European Network of Transmission System Operators for Electricity

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HVAC NORDIC AND BALTIC GRID DISTURBANCE STATISTICS 2024

19 November 2025

From: Regional Group Nordic

HVAC NORDIC AND BALTIC GRID DISTURBANCE STATISTICS 2024

Report rendered 19 November 2025

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 40 member TSOs, representing 36 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 interconnected power system in all time frames at pan-European level and the optimal functioning and development of the European interconnected electricity markets, while enabling the integration of electricity generated from renewable energy sources and of emerging technologies.

Our vision

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

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

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

Our values

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

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

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

Our contributions

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

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

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

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

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

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

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

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

Executive Summary

The Nordic and Baltic Grid Disturbance Statistics 2024 provides an overview of grid grid disturbances, faults, and energy not supplied (ENS) in the Nordic and Baltic 100–420 kV alternating current grids across the Nordic and Baltic regions. It should be noted that 2024 values for Finland and Sweden include only faults which affect Transmission System Operators' (TSO) networks. This impacts the values a lot for 100 kV – 150 kV level for 2024 compared to 2023, and to a lesser extent the 10-year averages.

In 2024, the total number of grid disturbances was 1176, much less than the 10-year average of 1560, but this difference is mainly caused by including less grid from Finland and Sweden as just explained. ENS due to faults amounted to 5075 MWh in the Nordic countries and 153 MWh in the Baltic countries, with a combined total of 5228 MWh—40 % higher than the 10-year average. The Nordic region saw a significant increase in ENS (142 % of the 10-year average), mainly due to extreme weather in Norway in early February, which accounted for nearly 90 % of Norway's total ENS. In contrast, the Baltic countries experienced ENS at 97 % of the 10-year average.

The number of faults in the Nordic region was significantly lower than average (766 faults, 62 % of average), while the Baltic region remained stable. Overhead lines were the primary contributors to ENS in most countries with environmental causes.

Key items for 2024 statistics:

- 2024 data for Finland includes all TSO's data and DSO's 110 kV branch lines
- 2024 data for Sweden includes only TSO data
- Total grid disturbances: 1176 (10-year avg: 1560)
- ENS: 5228 MWh (10-year avg: 3728 MWh)
- Nordic ENS: 5075 MWh (10-year avg: 3571 MWh)
- Baltic ENS: 153 MWh (10-year avg: 157 MWh)
- Notable event: Extreme weather in Norway, February 2024

Policies for examining the cause of line faults are listed in Appendix B on page 53.

Table 1 shows the key figures of this report for each participating country.

Table 1: The number of faults, the number of disturbances, the fault to disturbance ratio, and ENS in 2024 and the corresponding annual averages for the 10-year period 2015–2024.

	Number of faults		No. of disturbances		Ratio		ENS (MWh)	
Country	2024	Annual avg. 2015–2024	2024	Annual avg. 2015–2024	2024	2015–2024	2024	Annual avg. 2015–2024
Estonia	195	160	184	150	1.1	1.1	70	67
Latvia	160	141	152	126	1.1	1.1	53	53
Lithuania	127	152	126	142	1.0	1.1	30	37
Baltic total	482	453	462	418	1.0	1.1	153	157
Denmark	70	71	64	65	1.1	1.1	19	41
Finland	240	408	232	393	1.0	1.0	364	215
Iceland	21	64	20	45	1.1	1.4	352	795
Norway	339	316	301	283	1.1	1.1	4336	1322
Sweden	97	369	97	356	1.0	1.0	5	1198
Nordic total	767	1229	714	1142	1.1	1.1	5075	3571
Baltic & Nordic total	1249	1682	1176	1560	1.1	1.1	5228	3728

[1] 2024 values for Finland and Sweden include only transmission system operators' (TSO) networks.

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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. 18].
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. 18].
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. 10].
Fault cause "Cause relating to design, production, installation, operation or maintenance which results in a fault" [1, p. 14].
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. 8].
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".
ppm Parts per million.
Primary cause (of a fault) "Event or circumstance which leads to a fault" [1, p. 12].
Primary fault "A fault which initiates a grid disturbance" [1, p. 12].
RGN Regional Group Nordic.
Secondary fault A fault that aggravates a grid disturbance [1, p. 12].
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 HVAC NORDIC AND BALTIC GRID DISTURBANCE STATISTICS 2024 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 2024. 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.

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 *ENTSO-E Grid Disturbance Definitions for the Power System above 100 kV* [1].

The report is organised into six chapters. Chapter 2 has a short summary the statistics and, each TSO worst disturbances during the year 2024.

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

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.

Up untill 2022 the report included faults causing grid disturbances according to 'Nordel's Guidelines for the Classification of Grid Disturbances'. From 2023 the report includes faults causing grid disturbances according to the ENTSO-E Grid Disturbance Definitions for the Power Systems above 100 kV.

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

Figure 1.1: The Nordic and Baltic main grids [2] in 2024. 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.

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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* [3].

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.

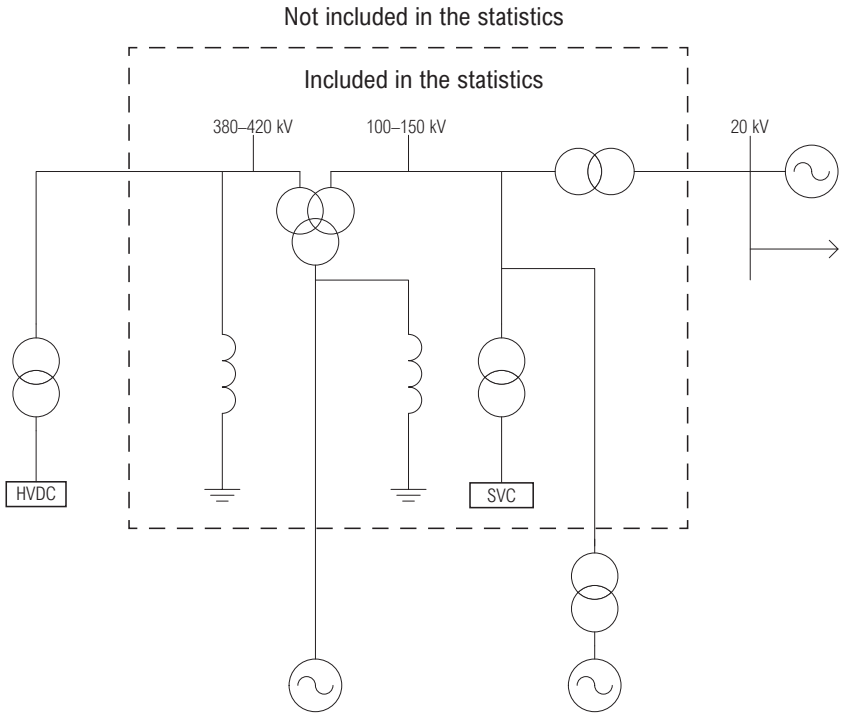

Figure 1.2: A graphical representation of the included grid components in the statistics.

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

The report includes all available data for 100–420 kV up till 2023. Finnish 2024 data include TSO's data and DSO's 110 kV branch lines connected to TSO Fingrid. Swedish 2024 data cover only TSO Svenska kraftnät.

Some of the tables in the report present aggregated numbers for the Baltic and Nordic regions, as well as for all participating countries. When the numbers for each country are normalised by consumption (e.g. Table 4.2), or the number of components or km (e.g. Table 6.9), the aggregated numbers for each region are calculated the same way as they are calculated for each country. This means that we take the total number of faults (or ENS) in a region and divide this number with the total number of components (or consumption) in the same region. That is opposed to summation of e.g. number of disturbances, number of faults or values for Energy Not Supplied (ENS), where we simply add up the numbers for each country to get the regional sum (e.g. Table 3.1).

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.

