European Network of
Transmission System Operators
for Electricity

2021 NORDIC AND BALTIC GRID DISTURBANCE STATISTICS

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2021 Nordic and Baltic Grid Disturbance Statistics

Report rendered 21 December 2022

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 2021 Nordic and Baltic Grid Disturbance Statistics 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.

The year 2021 was very good; disturbances had only minor effect on the end-users. ENS was only 21 % in Baltic and only 39 % in Nordic countries of the corresponding ten-year annual averages.

Year 2021 compared to ten-year annual averages:

- The number of faults and the number of disturbances was smaller in Baltic and on the same level in Nordic.
- The number of disturbances that caused ENS was clearly smaller in Baltic and on the same level in Nordic.

The grid component that had the largest share of faults in 2021 was overhead line for all other countries except for Iceland where adjoining grids had the highest share. The main causes of the overhead line faults were common; *lightning*, *other environmental causes* or *unknown*. How to categorise the cause of the line fault differs between countries and is explained in Appendix B.

The component with the next largest share of faults was control equipment, which accounted for 8–21 % of all faults in all countries except Lithuania. Almost all faults on control equipment are due to the causes *operation and maintenance* and *technical equipment*.

Table 1 shows the key figures of this report for each participating country: the numbers of faults and disturbances, the fault to disturbance ratio in 2021, and ENS in 2021 and the corresponding annual averages for these.

Table 1: The number of faults, the number of disturbances, the fault to disturbance ratio, and ENS in 2021 and the corresponding annual averages for the 10-year period 2012–2021.

	Number of faults		No. of disturbances		Ratio		ENS (MWh)	
Country	2021	Annual avg. 2012–2021	2021	Annual avg. 2012–2021	2021	2012–2021	2021	Annual avg. 2012–2021
Estonia	145	179	141	172	1.03	1.04	14	91
Latvia	121	148	105	134	1.15	1.10	10	81
Lithuania	165	167	159	156	1.04	1.07	21	38
Baltic total	431	494	405	462	1.06	1.07	44	211
Denmark	92	69	89	61	1.03	1.13	45	32
Finland	432	423	408	405	1.06	1.04	132	260
Iceland	66	62	46	43	1.43	1.46	64	1016
Norway	251	328	215	288	1.17	1.14	986	2225
Sweden	489	459	445	439	1.10	1.05	742	1467
Nordic total	1330	1341	1203	1236	1.11	1.09	1969	5000
Baltic & Nordic total	1761	1835	1608	1698	1.10	1.08	2013	5211

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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].
HVAC High-voltage alternating current. As explained in Section 1.3, this report encompasses HVAC components in the 100–420 kV voltage range.
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.

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1 Introduction

1.1 Description of the report

The 2021 Nordic and Baltic Grid Disturbance Statistics 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 2021. 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 2021.

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 it is the latest available map of interconnected Northern Europe. All of Denmark is included in the disturbance data of this report although only the grid of eastern Denmark belongs to the Nordic synchronous area.

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.

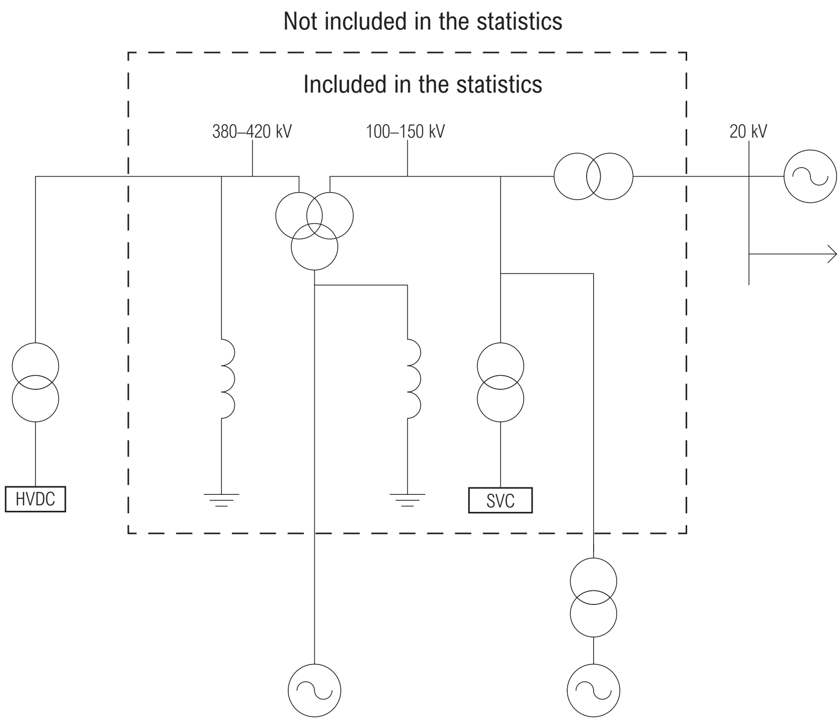

Figure 1.2: A graphical representation of the included grid components in the statistics.

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 2021 or for 2012–2021. 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 since 1995. In these cases, the figures and tables show all the available data.

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.

Country		Statistical voltage range, kV		
		100–150 kV	220–330 kV	380–420 kV
Denmark	U_N / p %	150 kV / 64 % 132 kV / 36 %	220 kV / 100 %	400 kV / 100 %
Estonia	U_N / p %	110 kV / 100 %	330 kV / 100 %	–
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.

Country	Voltage level		
	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

In 2021, 1608 grid disturbances occurred in the Nordic and Baltic 100–420 kV grids, which is below the 10-year annual average of 1698 disturbances. The energy not supplied (ENS) due to faults in the Nordic grids amounted to 1969 MWh and 44 MWh in the Baltic. There were 2013 MWh of ENS in the Nordic and Baltic grids, which is also significantly below the 10-year annual average of 5211 MWh of ENS. Out of all disturbances, 358 caused ENS in 2021.

The following sections present the summaries for each Nordic and Baltic country including the most significant issues in 2021.

2.1 Summary of Denmark

In Denmark, the ENS caused by grid disturbances was 45 MWh in 2021 (10-year annual average 32 MWh). There were 89 grid disturbances (10-year annual average 61) and 6 of them caused ENS.

In 2021, 100 % of the total ENS was caused by substation faults. The most significant reasons for ENS caused by disturbances were operation and maintenance (71 %) and technical equipment (29 %). Disturbances were caused most by technical equipment (24 %) and other environmental causes (21 %).

Secondary faults in Denmark accounted for 3 % of all faults in 2021 and caused no ENS. Secondary faults were primarily caused by other causes (67 %) and technical equipment (33 %).

The three most significant disturbances in 2021 were the following:

- During work at 150 kV substation, a switching error (due to human error) occurred by connecting to temporary earthing. This disconnected the entire station because busbar protection was not implemented. The resulting ENS was 18.0 MWh.
- A summation of alarms had unintentionally been implemented in the transformer differential protection. A fault in the low-voltage grid tripped the protection because there was an unwanted function that tripped the transformer when it should not have. The resulting ENS was 9.2 MWh.
- The current transformer on the 150 kV side of a 400 kV transformer failed and tripped the transformer. The current transformer malfunctioned due to age based on investigations of comparable transformers. The resulting ENS was 7.7 MWh.

2.2 Summary of Estonia

In Estonia, the ENS caused by grid disturbances was 14 MWh in 2021 (10-year annual average 91 MWh). There were 141 grid disturbances (10-year annual average 172) and 15 of them caused ENS.

In 2021, 48 % of the total ENS was caused by substation faults, and 2 % by overhead line faults. The most significant reasons for ENS caused by disturbances were other causes (50 %) and technical equipment (47 %). Disturbances were caused most by technical equipment (27 %) and external influences (20 %).

Secondary faults in Estonia accounted for 3 % of all faults in 2021 and caused approximately 9 % of the total ENS. All secondary faults were caused by technical equipment (100 %).

The three most significant disturbances in the 110–400 kV grid in 2021 were the following:

- One of the phase conductors of a 110 kV overhead line broke while energising a 110 kV substation. ENS was 5.13 MWh.
- A 110 kV transformer tripped due to an erroneously made connection by personnel. The connection was made during the dismantling and restoration work after a substation fire. ENS was 4.39 MWh.
- A fire on a 110 kV current transformer caused an outage. ENS was 1.19 MWh.

2.3 Summary of Finland

In Finland, the ENS caused by grid disturbances was 132 MWh in 2021 (10-year annual average 260 MWh). There were 408 grid disturbances (10-year annual average 405) and 85 of them caused ENS.

In 2021, 67 % of the total ENS was caused by overhead line faults, and 44 % by substation faults. The most significant reasons for ENS caused by disturbances were operation and maintenance (44 %) and unknown causes (25 %). Disturbances were caused most by other environmental causes (32 %) and unknown causes (28 %).

Secondary faults in Finland accounted for 4 % of all faults in 2021 and caused approximately 12 % of the total ENS. Secondary faults were primarily caused by operation and maintenance (38 %) and other environmental causes (25 %), and the ENS of the secondary faults was mainly due to other environmental causes (89 %).

The three most significant disturbances in the 110–400 kV grid in 2021 were:

- 110 kV line protection overcurrent relay fault. ENS 30 MWh. Loss of 20 000 end customers.
- One-phase fault on 110 kV line due to environmental causes. ENS 17 MWh.
- Three-phase fault on 110 kV line because of fallen tower. ENS 12 MWh.

2.4 Summary of Iceland

In Iceland, the ENS caused by grid disturbances was 64 MWh in 2021 (10-year annual average 1016 MWh). There were 46 grid disturbances (10-year annual average 43) and 11 of them caused ENS. On average, 19.5 disturbances per year have caused ENS in 2012–2021.

In 2021, 38 % of the total ENS was caused by overhead line faults, and 29 % by substation faults. The most significant reasons for ENS caused by disturbances were other environmental causes (55 %) and other causes (33 %). Disturbances were caused most by other causes (50 %) and other environmental causes (28 %).

Secondary faults in Iceland accounted for 21 % of all faults in 2021 and caused approximately 7 % of the total ENS. Secondary faults were primarily caused by other causes (79 %) and technical equipment (14 %), and the ENS of the secondary faults was mainly due to technical equipment (76 %).

The number of disturbances in the 132–220 kV voltage levels in 2021 was under the 10-year average. The ENS by these disturbances was the lowest amount of ENS in the last 17 years. The majority of ENS was caused by three events.

The most significant disturbances in 2021 were the following:

- The 132 kV line SI4/PB1 tripped due to strong winds causing 19 MWh of ENS.
- The emergency trip of an aluminium smelter had widespread consequences: three islands were formed in the power system, two transformers tripped (due to unintentional protection activation), and five hydro units were disconnected from the grid (of which four also tripped). ENS 11.5 MWh.
- A trip of the two 132 kV lines VA1 and HT1 resulted in ENS 10.4 MWh.

2.5 Summary of Latvia

In Latvia, the ENS caused by grid disturbances was 10 MWh in 2021 (10-year annual average 81 MWh). There were 105 grid disturbances (10-year annual average 134) and 8 of them caused ENS.

In 2021, 87 % of the total ENS was caused by substation faults, and 12 % by overhead line faults. The most significant reasons for ENS caused by disturbances were unknown causes (45 %) and technical equipment (42 %). Disturbances were caused most by external influences (26 %) and unknown causes (24 %).

Secondary faults in Latvia accounted for 13 % of all faults in 2021 and caused approximately 84 % of the total ENS. Secondary faults were primarily caused by operation and maintenance (62 %) and technical equipment (38 %), and all ENS of the secondary faults was due to operation and maintenance.

The most significant disturbances in 2021 were the following:

- A primary fault on a 330 kV overhead line induced three underlying secondary faults in independent control equipment, which caused outages of four overhead lines and two power transformers and 4.5 MWh of ENS.
- Internal short-circuit in a voltage transformer of an overhead line caused a secondary fault in the control equipment of a power transformer in another substation. The disturbance resulted in 4.1 MWh of ENS.
- Three unrelated faults on different overhead lines occurred within a short time and caused repeating wrong operation of control equipment in one substation. This resulted in three automatic reconnections of one overhead line until the malfunction was disabled manually.

2.6 Summary of Lithuania

In Lithuania, the ENS caused by grid disturbances was 21 MWh in 2021 (10-year annual average 38 MWh). There were 159 grid disturbances (10-year annual average 156) and 15 of them caused ENS.

In 2021, 88 % of the total ENS was caused by overhead line faults, and 12 % by substation faults. The most significant reasons for ENS caused by disturbances were external influences (50 %) and other environmental causes (33 %). Disturbances were caused most by unknown causes (50 %) and other causes (16 %).

There were no secondary faults in Lithuania in 2021.

The most significant disturbances in 2021 were the following:

- On 3 May 2021, there was a disconnection of multiple 110 kV overhead lines during heavy and wet snow fall and high winds that caused a tree to fall on one line and contact phase wires on other lines. ENS was 5.8 MWh.
- On 1 July 2021, two 110 kV overhead lines tripped when a yacht contacted the lines. ENS was 3 MWh.
- On 20 November 2021, multiple 110 kV overhead lines were disconnected due to very high winds which caused trees to fall on the lines. ENS was 6.2 MWh.

2.7 Summary of Norway

In Norway, the ENS caused by grid disturbances was 986 MWh in 2021 (10-year annual average 2225 MWh). There were 215 grid disturbances (10-year annual average 288) and 68 of them caused ENS.

In 2021, 51 % of the total ENS was caused by overhead line faults, and 48 % by substation faults. The most significant reasons for ENS caused by disturbances were other environmental causes (46 %) and operation and maintenance (37 %). Disturbances were caused most by other environmental causes (31 %) and technical equipment (23 %).

Secondary faults in Norway accounted for 14 % of all faults in 2021 and caused approximately 13 % of the total ENS. Secondary faults were primarily caused by other environmental causes (40 %) and technical equipment (20 %), and the ENS of the secondary faults was mainly due to other environmental causes (92 %).

The most significant disturbances in 2021 were the following:

- A short-circuit in a disconnector tripped a 400/132 kV transformer and a 132 kV overhead line supplying a steel mill in northern Norway. The steel mill, with 125 MW of load at the time of the incident, was restored gradually and fully restored after 1.5 hours. The disturbance caused 160 MWh of ENS.
- Draining of SF6 gas from the wrong chamber during maintenance preparation caused a line-to-earth short-circuit that tripped breakers in the neighbouring stations. The reason for this incident was incorrect labelling of a gas valve. The disturbance resulted in an interruption of a large gas processing plant and an offshore oil platform in western Norway for 2 hours. The disturbance caused 328 MWh of ENS.
- A 22 kV circuit breaker broke while energising a transformer in a power station in northern Norway. The generator transformer tripped as a consequence. The transformer was reconnected after inspection and a short-circuit occurred in the transformer. Simultaneously, there was a functional failure on its 132 kV circuit breaker (it did not disconnect) and the fault was cleared at the voltage level above. During reconfiguration of the network after the disturbance the faulty transformer was erroneously energised again due to the functional failure of its circuit breaker and a new short-circuit occurred. The transformer and generator was unavailable for nearly 4 months. About 12 000 end-users were interrupted causing 222 MW of interrupted power and 8 MWh of ENS.

2.8 Summary of Sweden

In Sweden, the ENS caused by grid disturbances was 742 MWh in 2021 (10-year annual average 1467 MWh). There were 445 grid disturbances (10-year annual average 439) and 150 of them caused ENS.

