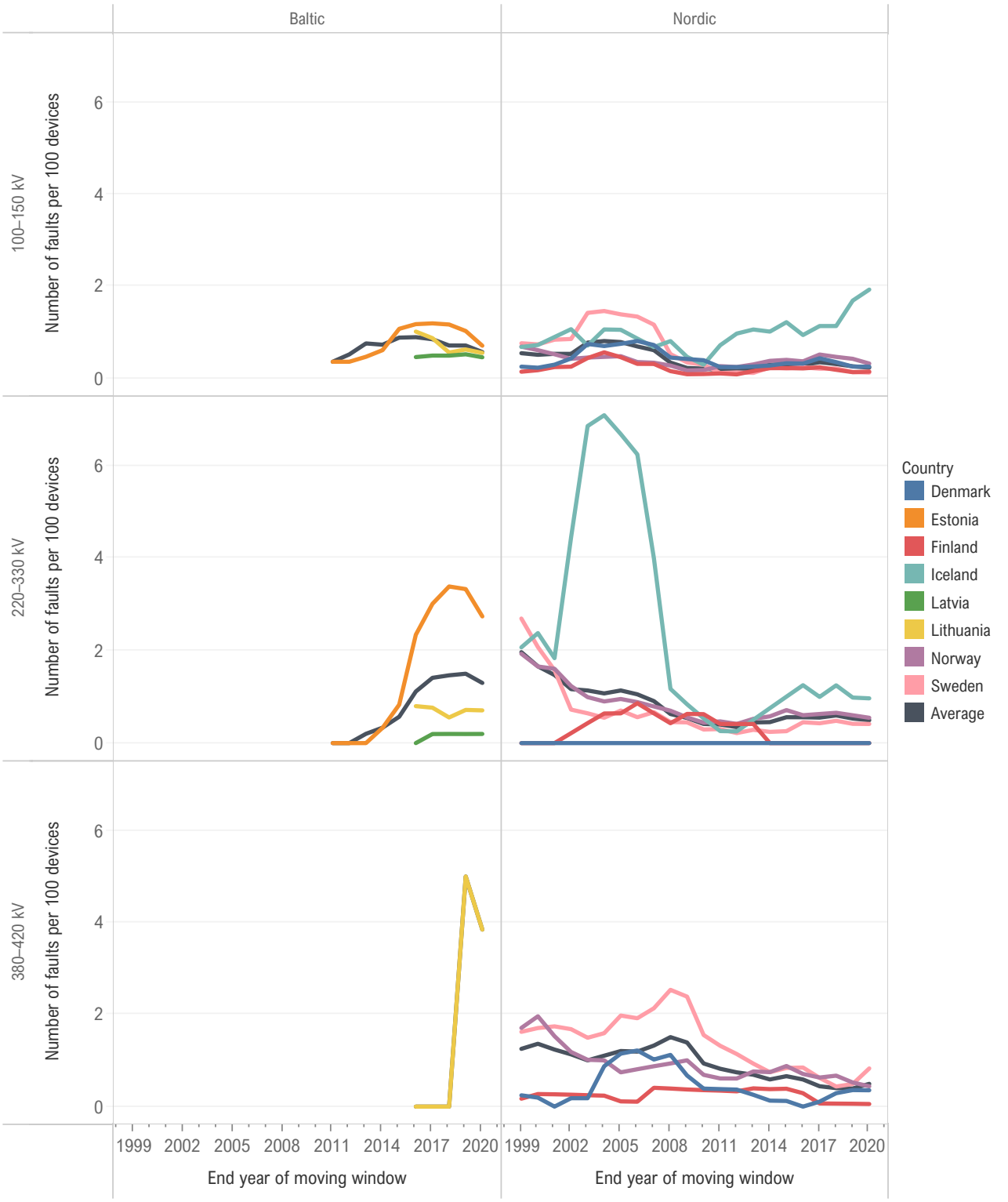

Figure 6.3: 5-year moving average of circuit breaker faults per 100 devices. Estonia has data since 2007, and Latvia and Lithuania have data since 2012. Estonia, Iceland and Latvia do not own 380–420 kV transmission grids.

6.6 Faults in control equipment

This section presents control equipment faults in 2020 and for 2011–2020. Protection devices are considered as part of the control equipment in this report. Control equipment embedded in other components are not included in this category as they are deemed to be a part of the other component.

In these statistics, human error is registered under operation and maintenance, separated from the category technical equipment. Human errors include, for example, incorrect settings in control or protection equipment.

Table 6.22 presents the number of control equipment and the number of faults in 2020, and the 10-year annual average of the number of faults for 2011–2020. Table 6.23 presents the number of faults per 100 devices in 2020 and the annual averages for 2011–2020.

Table 6.24 presents the percentage allocation of control equipment faults by cause in 2020. Table 6.25 presents the respective percentages over 2011–2020.

Figure 6.4 presents the 5-year moving average of control equipment faults per 100 devices.

Table 6.22: Number of control equipment and their faults in 2020, and the annual average number of faults for 2011–2020, grouped by voltage level. The data of Latvia and Lithuania cover 2012–2020. Control equipment embedded in other components are not included in this category as they are deemed to be a part of the other component.

Country	100–150 kV			220–330 kV			380–420 kV		
	Number of devices in 2020	Number of faults in 2020	10-year ann. avg of faults	Number of devices in 2020	Number of faults in 2020	10-year ann. avg of faults	Number of devices in 2020	Number of faults in 2020	10-year ann. avg of faults
Estonia	660	29	10.4	137	3	1.6	0	0	0.0
Latvia	653	9	17.7	100	3	2.9	0	0	0.0
Lithuania	890	6	13.1	115	5	3.2	6	0	0.0
Denmark	946	10	6.4	36	1	0.3	226	2	2.1
Finland	2 800	21	21.4	77	3	4.7	365	4	5.3
Iceland	125	4	4.6	87	4	3.4	0	0	0.0
Norway	2 491	7	28.6	730	20	20.8	453	15	14.0
Sweden	2 717	16	16.2	341	6	10.4	661	20	21.8
Baltic & Nordic	11 282	102	118.4	1 623	45	47.3	1 711	41	43.2

Table 6.23: Number of control equipment faults per 100 devices in 2020 and the annual average for 2011–2020, grouped by voltage level. The data of Latvia and Lithuania cover 2012–2020. Control equipment embedded in other components are not included in this category as they are deemed to be a part of the other component.

Country	100–150 kV		220–330 kV		380–420 kV	
	Number of faults / 100 devices in 2020	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2020	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2020	10-year ann. avg no. of faults / 100 devices
Estonia	4.39	1.78	2.19	1.37	0.00	0.00
Latvia	1.38	2.87	3.00	2.84	0.00	0.00
Lithuania	0.67	1.53	4.35	3.04	0.00	0.00
Denmark	1.06	0.76	2.78	1.88	0.88	1.13
Finland	0.75	0.87	3.90	5.68	1.10	1.74
Iceland	3.20	2.89	4.60	4.19	0.00	0.00
Norway	0.28	1.26	2.74	2.86	3.31	3.87
Sweden	0.59	0.73	1.76	3.22	3.03	3.71
Baltic & Nordic	0.90	1.17	2.77	3.04	2.40	2.99

Table 6.24: Percentage allocation of control equipment faults by cause in 2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	0%	0%	0%	25%	44%	13%	19%
Latvia	0%	0%	0%	25%	75%	0%	0%
Lithuania	0%	0%	0%	18%	9%	45%	27%
Denmark	0%	8%	0%	62%	31%	0%	0%
Finland	18%	21%	0%	11%	7%	39%	4%
Iceland	0%	0%	0%	25%	0%	75%	0%
Norway	0%	7%	2%	36%	48%	0%	7%
Sweden	2%	0%	0%	31%	62%	0%	5%