1.6 Fault causes

Each grid disturbance and fault has a cause connected to it. The used causes in this report are detailed in Figure 1.3. Appendix B describes how each Nordic and Baltic TSO examines the cause of line faults. The fault causes used in these statistics are explained in detail in the ENTSO-E guidelines [1, Tab. 5.1].

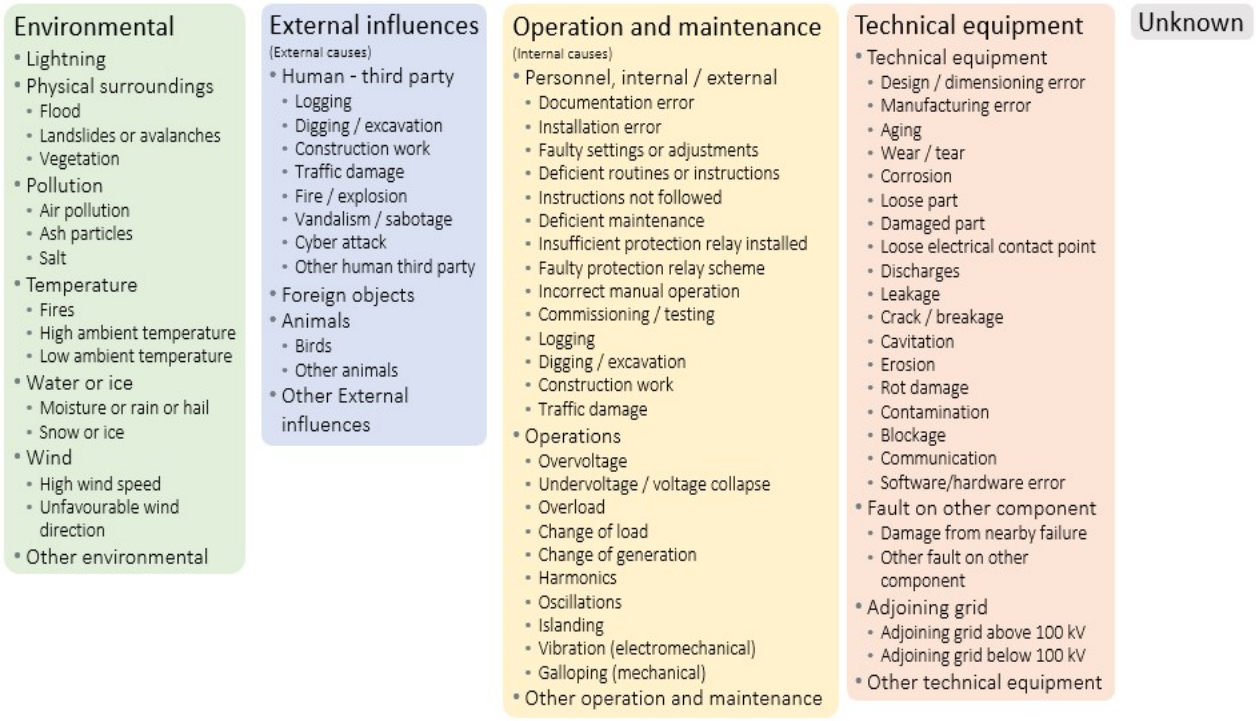

Figure 1.3: The cause scheme with 5 top-level categories: environmental causes, external influences, operation and maintenance, technical equipment, and unknown.

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 1.1 presents the statistical voltage levels used in this report and their percentage allocation. Table 1.2 presents the coverage of the statistics in each country.

Table 1.1: Nominal voltage levels (U_N) included in this report and their percentage (p) allocation. Because slightly different voltage levels are used in each country, this report groups the voltage levels into the ranges below.

		Statistical voltage range, kV		
Country		100–150 kV	220–330 kV	380–420 kV
Denmark	U_N / p %	150 kV / 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	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 1.2: Percentage of networks included in the statistics per statistical voltage level in 2024. The percentage is estimated per line length.

	Voltage level		
Country	100–150 kV	220–330 kV	380–420 kV
Denmark	100 %	100 %	100 %
Estonia	100 %	100 %	–
Finland	50 %	100 %	100 %
Iceland	100 %	100 %	–
Latvia	100 %	100 %	–
Lithuania	100 %	100 %	100 %
Norway	100 %	100 %	100 %
Sweden	76 %	99 %	100 %

2 Summary

In 2024, 1 176 grid disturbances occurred in the Nordic and Baltic 100–420 kV grids, which is much less than the 10-year annual average of 1 560 disturbances. The energy not supplied (ENS) due to faults in the Nordic grids amounted to 5 075 MWh and 153 MWh in the Baltic. In total, there were 5 228 MWh of ENS in the Nordic and Baltic grids, which is 40 % higher than the 10-year annual average. Out of all 1 176 disturbances, 161 caused ENS in 2024. For Finland and Sweden, the figures cover only disturbances reported by the transmission system operators (TSOs).

The following sections present the summaries for each Nordic and Baltic country including the most significant issues in 2024.

2.1 Summary of Denmark

In Denmark, the ENS caused by grid disturbances was 19 MWh in 2024 (10-year annual average 41 MWh). There were 64 grid disturbances (10-year annual average 65) and 2 of them caused ENS.

In 2024, 60 % of the total ENS was caused by substation faults, and 40 % by faults in Lines. The most significant reasons for ENS caused by disturbances were operation and maintenance (60 %) and environmental causes (40 %). Disturbances were caused most by external influences (48 %) and technical equipment (31 %).

Secondary faults in Denmark accounted for 9 % of all faults in 2024 and caused 0 % of the total ENS. Secondary faults were caused by operation and maintenance (67 %) and technical equipment (33 %).

The three most significant disturbances in 2024 were the following:

- Due to an installation error of a relay, a transformer tripped while troubleshooting a ground fault. The resulting ENS was 11.2 MWh.
- Lack of vegetation management caused an overhead line to trip and automatically reclose. Two transformers in a substation tripped as they were connected through a T-junction between two lines. The resulting ENS was 7.5 MWh.
- A 400 kV busbar tripped due to an installation error when reinvesting a reactor. The point-of-wave-relay was by-passed which led the breakers to reignite when the breakers open. This fault did not cause ENS.

2.2 Summary of Estonia

In Estonia, there were 184 grid disturbances (10-year annual average 150), of which 10 caused ENS. The ENS caused by grid disturbances was 69.6 MWh in 2024 (10-year annual average 67.4 MWh).

In 2024, 87 % of the total ENS was caused by overhead line faults, and 13 % by substation faults. The most significant reasons for ENS were environmental causes (92 %) and operation and maintenance (7 %). Disturbances occurred most often due to technical equipment (39 %) and environmental causes (26 %).

Secondary faults in Estonia accounted for 6 % of all faults in 2024 and caused an ENS of 3.18 MWh. Secondary faults were primarily due to operation and maintenance (45 %) and technical equipment (27 %).

The three most significant disturbances in the 110–330 kV grid in 2024 were:

- Single-phase earth fault in a 110 kV substation. A 110 kV surge arrester in a transformer bay was damaged due to lightning, causing an ENS of 4.64 MWh.
- Two-phase earth fault on a 110 kV overhead line caused by a combination of ice accumulation on the phase wires and strong wind. ENS was 12.77 MWh.
- Two-phase earth fault on a 110 kV overhead line caused by a combination of ice accumulation on the phase wires and strong wind. ENS was 42.49 MWh.

2.3 Summary of Finland

The Finnish data from 2024 onwards include the length of the main transmission grid owned by Fingrid and length of the 110 kV branch lines connected to the main transmission grid owned by the distribution network companies. Faults on the 110 kV branch lines are included if they affect the main transmission. For 220 kV – 400 kV lines crossing the national border, only the length of the AC network owned by Fingrid and those faults whose fault location is on a line owned by Fingrid have been recorded in the statistics. The data covers almost all 220 kV and 400 kV grid and about 50 % of length of all 110 kV grids in Finland. There were 232 grid disturbances and 240 faults in Fingrid in 2024. Disturbances were caused most by environmental causes (82 %). Energy not supplied (ENS) was 364 MWh. Overhead line faults caused 75 % of the ENS. The most significant reasons for ENS caused by faults were operation and maintenance (74 %) and technical equipment (24 %). Secondary faults in Finland accounted for 3 % of all faults in 2024 and caused 6 % of the total ENS.