In 2021, 53 % of the total ENS was caused by overhead line faults, and 32 % by substation faults. The most significant reasons for ENS caused by disturbances were lightning (23 %) and technical equipment (22 %). Disturbances were caused most by lightning (39 %) and unknown causes (30 %).

Secondary faults in Sweden accounted for 6 % of all faults in 2021 and caused approximately 1 % of the total ENS. Secondary faults were caused by technical equipment (96 %) and unknown causes (4 %), and all ENS of the secondary faults was due to technical equipment.

There was one grid disturbance in 2021 that stood out from the others. It was a 1-phase earth fault on a 220 kV overhead line with a secondary fault on the control equipment of a 220/400 kV power transformer. The faults disconnected and formed an island of the remaining 220 kV. Moreover, the island couldn't maintain itself, got de-energised and resulted in 13.2 MWh of ENS. Both fault causes were unknown.

3 Disturbances

3.1 Overview

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

Table 3.1 presents the number of grid disturbances in 2021 by country and the annual averages for 2012–2021, and Figure 3.1 shows the annual number of disturbances for 2012–2021, 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 2021, and their annual averages for 2012–2021 in the 100–420 kV grids.

	Disturbances		Disturbances causing ENS	
Country	Number 2021	Annual average 2012–2021	Number 2021	Annual average 2012–2021
Estonia	141	172.4	15	27.2
Latvia	105	133.9	8	15.3
Lithuania	159	156.2	15	18.1
Baltic total	405	462.5	38	60.6
Denmark	89	61.1	6	6.5
Finland	408	405.4	85	71.6
Iceland	46	42.7	11	19.6
Norway	215	287.7	68	76.8
Sweden	445	438.8	150	144.3
Nordic total	1203	1235.7	320	318.8
Baltic & Nordic total	1608	1698.2	358	379.4

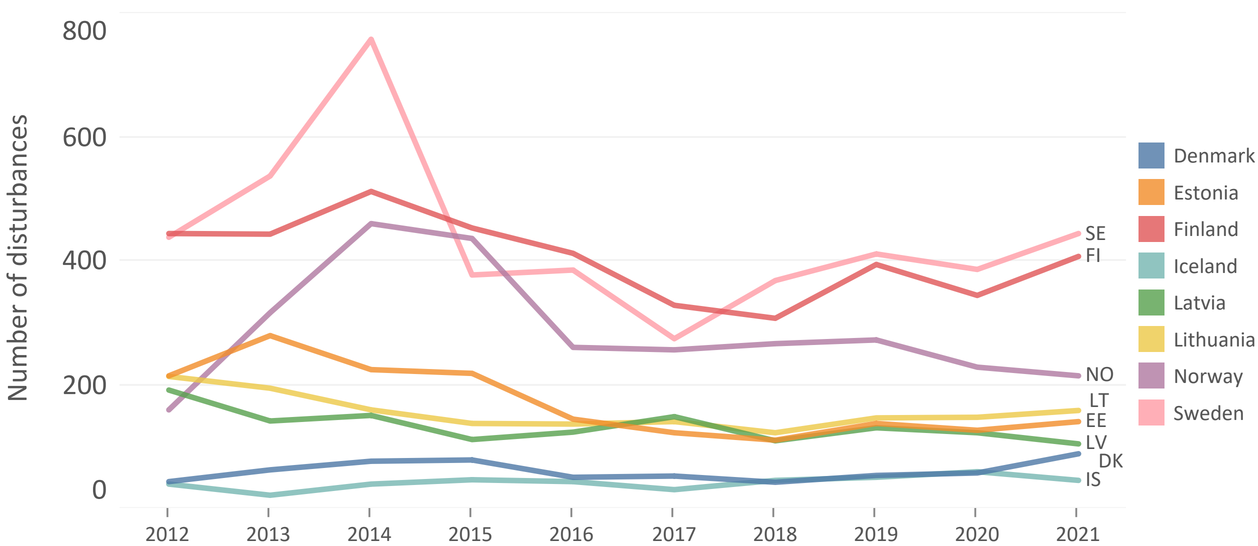

Figure 3.1: Annual number of grid disturbances in the 100–420 kV grids.

3.2 Disturbances by month

Table 3.2 presents the percentage allocation of grid disturbances in the 100–420 kV grids by month in 2021. Table 3.3 presents percentage allocation by month over 2012–2021.

Table 3.2: Percentage allocation of grid disturbances in the 100–420 kV grids by month in 2021. Proportionately higher percentage values are highlighted in yellow and red.

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Estonia	4%	2%	9%	14%	12%	16%	11%	15%	6%	6%	4%	2%
Latvia	6%	3%	6%	5%	8%	20%	15%	16%	5%	9%	2%	7%
Lithuania	9%	1%	4%	5%	13%	15%	17%	25%	2%	3%	3%	3%
Denmark	13%	6%	6%	6%	4%	6%	13%	4%	7%	6%	3%	26%
Finland	5%	3%	5%	6%	12%	20%	14%	13%	5%	3%	4%	8%
Iceland	15%	9%	11%	11%	7%	2%	4%	0%	17%	13%	4%	7%
Norway	14%	5%	12%	5%	6%	7%	13%	7%	4%	9%	14%	4%
Sweden	7%	3%	4%	3%	4%	18%	29%	16%	5%	4%	4%	4%

Table 3.3: Percentage allocation of grid disturbances in the 100–420 kV grids by month over 2012–2021. Proportionately higher percentage values are highlighted in yellow and red.

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Estonia	4%	3%	5%	6%	9%	13%	18%	20%	7%	7%	4%	4%
Latvia	4%	3%	6%	5%	9%	13%	14%	21%	8%	7%	5%	6%
Lithuania	3%	2%	7%	6%	9%	11%	18%	27%	5%	5%	3%	4%
Denmark	7%	7%	6%	7%	8%	8%	9%	11%	8%	9%	8%	13%
Finland	6%	4%	3%	6%	10%	15%	22%	13%	7%	4%	3%	5%
Iceland	12%	13%	13%	5%	4%	6%	6%	3%	7%	7%	8%	17%
Norway	15%	8%	9%	4%	4%	8%	12%	8%	6%	6%	8%	11%
Sweden	5%	4%	4%	4%	7%	13%	23%	18%	7%	5%	5%	6%

3.3 Disturbances by cause

This section presents grid disturbances in the 100–420 kV grids by 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 2021. Table 3.5 shows the respective percentages over 2012–2021.

Table 3.6 presents the percentage allocation of grid disturbances that caused ENS by cause in terms of the primary fault in 2021. Table 3.7 shows the respective percentages over 2012–2021.

Table 3.4: Grid disturbances (%) by cause for 2021. 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	8%	2%	20%	13%	27%	13%	16%
Latvia	7%	17%	26%	3%	17%	7%	24%
Lithuania	1%	11%	11%	8%	3%	16%	50%
Denmark	2%	21%	18%	20%	24%	15%	0%
Finland	22%	32%	3%	9%	6%	0%	28%
Iceland	0%	28%	0%	7%	13%	50%	2%
Norway	19%	31%	4%	13%	23%	7%	4%
Sweden	39%	3%	2%	7%	10%	9%	30%

Table 3.5: Percentage allocation of grid disturbances by cause over 2012–2021. 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%	25%	8%	15%	24%	12%	7%
Latvia	10%	23%	24%	6%	9%	9%	19%
Lithuania	8%	5%	23%	7%	6%	15%	35%
Denmark	8%	10%	22%	19%	18%	12%	10%
Finland	21%	32%	1%	6%	4%	18%	17%
Iceland	2%	37%	2%	10%	12%	33%	3%
Norway	19%	34%	2%	14%	19%	9%	4%
Sweden	35%	4%	1%	7%	14%	10%	28%

Table 3.6: Percentage allocation of grid disturbances that caused ENS by cause in 2021. 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%	20%	20%	13%	40%	7%
Latvia	0%	25%	0%	13%	25%	13%	25%
Lithuania	0%	20%	33%	47%	0%	0%	0%
Denmark	0%	0%	0%	50%	50%	0%	0%
Finland	19%	18%	5%	16%	8%	1%	33%
Iceland	0%	55%	0%	27%	9%	9%	0%
Norway	25%	25%	3%	22%	13%	6%	6%
Sweden	38%	2%	3%	6%	8%	18%	25%

Table 3.7: Percentage allocation of grid disturbances that caused ENS by cause over 2012–2021. 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%	9%	8%	27%	20%	25%	7%
Latvia	1%	30%	24%	18%	16%	7%	4%
Lithuania	4%	10%	37%	24%	13%	4%	8%
Denmark	3%	6%	0%	49%	25%	11%	6%
Finland	17%	15%	3%	10%	8%	14%	33%
Iceland	3%	48%	2%	12%	13%	21%	1%
Norway	25%	27%	2%	20%	15%	9%	2%
Sweden	37%	2%	2%	9%	13%	8%	28%

4 Energy not supplied

This chapter presents energy not supplied (ENS) caused by grid disturbances. The presentation includes the amount of ENS in 2021 by country and the annual averages for 2012–2021. 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 2021 by country and the annual averages for 2012–2021.

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 2021 and the annual averages for 2012–2021.

	ENS (MWh)	
Country	2021	Annual average 2012–2021
Estonia	13.5	91.3
Latvia	10.3	81.0
Lithuania	20.5	38.4
Baltic total	44.4	210.8
Denmark	45.4	32.0
Finland	131.7	259.6
Iceland	63.6	1016.2
Norway	986.0	2225.4
Sweden[1]	741.9	1467.1
Nordic total	1968.6	5000.3
Baltic & Nordic total	2012.9	5211.1

[1] 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 2021 and the corresponding annual averages for 2012–2021. Ppm (parts per million) represents ENS (MWh) as a proportional value of the consumed energy (TWh).

	Consumption	ENS	ENS / consumption (ppm)	
Country	(TWh) 2021	(MWh) 2021	2021	Annual average 2012–2021
Estonia	9.0	13.5	1.5	11.1
Latvia	7.4	10.3	1.4	11.4
Lithuania	12.8	20.5	1.6	3.5
Baltic total	29.1	44.4	1.5	8.0
Denmark	36.3	45.4	1.3	0.9
Finland	84.7	131.7	1.6	3.1
Iceland	18.7	63.6	3.4	56.1
Norway	132.9	986.0	7.4	17.0
Sweden	139.9	741.9	5.3	10.6
Nordic total	412.5	1968.6	4.8	12.3
Baltic & Nordic total	441.6	2012.9	4.6	12.1

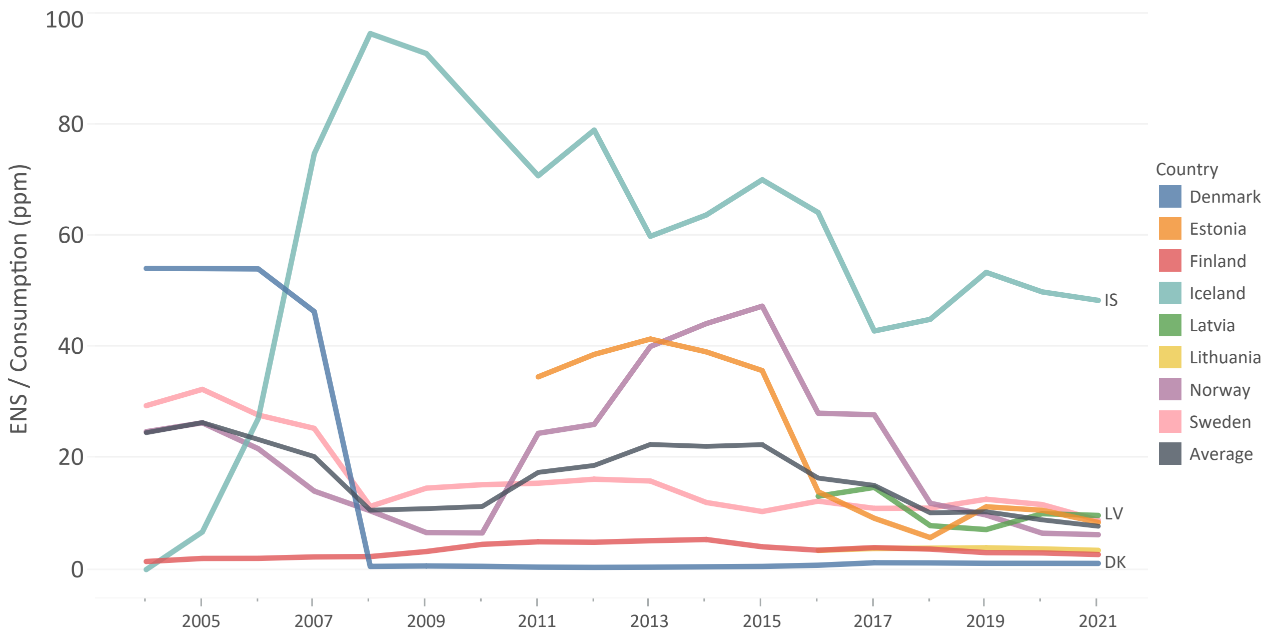

Figure 4.1: 5-year moving average for the amount of ENS divided by consumption (ppm) since 2000. Estonia has data since 2007 and since Latvia and Lithuania have data since 2012. Ppm (parts per million) represents ENS (MWh) as a proportional value of the consumed energy (TWh).

4.3 Energy not supplied by month

This section presents ENS due to disturbances that occurred in the 100–420 kV grids by month. Table 4.3 shows the percentage allocation of ENS by month in 2021 and Table 4.4 presents the respective percentage values over 2012–2021.

Table 4.3: ENS (%) by month in 2021. Proportionately higher percentage values are highlighted in yellow and red.

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Estonia	0%	0%	49%	2%	21%	0%	0%	10%	18%	0%	0%	1%
Latvia	0%	0%	0%	0%	43%	0%	3%	1%	51%	2%	0%	0%
Lithuania	6%	1%	2%	0%	28%	9%	15%	7%	0%	0%	30%	3%
Denmark	0%	5%	0%	0%	0%	7%	0%	60%	28%	0%	0%	0%
Finland	0%	2%	4%	17%	8%	5%	13%	6%	3%	0%	7%	35%
Iceland	49%	0%	36%	0%	0%	0%	0%	0%	8%	0%	1%	6%
Norway	15%	0%	3%	3%	0%	3%	1%	2%	1%	1%	71%	0%
Sweden	10%	4%	5%	7%	6%	15%	27%	7%	2%	7%	4%	5%

Table 4.4: Percentage allocation of ENS by month over 2012–2021. Proportionately higher percentage values are highlighted in yellow and red.

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Estonia	8%	6%	4%	5%	6%	4%	6%	5%	9%	29%	5%	13%
Latvia	1%	0%	2%	0%	3%	23%	8%	9%	8%	35%	4%	6%
Lithuania	3%	7%	13%	6%	7%	23%	18%	7%	2%	10%	3%	3%
Denmark	4%	15%	4%	5%	7%	5%	1%	12%	10%	27%	3%	8%
Finland	7%	2%	11%	6%	4%	8%	16%	17%	3%	6%	6%	15%
Iceland	39%	13%	5%	1%	1%	6%	3%	0%	4%	1%	4%	24%
Norway	10%	9%	46%	4%	1%	5%	3%	3%	3%	2%	8%	5%
Sweden	5%	6%	3%	3%	6%	13%	22%	13%	5%	10%	5%	8%

4.4 Energy not supplied by cause

This section presents ENS by 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 2021. Table 4.6 shows the respective percentages over 2012–2021.