Table 6.25: Percentage allocation of control equipment faults by cause over 2011–2020, except for Latvia and Lithuania the data covers 2012–2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	0%	0%	0%	35%	47%	7%	12%
Latvia	1%	1%	1%	46%	45%	1%	6%
Lithuania	0%	0%	6%	39%	14%	10%	31%
Denmark	5%	3%	3%	51%	22%	11%	5%
Finland	2%	4%	1%	54%	18%	11%	11%
Iceland	0%	0%	0%	43%	38%	20%	0%
Norway	2%	4%	3%	47%	30%	10%	4%
Sweden	2%	4%	0%	28%	52%	5%	9%

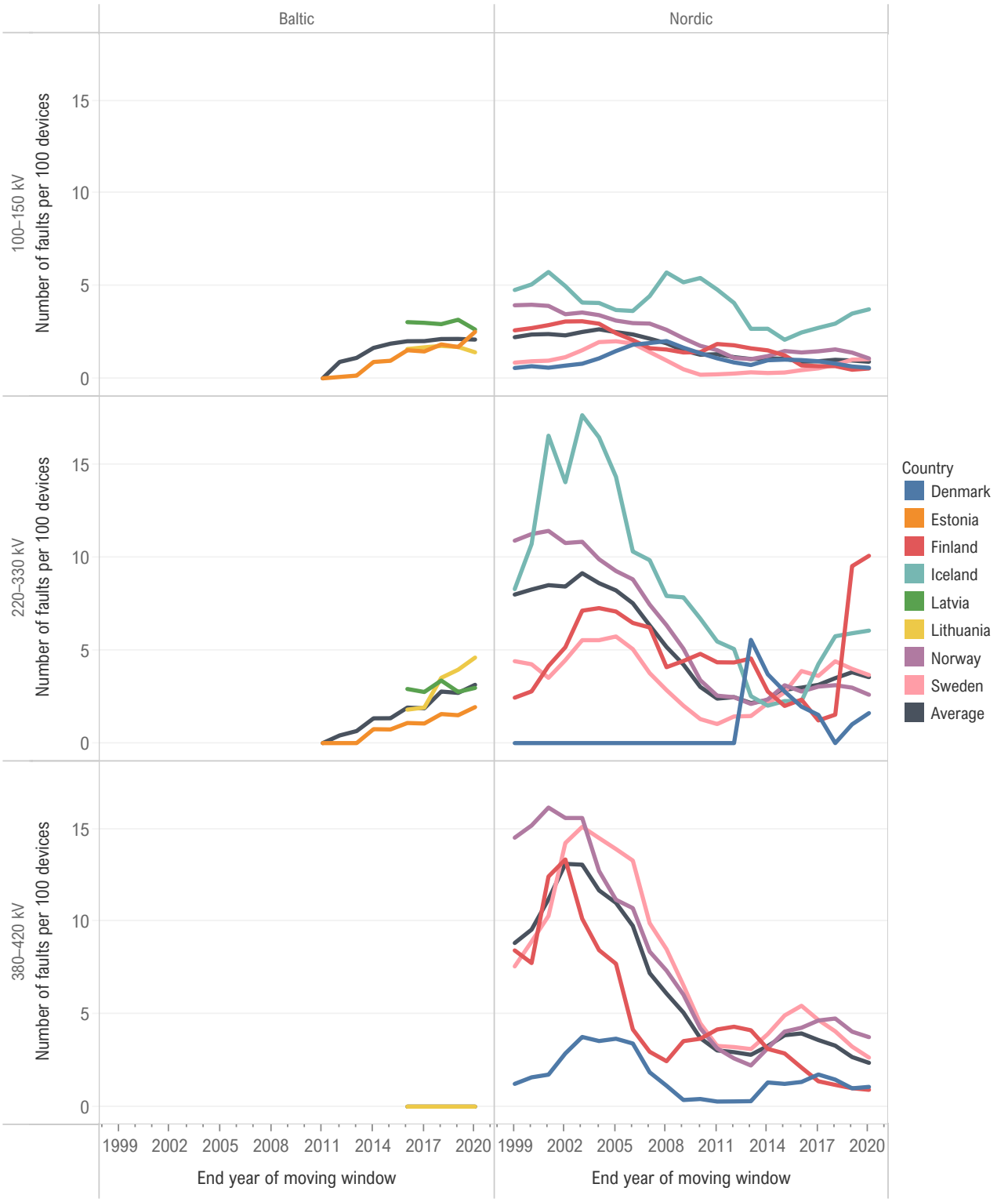

Figure 6.4: 5-year moving average of control equipment faults per 100 devices. Estonia has data since 2007, and Latvia and Lithuania have data since 2012. Estonia, Iceland and Latvia do not own 380–420 kV transmission grids. Control equipment embedded in other components are not included in this category as they are deemed to be a part of the other component.

6.7 Faults in instrument transformers

This section presents instrument transformer faults in 2020 and for 2011–2020.

Table 6.26 presents the number of instrument transformers and the number of faults in 2020, and the 10-year annual average of the number of faults for 2011–2020. Table 6.27 presents the number of faults per 100 devices in 2020 and the annual averages for 2011–2020.

Table 6.28 presents the percentage allocation of instrument transformer faults by cause in 2020. Table 6.29 presents the respective percentages over 2011–2020.

Figure 6.5 presents the 5-year moving average of instrument transformer faults per 100 devices.

Table 6.26: Number of instrument transformers and their faults in 2020, and the annual average number of faults for 2011–2020, grouped by voltage level. The data of Latvia and Lithuania cover 2012–2020. The number of instrument transformers in Sweden is not accurate due to missing data from some regional grid owners.

Country	100–150 kV			220–330 kV			380–420 kV		
	Number of devices in 2020	Number of faults in 2020	10-year ann. avg of faults	Number of devices in 2020	Number of faults in 2020	10-year ann. avg of faults	Number of devices in 2020	Number of faults in 2020	10-year ann. avg of faults
Estonia	3 238	3	1.5	937	0	0.7	0	0	0.0
Latvia	2 261	2	1.2	428	0	0.1	0	0	0.0
Lithuania	3 277	2	1.0	635	0	0.3	27	0	0.0
Denmark	5 457	0	1.3	196	0	0.1	1 155	0	0.4
Finland	10 482	0	2.7	452	0	0.1	2 009	1	0.3
Iceland	375	0	0.1	261	0	0.0	0	0	0.0
Norway	7 768	1	3.5	2 805	3	2.0	930	2	1.7
Sweden	8 656	5	3.9	1 903	0	0.2	3 470	1	1.8
Baltic & Nordic	41 514	13	15.2	7 617	3	3.5	7 591	4	4.2

Table 6.27: Number of instrument transformer faults per 100 devices in 2020 and the annual average for 2011–2020, grouped by voltage level. The data of Latvia and Lithuania cover 2012–2020.