Four most significant disturbances in the Fingrid's 110–400 kV grid in 2024 were:

- 110 kV overhead line tower fell in July 2024. A total of approximately 10,000 distribution network customers were initially without power in the area. Power was restored to 4,000 customers using replacement connections in three hours and to 7,000 customers in eleven hours. The fallen 110 kV tower was replaced and the power line was restored to service in 23 hours. After this, the distribution network companies restored electricity to all their customers. ENS 209 MWh.
- Current transformer failure at a 110 kV substation, resulting in the entire substation being de-energized by the busbar protection in May. ENS 57 MWh.
- Unjustified relay protection operation at a 110 kV substation during an exceptional switching situation in April. ENS 21 MWh.
- The hurricane knocked down two 400 kV transmission line towers in November. The repair work went well, and the line was restored to service in seven days. The disturbance caused voltage and frequency fluctuations in the main grid. No ENS.

2.4 Summary of Iceland

In Iceland, the ENS caused by grid disturbances was 352 MWh in 2024 (10-year annual average 757 MWh). There were 20 grid disturbances (10-year annual average 42) and 10 of them caused ENS.

In 2024, 60 % of the total ENS was caused by overhead line faults, 20 % by substation faults. The most significant reason for ENS caused disturbances were weather (50 %) and adjoining grid (20 %).

Secondary faults in Iceland accounted for 5 % of all faults in 2024 and caused 0 % of the total ENS. Secondary faults were all caused by technical equipment.

Secondary faults were caused by technical equipment:

- January 25 – The 132 kV overhead line SN1 tripped due to a lightning strike. The total ENS was 50.5 MWh.
- October 2 – An emergency trip on the power-intensive user side affected the relay protection scheme, resulting in a system split. Due to weak 132 kV connections between the northeast and southwest parts of the grid, the system's stability threshold was low. Power flows exceeded stability limits, and the grid sections began to separate, causing widespread load shedding. The total ENS was 197.4 MWh.
- November 21 – The 132 kV overhead line SM1 tripped due to a volcanic eruption. Lava flowed beneath the line at one location between two towers, causing the conductors to melt and leading to the outage. The total ENS was 66 MWh.

2.5 Summary of Latvia

In Latvia, the ENS caused by grid disturbances was 53.4 MWh in 2024 (10-year annual average 51 MWh). There were 152 grid disturbances (10-year annual average 126) and 13 of them caused ENS.

In 2024, 67 % of the total ENS was caused by overhead line faults, and 33 % by control equipment faults.

The most significant reasons for ENS caused by disturbances were environmental causes (65 %) and operations and maintenance causes (32 %). Disturbances were caused most by environmental causes (34 %) and external influences causes (33 %). Secondary faults in Latvia accounted for 5 % of all faults in 2024 and almost did not cause ENS. Secondary faults were primarily caused by operation and maintenance (25 %) and technical equipment (75 %).

The most significant disturbances in 2024 were the following:

- Multiple human errors working on control equipment and operations in combination with only one feeding line led to an outage of one substation for 2.5 h and resulted in 17 MWh of ENS (32 % from annual ENS). Disturbance caused almost all annual ENS for fault type “control equipment” and cause type “operations and maintenance”.
- Series of faults in one day period due to summer storm caused an outage of 20 OHL and 6 substations and resulted with 28 MWh of overall ENS (52 % from annual ENS).
- Third person intendedly damaged 110 kV power cable. The repair of the cable, due to time period necessary for procurement of spare parts, took more than 6 months.

2.6 Summary of Lithuania

In Lithuania, the ENS caused by grid disturbances was 29.6 MWh in 2024 (10-year annual average 36.5 MWh). There were 126 grid disturbances (10-year annual average 142), of which 14 caused ENS.

In 2024, 94 % of the total ENS was caused by overhead line faults, and 3 % each by power transformer faults and adjacent grid faults. The most significant reasons for ENS caused by disturbances were environmental causes (51 %) and technical equipment (43 %). Disturbances occurred most often due to technical equipment (23 %), unknown causes (23 %) and external influences (21 %).

Secondary faults in Lithuania accounted for less than 1 % of all faults in 2024 and did not cause any ENS. Secondary faults were primarily due to operation and maintenance (100 %).

The most significant disturbances in 2024 were the following:

- On 8 January 2024, a poorly installed 110 kV OHL conductor connection, under low ambient temperature, caused a phase conductor failure, resulting in power supply interruption to four transformer substations. ENS was 10.3 MWh.
- On 7 July 2024, a motorized hang glider flew into a 110 kV overhead line and became suspended on one phase conductor and the shield wire, which caused the interruption of electricity supply to four substations. ENS was 5.09 MWh.
- On 29 July 2024, a series of faults caused by very strong winds (up to 27.9 m/s in places) led to the outage of five 110 kV OHLs and six substations, resulting in 9.9 MWh of overall ENS.

2.7 Summary of Norway

Energy not supplied (ENS) caused by disturbances in the 100–420 kV grid was the highest in 10 years with 4336 MWh, while the number of grid disturbances (301) was just above the average for the same 10-year period (283). Extreme weather at the end of January and beginning of February caused many grid disturbances on the north-west coast of Norway. Several of these caused large interruption consequences. In the period from 1 to 4 February, faults in the network above 100 kV led to ENS of around 3800 MWh, which corresponds to 88 % of the total ENS at these voltage levels in the whole of 2024.

In total, 83 % of the ENS was caused by overhead line faults and 11 % by substation faults. This unusually high share of ENS from overhead lines was mainly due to the extreme weather. The most significant reasons for ENS caused by grid disturbances were environmental causes (95 %). The disturbance with the highest number of end-users affected and the largest power interruption was a short circuit on a 420 kV overhead line in February during very strong winds. This fault led to interruption of 26,000 end-users with approximately 285 MW interrupted load. One large end-user was out of service for 14 hours due to a permanent fault on the overhead line. Due to the extreme weather and darkness, it was impossible to locate the fault and carry out the repair work any sooner.

2.8 Summary of Sweden

In Sweden, the ENS caused by grid disturbances was 4.7 MWh in 2024. There were 97 grid disturbances and 8 of them caused ENS.

In 2024, 100 % of the total ENS was caused by overhead line faults.

Secondary faults in Sweden accounted for 0 % of all faults in 2024 and did not cause any ENS.

The year 2024 was a calm year as a whole. The most significant grid disturbances during 2024 were:

- When attempting to re-connect a reactor, a faulty blocking device for a disconnecting breaker caused a fault and subsequent outage when reconnection failed for one of the phases.
- One series capacitor bank had four short outages throughout the year due to a faulty spark gap.
- One power line had ENS of 1,1 MWh due to lightning strikes that caused a short outage with ENS. The outage was in part due to that maintenance outage was being done in the area and that automatic re-connection therefore had been disabled.

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3 Disturbances

3.1 Overview

This chapter presents grid disturbances, including an overview (Section 3.1), disturbances by month (Section 3.2), and by cause (Section 3.3).

Table 3.1 shows the number of grid disturbances in 2024 by country and the annual averages for 2015–2024, and Figure 3.1 the annual number of disturbances for 2015–2024, both in the 100–420 kV grids.

A grid disturbance is defined as:

> "Automatic, unintended, or manual undeferrable outage affecting at least one system unit as a result of faults in the power grid" [1, p. 8].

It is essential to distinguish a grid disturbance from a fault: a disturbance is initiated by a primary fault and may be followed by consequential secondary faults. Only secondary faults that extend or aggravate a disturbance are included. The voltage level of a grid disturbance is determined by that of its primary fault.