Table 4.5: ENS (%) by cause in 2021. 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%	2%	1%	47%	50%	0%
Latvia	0%	12%	0%	84%	1%	0%	1%
Lithuania	0%	33%	50%	16%	0%	0%	0%
Denmark	0%	0%	0%	71%	29%	0%	0%
Finland	12%	17%	4%	39%	4%	1%	23%
Iceland	0%	55%	0%	7%	6%	33%	0%
Norway	4%	45%	1%	37%	10%	1%	0%
Sweden	23%	0%	4%	17%	23%	17%	16%

Table 4.6: Percentage allocation of ENS by cause over 2012–2021. 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%	2%	1%	13%	45%	39%	1%
Latvia	0%	40%	12%	39%	9%	0%	0%
Lithuania	1%	14%	33%	14%	33%	3%	2%
Denmark	0%	7%	0%	58%	27%	6%	1%
Finland	11%	15%	3%	11%	25%	24%	11%
Iceland	2%	52%	1%	12%	11%	22%	0%
Norway	5%	55%	1%	8%	20%	10%	2%
Sweden	26%	1%	4%	10%	31%	10%	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 by voltage level

Table 4.7 and Table 4.8 show the amount of ENS and its allocation by voltage level in 2021 and for 2012–2021.

Table 4.7: ENS in 2021 and its annual average for 2012–2021, and the annual average amount of ENS by voltage level for 2012–2021.

	ENS (MWh)		Average annual ENS (MWh) by voltage level over 2012–2021			
Country	2021	Annual average 2012–2021	100–150 kV	220–330 kV	380–420 kV	Other[1]
Estonia	13.5	91.3	64.8	5.3	0.0	30.6
Latvia	10.3	81.0	63.4	17.5	0.0	0.1
Lithuania	20.5	38.4	37.1	0.9	0.0	0.6
Baltic total	44.4	210.8	165.3	23.6	0.0	31.4
Denmark	45.4	32.0	30.0	0.0	1.0	1.4
Finland	131.7	259.6	236.7	2.7	0.6	35.2
Iceland	63.6	1016.2	367.2	577.5	0.0	207.8
Norway	986.0	2225.4	847.2	325.5	1039.3	12.6
Sweden	741.9	1467.1	1160.7	88.5	53.0	107.1
Nordic total	1968.6	5000.3	2641.8	994.2	1093.8	364.1
Baltic & Nordic total	2012.9	5211.1	2807.2	1017.9	1093.8	395.4

[1] The category *Other* contains ENS from, for example, system faults, lower voltage level networks and connections to foreign countries.

Table 4.8: ENS (MWh) by statistical voltage level in 2021.

Country	100–150 kV	220–330 kV	380–420 kV
Estonia	6.8	0.0	0.0
Latvia	10.3	0.0	0.0
Lithuania	20.4	0.1	0.0
Denmark	37.6	0.0	7.7
Finland	130.7	0.0	0.0
Iceland	42.6	0.0	0.0
Norway	553.4	397.0	27.6
Sweden	599.3	26.9	10.5
Baltic & Nordic	1401.0	424.0	45.7

4.6 Energy not supplied by component

Table 4.9 presents the percentage allocation of ENS by component in 2021, and Table 4.10 shows the respective percentages over 2012–2021. The ENS is allocated to the component where each fault occurred. The total amount of ENS in 2021 and the annual average values for 2012–2021 are in Table 4.7.

Table 4.9: ENS (%) by component in 2021. 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		
	Cables	Overhead lines	Total	Busbars	Circuit breakers	Common ancillary equipment	Control equipment	Disconnectors	Instrument transformers	Power transformers	Surge arresters and spark gaps	Other high voltage appliances	Total	Reactors	Series capacitors	Shunt capacitors	SVC	Synchronous compensators	Total	Adjoining grid	System faults	Total
Estonia	0%	2%	2%	0%	0%	0%	1%	38%	9%	0%	0%	0%	48%	0%	0%	0%	0%	0%	0%	50%	0%	50%
Latvia	0%	12%	12%	0%	1%	0%	85%	0%	0%	1%	0%	0%	87%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Lithuania	0%	88%	88%	0%	0%	0%	1%	3%	8%	0%	0%	0%	12%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Denmark	0%	0%	0%	51%	0%	0%	25%	0%	17%	7%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Finland	0%	60%	60%	0%	0%	0%	34%	4%	0%	0%	0%	1%	40%	0%	0%	0%	0%	0%	0%	1%	0%	1%
Iceland	0%	38%	38%	16%	0%	0%	12%	0%	0%	0%	0%	0%	29%	0%	0%	0%	0%	0%	0%	33%	0%	33%
Norway	0%	51%	51%	0%	2%	0%	5%	0%	39%	1%	0%	0%	48%	0%	0%	0%	0%	0%	0%	0%	1%	1%
Sweden	1%	53%	53%	0%	5%	0%	15%	1%	9%	2%	0%	0%	32%	0%	0%	0%	0%	0%	0%	14%	0%	14%

Table 4.10: Percentage allocation of ENS by component over 2012–2021. 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		
	Cables	Overhead lines	Total	Busbars	Circuit breakers	Common ancillary equipment	Control equipment	Disconnectors	Instrument transformers	Power transformers	Surge arresters and spark gaps	Other high voltage appliances	Total	Reactors	Series capacitors	Shunt capacitors	SVC	Synchronous compensators	Total	Adjoining grid	System faults	Total
Estonia	0%	22%	22%	1%	3%	0%	14%	1%	1%	2%	0%	19%	41%	0%	0%	3%	0%	0%	3%	34%	0%	34%
Latvia	0%	51%	51%	2%	0%	0%	39%	3%	1%	3%	0%	0%	49%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Lithuania	1%	54%	54%	1%	7%	0%	24%	8%	2%	1%	1%	0%	44%	0%	0%	0%	0%	0%	0%	1%	0%	1%
Denmark	0%	2%	2%	49%	10%	0%	13%	7%	8%	6%	0%	0%	94%	0%	0%	0%	0%	0%	0%	4%	0%	4%
Finland	0%	58%	58%	2%	4%	0%	7%	1%	6%	4%	0%	2%	27%	0%	1%	0%	0%	0%	1%	13%	1%	14%
Iceland	1%	14%	15%	0%	30%	0%	12%	0%	0%	14%	0%	8%	65%	0%	0%	0%	0%	0%	0%	12%	8%	21%
Norway	4%	57%	61%	3%	2%	1%	13%	4%	4%	2%	4%	6%	38%	0%	0%	0%	0%	0%	0%	0%	1%	1%
Sweden	5%	46%	51%	5%	3%	0%	8%	2%	7%	8%	2%	5%	39%	0%	0%	1%	0%	0%	1%	8%	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 2021.

	Faults in 2021			Secondary faults in 2021	
Country	Number	causing ENS	ENS (MWh)	Number	ENS (MWh)
Estonia	145	16	13.5	4	1.2
Latvia	121	8	10.3	16	8.6
Lithuania	165	15	20.5	0	0.0
Baltic total	431	39	44.4	20	9.8
Denmark	92	6	45.4	3	0.0
Finland	432	86	131.7	16	15.3
Iceland	66	14	63.6	14	4.7
Norway	250	74	986.0	35	130.7
Sweden	489	151	741.9	27	10.2
Nordic total	1329	331	1968.6	95	160.9
Baltic & Nordic total	1760	370	2012.9	115	170.8

5.2 Statistics of secondary faults

Table 5.2 presents the percentage allocation of secondary faults by cause in 2021, and Table 5.3 shows the respective values over 2017–2021. Table 5.4 presents the annual number of secondary faults for 2017–2021.

Table 5.5 presents the percentage allocation of ENS due to secondary faults in 2021, and Table 5.6 shows the respective values over 2017–2021. Table 5.7 presents the annual amounts of ENS caused by the secondary faults for 2017–2021.

Data about secondary faults have been collected since 2017.

Table 5.2: Percentage allocation of secondary faults by cause in 2021. 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%	100%	0%	0%
Latvia	0%	0%	0%	63%	38%	0%	0%
Lithuania	0%	0%	0%	0%	0%	0%	0%
Denmark	0%	0%	0%	0%	33%	67%	0%
Finland	0%	25%	13%	38%	25%	0%	0%
Iceland	0%	7%	0%	0%	14%	79%	0%
Norway	17%	39%	0%	8%	22%	14%	0%
Sweden	0%	0%	0%	0%	96%	0%	4%

Table 5.3: Percentage allocation of secondary faults by cause over 2017–2021. 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%	7%	7%	26%	35%	21%	5%
Latvia	0%	0%	0%	38%	51%	7%	5%
Lithuania	2%	0%	0%	27%	21%	13%	38%
Denmark	0%	0%	4%	77%	4%	15%	0%
Finland	10%	13%	6%	32%	10%	18%	11%
Iceland	0%	11%	0%	5%	11%	73%	0%
Norway	14%	15%	1%	21%	32%	10%	6%
Sweden	6%	0%	0%	4%	73%	6%	10%

Table 5.4: Annual number of secondary faults for 2017–2021.

Country	2017	2018	2019	2020	2021	Annual average
Estonia	9	8	7	15	4	8.6
Latvia	20	20	23	9	16	11.2
Lithuania	13	19	18	6	0	17.6
Denmark	9	3	6	5	3	5.2
Finland	13	9	6	18	16	12.4
Iceland	8	18	26	22	14	17.6
Norway	30	34	26	28	36	30.8
Sweden	10	7	14	9	27	13.4
Baltic & Nordic	112	118	126	112	116	116.8

Table 5.5: Percentage allocation of ENS due to secondary faults by cause in 2021. 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%	100%	0%	0%
Latvia	0%	0%	0%	100%	0%	0%	0%
Lithuania	0%	0%	0%	0%	0%	0%	0%
Denmark	0%	0%	0%	0%	0%	0%	0%
Finland	0%	89%	3%	8%	0%	0%	0%
Iceland	0%	24%	0%	0%	76%	0%	0%
Norway	3%	92%	0%	0%	4%	0%	0%
Sweden	0%	0%	0%	0%	100%	0%	0%

Table 5.6: Percentage allocation of ENS due to secondary faults by cause over 2017–2021. 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%	1%	19%	77%	2%	0%
Latvia	0%	0%	0%	95%	5%	0%	0%
Lithuania	0%	0%	0%	1%	95%	4%	0%
Denmark	0%	0%	0%	76%	0%	24%	0%
Finland	9%	20%	1%	10%	7%	51%	2%
Iceland	0%	2%	0%	0%	4%	94%	0%
Norway	1%	24%	30%	9%	1%	35%	0%
Sweden	0%	0%	0%	0%	20%	63%	16%

Table 5.7: Annual amount of ENS (MWh) due to secondary faults for 2017–2021.

Country	2017	2018	2019	2020	2021	Annual average
Estonia	0.1	0.3	0.1	0.1	1.2	0.4
Latvia	16.0	34.1	2.2	163.3	8.6	44.8
Lithuania	50.0	25.2	0.5	24.1	0.0	20.0
Denmark	4.0	0.3	4.7	0.0	0.0	1.8
Finland	6.0	48.2	12.6	12.9	15.3	19.0
Iceland	0.0	0.0	0.2	84.1	4.7	17.8
Norway	58.8	131.3	71.3	167.2	130.9	111.9
Sweden	32.0	0.0	8.4	0.0	10.2	10.1
Baltic & Nordic	166.9	239.3	100.0	451.7	170.9	225.8

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 2021 and for 2012–2021. Table 6.2 shows the number of faults and number of grid disturbances in 2021, their annual averages for 2012–2021, and the faults to disturbance ratio over 2012–2021.

Table 6.3 shows the percentage allocation of faults per component in 2021, and Table 6.4 shows the respective percentages over 2012–2021. 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 2021 and their annual averages for 2012–2021.

	Number of faults		No. of faults with ENS		ENS (MWh)	
Country	2021	Annual avg. 2012–2021	2021	Annual avg. 2012–2021	2021	Annual avg. 2012–2021
Estonia	145	179.0	16.0	27.3	13.5	91.3
Latvia	121	147.7	8.0	17.1	10.3	81.0
Lithuania	165	167.3	15.0	18.2	20.5	38.4
Baltic total	431	494.0	39.0	62.6	44.4	210.8
Denmark	92	68.8	6.0	7.3	45.4	32.0
Finland	432	423.1	86.0	77.7	131.7	259.6
Iceland	66	62.2	14.0	21.9	63.6	1016.2
Norway	250	328.4	74.0	86.5	986.0	2225.4
Sweden	489	458.8	151.0	169.5	741.9	1467.1
Nordic total	1329	1341.3	331.0	362.9	1968.6	5000.3
Baltic & Nordic total	1760	1835.3	370.0	425.5	2012.9	5211.1

Table 6.2: The number of faults and the number of grid disturbances in 2021, their annual averages for 2012–2021, and the fault to disturbance ratio in 2021 and over 2012–2021.

Country	Number of faults 2021	Number of faults Annual avg. 2012–2021	No. of disturbances 2021	No. of disturbances Annual avg. 2012–2021	Ratio 2021	Ratio Annual avg. 2012–2021
Estonia	145	179.0	141	172.4	1.03	1.04
Latvia	121	147.7	105	133.9	1.15	1.10
Lithuania	165	167.3	159	156.2	1.04	1.07
Baltic total	431	494.0	405	462.5	1.06	1.07
Denmark	92	68.8	89	61.1	1.03	1.13
Finland	432	423.1	408	405.4	1.06	1.04
Iceland	66	62.2	46	42.7	1.43	1.46
Norway	250	328.4	215	287.7	1.16	1.14
Sweden	489	458.8	445	438.8	1.10	1.05
Nordic total	1329	1341.3	1203	1235.7	1.10	1.09
Baltic & Nordic total	1760	1835.3	1608	1698.2	1.09	1.08

Table 6.3: Percentage allocation of faults by component in 2021. 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		
	Cables	Overhead lines	Total	Busbars	Circuit breakers	Common ancillary equipment	Control equipment	Disconnectors	Instrument transformers	Power transformers	Surge arresters and spark gaps	Other high voltage appliances	Total	Reactors	Series capacitors	Shunt capacitors	SVC	Synchronous compensators	Total	Adjoining grid	System faults	Total
Estonia	1%	46%	48%	1%	8%	3%	11%	3%	6%	7%	0%	0%	41%	0%	0%	0%	0%	0%	0%	12%	0%	12%
Latvia	0%	64%	64%	0%	2%	0%	16%	0%	7%	5%	0%	0%	31%	0%	0%	0%	0%	0%	0%	6%	0%	6%
Lithuania	0%	78%	78%	0%	0%	0%	1%	3%	2%	1%	1%	0%	7%	0%	0%	0%	0%	0%	0%	15%	1%	15%
Denmark	1%	50%	51%	3%	2%	0%	12%	0%	4%	5%	1%	0%	28%	1%	0%	0%	1%	3%	5%	15%	0%	15%
Finland	0%	82%	82%	0%	0%	0%	8%	1%	0%	2%	1%	4%	16%	0%	2%	0%	0%	0%	2%	0%	0%	0%
Iceland	0%	20%	20%	2%	8%	0%	12%	0%	0%	3%	0%	2%	26%	0%	0%	0%	0%	0%	0%	33%	21%	55%
Norway	1%	55%	56%	0%	5%	1%	21%	1%	2%	4%	1%	2%	37%	0%	0%	1%	2%	2%	4%	0%	2%	2%
Sweden	1%	68%	69%	0%	2%	0%	15%	0%	1%	2%	0%	0%	21%	1%	2%	0%	0%	0%	4%	7%	0%	7%

Table 6.4: Percentage allocation of faults by component over 2012–2021. Proportionately higher percentage values are highlighted in yellow and red. The symbols are presented in Table 6.3.