Country	100–150 kV		220–330 kV		380–420 kV	
	Number of faults / 100 devices in 2020	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2020	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2020	10-year ann. avg no. of faults / 100 devices
Estonia	0.09	0.10	0.00	0.18	0.00	0.00
Latvia	0.09	0.08	0.00	0.04	0.00	0.00
Lithuania	0.06	0.06	0.00	0.09	0.00	0.00
Denmark	0.00	0.05	0.00	0.21	0.00	0.08
Finland	0.00	0.05	0.00	0.04	0.05	0.03
Iceland	0.00	0.02	0.00	0.00	0.00	0.00
Norway	0.01	0.05	0.11	0.07	0.22	0.18
Sweden	0.06	0.09	0.00	0.02	0.03	0.10
Baltic & Nordic	0.03	0.06	0.04	0.06	0.05	0.10

Table 6.28: Percentage allocation of instrument transformer faults by cause in 2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	0%	0%	0%	0%	33%	0%	67%
Latvia	0%	0%	0%	0%	100%	0%	0%
Lithuania	0%	0%	0%	0%	50%	50%	0%
Denmark	0%	0%	0%	0%	0%	0%	0%
Finland	0%	0%	0%	100%	0%	0%	0%
Iceland	0%	0%	0%	0%	0%	0%	0%
Norway	17%	0%	0%	33%	33%	17%	0%
Sweden	17%	0%	0%	33%	17%	0%	33%

Table 6.29: Percentage allocation of instrument transformer faults by cause over 2011–2020, except for Latvia and Lithuania the data covers 2012–2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	0%	0%	0%	9%	82%	0%	9%
Latvia	0%	0%	0%	0%	100%	0%	0%
Lithuania	0%	0%	0%	8%	83%	8%	0%
Denmark	0%	0%	6%	11%	67%	6%	11%
Finland	3%	0%	0%	10%	61%	10%	16%
Iceland	0%	0%	0%	0%	0%	100%	0%
Norway	13%	3%	1%	18%	43%	18%	4%
Sweden	8%	0%	0%	5%	80%	0%	7%

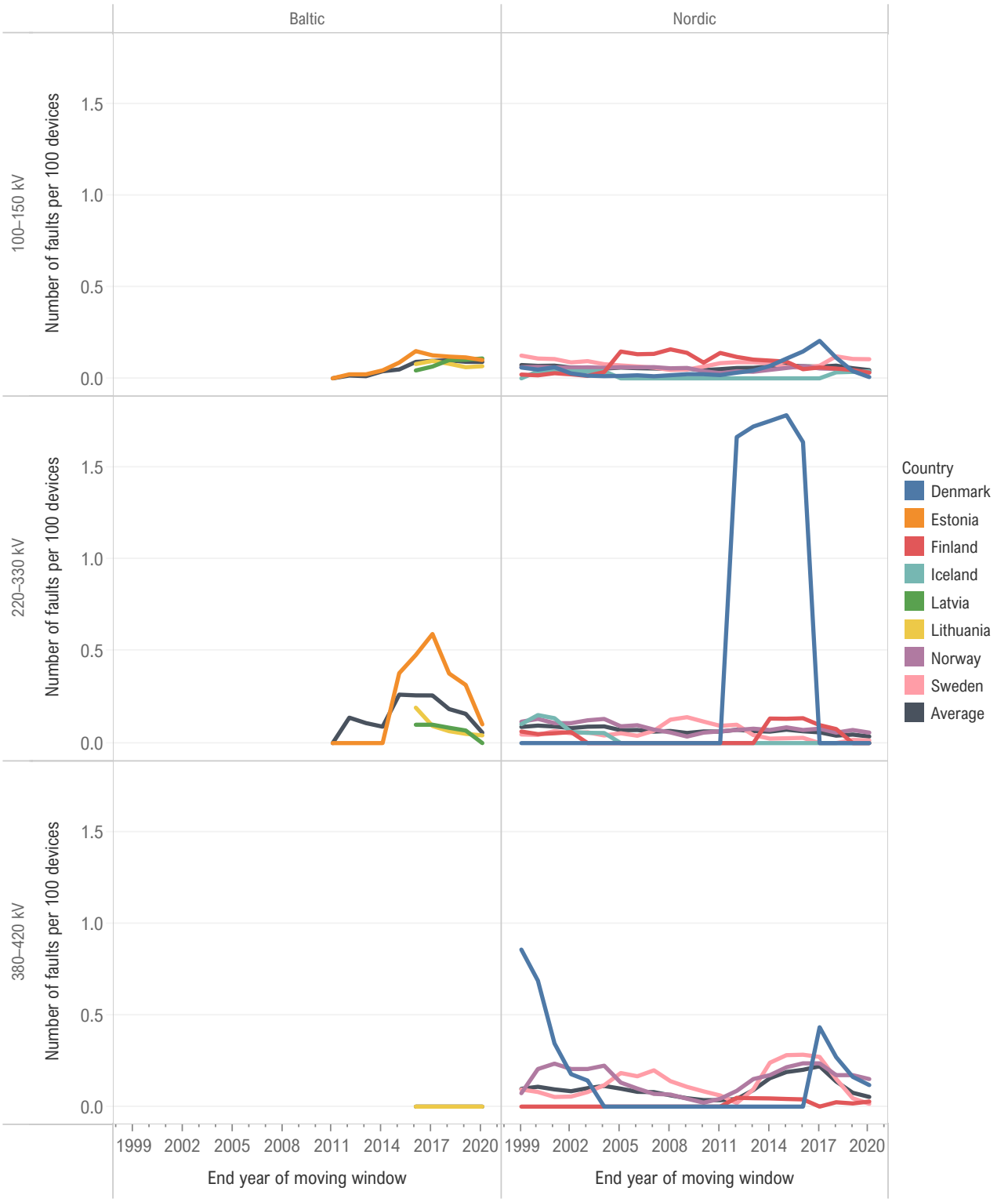

Figure 6.5: 5-year moving average of instrument transformer faults per 100 devices. Estonia has data since 2007, and Latvia and Lithuania have data since 2012. Estonia, Iceland and Latvia do not own 380–420 kV transmission grids. Denmark's high values during 2012–2016 are caused by one fault in 2012.

6.8 Faults in power transformers

This section presents power transformer faults in 2020 and for 2011–2020. The rated voltage of a power transformer is defined in these statistics as the winding with the highest voltage, as stated in the guidelines [1, p. 26].

Table 6.30 presents the number of power transformers and the number of faults in 2020, and the 10-year annual average of the number of faults for 2011–2020. Table 6.31 presents the number of faults per 100 devices in 2020 and the annual averages for 2011–2020.

Table 6.32 shows the percentage allocation of power transformer faults by cause in 2020. Table 6.33 presents the respective percentages over 2011–2020.

Figure 6.6 presents the 5-year moving average of power transformer faults per 100 devices.

Table 6.30: Number of power transformers and their faults in 2020, and the annual average number of faults for 2011–2020, grouped by voltage level. The data of Latvia and Lithuania cover 2012–2020.

Country	100–150 kV			220–330 kV			380–420 kV		
	Number of devices in 2020	Number of faults in 2020	10-year ann. avg of faults	Number of devices in 2020	Number of faults in 2020	10-year ann. avg of faults	Number of devices in 2020	Number of faults in 2020	10-year ann. avg of faults
Estonia	216	5	7.6	26	1	2.8	0	0	0.0
Latvia	246	1	4.4	27	0	1.2	0	0	0.0
Lithuania	369	1	0.3	23	2	1.1	0	0	0.0
Denmark	244	0	3.2	13	0	0.1	50	1	1.1
Finland	1 139	5	6.9	25	0	1.2	64	0	1.0
Iceland	14	3	1.8	16	2	0.9	0	0	0.0
Norway	913	3	4.5	266	1	1.5	100	2	1.8
Sweden	867	4	19.0	115	0	3.6	84	0	1.5
Baltic & Nordic	4 008	22	47.8	511	6	12.4	298	3	5.4

Table 6.31: Number of power transformer faults per 100 devices in 2020 and the annual average for 2011–2020, grouped by voltage level. The data of Latvia and Lithuania cover 2012–2020.