Table 3.1: The number of disturbances and disturbances causing ENS in 2024, and their annual averages for 2015–2024 in the 100–420 kV grids.

	Disturbances		Disturbances causing ENS	
Country	Number 2024	Annual average 2015–2024	Number 2024	Annual average 2015–2024
Estonia	184	150	10	21.3
Latvia	152	126	13	13.3
Lithuania	126	142	14	15.0
Baltic total	462	418	37	49.6
Denmark	64	65	2	5.4
Finland[1]	232	393	9	63.5
Iceland	20	45.0	10	18.1
Norway	301	283	95	71.5
Sweden[1]	97	356	8	129.8
Nordic total	714	1142	124	288.3
Baltic & Nordic total	1176	1560	161	337.9

[1] 2024 values for Finland and Sweden include only transmission system operators' (TSO) networks.

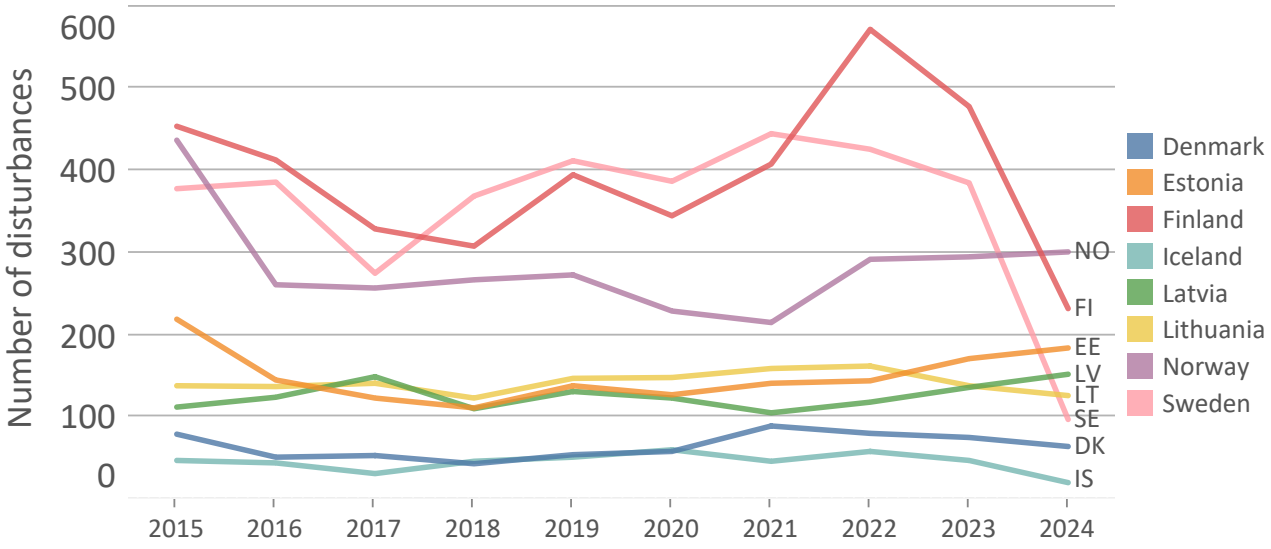

Figure 3.1: Annual number of grid disturbances in the 100–420 kV grids.

3.2 Disturbances by month

Table 3.2 presents the percentage allocation of grid disturbances in the 100–420 kV grids by month in 2024. Table 3.3 presents percentage allocation by month over 2015–2024.

Table 3.2: Percentage allocation of grid disturbances in the 100–420 kV grids by month in 2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Estonia	6.0	7.6	2.7	17.4	16.8	8.2	6.0	13.6	5.4	3.8	5.4	7.1
Latvia	2.6	2.0	3.3	6.6	7.9	10.5	26.3	18.4	2.6	6.6	8.6	4.6
Lithuania	4.8	1.6	3.2	9.5	18.3	9.5	15.9	17.5	11.1	4.8	1.6	2.4
Denmark	4.7	3.1	6.3	14.1	6.3	4.7	18.8	9.4	9.4	12.5	4.7	6.3
Finland	3.0	1.7	0.9	7.3	19.8	16.4	18.1	13.8	6.9	2.6	5.6	3.9
Iceland	15.0	10.0	5.0	5.0	5.0	0.0	5.0	10.0	0.0	15.0	10.0	20.0
Norway	15.3	18.6	1.7	3.0	12.0	10.0	6.6	5.6	8.3	2.3	6.0	10.6
Sweden	9.3	4.1	10.3	6.2	14.4	12.4	11.3	10.3	7.2	10.3	1.0	3.1

Table 3.3: Percentage allocation of grid disturbances in the 100–420 kV grids by month over 2015–2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Estonia	5.7	5.2	5.1	8.5	11.2	12.0	13.2	15.2	7.3	6.0	4.9	5.7
Latvia	4.8	2.8	6.7	5.4	6.5	12.9	12.9	22.1	7.5	7.9	4.8	5.7
Lithuania	4.3	2.4	7.0	5.9	10.2	12.1	16.6	24.4	6.1	4.2	3.5	3.3
Denmark	8.8	5.9	5.3	6.8	6.5	7.3	9.8	11.3	10.7	8.5	7.6	11.6
Finland	7.3	3.4	3.3	6.5	9.6	13.8	19.4	14.2	6.8	4.1	4.0	7.7
Iceland	10.2	18.7	12.2	5.3	5.3	5.8	6.4	3.3	7.1	8.2	4.7	12.7
Norway	18.1	11.6	5.0	3.7	5.3	9.2	9.8	7.5	6.3	6.3	8.0	9.2
Sweden	5.8	4.2	4.2	4.8	7.1	14.8	19.4	17.5	7.4	5.4	4.7	4.7

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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, 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 2024. Table 3.5 shows the respective percentages over 2015–2024.

Table 3.6 presents the percentage allocation of grid disturbances that caused ENS by cause in terms of the primary fault in 2024. Table 3.7 shows the respective percentages over 2015–2024.

Table 3.4: Grid disturbances (%) by cause for 2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	26.1	6.0	14.7	39.1	14.1
Latvia	33.6	32.9	3.3	17.1	13.2
Lithuania	15.9	21.4	16.7	23.0	23.0
Denmark	4.7	48.4	14.1	31.3	1.6
Finland	81.9	1.7	9.9	6.5	0.0
Iceland	40.0	0.0	15.0	45.0	0.0
Norway	56.8	3.0	19.3	17.3	3.7
Sweden	39.2	6.2	12.4	22.7	19.6

Table 3.5: Percentage allocation of grid disturbances by cause over 2015–2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	21.5	10.2	16.0	39.7	12.5
Latvia	36.3	23.6	4.8	19.4	15.9
Lithuania	12.8	27.0	8.3	24.0	27.9
Denmark	15.6	27.2	19.5	31.7	5.9
Finland	55.7	2.0	6.3	16.9	19.1
Iceland	38.2	1.3	11.6	46.0	2.9
Norway	51.6	2.6	17.2	23.5	5.2
Sweden	33.6	2.1	8.9	23.8	31.6

Table 3.6: Percentage allocation of grid disturbances that caused ENS by cause in 2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	50.0	20.0	20.0	10.0	0.0
Latvia	61.5	0.0	23.1	15.4	0.0
Lithuania	28.6	0.0	28.6	42.9	0.0
Denmark	50.0	0.0	50.0	0.0	0.0
Finland	11.1	0.0	44.4	44.4	0.0
Iceland	60.0	0.0	20.0	20.0	0.0
Norway	55.8	5.3	24.2	11.6	3.2
Sweden	100.0	0.0	0.0	0.0	0.0

Table 3.7: Percentage allocation of grid disturbances that caused ENS by cause over 2015–2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	14.1	11.3	24.9	40.4	9.4
Latvia	41.4	22.6	13.5	18.8	3.8
Lithuania	13.3	40.0	24.0	20.0	2.7
Denmark	13.0	3.7	53.7	29.6	0.0
Finland	30.4	3.6	10.4	20.3	35.3
Iceland	55.2	2.2	12.2	29.8	0.6
Norway	48.0	3.1	23.5	21.5	3.9
Sweden	36.1	1.7	10.1	23.1	29.0

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4 Energy not supplied

This chapter presents energy not supplied (ENS) caused by grid disturbances. The presentation includes the amount of ENS in 2024 by country and the annual averages for 2015–2024. 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 2024 by country and the annual averages for 2015–2024.