	Lines			Substation components										Compensation devices						Other		
	Cables	Overhead lines	Total	Busbars	Circuit breakers	Common ancillary equipment	Control equipment	Disconnectors	Instrument transformers	Power transformers	Surge arresters and spark gaps	Other high voltage appliances	Total	Reactors	Series capacitors	Shunt capacitors	SVC	Synchronous compensators	Total	Adjoining grid	System faults	Total
Estonia	0%	54%	54%	3%	5%	1%	8%	4%	2%	6%	0%	6%	34%	1%	0%	1%	0%	0%	2%	10%	0%	10%
Latvia	0%	67%	67%	1%	2%	0%	14%	1%	1%	4%	0%	0%	23%	0%	0%	0%	0%	0%	0%	9%	0%	9%
Lithuania	0%	68%	68%	1%	4%	1%	9%	1%	1%	1%	1%	0%	19%	0%	0%	0%	0%	0%	0%	13%	0%	13%
Denmark	5%	44%	49%	4%	4%	0%	14%	2%	3%	7%	1%	3%	37%	2%	0%	0%	1%	3%	5%	9%	0%	9%
Finland	0%	82%	82%	0%	1%	0%	6%	0%	1%	2%	0%	2%	13%	0%	1%	0%	0%	0%	2%	4%	0%	4%
Iceland	0%	32%	32%	0%	6%	0%	13%	0%	0%	5%	0%	4%	28%	0%	0%	1%	0%	0%	1%	21%	18%	38%
Norway	1%	49%	51%	1%	4%	2%	19%	1%	2%	2%	1%	8%	40%	0%	0%	1%	5%	1%	8%	0%	2%	2%
Sweden	1%	62%	63%	1%	2%	0%	12%	1%	1%	5%	0%	1%	24%	2%	1%	0%	1%	0%	5%	8%	0%	8%

6.2 Faults by 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 2021. Table 6.6 shows the respective percentages over 2012–2021.

Table 6.7 presents the percentage allocation of faults that caused ENS by cause in 2021. Table 6.8 shows the respective percentages over 2012–2021.

Table 6.5: Percentage allocation of the number of faults by cause in 2021. 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	8%	2%	19%	13%	29%	13%	16%
Latvia	6%	15%	22%	11%	20%	6%	21%
Lithuania	1%	12%	12%	7%	4%	16%	48%
Denmark	2%	21%	17%	20%	24%	16%	0%
Finland	21%	31%	3%	9%	6%	0%	28%
Iceland	0%	21%	0%	5%	15%	58%	2%
Norway	19%	32%	4%	12%	22%	8%	4%
Sweden	36%	3%	2%	9%	14%	8%	28%

Table 6.6: Percentage allocation of the number of faults by cause over 2012–2021. 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%	24%	7%	15%	25%	11%	7%
Latvia	9%	21%	21%	9%	13%	9%	18%
Lithuania	8%	5%	22%	9%	7%	15%	35%
Denmark	8%	10%	20%	22%	18%	13%	9%
Finland	20%	31%	2%	7%	5%	19%	17%
Iceland	2%	30%	1%	7%	12%	47%	1%
Norway	19%	31%	2%	15%	19%	10%	4%
Sweden	33%	4%	1%	8%	15%	12%	26%

Table 6.7: Percentage allocation of the number of faults that caused ENS by cause in 2021. 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%	19%	19%	19%	38%	6%
Latvia	0%	25%	0%	38%	13%	13%	13%
Lithuania	0%	20%	33%	47%	0%	0%	0%
Denmark	0%	0%	0%	50%	50%	0%	0%
Finland	20%	17%	5%	16%	8%	1%	33%
Iceland	0%	50%	0%	21%	21%	7%	0%
Norway	28%	24%	3%	20%	14%	5%	5%
Sweden	38%	2%	3%	6%	9%	18%	25%

Table 6.8: Percentage allocation of the number of faults that caused ENS by cause over 2012–2021. 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%	9%	8%	27%	20%	25%	7%
Latvia	1%	22%	14%	30%	26%	3%	4%
Lithuania	3%	10%	35%	25%	14%	5%	7%
Denmark	3%	5%	0%	47%	25%	15%	5%
Finland	16%	14%	3%	12%	7%	15%	33%
Iceland	3%	46%	1%	11%	14%	25%	0%
Norway	24%	25%	2%	21%	16%	10%	2%
Sweden	34%	2%	2%	9%	15%	12%	26%

6.3 Faults in cables

This section presents cable faults in 2021 and for 2012–2021.

Table 6.9 presents the length of cables and the number of faults in 2021, and the 10-year annual average of the number of faults for 2012–2021. Table 6.10 presents the number of faults per 100 km of cable in 2021 and the annual averages for 2012–2021.

Table 6.11 shows the percentage allocation of cable faults by cause in 2021. Table 6.12 presents the respective percentages over 2012–2021.

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 2021, and the annual average number of faults for 2012–2021, grouped by voltage level.

Country	100–150 kV			220–330 kV			380–420 kV		
	km in 2021	Number of faults in 2021	10-year ann. avg of faults	km in 2021	Number of faults in 2021	10-year ann. avg of faults	km in 2021	Number of faults in 2021	10-year ann. avg of faults
Estonia	103.0	2	0.4	0.0	0	0.0	0.0	0	0.0
Latvia	82.9	0	0.1	22.4	0	0.2	0.0	0	0.0
Lithuania	111.8	0	0.2	0.3	0	0.0	0.0	0	0.0
Denmark	1 674.0	0	2.7	366.0	0	0.3	222.0	1	0.2
Finland	290.0	1	1.2	0.0	0	0.0	0.0	0	0.0
Iceland	90.0	0	0.2	0.0	0	0.0	0.0	0	0.0
Norway	497.0	3	3.6	123.0	0	0.0	22.0	0	0.8
Sweden	504.0	3	2.5	127.0	2	1.5	27.5	0	0.4
Baltic & Nordic	3 352.6	9	10.9	638.7	2	2.0	271.5	1	1.4

Table 6.10: Number of cable faults per 100 km in 2021 and the annual average for 2012–2021, grouped by voltage level.

Country	100–150 kV		220–330 kV		380–420 kV	
	Number of faults / 100 km in 2021	10-year ann. avg no. of faults / 100 km	Number of faults / 100 km in 2021	10-year ann. avg no. of faults / 100 km	Number of faults / 100 km in 2021	10-year ann. avg no. of faults / 100 km
Estonia	1.94	0.58	0.00	0.00	0.00	0.00
Latvia	0.00	0.13	0.00	1.27	0.00	0.00
Lithuania	0.00	0.24	0.00	0.00	0.00	0.00
Denmark	0.00	0.20	0.00	0.17	0.45	0.13
Finland	0.34	0.60	0.00	0.00	0.00	0.00
Iceland	0.00	0.18	0.00	0.00	0.00	0.00
Norway	0.60	1.05	0.00	0.00	0.00	3.24
Sweden	0.60	0.57	1.57	1.17	0.00	2.75
Baltic & Nordic	0.27	0.41	0.31	0.49	0.37	0.73

Table 6.11: Percentage allocation of cable faults by cause in 2021. 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%	0%	0%	0%
Lithuania	0%	0%	0%	0%	0%	0%	0%
Denmark	0%	0%	0%	0%	100%	0%	0%
Finland	0%	0%	0%	0%	100%	0%	0%
Iceland	0%	0%	0%	0%	0%	0%	0%
Norway	0%	0%	0%	0%	100%	0%	0%
Sweden	0%	0%	0%	0%	80%	20%	0%

Table 6.12: Percentage allocation of cable faults by cause over 2012–2021. 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%	75%	0%	25%	0%	0%
Latvia	0%	0%	0%	0%	100%	0%	0%
Lithuania	0%	0%	50%	0%	50%	0%	0%
Denmark	0%	0%	9%	16%	69%	0%	6%
Finland	0%	8%	8%	25%	17%	25%	17%
Iceland	0%	50%	0%	0%	0%	50%	0%
Norway	0%	25%	7%	5%	41%	18%	5%
Sweden	4%	0%	2%	11%	64%	4%	15%

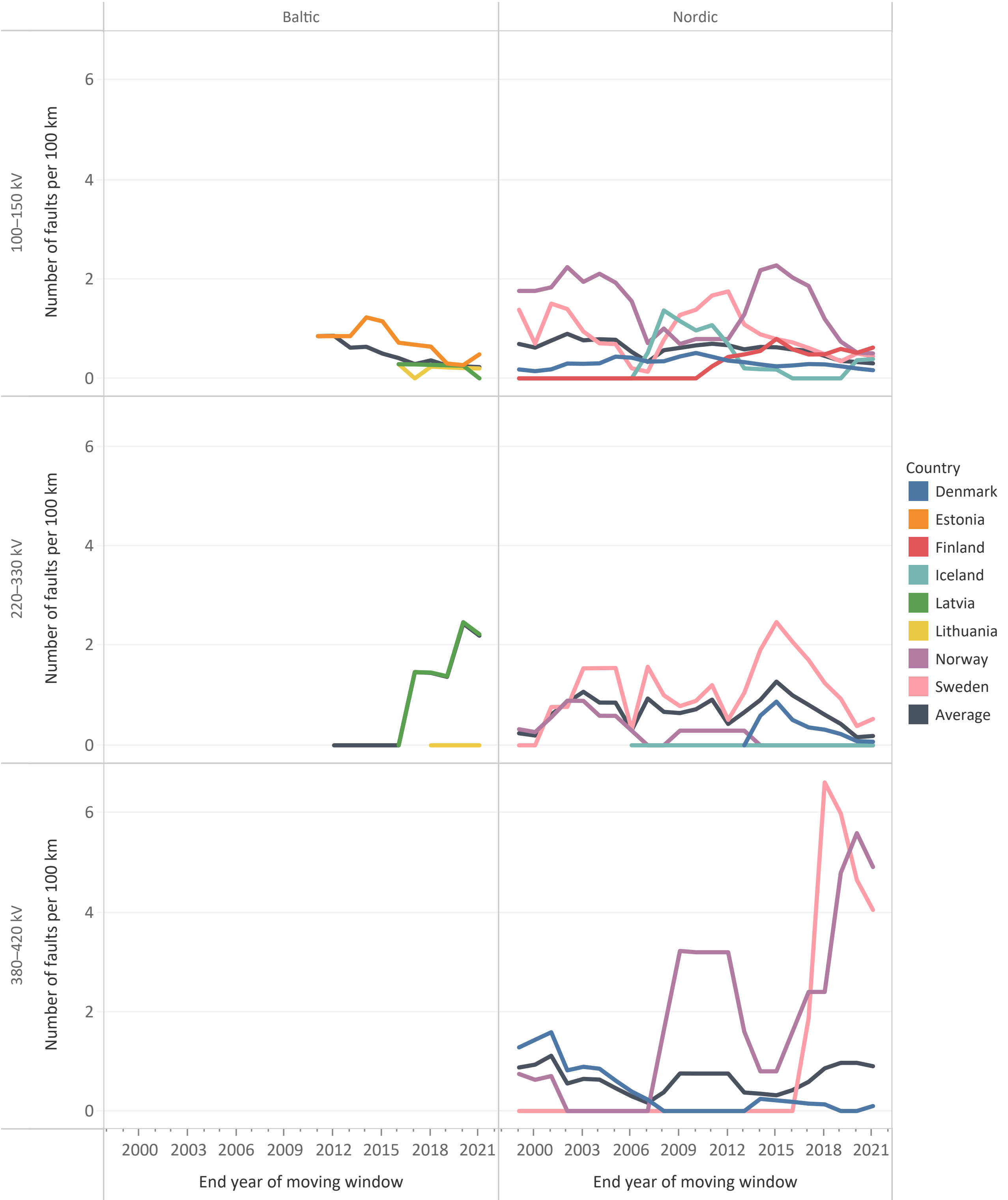

Figure 6.1: 5-year moving average of cable faults per 100 km. Estonia has data since 2007, and Latvia and Lithuania have data since 2012. Estonia, Finland and Lithuania do not own 220–330 kV cables. Estonia, Finland, Iceland, Latvia and Lithuania do not own 380–420 kV cables.

6.4 Faults on overhead lines

This section presents overhead line faults in 2021 and for 2012–2021.

Table 6.13 presents the length of overhead lines and the number of faults in 2021, and the 10-year annual average of the number of faults for 2012–2021. Table 6.14 presents the number of faults per 100 km of overhead line in 2021 and the annual averages for 2012–2021.

Table 6.15 presents the number of faults and the number of permanent faults for 2021 and their 10-year respective average values for 2012–2021.

Table 6.16 shows the percentage allocation of overhead line faults by cause in 2021. Table 6.17 presents the respective percentages over 2012–2021.

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 2021, and the annual average number of faults for 2012–2021, grouped by voltage level.

Country	100–150 kV			220–330 kV			380–420 kV		
	km in 2021	Number of faults in 2021	10-year ann. avg of faults	km in 2021	Number of faults in 2021	10-year ann. avg of faults	km in 2021	Number of faults in 2021	10-year ann. avg of faults
Estonia	3 373.0	53	84.4	1 886.0	14	12.0	0.0	0	0.0
Latvia	3 776.8	71	89.0	1 720.0	6	9.9	0.0	0	0.0
Lithuania	4 988.0	119	102.4	1 894.0	8	11.0	102.7	1	0.6
Denmark	2 781.0	33	25.3	0.0	0	0.3	1 369.0	13	4.5
Finland	16 470.3	334	323.1	1 427.0	8	12.9	5 473.0	11	9.2
Iceland	1 247.0	13	16.4	919.0	0	3.2	0.0	0	0.0
Norway	10 963.0	92	89.2	4 264.0	22	34.7	4 701.0	24	38.1
Sweden	15 143.2	253	214.5	3 466.8	30	28.3	9 542.0	49	35.9
Baltic & Nordic	58 742.3	968	944.3	15 576.8	88	112.3	21 187.7	98	88.3

Table 6.14: Number of overhead line faults per 100 km in 2021 and the annual average for 2012–2021, grouped by voltage level.

Country	100–150 kV		220–330 kV		380–420 kV	
	Number of faults / 100 km in 2021	10-year ann. avg no. of faults / 100 km	Number of faults / 100 km in 2021	10-year ann. avg no. of faults / 100 km	Number of faults / 100 km in 2021	10-year ann. avg no. of faults / 100 km
Estonia	1.57	2.47	0.74	0.65	0.00	0.00
Latvia	1.88	2.33	0.35	0.68	0.00	0.00
Lithuania	2.39	2.06	0.42	0.61	0.97	0.98
Denmark	1.19	0.82	0.00	0.55	0.95	0.34
Finland	2.03	1.95	0.56	0.67	0.20	0.17
Iceland	1.04	1.32	0.00	0.37	0.00	0.00
Norway	0.84	0.83	0.52	0.66	0.51	1.18
Sweden	1.67	1.42	0.87	0.73	0.51	0.34
Baltic & Nordic	1.65	1.60	0.56	0.66	0.46	0.43

Table 6.15: Number of overhead lines faults and permanent faults in 2021 and their 10-year annual average values for 2012–2021, grouped by voltage level.