Country	100–150 kV		220–330 kV		380–420 kV	
	Number of faults / 100 devices in 2020	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2020	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2020	10-year ann. avg no. of faults / 100 devices
Estonia	2.31	3.54	3.85	11.81	0.00	0.00
Latvia	0.41	1.80	0.00	4.78	0.00	0.00
Lithuania	0.27	0.08	8.70	4.67	0.00	0.00
Denmark	0.00	1.34	0.00	1.41	2.00	3.23
Finland	0.44	0.63	0.00	4.72	0.00	1.54
Iceland	21.43	4.97	12.50	6.82	0.00	0.00
Norway	0.33	0.55	0.38	0.57	2.00	2.20
Sweden	0.46	2.45	0.00	3.50	0.00	2.17
Baltic & Nordic	0.55	1.25	1.17	2.54	1.01	2.16

Table 6.32: Percentage allocation of power transformer faults by cause in 2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	0%	0%	0%	17%	50%	17%	17%
Latvia	0%	0%	0%	0%	100%	0%	0%
Lithuania	0%	0%	33%	33%	33%	0%	0%
Denmark	0%	0%	0%	0%	100%	0%	0%
Finland	20%	20%	0%	40%	0%	0%	20%
Iceland	0%	0%	0%	20%	0%	80%	0%
Norway	17%	0%	0%	33%	50%	0%	0%
Sweden	0%	0%	75%	0%	25%	0%	0%

Table 6.33: Percentage allocation of power transformer faults by cause over 2011–2020, except for Latvia and Lithuania the data covers 2012–2020. Proportionately higher percentage values are highlighted in yellow and red.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	1%	3%	3%	20%	67%	1%	5%
Latvia	0%	0%	29%	29%	37%	0%	4%
Lithuania	0%	0%	8%	31%	38%	0%	23%
Denmark	0%	23%	0%	27%	41%	7%	2%
Finland	16%	2%	2%	18%	22%	25%	14%
Iceland	0%	19%	0%	11%	41%	30%	0%
Norway	9%	19%	1%	19%	28%	18%	5%
Sweden	21%	1%	3%	19%	22%	7%	27%

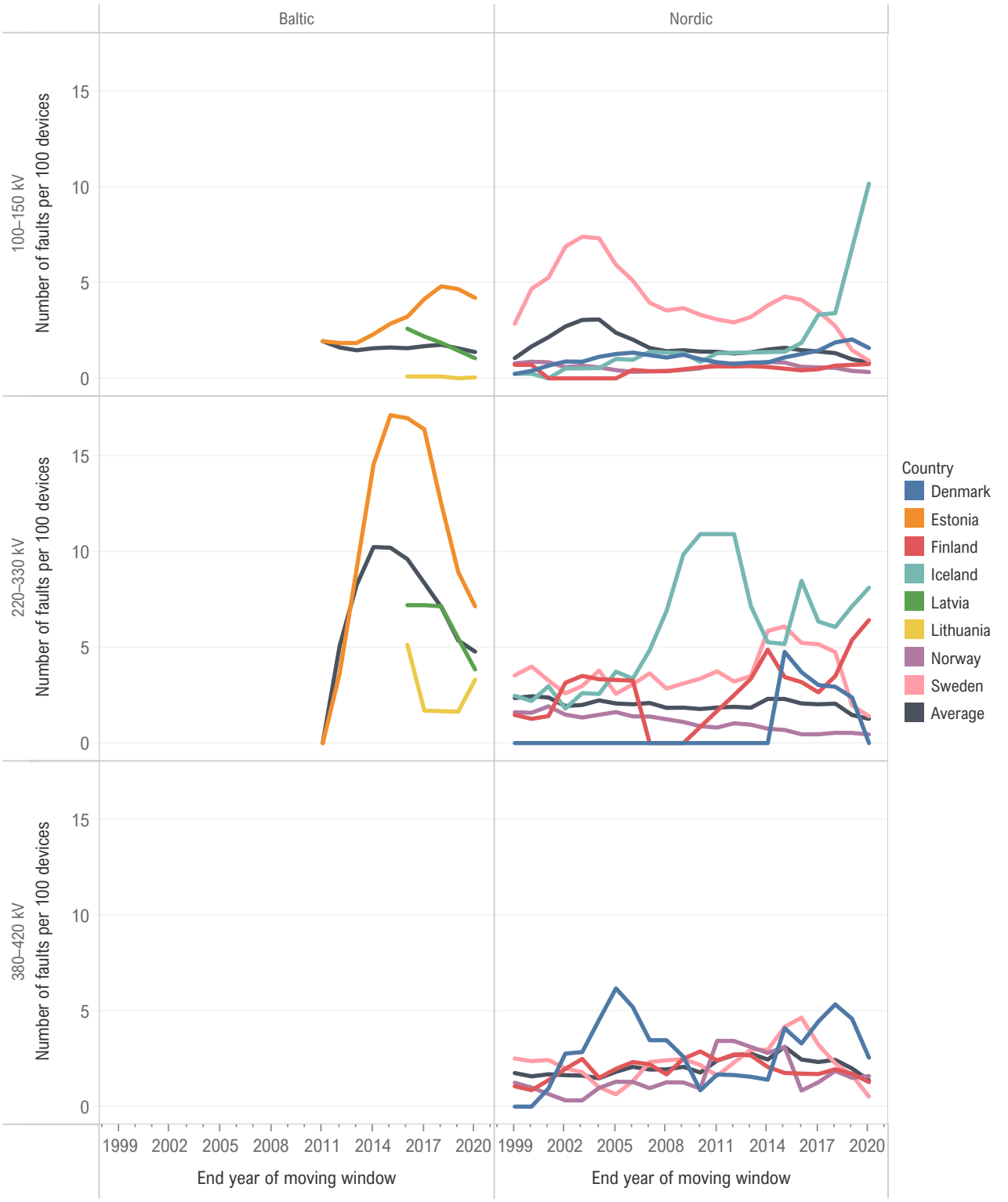

Figure 6.6: 5-year moving average of power transformer faults per 100 devices. Estonia has data since 2007, and Latvia and Lithuania have data since 2012. Estonia, Iceland, Latvia and Lithuania do not own 380–420 kV power transformers in their transmission grids.

6.9 Faults in compensation devices

The following sections present fault statistics for compensation devices. The following compensation devices are presented in this section: reactors, series capacitors, shunt capacitors and Static var compensators (SVCs). The statistics include the number of devices and their faults, number of faults per 100 devices and ENS in 2020 and their annual averages for 2011–2020.

The voltage level of compensation devices is not registered in the collected data for this report.

6.9.1 Faults in reactors

Table 6.34 presents the number of reactors and their faults, the number of faults per 100 devices, and the amount of ENS.

Table 6.34: The number of reactors and their faults in 2020, the number of faults per 100 devices, the amount of ENS due to reactor faults in 2020 and their annual averages for 2011–2020.

	Devices	Faults	Faults per 100 devices		ENS (MWh)	
				Annual avg.		Annual avg.
Country	2020	2020	2020	2011–2020	2020	2011–2020
Estonia	30	2	6.7	9.2	0.0	0.0
Latvia[1]	18	0	0.0	5.3	0.0	0.0
Lithuania[1]	2	0	0.0	0.0	0.0	0.0
Baltic total	50	2	4.0	6.7	0.0	0.0
Denmark	121	2	1.7	1.7	0.0	0.2
Finland[2]	150	0	0.0	0.2	0.0	1.0
Iceland	0	0	0.0	0.0	0.0	0.0
Norway	36	1	2.8	3.6	0.0	0.0
Sweden[3]	825	3	0.4	2.7	0.0	12.9
Nordic total	1132	6	0.5	2.1	0.0	14.1
Baltic & Nordic Total	1182	8	0.7	2.5	0.0	14.1

[1] The data of Latvia and Lithuania cover 2012–2020.
[2] In Finland, reactors compensating the reactive power of 400 kV lines are connected to the 20 kV tertiary winding of the 400/110/20 kV power transformers.
[3] The fault data for Sweden's reactors is still under review. The data will be followed up in the next report 2021.