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].

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 2024 and the annual averages for 2015–2024.

	ENS (MWh)	
Country	2024	Annual average 2015–2024
Estonia	69.6	67.4
Latvia	53.4	52.9
Lithuania	29.6	36.5
Baltic total	152.7	156.8
Denmark	18.6	41.1
Finland[1]	364.1	215.3
Iceland	351.6	794.7
Norway	4336.4	1321.6
Sweden[1]	4.7	1198.3
Nordic total	5075.4	3571.0
Baltic & Nordic total	5228.1	3727.8

[1] 2024 values for Finland and Sweden include only transmission system operators' (TSO) networks.

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 2024 and the corresponding annual averages for 2015–2024. Ppm (parts per million) represents ENS (MWh) as a proportional value of the consumed energy (TWh).

	Consumption	ENS	ENS / consumption (ppm)	
Country	(TWh) 2024	(MWh) 2024	2024	Annual average 2015–2024
Estonia	8.3	69.6	8.4	7.9
Latvia	7.0	53.4	7.7	7.5
Lithuania	12.4	29.6	2.4	3.1
Baltic total	27.6	152.7	5.5	5.7
Denmark	38.4	18.6	0.5	1.2
Finland	82.0	364.1	4.4	2.6
Iceland	18.7	351.6	18.8	42.9
Norway	136.8	4336.4	31.7	9.9
Sweden	136.4	4.7	0.0	8.7
Nordic total	412.3	5075.4	12.3	8.8
Baltic & Nordic total	439.9	5228.1	11.9	8.6

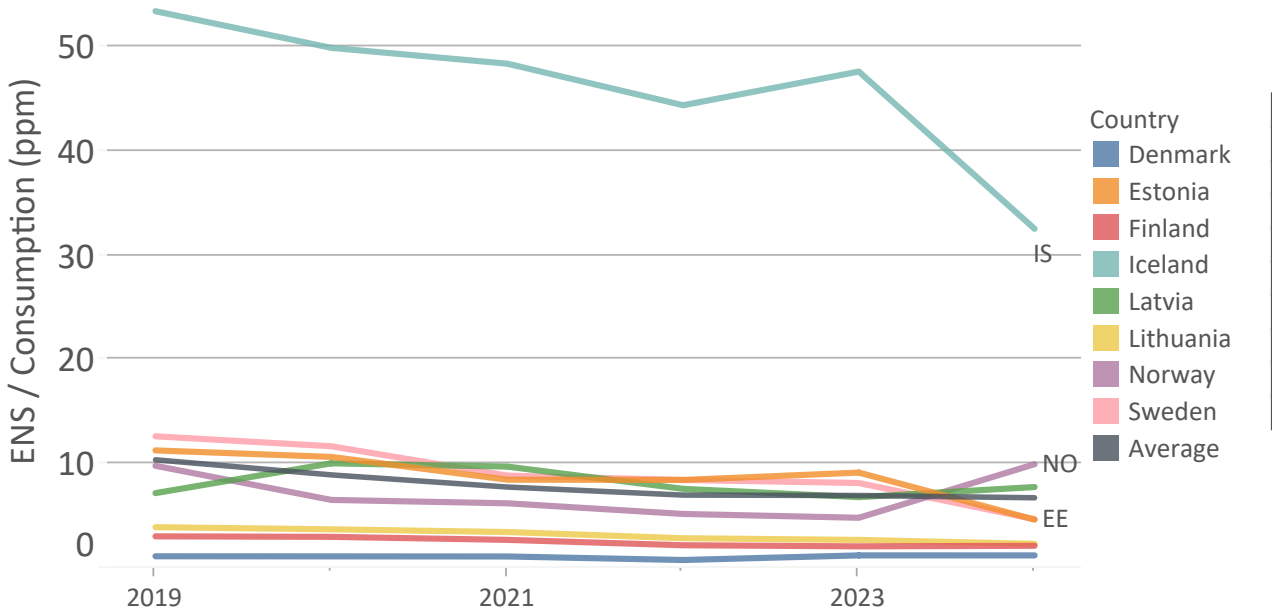

Figure 4.1: 5-year moving average for the amount of ENS divided by consumption (ppm). Ppm (parts per million) represents ENS (MWh) as a proportional value of the consumed energy (TWh).

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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 2024 and Table 4.4 presents the respective percentage values over 2015–2024.

Table 4.3: ENS (%) by month in 2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Estonia	24.1	0.0	0.0	61.0	0.0	6.7	0.0	0.0	0.0	0.0	3.3	5.0
Latvia	0.7	0.3	0.0	0.0	0.0	0.4	84.0	0.0	0.0	2.2	12.4	0.0
Lithuania	34.8	0.0	1.0	0.2	0.0	0.0	53.2	3.7	1.4	0.8	0.0	5.1
Denmark	0.0	0.0	0.0	0.0	0.0	40.0	0.0	60.0	0.0	0.0	0.0	0.0
Finland	4.8	0.0	0.0	5.9	22.2	2.0	59.6	0.0	5.3	0.0	0.0	-
Iceland	15.1	1.0	0.0	0.0	0.0	0.0	8.0	0.2	0.0	56.1	19.6	0.1
Norway	1.2	93.2	0.1	0.2	0.7	1.6	0.9	0.2	0.9	0.3	0.1	0.7
Sweden	21.3	0.0	0.0	0.0	46.8	29.8	2.1	0.0	0.0	0.0	0.0	0.0

Table 4.4: Percentage allocation of ENS by month over 2015–2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Estonia	12.5	8.1	3.2	15.2	6.9	3.3	4.1	4.7	10.9	21.0	6.0	4.1
Latvia	2.0	0.1	2.3	0.4	3.9	31.9	14.7	12.3	10.2	9.7	5.5	6.8
Lithuania	8.6	2.4	12.9	5.0	6.9	23.9	21.5	7.6	2.1	4.6	2.6	2.0
Denmark	9.4	10.4	6.7	3.6	1.2	3.2	2.0	11.7	12.5	20.4	4.1	14.9
Finland	5.5	2.5	2.6	6.0	7.6	9.5	22.4	17.4	3.2	4.1	2.5	16.7
Iceland	19.0	23.3	6.3	1.1	0.4	2.5	3.4	2.7	3.4	7.6	3.4	26.7
Norway	14.4	43.0	0.7	3.6	1.8	9.3	3.6	3.0	3.8	2.6	11.9	2.4
Sweden	6.1	5.9	3.3	2.8	7.6	15.9	20.1	16.3	6.5	6.2	4.6	4.6

4.4 Energy not supplied by cause

This section presents ENS by the cause of each fault. The used causes are lightning, 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 2024. Table 4.6 shows the respective percentages over 2015–2024.

Table 4.5: ENS (%) by cause in 2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	91.7	0.4	6.6	1.2	0.0
Latvia	63.7	0.0	33.4	2.9	0.0
Lithuania	50.6	0.0	6.0	43.4	0.0
Denmark	40.0	0.0	60.0	0.0	0.0
Finland	1.9	0.0	74.0	24.1	0.0
Iceland	35.0	0.0	8.7	56.3	0.0
Norway	95.0	0.3	2.9	1.8	0.1
Sweden	100.0	0.0	0.0	0.0	0.0

Table 4.6: Percentage allocation of ENS by cause over 2015–2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	13.6	11.9	9.7	63.9	0.9
Latvia	22.2	12.9	53.8	11.0	0.2
Lithuania	14.9	31.3	14.1	39.1	0.6
Denmark	11.4	0.0	63.4	25.2	0.0
Finland	23.4	2.8	21.4	40.3	12.1
Iceland	43.5	2.9	14.3	39.2	0.0
Norway	57.8	1.9	10.2	27.4	2.7
Sweden	33.3	5.2	6.5	35.3	19.7

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 show the amount of ENS and its allocation by voltage level in 2024 and for 2015–2024, while Table 4.8 presents ENS for faults only.