	100–150 kV				220–330 kV				380–420 kV			
	Faults		Permanent faults		Faults		Permanent faults		Faults		Permanent faults	
Country	Number in 2021	10-year ann. avg	Number in 2021	10-year ann. avg	Number in 2021	10-year ann. avg	Number in 2021	10-year ann. avg	Number in 2021	10-year ann. avg	Number in 2021	10-year ann. avg
Estonia	53	84.4	18	14.7	14	12.0	6	3.8	0	0.0	0	0.0
Latvia	71	89.0	21	33.3	6	9.9	0	1.6	0	0.0	0	0.0
Lithuania	119	102.4	12	16.3	8	11.0	0	2.1	1	0.6	1	0.4
Denmark	33	25.3	8	2.0	0	0.3	0	0.0	13	4.5	2	0.7
Finland	334	323.1	24	22.5	8	12.9	0	1.4	11	9.2	1	1.1
Iceland	13	16.4	6	1.6	0	3.2	0	0.8	0	0.0	0	0.0
Norway	92	89.2	35	20.5	22	34.7	5	3.0	24	38.1	1	1.7
Sweden	253	214.5	9	8.0	30	28.3	3	1.6	49	35.9	3	1.4
Baltic & Nordic	968	944.3	133	118.9	88	112.3	14	14.3	98	88.3	8	5.3

Table 6.16: Percentage allocation of overhead line faults by cause in 2021.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	16%	3%	39%	6%	7%	3%	25%
Latvia	9%	23%	35%	0%	3%	0%	30%
Lithuania	2%	15%	15%	5%	2%	2%	60%
Denmark	4%	41%	35%	7%	13%	0%	0%
Finland	26%	37%	4%	2%	2%	0%	29%
Iceland	0%	100%	0%	0%	0%	0%	0%
Norway	33%	54%	4%	4%	1%	0%	4%
Sweden	52%	4%	2%	3%	2%	0%	37%

Table 6.17: Percentage allocation of overhead line faults by cause over 2012–2021.

Country	Lightning	Other environmental causes	External influences	Operation and maintenance	Technical equipment	Other	Unknown
Estonia	19%	41%	13%	13%	7%	0%	8%
Latvia	13%	31%	29%	1%	1%	0%	25%
Lithuania	11%	7%	30%	2%	3%	1%	45%
Denmark	17%	17%	41%	4%	3%	1%	17%
Finland	24%	37%	1%	2%	1%	16%	19%
Iceland	5%	84%	3%	1%	3%	4%	1%
Norway	35%	56%	1%	1%	3%	2%	2%
Sweden	51%	5%	2%	2%	3%	2%	35%

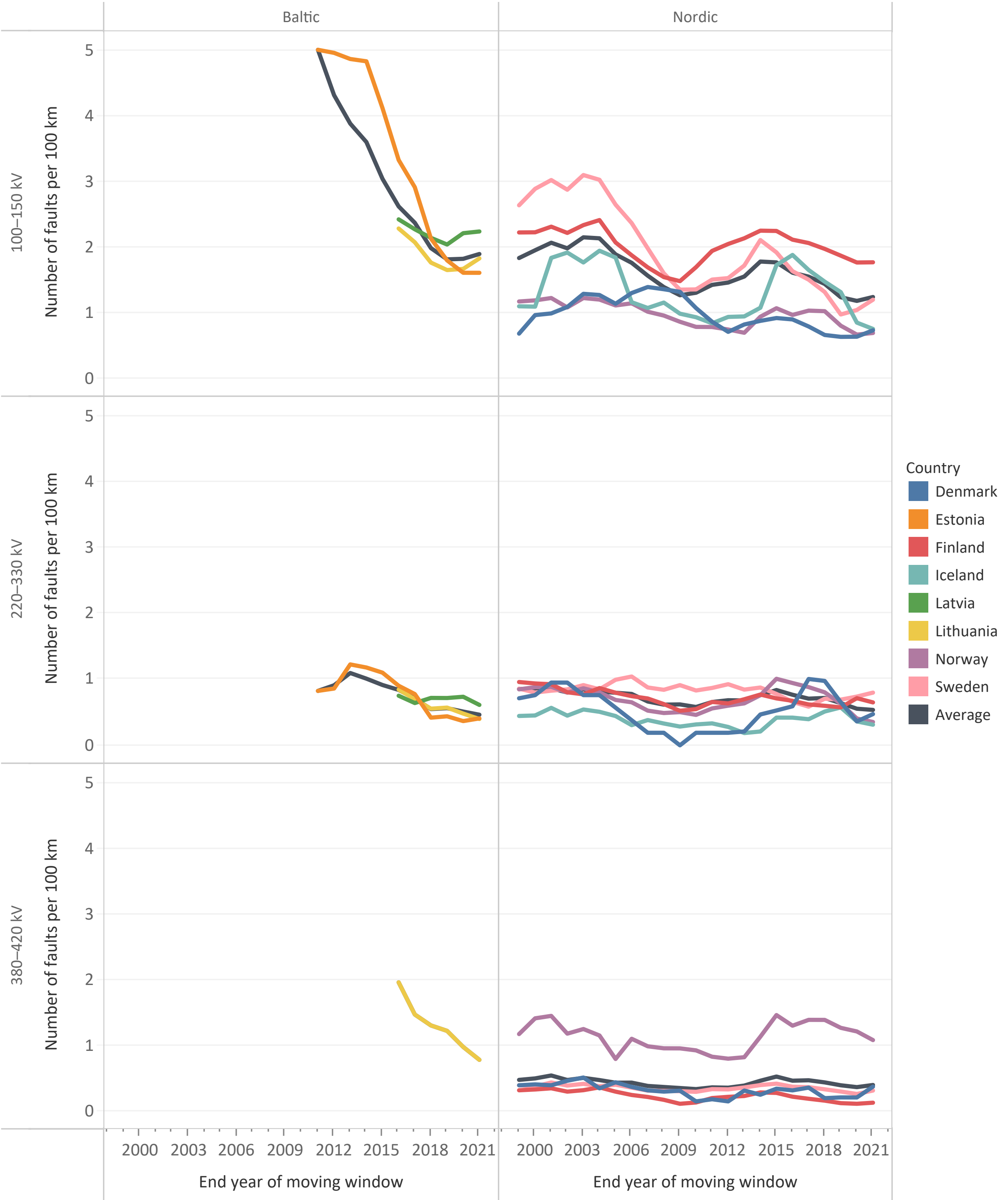

Figure 6.2: 5-year moving average of overhead line faults per 100 km. Estonia has data since 2007, and Latvia and Lithuania have data since 2012. Estonia, Iceland and Latvia do not own 380–420 kV transmission grids.

6.5 Faults in circuit breakers

This section presents circuit breaker faults in 2021 and for 2012–2021.

Table 6.18 presents the number of circuit breakers and the number of faults in 2021, and the 10-year annual average of the number of faults for 2012–2021. Table 6.19 presents the number of faults per 100 devices in 2021 and the annual averages for 2012–2021.

Table 6.20 presents the percentage allocation of circuit breaker faults by cause in 2021. Table 6.21 presents the respective percentages over 2012–2021.

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 2021, and the annual average number of faults for 2012–2021, grouped by voltage level.

Country	100–150 kV			220–330 kV			380–420 kV		
	Number of devices in 2021	Number of faults in 2021	10-year ann. avg of faults	Number of devices in 2021	Number of faults in 2021	10-year ann. avg of faults	Number of devices in 2021	Number of faults in 2021	10-year ann. avg of faults
Estonia	677	11	6.1	129	1	2.3	0	0	0.0
Latvia	602	3	2.7	100	0	0.1	0	0	0.0
Lithuania	803	0	6.0	127	0	0.7	11	0	0.1
Denmark	964	1	2.5	37	1	0.1	266	0	0.4
Finland	2 875	2	4.4	74	0	0.0	371	0	0.5
Iceland	125	2	2.4	87	3	1.1	0	0	0.0
Norway	2 574	5	7.7	694	5	4.4	602	3	2.4
Sweden	2 835	5	4.1	362	2	1.3	714	4	4.9
Baltic & Nordic	11 455	29	35.9	1 610	12	10.0	1 964	7	8.3

Table 6.19: Number of circuit breaker faults per 100 devices in 2021 and the annual average for 2012–2021, grouped by voltage level.

Country	100–150 kV		220–330 kV		380–420 kV	
	Number of faults / 100 devices in 2021	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2021	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2021	10-year ann. avg no. of faults / 100 devices
Estonia	1.62	1.01	0.78	1.87	0.00	0.00
Latvia	0.50	0.44	0.00	0.10	0.00	0.00
Lithuania	0.00	0.70	0.00	0.65	0.00	2.70
Denmark	0.10	0.29	2.70	0.51	0.00	0.20
Finland	0.07	0.17	0.00	0.00	0.00	0.16
Iceland	1.60	1.52	3.45	1.34	0.00	0.00
Norway	0.19	0.33	0.72	0.61	0.50	0.61
Sweden	0.18	0.18	0.55	0.40	0.56	0.81
Baltic & Nordic	0.25	0.35	0.75	0.64	0.36	0.54

Table 6.20: Percentage allocation of circuit breakers faults by cause in 2021. 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%	8%	83%	0%	8%
Latvia	0%	0%	0%	0%	100%	0%	0%
Lithuania	0%	0%	0%	0%	0%	0%	0%
Denmark	0%	0%	0%	0%	100%	0%	0%
Finland	0%	0%	0%	50%	50%	0%	0%
Iceland	0%	0%	0%	0%	100%	0%	0%
Norway	0%	15%	8%	8%	62%	0%	8%
Sweden	0%	0%	0%	18%	55%	9%	18%

Table 6.21: Percentage allocation of circuit breaker faults over 2012–2021. 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%	79%	1%	8%
Latvia	0%	0%	4%	11%	86%	0%	0%
Lithuania	1%	0%	3%	32%	43%	4%	16%
Denmark	0%	0%	0%	77%	20%	0%	3%
Finland	6%	2%	4%	27%	29%	10%	22%
Iceland	0%	11%	3%	9%	49%	29%	0%
Norway	2%	3%	3%	35%	33%	8%	15%
Sweden	11%	0%	0%	12%	68%	2%	8%

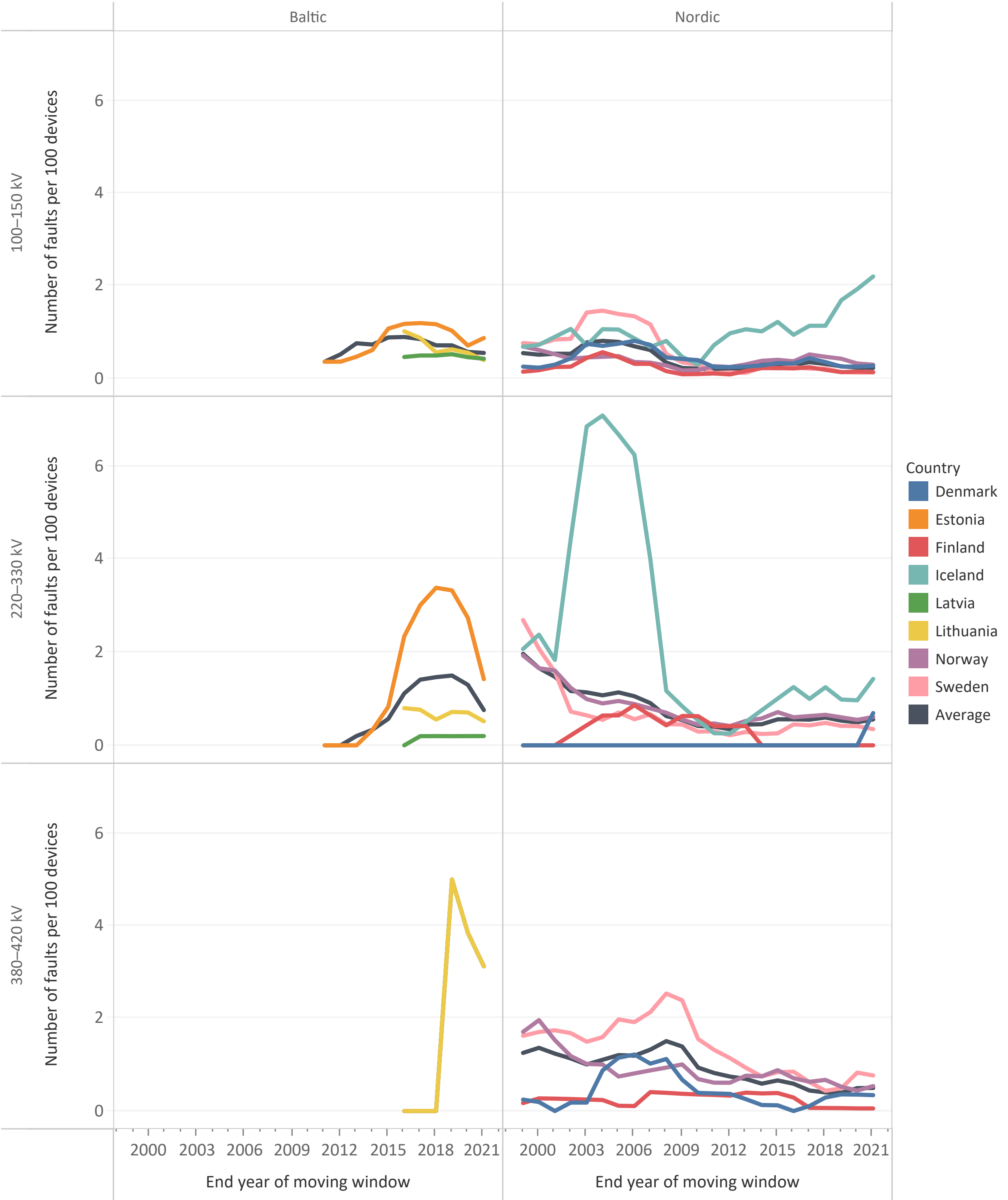

Figure 6.3: 5-year moving average of circuit breaker faults per 100 devices. Estonia has data since 2007, and Latvia and Lithuania have data since 2012. Estonia, Iceland and Latvia do not own 380–420 kV transmission grids.

6.6 Faults in control equipment

This section presents control equipment faults in 2021 and for 2012–2021. 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 2021, and the 10-year annual average of the number of faults for 2012–2021. Table 6.23 presents the number of faults per 100 devices in 2021 and the annual averages for 2012–2021.

Table 6.24 presents the percentage allocation of control equipment faults by cause in 2021. Table 6.25 presents the respective percentages over 2012–2021.