6.9.2 Faults in series capacitors

Table 6.35 presents the number of series capacitors and their faults, the number of faults per 100 devices and the amount of ENS.

Table 6.35: The number of series capacitors and their faults in 2020, the number of faults per 100 devices, the amount of ENS due to series capacitor faults in 2020 and their annual averages for 2011–2020.

	Devices	Faults	Faults per 100 devices		ENS (MWh)	
				Annual avg.		Annual avg.
Country	2020	2020	2020	2011–2020	2020	2011–2020
Estonia	0	0	0.0	0.0	0.0	0.0
Latvia[1]	0	0	0.0	0.0	0.0	0.0
Lithuania[1]	0	0	0.0	0.0	0.0	0.0
Baltic total	10	2	20.0	3.6	0.0	0.0
Denmark	0	0	0.0	0.0	0.0	0.0
Finland	11	4	36.4	52.5	0.0	1.9
Iceland	1	0	0.0	20.0	0.0	0.0
Norway	3	0	0.0	3.3	0.0	0.0
Sweden	17	2	11.8	67.8	0.0	0.0
Nordic total	32	6	18.8	52.3	0.0	1.9
Baltic & Nordic Total	42	8	19.0	43.6	0.0	1.9

[1] The data of Latvia and Lithuania cover 2012–2020.

6.9.3 Faults in shunt capacitors

Table 6.36 presents the number of shunt capacitors (including filters) and their faults, the number of faults per 100 devices and the amount of ENS.

Table 6.36: The number of shunt capacitors and their faults in 2020, the number of faults per 100 devices, the amount of ENS due to shunt capacitor faults in 2020 and their annual average for 2011–2020.

	Devices	Faults	Faults per 100 devices		ENS (MWh)	
				Annual average		Annual average
Country	2020	2020	2020	2011–2020	2020	2011–2020
Estonia	10	2	20.0	9.1	0.0	3.0
Latvia[1]	2	0	0.0	0.0	0.0	0.0
Lithuania[1]	2	0	0.0	0.0	0.0	0.0
Baltic total	4	0	0.0	7.5	0.0	3.0
Denmark	43	0	0.0	0.4	0.0	0.0
Finland	24	3	12.5	4.2	0.0	0.0
Iceland	13	0	0.0	4.0	0.0	0.0
Norway	194	0	0.0	2.1	0.0	0.0
Sweden	153	1	0.7	0.7	0.0	15.2
Nordic total	427	4	0.9	1.8	0.0	15.2
Baltic & Nordic Total	431	4	0.9	2.0	0.0	18.2

[1] The data of Latvia and Lithuania cover 2012–2020.

6.9.4 Faults in SVC devices

Table 6.37 presents the number of SVCs and their faults, the number of faults per 100 devices and the amount of ENS.

Table 6.37: The number of SVCs and their faults in 2020, the number of faults per 100 devices, the amount of ENS due to SVC faults in 2020 and their annual averages for 2011–2020.

	Devices	Faults	Faults per 100 devices		ENS (MWh)	
				Annual avg.		Annual avg.
Country	2020	2020	2020	2011–2020	2020	2011–2020
Estonia	0	0	0.0	0.0	0.0	0.0
Latvia[1]	1	0	0.0	0.1	0.0	0.0
Lithuania[1]	12	0	0.0	3.1	0.0	0.0
Baltic total	13	0	0.0	0.2	0.0	0.0
Denmark	1	0	0.0	40.0	0.0	0.0
Finland	1	0	0.0	13.3	0.0	0.0
Iceland	2	0	0.0	12.5	0.0	0.0
Norway	25	16	64.0	87.5	0.0	0.0
Sweden	2	2	100.0	298.2	0.0	0.0
Nordic total	31	18	58.1	94.2	0.0	0.0
Baltic & Nordic Total	44	18	40.9	10.3	0.0	0.0

[1] The data of Latvia and Lithuania cover 2012–2020.

References

[1] Nordel, "Nordel's Guidelines for the Classification of Grid Disturbances, Version 3.3." https://eepublicdownloads.entsoe.eu/clean-documents/pre2015/publications/nordic/operations/Nordel_guidelines_2008_07_02_ENG_G_V2.pdf, July 2008.

[2] IEC 60050-826:2004: Electrical installations, 2020.

[3] ENTSO-E, "The Interconnected network of Northern Europe 2019." https://eepublicdownloads.entsoe.eu/clean-documents/Publications/maps/2019/Map_Northern-Europe-3.000.000.pdf. [Online; accessed 2.11.2021].

[4] ENTSO-E, "ENTSO-E HVDC Utilisation and Unavailability Statistics." https://www.entsoe.eu/publications/system-operations-reports/#fault-statistics.

Appendices

A Calculation of energy not supplied

Every country has its own method to calculate energy not supplied (ENS). The process for each country is described below.

Denmark

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.

Estonia

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 the previous or next day shall be taken into account, and ENS is calculated per these load profiles.

Finland

In Finland, ENS in the transmission grid is counted for those faults that caused an outage at the point of supply, which is 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.

Iceland

In Iceland, ENS is computed per 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. However, distribution systems register ENS caused by outages in the transmission and distribution systems with end-user impact. Mutual rules for registration of faults and ENS in all grids are used in Iceland.

Latvia

In Latvia, the ENS is linked to the end-user, that is, ENS is not counted if the end-user receives energy through the distribution grid. Note that the distribution grid is 100 % dependent on the TSO supply due to undeveloped energy generation. The amount of ENS is calculated by multiplying the pre-outage load with the duration of the outage.

Lithuania

In Lithuania, ENS is calculated at the end-customer's point of supply, which is the low voltage side of the 110/35/10 kV or 110/10 kV transformer at the low voltage customer's connection point. ENS for outages in radial 110 kV connections is calculated by the Distribution System Operator (DSO), which during the outage, considers the possibility to supply the energy from the other 35 kV or 10 kV voltage substations. The DSO then uses the average load before the outage multiplied by its duration to calculate ENS. All events with the energy not supplied are investigated with the DSO or the Significant Grid Users (SGUs) directly connected to 110 kV network. All parties also agree and confirm the amounts of energy not supplied.

Norway

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 per a standardised method that has been established by the authority.

Sweden

In Sweden as of 2020, ENS is calculated by using the annual average output.

Prior to 2020, ENS was calculated by multiplying the outage duration with the detected pre-outage load. However, some companies used instead the rated power at the point of supply because the pre-outage load was rarely registered.

B Policies for examining the cause of line faults

Denmark

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. It is also a fact that every line fault is not inspected, which may lead to a cause stated as unknown.

Estonia

In Estonia, the cause of a line fault is determined by inspections or by identifying possible cause origins. The fault location is usually found as disturbance recorders measure it, although the accuracy may vary a lot. The 110 kV lines have many trips with a successful automatic reclosing at nights during summer months. After investigations, it turned out that stork contamination on insulators was causing the flashovers. In these cases, the fault sites are not always inspected. Elering has access to the lightning detection system, which allows identifying the line faults caused by lightning. If no signs are referring to a particular cause, the cause for a fault is reported as unknown.

Finland

In Finland, Fingrid Oyj changed the classification policy of faults in July 2011, and more effort is put into clarifying causes. Even if the cause is not 100 % certain, but if the expert opinion is that the cause is, for example, lightning, the cause is reported as lightning. Additionally, the category 'other environmental causes' is used more often. Therefore, the number of unknown faults has decreased.

Iceland

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. System operation staff analyses monthly interferences, and corrections are made to the data if needed. In 2016, 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 initially reported. This process also helps in understanding how disturbances are listed in the disturbance database for these parties.