Table 4.7: ENS in 2024 and its annual average for 2015–2024, and the annual average amount of ENS by voltage level for 2015–2024.

	ENS (MWh)		Average annual ENS (MWh) by voltage level over 2015–2024			
Country	2024	Annual average 2015–2024	100–150 kV	220–330 kV	380–420 kV	Other[1]
Estonia	69.6	67.4	54.7	5.5	0.0	13.2
Latvia	53.4	52.9	35.4	17.4	0.0	0.2
Lithuania	29.6	36.5	35.0	0.3	0.0	1.2
Baltic total	152.7	156.8	125.1	23.1	0.0	14.6
Denmark	18.6	41.1	38.2	0.0	1.0	2.0
Finland	364.1	215.3	206.3	0.6	0.0	10.3
Iceland	351.6	794.7	318.1	319.7	0.0	194.9
Norway	4336.4	1321.6	639.9	253.6	397.2	30.9
Sweden	4.7	1198.3	952.6	128.7	24.7	122.7
Nordic total	5075.4	3571.0	2155.2	702.7	422.8	360.8
Baltic & Nordic total	5228.1	3727.8	2280.3	725.8	422.8	375.4

[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 2024.

Region	Country	100–150 kV	220–330 kV	380–420 kV
Baltic	Estonia	69.6	0.0	0.0
	Latvia	53.4	0.0	0.0
	Lithuania	28.6	0.0	0.0
	Total	151.7	0.0	0.0
Nordic	Denmark	18.6	0.0	0.0
	Finland	364.1	0.0	0.0
	Iceland	125.4	28.2	0.0
	Norway	570.7	361.5	3370.4
	Sweden	0.0	4.5	0.2
	Total	1078.8	394.2	3370.6
Baltic & Nordic total		1230.5	394.2	3370.6

4.6 Energy not supplied by component

Table 4.9 presents the percentage allocation of ENS by component in 2024, and Table 4.10 shows the respective percentages over 2015–2024. The ENS is allocated to the component where each fault occurred. The total amount of ENS in 2024 and the annual average values for 2015–2024 are in Table 4.7.

Table 4.9: ENS (%) by component in 2024. The ENS is allocated to the component where each fault occurred. Proportionately higher percentage values are highlighted in yellow and red.

Lines: Cables, Overhead lines
Substation components: Busbars, Circuit breakers, Common ancillary equipment, Control equipment, Disconnectors, Instrument transformers, Power transformers, Surge arresters and spark gaps, Other high voltage appliances
Compensation devices: Reactors, Series capacitors, Shunt capacitors, SVC and statcom, Synchronous compensators
Other: Adjoining grid, System faults

	Lines			Substation components										Compensation devices						Other		
			Total										Total				SVC		Total			Total
Estonia	0.0	86.7	86.7	0.0	0.0	4.6	0.0	0.0	2.0	0.0	6.7	0.0	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Latvia	0.0	66.6	66.6	0.0	0.0	0.0	33.3	0.0	0.0	0.1	0.0	0.0	33.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lithuania	0.0	94.0	94.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.0	3.4
Denmark	0.0	40.0	40.0	0.0	0.0	0.0	60.0	0.0	0.0	0.0	0.0	0.0	60.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Finland	0.0	75.4	75.4	0.0	0.0	0.0	8.3	0.0	16.3	0.0	0.0	0.0	24.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Iceland	0.0	35.0	35.0	0.0	0.0	0.0	8.7	0.0	0.0	0.0	0.0	0.0	8.7	0.0	0.0	0.0	0.0	0.0	0.0	56.3	0.0	56.3
Norway	5.4	83.2	88.6	7.1	0.1	0.0	2.5	0.0	0.0	0.4	0.3	0.3	10.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.8
Sweden	0.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 4.10: Percentage allocation of ENS by component over 2015–2024. The ENS is allocated to the component where each fault occurred. Proportionately higher percentage values are highlighted in yellow and red. The symbols are presented in Table 4.9.

	Lines			Substation components										Compensation devices						Other		
			Total										Total				SVC		Total			Total
Estonia	0.0	22.9	22.9	0.1	10.3	0.5	19.6	2.4	1.4	1.9	0.7	16.3	53.1	0.0	0.0	4.4	0.0	0.0	4.4	19.6	0.0	19.6
Latvia	0.0	34.9	34.9	0.7	0.5	0.0	55.4	4.5	1.3	2.5	0.0	0.0	64.8	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.3
Lithuania	0.5	58.1	58.6	3.1	5.6	0.0	18.5	7.4	1.4	0.3	1.4	0.4	38.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.0	3.4
Denmark	4.0	4.9	8.9	43.9	5.0	0.0	24.4	2.2	5.8	4.8	0.0	0.0	86.2	0.0	0.0	0.0	0.0	0.0	0.0	4.9	0.0	4.9
Finland	0.0	63.8	63.8	2.2	4.4	0.5	7.5	1.9	7.8	5.1	0.0	0.7	30.1	0.5	0.9	0.0	0.0	0.0	1.3	4.0	0.8	4.8
Iceland	0.8	27.2	28.0	0.1	5.1	0.0	14.5	0.2	2.1	17.4	1.0	7.0	47.4	0.0	0.0	0.0	0.0	0.0	0.0	22.0	2.6	24.5
Norway	4.9	49.6	54.5	6.9	3.2	1.5	17.9	5.5	5.1	0.5	0.9	1.6	43.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	2.3	2.3
Sweden	1.5	47.8	49.3	3.1	3.2	1.6	9.1	4.4	4.1	4.6	2.8	5.3	38.1	1.1	0.0	1.3	0.0	0.0	2.3	10.1	0.1	10.2

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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 2024.

	Faults in 2024			Secondary faults in 2024	
Country	Number	causing ENS	ENS (MWh)	Number	ENS (MWh)
Estonia	195	10	69.6	11	3.2
Latvia	160	13	53.4	8	0.8
Lithuania	127	14	29.6	1	0.0
Baltic total	482	37	152.7	20	4.0
Denmark	70	2	18.6	6	0.0
Finland[1]	240	10	364.1	8	20.5
Iceland	21	10	351.6	1	0.0
Norway	339	101	4336.4	38	2.5
Sweden[1]	97	8	4.7	0	0.0
Nordic total	767	131	5075.4	53	23.0
Baltic & Nordic total	1249	168	5228.1	73	27.0

[1] 2024 values for Finland and Sweden include only transmission system operators' (TSO) networks.

5.2 Statistics of secondary faults

Table 5.2 presents the percentage allocation of secondary faults by cause in 2024, and Table 5.3 shows the respective values over 2017–2024. Table 5.4 presents the annual number of secondary faults for 2017–2024.

Table 5.5 presents the percentage allocation of ENS due to secondary faults in 2024, and Table 5.6 shows the respective values over 2017–2024. Table 5.7 presents the annual amounts of ENS caused by the secondary faults for 2017–2024.

Data about secondary faults have been collected since 2017.