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 2021, and the annual average number of faults for 2012–2021, grouped by voltage level. 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 2021	Number of faults in 2021	10-year ann. avg of faults	Number of devices in 2021	Number of faults in 2021	10-year ann. avg of faults	Number of devices in 2021	Number of faults in 2021	10-year ann. avg of faults
Estonia	677	13	11.7	129	3	1.9	0	0	0.0
Latvia	653	19	17.8	100	0	2.6	0	0	0.0
Lithuania	803	1	11.9	127	0	2.9	11	0	0.0
Denmark	964	8	6.7	37	1	0.4	266	2	2.3
Finland	2 875	25	15.9	74	2	4.7	371	6	4.6
Iceland	125	6	4.9	87	2	3.3	0	0	0.0
Norway	2 574	26	28.2	694	11	19.5	602	16	14.6
Sweden	2 835	19	17.4	362	18	12.2	714	35	25.3
Baltic & Nordic	11 506	117	114.5	1 610	37	47.5	1 964	59	46.8

Table 6.23: Number of control equipment faults per 100 devices in 2021 and the annual average for 2012–2021, grouped by voltage level. 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 2021	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2021	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2021	10-year ann. avg no. of faults / 100 devices
Estonia	1.92	1.96	2.33	1.60	0.00	0.00
Latvia	2.91	2.88	0.00	2.56	0.00	0.00
Lithuania	0.12	1.40	0.00	2.68	0.00	0.00
Denmark	0.83	0.78	2.70	2.05	0.75	1.15
Finland	0.87	0.63	2.70	5.84	1.62	1.45
Iceland	4.80	3.11	2.30	4.03	0.00	0.00
Norway	1.01	1.21	1.59	2.69	2.66	3.68
Sweden	0.67	0.75	4.97	3.73	4.90	4.16
Baltic & Nordic	1.02	1.12	2.30	3.04	3.00	3.07

Table 6.24: Percentage allocation of control equipment faults by cause in 2021. 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%	63%	13%	0%	25%
Latvia	0%	0%	0%	53%	37%	0%	11%
Lithuania	0%	0%	0%	100%	0%	0%	0%
Denmark	0%	0%	0%	55%	45%	0%	0%
Finland	0%	0%	0%	91%	3%	0%	6%
Iceland	0%	0%	0%	38%	50%	13%	0%
Norway	0%	2%	4%	34%	40%	17%	4%
Sweden	0%	0%	0%	35%	51%	4%	10%

Table 6.25: Percentage allocation of control equipment faults by cause over 2012–2021. 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%	38%	43%	6%	13%
Latvia	0%	0%	0%	47%	44%	1%	6%
Lithuania	0%	0%	6%	39%	14%	10%	31%
Denmark	4%	3%	3%	52%	23%	11%	3%
Finland	2%	4%	1%	64%	13%	11%	5%
Iceland	0%	0%	0%	39%	40%	21%	0%
Norway	1%	4%	4%	47%	30%	10%	4%
Sweden	2%	4%	0%	28%	53%	4%	9%

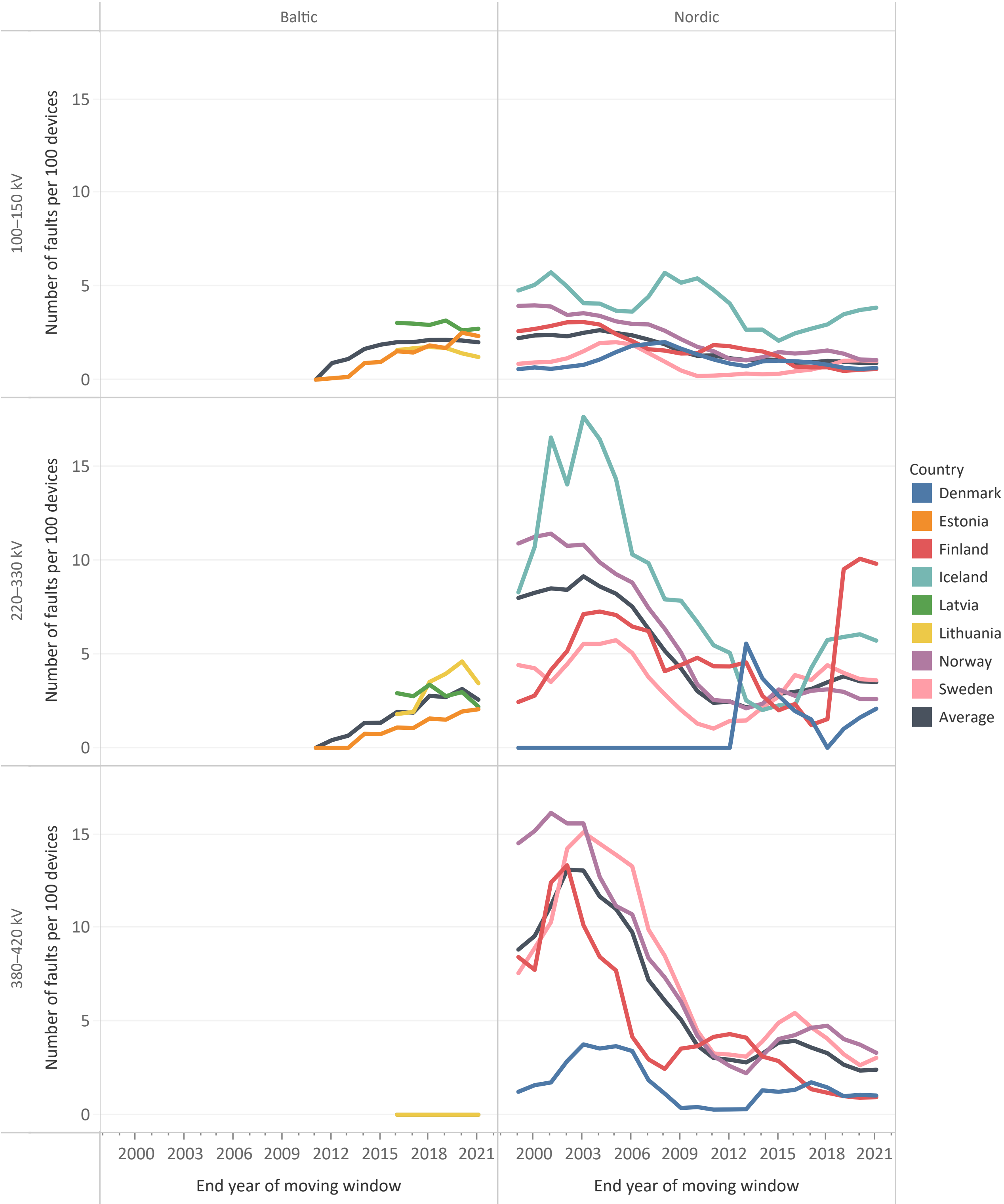

Figure 6.4: 5-year moving average of control equipment faults per 100 devices. Estonia has data since 2007, and Latvia and Lithuania have data since 2012. Estonia, Iceland and Latvia do not own 380–420 kV transmission grids. Control equipment embedded in other components are not included in this category 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 2021 and for 2012–2021.

Table 6.26 presents the number of instrument transformers and the number of faults in 2021, and the 10-year annual average of the number of faults for 2012–2021. Table 6.27 presents the number of faults per 100 devices in 2021 and the annual averages for 2012–2021.

Table 6.28 presents the percentage allocation of instrument transformer faults by cause in 2021. Table 6.29 presents the respective percentages over 2012–2021.

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 2021, and the annual average number of faults for 2012–2021, grouped by voltage level. 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 2021	Number of faults in 2021	10-year ann. avg of faults	Number of devices in 2021	Number of faults in 2021	10-year ann. avg of faults	Number of devices in 2021	Number of faults in 2021	10-year ann. avg of faults
Estonia	3 300	7	2.2	923	2	0.9	0	0	0.0
Latvia	2 261	9	2.0	428	0	0.1	0	0	0.0
Lithuania	3 156	3	1.2	687	0	0.3	66	0	0.0
Denmark	5 848	2	1.4	243	0	0.1	1 474	2	0.6
Finland	10 806	0	1.9	398	0	0.1	1 943	0	0.3
Iceland	375	0	0.1	261	0	0.0	0	0	0.0
Norway	7 768	3	3.7	2 805	1	1.8	930	0	1.6
Sweden	9 212	3	3.9	1 976	0	0.2	3 741	1	1.9
Baltic & Nordic	42 726	27	16.4	7 721	3	3.5	8 154	3	4.4

Table 6.27: Number of instrument transformer faults per 100 devices in 2021 and the annual average for 2012–2021, grouped by voltage level.

Country	100–150 kV		220–330 kV		380–420 kV	
	Number of faults / 100 devices in 2021	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2021	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2021	10-year ann. avg no. of faults / 100 devices
Estonia	0.21	0.12	0.22	0.19	0.00	0.00
Latvia	0.40	0.13	0.00	0.03	0.00	0.00
Lithuania	0.10	0.06	0.00	0.08	0.00	0.00
Denmark	0.03	0.05	0.00	0.14	0.14	0.10
Finland	0.00	0.03	0.00	0.03	0.00	0.03
Iceland	0.00	0.02	0.00	0.00	0.00	0.00
Norway	0.04	0.05	0.04	0.06	0.00	0.17
Sweden	0.03	0.08	0.00	0.02	0.03	0.09
Baltic & Nordic	0.06	0.06	0.04	0.06	0.04	0.09

Table 6.28: Percentage allocation of instrument transformer faults by cause in 2021. 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%	100%	0%	0%
Latvia	0%	0%	0%	0%	100%	0%	0%
Lithuania	0%	0%	0%	67%	33%	0%	0%
Denmark	0%	0%	0%	25%	75%	0%	0%
Finland	0%	0%	0%	0%	0%	0%	0%
Iceland	0%	0%	0%	0%	0%	0%	0%
Norway	25%	0%	0%	25%	50%	0%	0%
Sweden	25%	25%	0%	0%	25%	25%	0%

Table 6.29: Percentage allocation of instrument transformer faults by cause over 2012–2021. 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%	6%	87%	0%	6%
Latvia	0%	0%	0%	0%	100%	0%	0%
Lithuania	0%	0%	0%	20%	73%	7%	0%
Denmark	0%	0%	5%	14%	67%	5%	10%
Finland	4%	0%	0%	13%	65%	13%	4%
Iceland	0%	0%	0%	0%	0%	100%	0%
Norway	13%	3%	1%	20%	42%	18%	3%
Sweden	10%	2%	0%	5%	72%	3%	8%

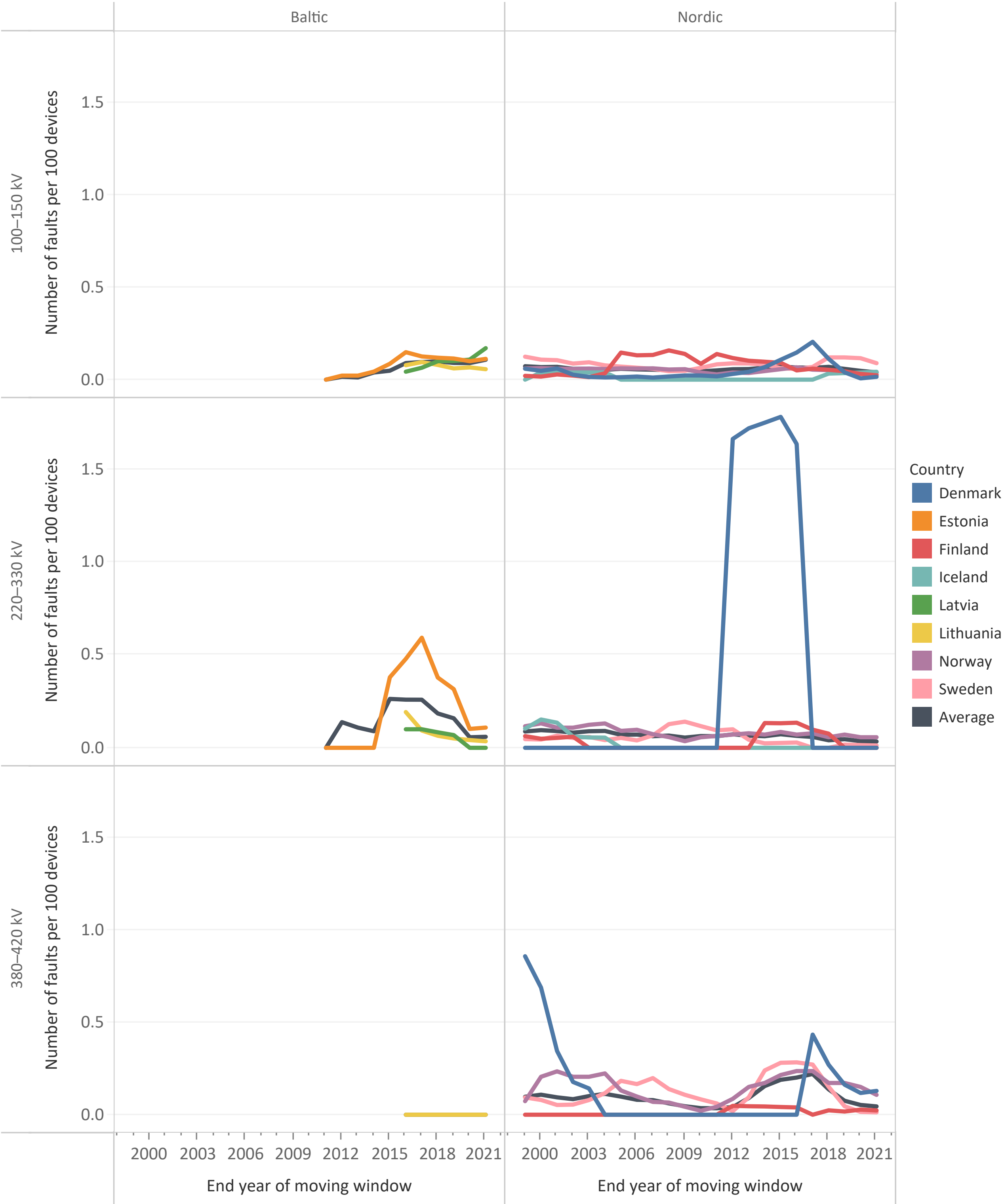

Figure 6.5: 5-year moving average of instrument transformer faults per 100 devices. Estonia has data since 2007, and Latvia and Lithuania have data since 2012. Estonia, Iceland and Latvia do not own 380–420 kV transmission grids. Denmark's high values during 2012–2016 are caused by one fault in 2012.

6.8 Faults in power transformers

This section presents power transformer faults in 2021 and for 2012–2021. 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 2021, and the 10-year annual average of the number of faults for 2012–2021. Table 6.31 presents the number of faults per 100 devices in 2021 and the annual averages for 2012–2021.

Table 6.32 shows the percentage allocation of power transformer faults by cause in 2021. Table 6.33 presents the respective percentages over 2012–2021.

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 2021, and the annual average number of faults for 2012–2021, grouped by voltage level.

Country	100–150 kV			220–330 kV			380–420 kV		
	Number of devices in 2021	Number of faults in 2021	10-year ann. avg of faults	Number of devices in 2021	Number of faults in 2021	10-year ann. avg of faults	Number of devices in 2021	Number of faults in 2021	10-year ann. avg of faults
Estonia	184	6	7.7	28	4	3.2	0	0	0.0
Latvia	245	3	4.3	26	3	1.4	0	0	0.0
Lithuania	379	0	0.3	23	2	1.2	3	0	0.0
Denmark	243	3	3.2	12	1	0.2	51	1	1.1
Finland	1 149	7	6.7	16	0	1.1	63	0	0.9
Iceland	14	2	1.9	16	0	0.9	0		0.0
Norway	806	6	4.1	164	2	1.4	110	3	1.3
Sweden	881	9	18.4	116	0	3.2	86	0	1.5
Baltic & Nordic	3 901	36	46.6	401	12	12.6	313	4	4.8

Table 6.31: Number of power transformer faults per 100 devices in 2021 and the annual average for 2012–2021, grouped by voltage level.