Latvia

In Latvia, disturbance recorders, relay protection systems, on-sight inspections and information from witnesses are used to find the cause of a disturbance. If enough evidence is available, the cause is set accordingly. 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.

Lithuania

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 per 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.

Norway

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 is usually 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.

Sweden

In Sweden regarding lightning, data from disturbance recorders and other gathered information might not be 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. If a successful reclosing has taken place, Svenska kraftnät prefers to declare the cause as unknown instead of lightning, which may be the most probable cause.

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D Contact persons for the distribution network statistics

ENTSO-E Regional Group Nordic provides no statistics for distribution networks (voltage voltages lower than 100 kV). Contact persons for the distribution network statistics are listed below:

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E Additional figures

This appendix was introduced to allow experimenting with new kinds of figures without affecting the rest of the report. Furthermore, it shows what kind of statistical data can be derived from the collected data.

Section E.1 and Section E.2 show statistics about other environmental causes and operation and maintenance, respectively.

E.1 Faults due to other environmental causes

The following two figures show 5-year moving averages for fault causes due to other environmental causes. Figure E.1 is for all component faults, and Figure E.2 is for overhead line faults only. The cause category 'Other environmental causes' is explained in Section 1.6.

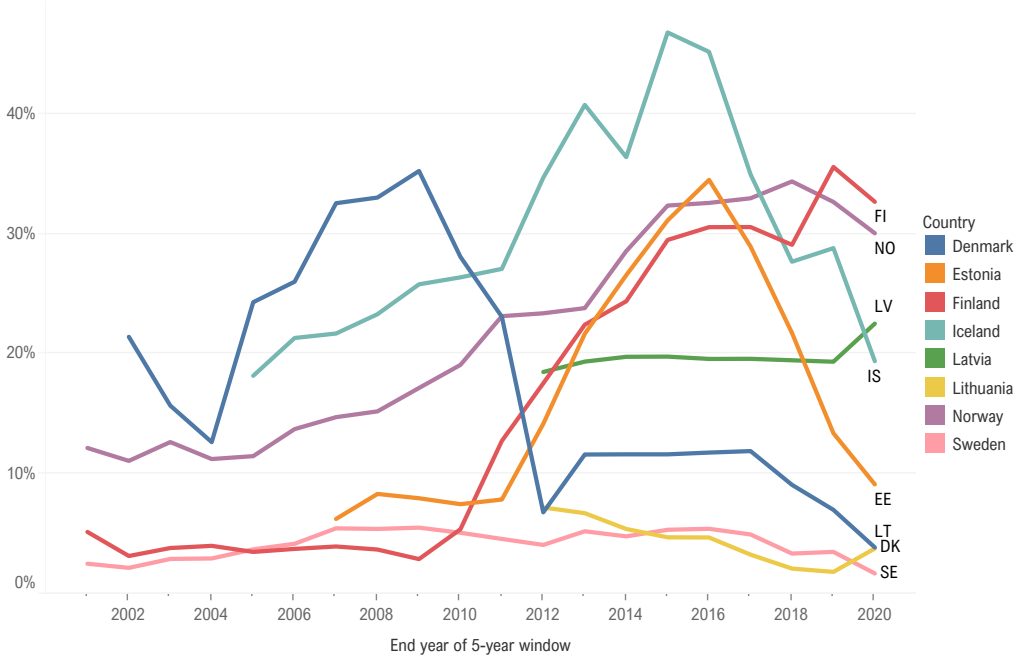

Figure E.1: 5-year moving average for fault causes due to other environmental causes. All components are included.

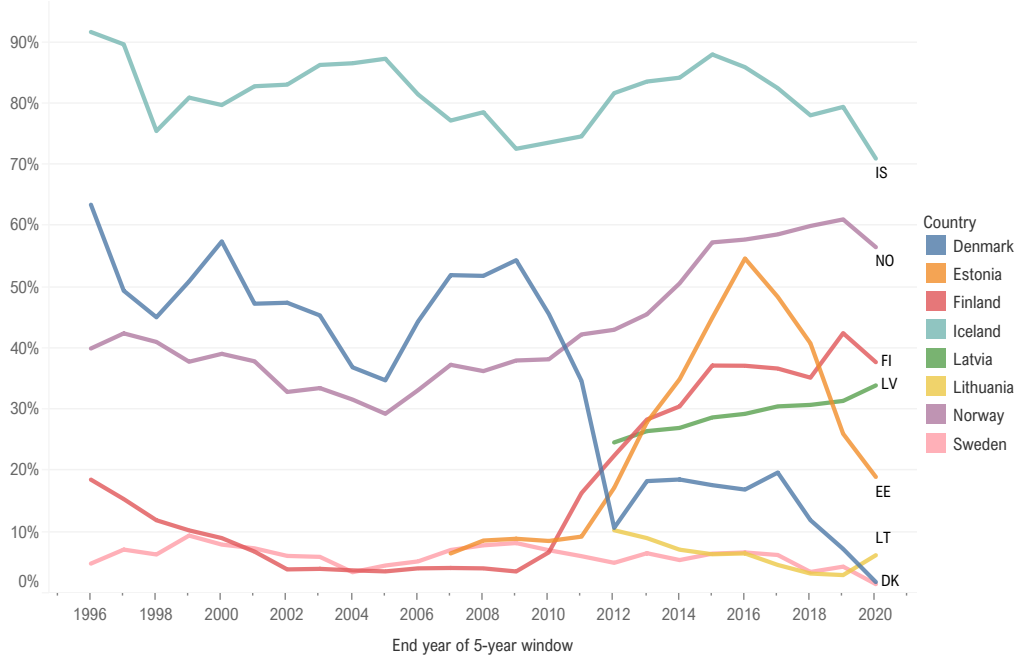

Figure E.2: 5-year moving average of overhead line fault causes due to other environmental causes.

E.2 Faults due to operation and maintenance

The following two figures show 5-year moving averages for faults due to operation and maintenance. Figure E.3 is for all component faults, and Figure E.4 is for overhead line faults only. The cause category 'Operation and maintenance' is explained in Section 1.6.

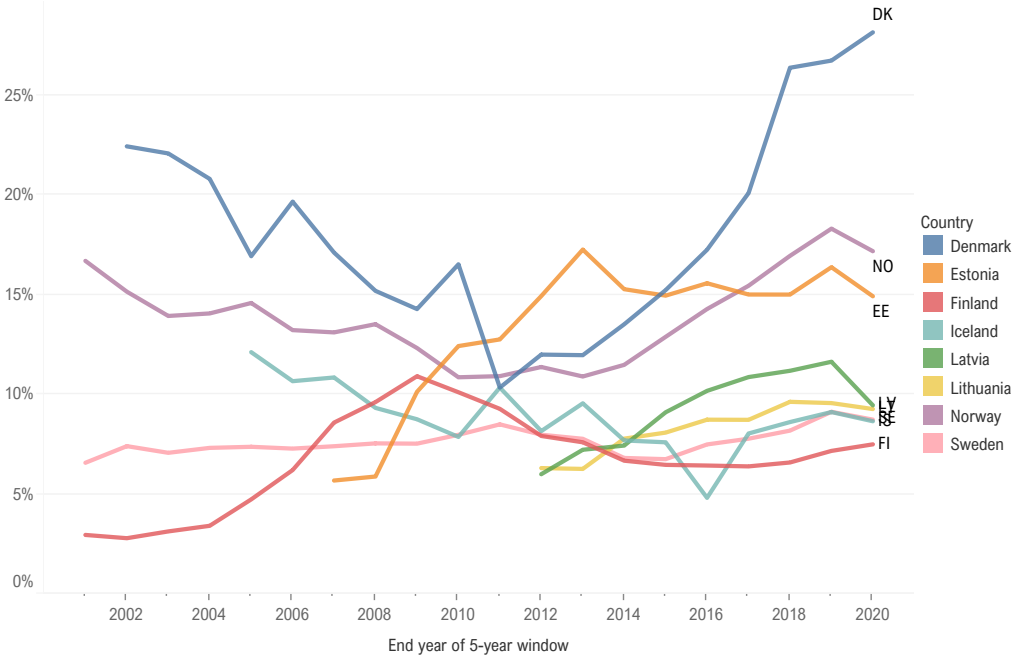

Figure E.3: 5-year moving average of fault causes due to operation and maintenance. All components are included.