Table 5.2: Percentage allocation of secondary faults by cause in 2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	9.1	0.0	45.5	27.3	18.2
Latvia	0.0	0.0	25.0	75.0	0.0
Lithuania	0.0	0.0	100.0	0.0	0.0
Denmark	0.0	0.0	66.7	33.3	0.0
Finland	37.5	0.0	50.0	12.5	0.0
Iceland	0.0	0.0	0.0	100.0	0.0
Norway	34.2	0.0	28.9	23.7	13.2
Sweden	-	-	-	-	-

Table 5.3: Percentage allocation of secondary faults by cause over 2017–2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	7.9	3.9	34.2	43.4	10.5
Latvia	0.0	0.0	36.9	59.8	3.3
Lithuania	1.4	0.0	31.9	36.2	30.4
Denmark	0.0	2.2	75.6	22.2	0.0
Finland	19.8	4.2	41.7	26.0	8.3
Iceland	12.5	0.0	16.3	71.2	0.0
Norway	28.5	0.8	27.3	37.2	6.3
Sweden	8.4	1.2	3.6	78.3	8.4

Table 5.4: Annual number of secondary faults for 2017–2024.

Country	2017	2018	2019	2020	2021	2022	2023	2024	Annual average
Estonia	9	8	7	15	4	5	17	11	9.5
Latvia	20	20	23	9	16	13	13	8	8.6
Lithuania	13	19	18	6	0	4	8	1	15.3
Denmark	9	3	6	5	3	5	8	6	5.6
Finland	13	9	6	18	16	19	7	8	12.0
Iceland	8	18	26	22	14	11	4	1	13.0
Norway	30	34	26	28	36	31	30	38	31.6
Sweden	10	7	14	9	27	9	7	0	10.4
Baltic & Nordic	112	118	126	112	116	97	94	73	106.0

Table 5.5: Percentage allocation of ENS due to secondary faults by cause in 2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	0.0	0.0	100.0	0.0	0.0
Latvia	0.0	0.0	100.0	0.0	0.0
Lithuania	-	-	-	-	-
Denmark	-	-	-	-	-
Finland	0.0	0.0	100.0	0.0	0.0
Iceland	-	-	-	-	-
Norway	73.9	0.0	3.2	21.4	1.5
Sweden	-	-	-	-	-

Table 5.6: Percentage allocation of ENS due to secondary faults by cause over 2017–2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	0.1	0.5	71.3	28.1	0.0
Latvia	0.0	0.0	94.6	5.1	0.4
Lithuania	0.0	0.0	2.8	97.2	0.0
Denmark	0.0	0.0	95.8	4.2	0.0
Finland	20.4	0.6	23.0	49.3	6.7
Iceland	3.7	0.0	0.0	96.3	0.0
Norway	19.7	22.0	25.4	32.9	0.0
Sweden	0.0	0.0	0.0	83.8	16.2

Table 5.7: Annual amount of ENS (MWh) due to secondary faults for 2017–2024.

Country	2017	2018	2019	2020	2021	2022	2023	2024
Estonia	0.1	0.3	0.1	0.1	1.2	0.0	0.0	3.2
Latvia	16.0	34.1	2.2	163.3	8.6	6.5	0.5	0.8
Lithuania	50.0	25.2	0.5	24.1	0.0	7.0	2.1	0.0
Denmark	4.0	0.3	4.7	0.0	0.0	16.4	24.8	0.0
Finland	6.0	48.2	12.6	12.9	15.3	7.7	10.5	20.5
Iceland	0.0	0.0	0.2	84.1	4.7	13.8	0.0	0.0
Norway	58.8	131.3	71.3	167.2	130.9	60.1	132.3	2.5
Sweden	32.0	0.0	8.4	0.0	10.2	0.0	0.0	0.0
Baltic & Nordic	166.9	239.3	100.0	451.7	170.9	111.6	170.2	27.0

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 2024 and for 2015–2024. Table 6.2 shows the number of faults and number of grid disturbances in 2024, their annual averages for 2015–2024, and the faults to disturbance ratio over 2015–2024.

Table 6.3 shows the percentage allocation of faults per component in 2024, and Table 6.4 shows the respective percentages over 2015–2024. 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 2024 and their annual averages for 2015–2024.

	Number of faults		No. of faults with ENS		ENS (MWh)	
Country	2024	Annual avg. 2015–2024	2024	Annual avg. 2015–2024	2024	Annual avg. 2015–2024
Estonia	195	160.3	10	21.6	69.6	67.4
Latvia	160	140.6	13	13.6	53.4	52.9
Lithuania	127	152.3	14	15.2	29.6	36.5
Baltic total	482	453.2	37	50.4	152.7	156.8
Denmark	70	70.7	2	6.1	18.6	41.1
Finland[1]	240	408.3	10	100.9	364.1	215.3
Iceland	21	64.5	10	19.1	351.6	794.7
Norway	339	316.0	101	78.7	4336.4	1321.6
Sweden[1]	97	369.3	8	154.2	4.7	1198.3
Nordic total	767	1228.8	131	359.0	5075.4	3571.0
Baltic & Nordic total	1249	1682.0	168	409.4	5228.1	3727.8

[1] 2024 values for Finland and Sweden include only transmission system operators' (TSO) networks.

Table 6.2: The number of faults and the number of grid disturbances in 2024, their annual averages for 2015–2024, and the fault to disturbance ratio in 2024 and over 2015–2024.

	Number of faults		No. of disturbances		Ratio	
Country	2024	Annual avg. 2015–2024	2024	Annual avg. 2015–2024	2024	Annual avg. 2015–2024
Estonia	195	160.3	184	150.3	1.1	1.1
Latvia	160	140.6	152	126.0	1.1	1.1
Lithuania	127	152.3	126	141.9	1.0	1.1
Baltic total	482	453.2	462	418.2	1.0	1.1
Denmark	70	70.7	64	64.6	1.1	1.1
Finland[1]	240	408.3	232	393.4	1.0	1.0
Iceland	21	64.5	20	45.0	1.1	1.4
Norway	339	316.0	301	282.7	1.1	1.1
Sweden[1]	97	369.3	97	356.0	1.0	1.0
Nordic total	767	1228.8	714	1141.7	1.1	1.1
Baltic & Nordic total	1249	1682.0	1176	1559.9	1.1	1.1

[1] 2024 values for Finland and Sweden include only transmission system operators' (TSO) networks.

Table 6.3: Percentage allocation of faults by component in 2024. Proportionately higher percentage values are highlighted in yellow and red.

Lines: Cables; Overhead lines

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

Compensation devices: Reactors; Series capacitors; Shunt capacitors; SVC and statcom; Synchronous compensators

Other: Adjoining grid; System faults

	Lines			Substation components										Compensation devices						Other		
			Total										Total				SVC		Total			Total
Estonia	0.0	39.5	39.5	2.6	7.2	2.1	12.3	4.1	5.6	4.1	1.5	0.0	39.5	4.1	0.0	0.0	0.0	3.6	7.7	13.3	0.0	13.3
Latvia	0.6	78.8	79.4	0.0	0.0	0.0	6.9	0.0	3.8	1.3	1.9	0.0	13.8	0.0	0.0	0.0	0.0	0.0	0.0	6.3	0.6	6.9
Lithuania	0.0	67.7	67.7	0.8	0.8	0.0	11.8	0.0	0.8	2.4	0.0	0.0	16.5	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.8	15.7
Denmark	0.0	50.0	50.0	0.0	0.0	0.0	12.9	0.0	4.3	17.1	0.0	0.0	34.3	0.0	0.0	8.6	0.0	1.4	10.0	5.7	0.0	5.7
Finland	0.0	86.2	86.2	0.0	1.7	0.4	4.6	0.0	0.4	1.3	0.0	1.3	9.6	0.8	2.1	0.4	0.8	0.0	4.2	0.0	0.0	0.0
Iceland	0.0	38.1	38.1	4.8	4.8	0.0	14.3	0.0	9.5	9.5	0.0	0.0	42.9	0.0	0.0	0.0	0.0	0.0	0.0	19.0	0.0	19.0
Norway	1.8	53.4	55.2	0.6	2.9	2.1	19.5	1.2	1.8	4.1	1.2	1.2	34.5	0.6	0.0	0.3	2.4	0.3	3.5	0.6	6.2	6.8
Sweden	0.0	60.8	60.8	0.0	2.1	0.0	18.6	1.0	1.0	1.0	0.0	1.0	24.7	2.1	11.3	0.0	1.0	0.0	14.4	0.0	0.0	0.0

Table 6.4: Percentage allocation of faults by component over 2015–2024. Proportionately higher percentage values are highlighted in yellow and red. The symbols are presented in Table 6.3.