Country	100–150 kV		220–330 kV		380–420 kV	
	Number of faults / 100 devices in 2021	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2021	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2021	10-year ann. avg no. of faults / 100 devices
Estonia	3.26	3.64	14.29	13.17	0.00	0.00
Latvia	1.22	1.74	11.54	5.47	0.00	0.00
Lithuania	0.00	0.07	8.70	5.06	0.00	0.00
Denmark	1.23	1.34	8.33	2.47	1.96	3.00
Finland	0.61	0.60	0.00	4.47	0.00	1.37
Iceland	14.29	5.71	0.00	6.57	0.00	0.00
Norway	0.74	0.50	1.22	0.55	2.73	1.50
Sweden	1.02	2.32	0.00	3.04	0.00	2.09
Baltic & Nordic	0.92	1.20	2.99	2.63	1.28	1.84

Table 6.32: Percentage allocation of power transformer faults by cause in 2021. 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%	10%	0%	20%	70%	0%	0%
Latvia	0%	0%	0%	50%	50%	0%	0%
Lithuania	0%	0%	50%	0%	50%	0%	0%
Denmark	0%	0%	0%	80%	20%	0%	0%
Finland	0%	29%	0%	0%	29%	0%	43%
Iceland	0%	0%	0%	0%	50%	50%	0%
Norway	0%	27%	9%	18%	36%	0%	9%
Sweden	22%	0%	11%	0%	44%	0%	22%

Table 6.33: Percentage allocation of power transformer faults by cause over 2012–2021. 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%	4%	3%	19%	69%	1%	5%
Latvia	0%	0%	26%	32%	39%	0%	4%
Lithuania	0%	0%	13%	27%	40%	0%	20%
Denmark	0%	22%	0%	33%	36%	7%	2%
Finland	14%	5%	2%	17%	22%	26%	14%
Iceland	0%	18%	0%	11%	39%	32%	0%
Norway	10%	18%	3%	18%	32%	13%	6%
Sweden	23%	2%	3%	18%	22%	6%	26%

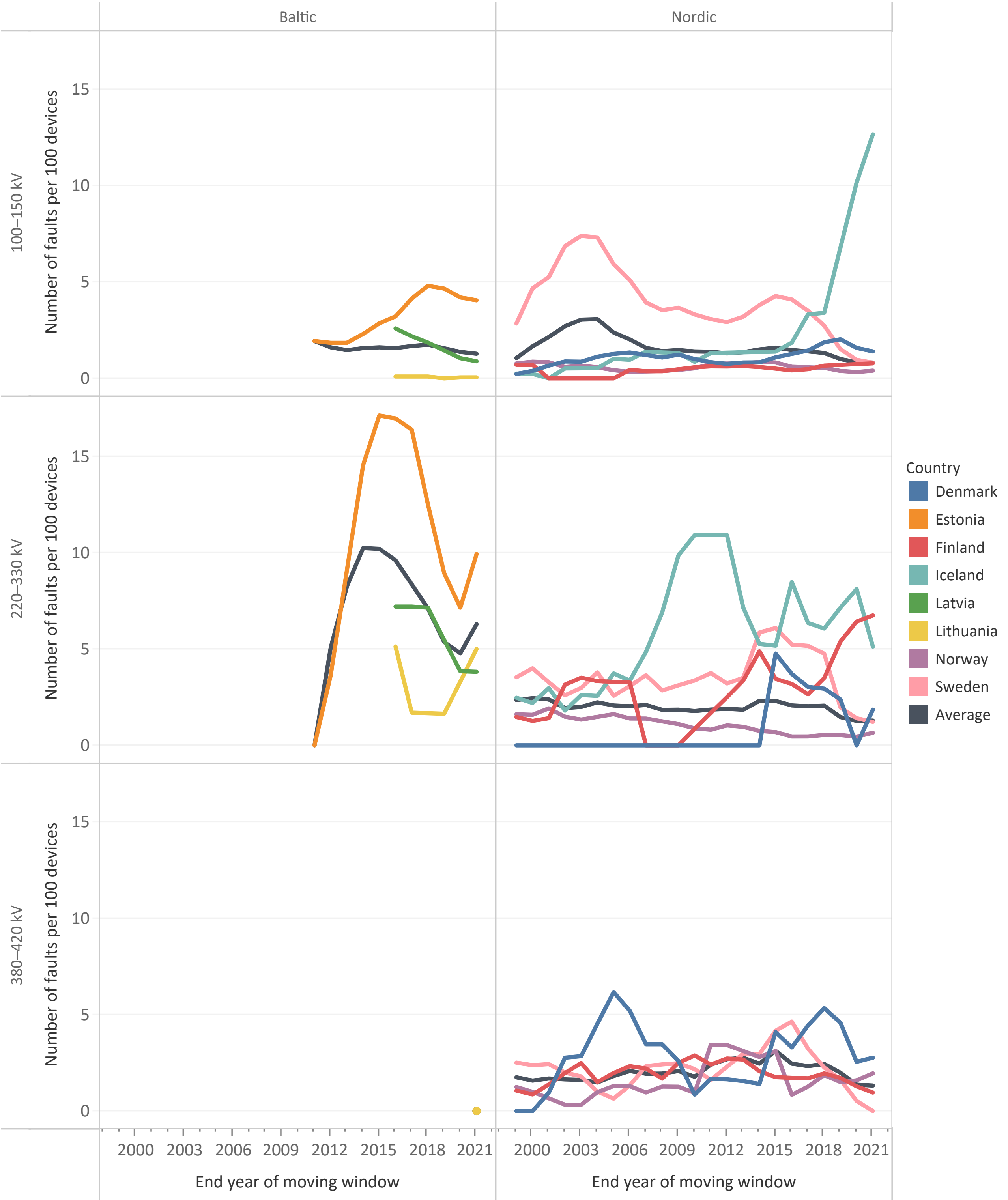

Figure 6.6: 5-year moving average of power transformer faults per 100 devices. Estonia has data since 2007, and Latvia and Lithuania have data since 2012. Estonia, Iceland, Latvia and Lithuania do not own 380–420 kV power transformers in their transmission grids.

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 2021 and their annual averages for 2012–2021.

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 2021, the number of faults per 100 devices, the amount of ENS due to reactor faults in 2021 and their annual averages for 2012–2021.

	Devices	Faults	Faults per 100 devices		ENS (MWh)	
Country	2021	2021	2021	Annual avg. 2012–2021	2021	Annual avg. 2012–2021
Estonia	32	0	0.0	7.9	0.0	0.0
Latvia	18	0	0.0	4.2	0.0	0.0
Lithuania	2	0	0.0	0.0	0.0	0.0
Baltic total	52	0	0.0	5.8	0.0	0.0
Denmark	123	1	0.8	1.4	0.0	0.0
Finland[1]	200	1	0.5	0.2	0.0	1.0
Iceland	–	–	–	–	–	–
Norway	57	0	0.0	3.4	0.0	0.0
Sweden[2]	855	6	0.7	1.9	0.0	0.0
Nordic total	1235	8	0.6	1.6	0.0	1.0
Baltic & Nordic total	1287	8	0.6	1.9	0.0	1.0

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

[2] The number of reactors in Sweden in 2019 was reported erroneously as 91 devices. The correct value was 803 devices, and the annual average value over 2012–2021 above is calculated with this corrected value.

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 2021, the number of faults per 100 devices, the amount of ENS due to series capacitor faults in 2021 and their annual averages for 2012–2021.

	Devices	Faults	Faults per 100 devices		ENS (MWh)	
Country	2021	2021	2021	Annual avg. 2012–2021	2021	Annual avg. 2012–2021
Estonia	–	–	–	–	–	–
Latvia	–	–	–	–	–	–
Lithuania	–	–	–	–	–	–
Baltic total	–	–	–	–	–	–
Denmark	–	–	–	–	–	–
Finland	11	7	63.6	49.5	0.0	1.9
Iceland	1	0	0.0	11.1	0.0	0.0
Norway	3	0	0.0	3.3	0.0	0.0
Sweden	17	10	58.8	52.5	0.0	0.0
Nordic total	32	17	53.1	44.1	0.0	1.9
Baltic & Nordic total	42	17	40.5	42.2	0.0	1.9

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 2021, the number of faults per 100 devices, the amount of ENS due to shunt capacitor faults in 2021 and their annual average for 2012–2021.

	Devices	Faults	Faults per 100 devices		ENS (MWh)	
Country	2021	2021	2021	Annual average 2012–2021	2021	Annual average 2012–2021
Estonia	10	0	0.0	9.4	0.0	3.0
Latvia	2	0	0.0	0.0	0.0	0.0
Lithuania	2	0	0.0	0.0	0.0	0.0
Baltic total	14	0	0.0	7.2	0.0	3.0
Denmark	43	0	0.0	0.3	0.0	0.0
Finland	20	0	0.0	4.0	0.0	0.0
Iceland	13	0	0.0	4.4	0.0	0.0
Norway	194	2	1.0	2.1	0.0	0.0
Sweden	153	1	0.7	0.8	0.0	15.2
Nordic total	423	3	0.7	1.8	0.0	15.2
Baltic & Nordic total	437	3	0.7	2.0	0.0	18.2

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 2021, the number of faults per 100 devices, the amount of ENS due to SVC faults in 2021 and their annual averages for 2012–2021.

Country	Devices 2021	Faults 2021	Faults per 100 devices 2021	Faults per 100 devices Annual avg. 2012–2021	ENS (MWh) 2021	ENS (MWh) Annual avg. 2012–2021
Estonia	–	–	–	–	–	–
Latvia	1	0	0.0	0.0	0.0	0.0
Lithuania	11	0	0.0	2.8	0.0	0.0
Baltic total	12	0	0.0	2.7	0.0	0.0
Denmark	1	1	100.0	50.0	0.0	0.0
Finland	1	0	0.0	13.3	0.0	0.0
Iceland	2	0	0.0	12.3	0	0.0
Norway	25	5	20.0	83.3	0.0	0.0
Sweden	3	1	33.3	210.9	0.0	0.0
Nordic total	32	7	21.9	82.6	0.0	0.0
Baltic & Nordic total	44	7	15.9	60.8	0.0	0.0

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 in the transmission grid is calculated for those faults that have caused an outage at the point of supply. When the outage lasts less than two hours, ENS is calculated with 5 minute average load before the outage and multiplied by the interruption time at the consumption point. If the interruption last longer, ENS is calculated based on the average load from the same period of the previous or next day, depending on if the interruption occurred during the working days or not, and multiplied by the time of outage. The outage time ends when power has been restored to the point of consumption regardless of whether the supply is restored by TSO or by the customer.

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 after directions from the Swedish regulator.

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, lightning is set as the fault cause if it can be concluded from the lightning detection system or other well known source. Without confirmation, Svenska kraftnät prefers to declare the cause as unknown even though lightning might 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.

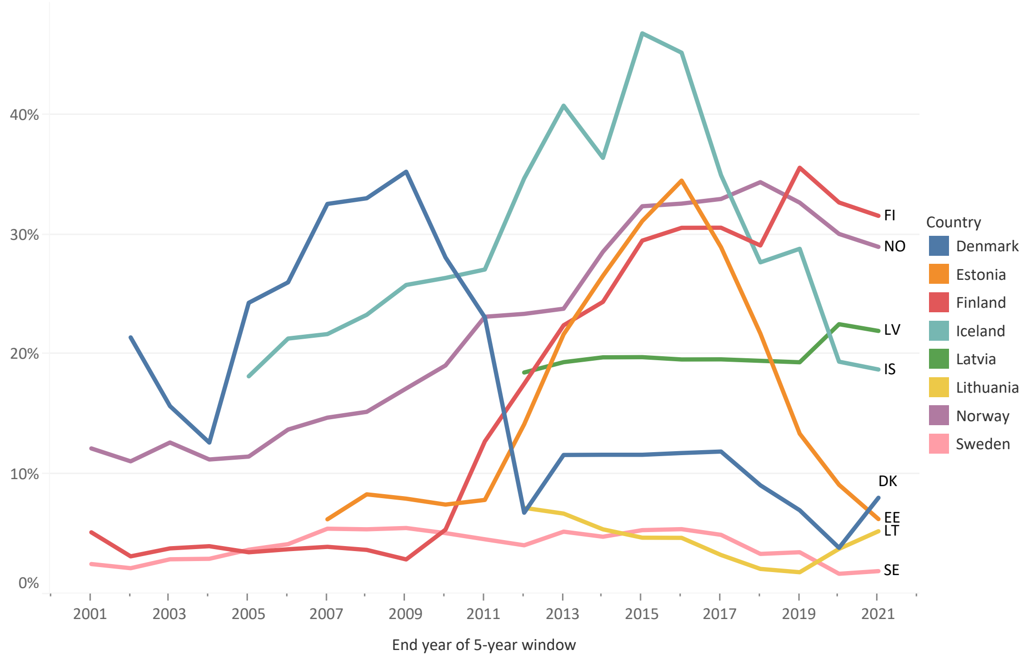

Figure E.1: 5-year moving average for fault causes due to other environmental causes. All components are included.

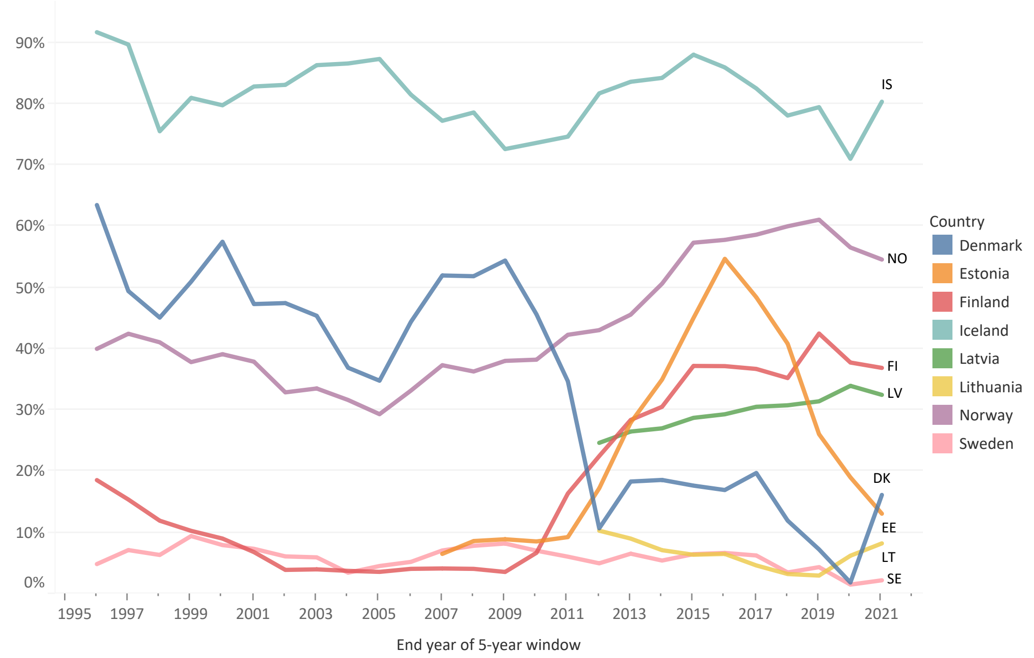

Figure E.2: 5-year moving average of overhead line fault causes due to other environmental causes.

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.