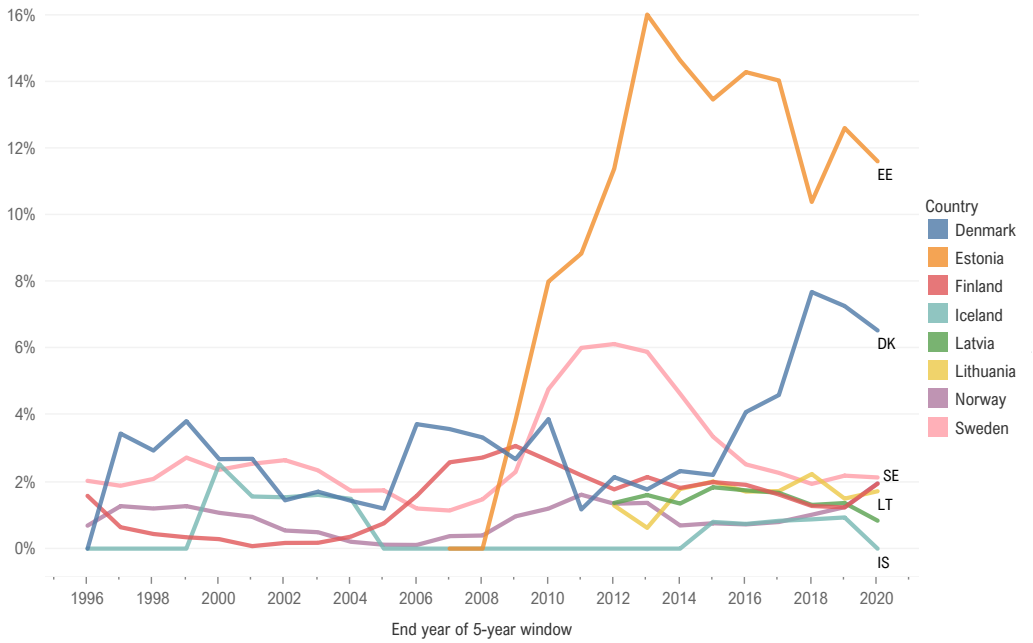

Figure E.4: 5-year moving average of overhead line fault causes due to operation and maintenance.

E.3 Installed components

This section presents the length of lines (km) and the number of components in the 100–420 kV grids at the end of each year.

Figure E.5 and Figure E.6 present the length of cables and overhead lines (km). Figure E.7–E.9 present the number of circuit breakers, control equipment, instrument transformers and power transformers.

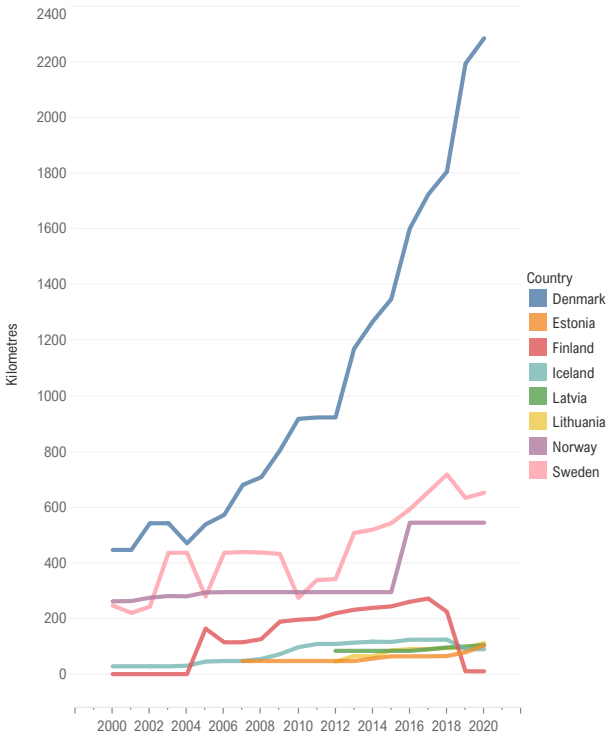

Figure E.5: Length of cables (km) in the 100–420 kV grids at the end of each year. Estonia has data since 2007, and Latvia and Lithuania have data since 2012.

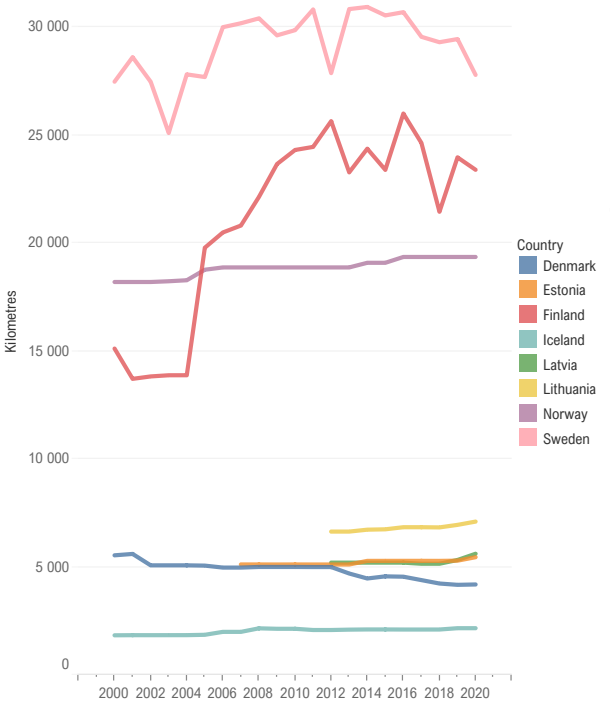

Figure E.6: Length of overhead lines (km) in the 100–420 kV grids at the end of each year. Estonia has data since 2007, and Latvia and Lithuania have data since 2012.

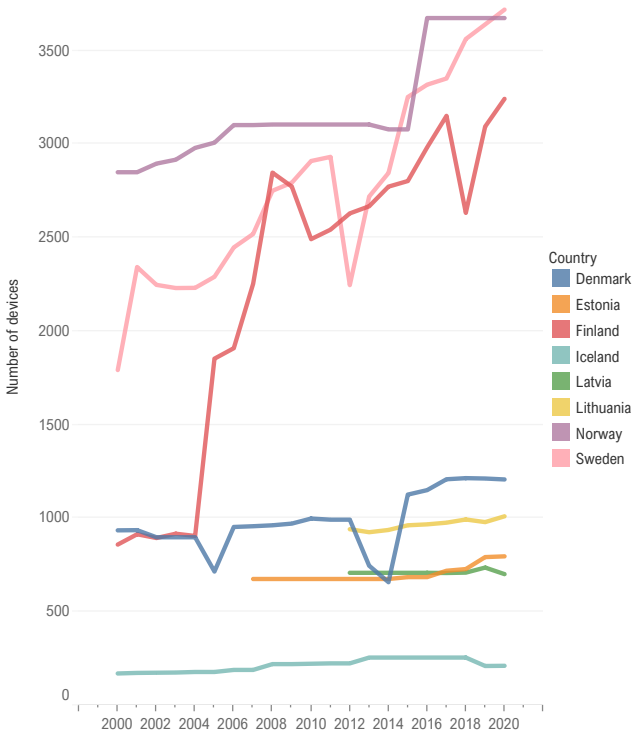

Figure E.7: Number of circuit breakers in the 100–420 kV grids at the end of each year. Estonia has data since 2007, and Latvia and Lithuania have data since 2012. The number of circuit breakers is equal to the number of control equipment.