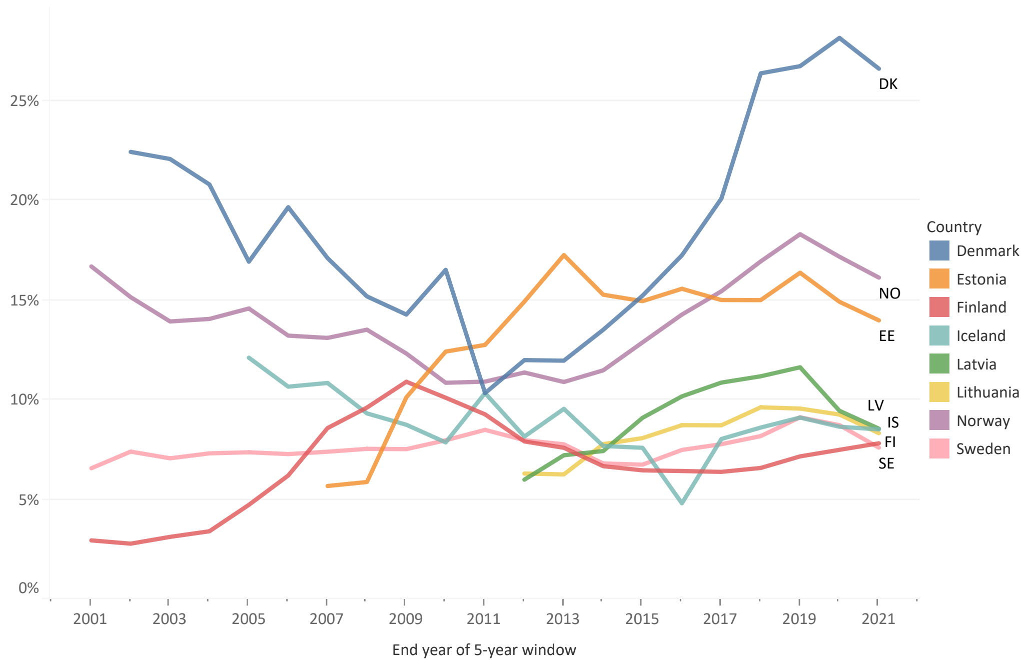

Figure E.3: 5-year moving average of fault causes due to operation and maintenance. All components are included.

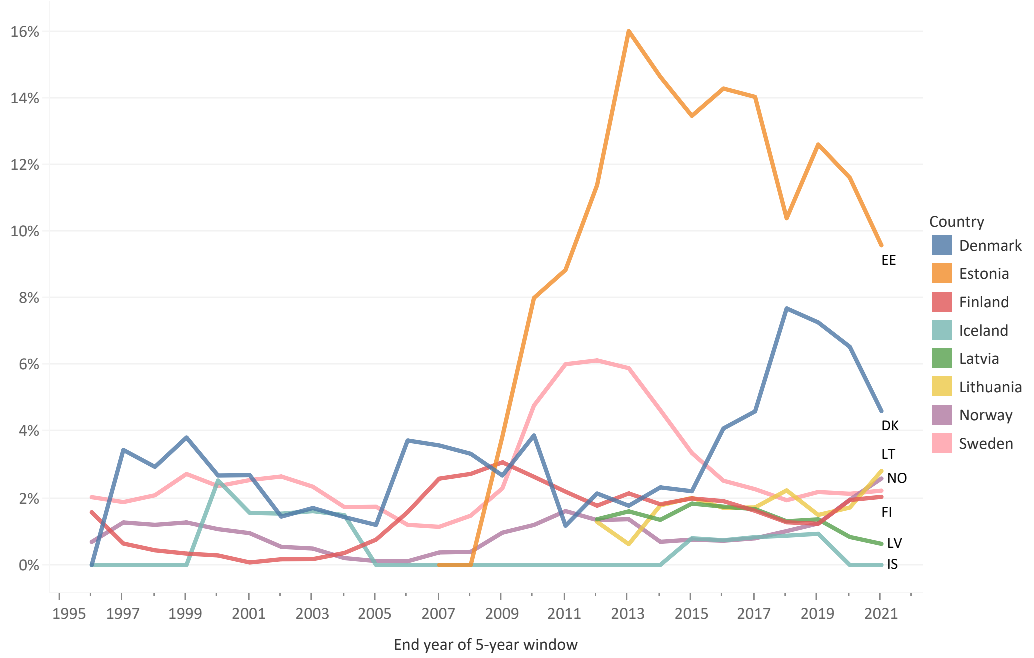

Figure E.4: 5-year moving average of overhead line fault causes due to operation and maintenance.

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.

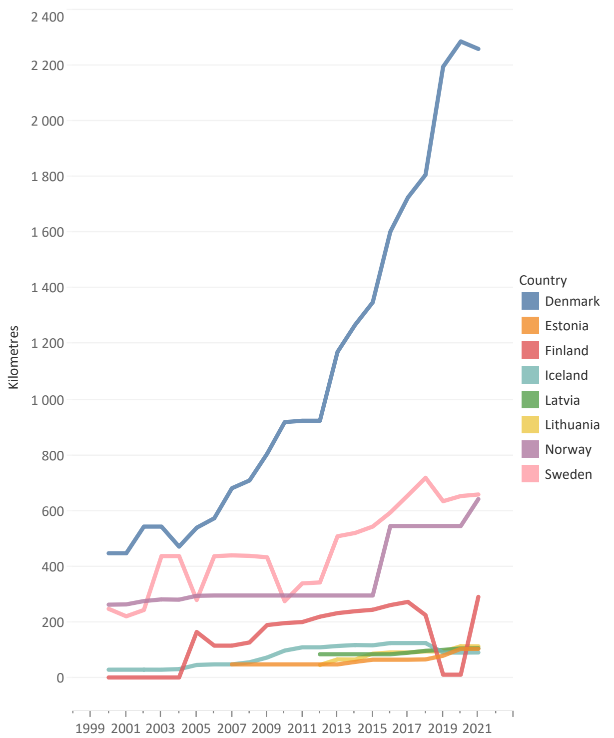

Figure E.5: Length of cables (km) in the 100–420 kV grids at the end of each year.

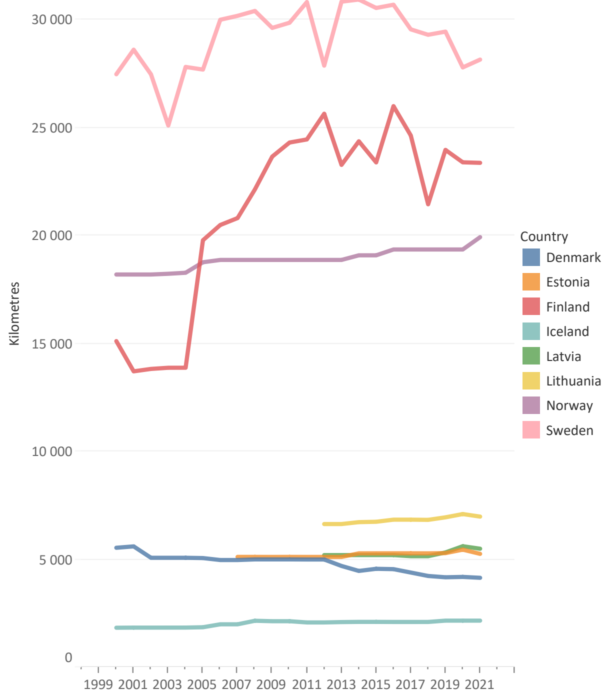

Figure E.6: Length of overhead lines (km) in the 100–420 kV grids at the end of each year.

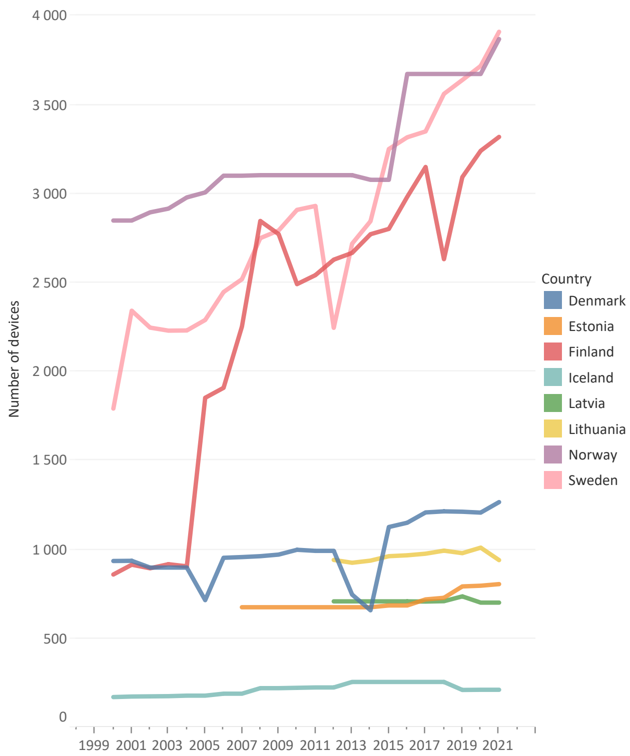

Figure E.7: Number of circuit breakers in the 100–420 kV grids at the end of each year. The number of circuit breakers is equal to the number of control equipment.

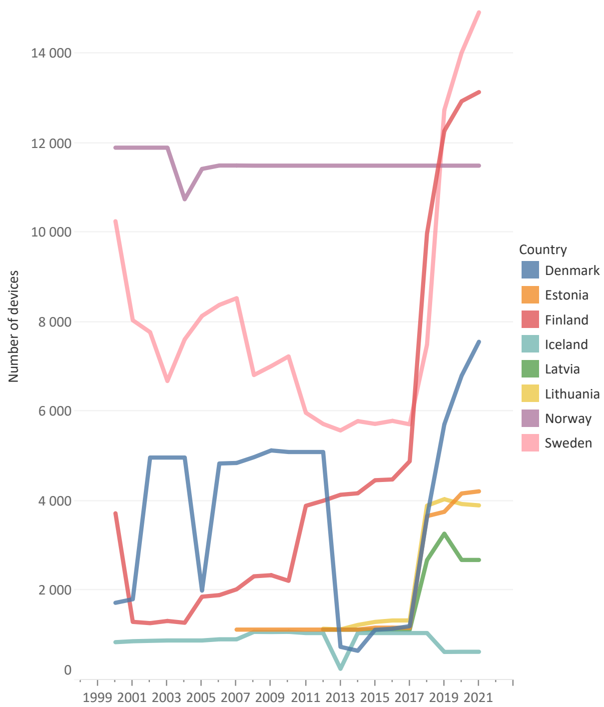

Figure E.8: Number of instrument transformers in the 100–420 kV grids at the end of each year.

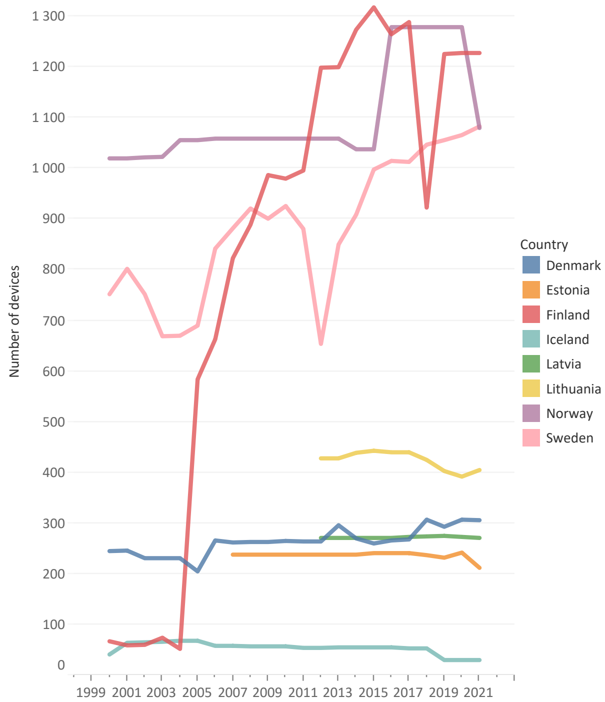

Figure E.9: Number of power transformers in the 100–420 kV grids at the end of each year.

E.4 ENS, consumption and line length

Figure E.10 presents the annual amount of ENS, consumption and total length of lines for 2012–2021. The total line length is the sum of the lengths of overhead lines and cables in the 100–420 kV grids.

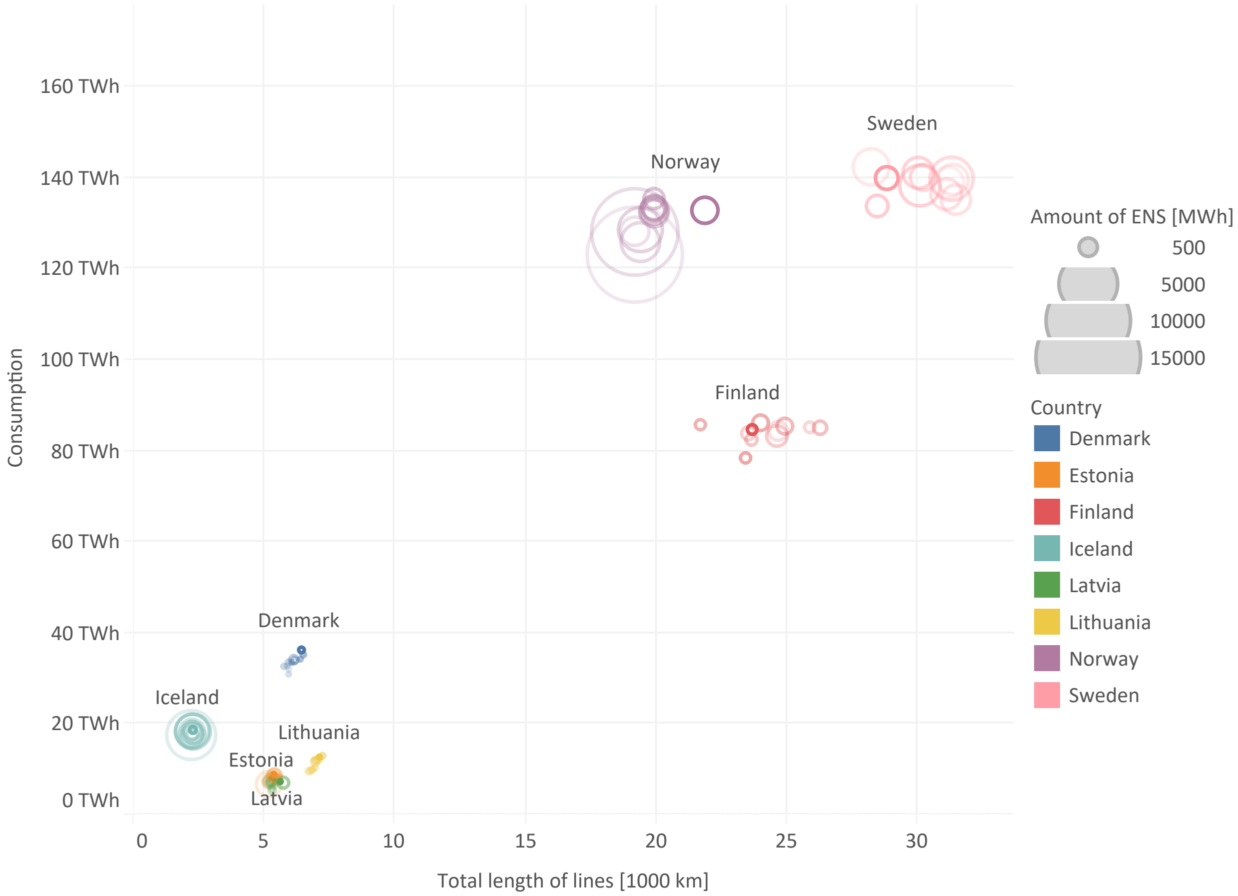

Figure E.10: The annual amount of ENS (circle size), length of lines (x-axis) and consumption (y-axis) for 2012–2021. The most recent statistical year 2021 is shown with the darkest colour. Each previous year is shown in a lighter colour.