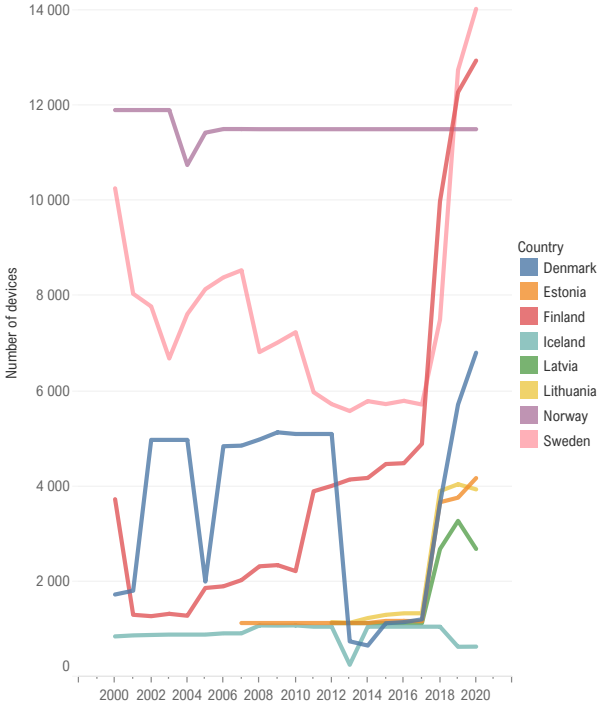

Figure E.8: Number of instrument transformers in the 100–420 kV grids at the end of each year. Estonia has data since 2007, and Latvia and Lithuania have data since 2012.

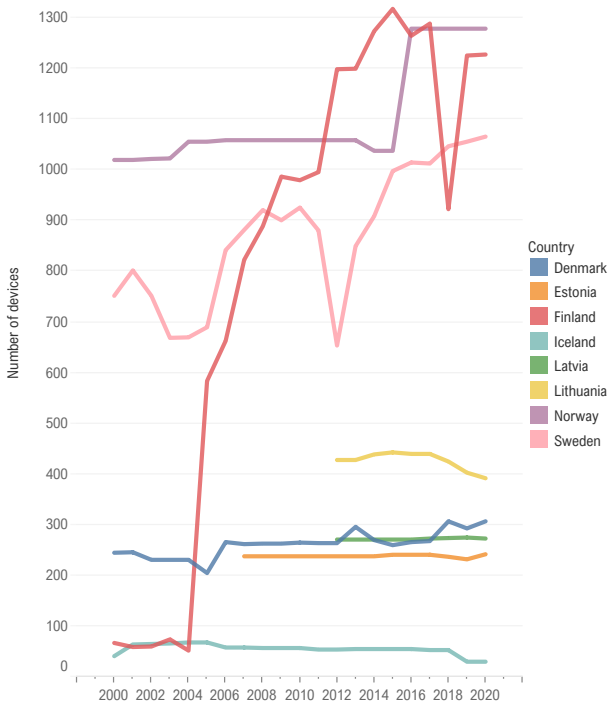

Figure E.9: Number of power transformers in the 100–420 kV grids at the end of each year. Estonia has data since 2007, and Latvia and Lithuania have data since 2012.

E.4 ENS, consumption and line length

Figure E.10 presents the annual amount of ENS, consumption and total length of lines for 2011–2020. The total line length is the sum of the lengths of overhead lines and cables in the 100–420 kV grids.

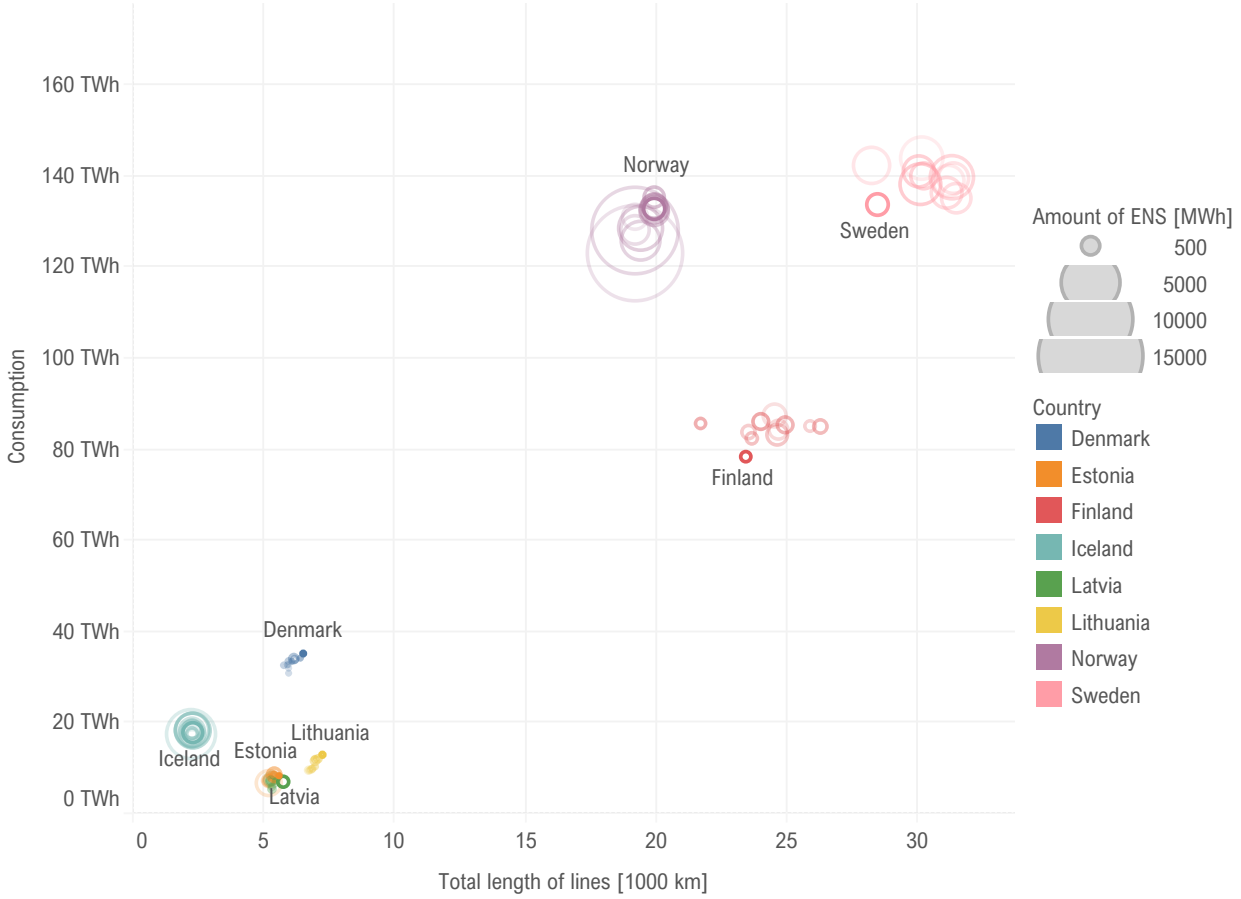

Figure E.10: The annual amount of ENS (circle size), length of lines (x-axis) and consumption (y-axis) for 2011–2020. The most recent statistical year 2020 is shown with the darkest colour. Each previous year is shown in a lighter colour.