	Lines			Substation components										Compensation devices						Other		
			Total										Total				SVC		Total			Total
Estonia	0.3	42.8	43.1	2.6	7.0	1.5	11.4	4.6	3.3	7.1	0.4	3.3	41.2	1.9	0.0	0.7	0.0	1.4	4.0	11.7	0.0	11.7
Latvia	0.4	67.6	68.0	0.6	1.8	0.1	13.2	0.8	2.4	2.7	0.7	0.2	22.4	0.4	0.0	0.0	0.0	0.0	0.4	9.1	0.1	9.2
Lithuania	0.1	66.6	66.6	1.0	2.6	0.4	9.5	0.9	1.0	0.7	0.8	0.6	17.3	0.0	0.0	0.0	0.2	0.0	0.2	15.6	0.3	15.8
Denmark	5.0	43.4	48.4	4.5	3.1	0.3	12.5	1.1	2.4	9.1	0.6	1.6	35.2	1.8	0.0	1.3	0.7	3.3	7.1	9.4	0.0	9.4
Finland	0.2	82.7	83.0	0.3	1.1	0.3	5.8	0.3	0.7	1.9	0.4	2.1	12.9	0.1	1.3	0.4	0.1	0.0	2.0	2.1	0.1	2.2
Iceland	0.3	31.8	32.1	1.6	4.7	0.2	12.4	0.8	0.6	5.6	0.5	3.9	30.1	0.0	0.2	0.8	0.3	0.0	1.2	23.1	13.5	36.6
Norway	1.3	50.1	51.4	0.8	4.2	2.0	20.6	1.2	2.1	2.4	0.9	4.0	38.3	0.5	0.0	1.1	4.5	0.8	7.0	0.1	3.2	3.3
Sweden	1.0	58.7	59.7	0.5	2.2	0.5	12.6	3.1	1.2	3.0	0.5	1.8	25.6	1.4	1.8	0.4	1.0	0.0	4.7	9.4	0.7	10.0

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, 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 Figure 1.3. 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 2024. Table 6.6 shows the respective percentages over 2015–2024.

Table 6.7 presents the percentage allocation of faults that caused ENS by cause in 2024. Table 6.8 shows the respective percentages over 2015–2024.

Table 6.5: Percentage allocation of the number of faults by cause in 2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	25.1	5.6	16.4	38.5	14.4
Latvia	31.9	31.3	4.4	20.0	12.5
Lithuania	15.7	21.3	17.3	22.8	22.8
Denmark	4.3	44.3	18.6	31.4	1.4
Finland	80.3	1.7	11.3	6.7	0.0
Iceland	38.1	0.0	14.3	47.6	0.0
Norway	54.3	2.7	20.4	18.0	4.7
Sweden	39.2	6.2	12.4	22.7	19.6

Table 6.6: Percentage allocation of the number of faults by cause over 2015–2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	20.6	9.6	16.8	40.4	12.6
Latvia	32.6	21.1	8.8	23.0	14.6
Lithuania	12.1	25.3	9.7	25.0	28.0
Denmark	14.4	25.0	23.8	31.4	5.4
Finland	54.4	2.1	7.3	17.2	19.1
Iceland	31.6	0.9	10.2	56.7	0.5
Norway	49.0	2.4	18.2	25.2	5.2
Sweden	32.0	2.0	8.9	27.4	29.7

Table 6.7: Percentage allocation of the number of faults that caused ENS by cause in 2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	50.0	10.0	30.0	10.0	0.0
Latvia	53.8	0.0	30.8	15.4	0.0
Lithuania	28.6	0.0	28.6	42.9	0.0
Denmark	50.0	0.0	50.0	0.0	0.0
Finland	10.0	0.0	50.0	40.0	0.0
Iceland	60.0	0.0	20.0	20.0	0.0
Norway	54.5	5.0	23.8	12.9	4.0
Sweden	100.0	0.0	0.0	0.0	0.0

Table 6.8: Percentage allocation of the number of faults that caused ENS by cause over 2015–2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	14.4	10.6	25.9	39.8	9.3
Latvia	30.9	11.8	31.6	22.8	2.9
Lithuania	11.8	37.5	25.7	22.4	2.6
Denmark	11.5	0.0	57.4	31.1	0.0
Finland	32.0	2.3	7.7	12.8	45.2
Iceland	55.5	1.6	11.5	31.4	0.0
Norway	44.7	3.2	24.8	23.6	3.7
Sweden	32.7	1.6	10.2	28.5	26.9

6.3 Faults in cables

This section presents cable faults in 2024 and for 2015–2024.

Table 6.9 presents the length of cables and the number of faults in 2024, and the 10-year annual average of the number of faults for 2015–2024. Table 6.10 presents the number of faults per 100 km of cable in 2024 and the annual averages for 2015–2024.

Table 6.11 shows the percentage allocation of cable faults by cause in 2024. Table 6.12 presents the respective percentages over 2015–2024.

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 2024, and the annual average number of faults for 2015–2024, grouped by voltage level.

Region	Country	100–150 kV			220–330 kV			380–420 kV		
		km in 2024	Number of faults in 2024	10-year ann. avg of faults	km in 2024	Number of faults in 2024	10-year ann. avg of faults	km in 2024	Number of faults in 2024	10-year ann. avg of faults
Baltic	Estonia	122	0	0.5	0	0	0.0	0	0	0.0
	Latvia	83	1	0.3	22	0	0.2	0	0	0.0
	Lithuania	118	0	0.1	0	0	0.0	0	0	0.0
	Total	322	1	0.9	23	0	0.2	0	0	0.0
Nordic	Denmark	1 912	0	3.1	366	0	0.3	245	0	0.1
	Finland	0	0	1.0	0	0	0.0	0	0	0.0
	Iceland	111	0	0.2	17	0	0.0	0	0	0.0
	Norway	571	4	2.9	116	2	0.6	44	0	0.7
	Sweden	0	0	2.1	17	0	1.1	14	0	0.4
	Total	2 594	4	9.3	517	2	2.0	303	0	1.2
Baltic & Nordic total		2 916	5	10.2	539	2	2.2	303	0	1.2

Table 6.10: Number of cable faults per 100 km in 2024 and the annual average for 2015–2024, grouped by voltage level.

Region	Country	100–150 kV		220–330 kV		380–420 kV	
		Number of faults / 100 km in 2024	10-year ann. avg no. of faults / 100 km	Number of faults / 100 km in 2024	10-year ann. avg no. of faults / 100 km	Number of faults / 100 km in 2024	10-year ann. avg no. of faults / 100 km
Baltic	Estonia	0.00	0.56	0.00	0.00	0.00	0.00
	Latvia	1.21	0.38	0.00	1.09	0.00	0.00
	Lithuania	0.00	0.10	0.00	0.00	0.00	0.00
	Total	0.31	0.33	0.00	1.07	0.00	0.00
Nordic	Denmark	0.00	0.20	0.00	0.11	0.00	0.05
	Finland	0.00	0.58	0.00	0.00	0.00	0.00
	Iceland	0.00	0.18	0.00	0.00	0.00	0.00
	Norway	0.70	0.50	1.72	0.53	0.00	1.63
	Sweden	0.00	0.51	0.00	0.92	0.00	2.18
	Total	0.15	0.33	0.39	0.39	0.00	0.46
Baltic & Nordic total		0.17	0.33	0.37	0.42	0.00	0.46

Table 6.11: Percentage allocation of cable faults by cause in 2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	-	-	-	-	-
Latvia	0.0	100.0	0.0	0.0	0.0
Lithuania	-	-	-	-	-
Denmark	-	-	-	-	-
Finland	-	-	-	-	-
Iceland	-	-	-	-	-
Norway	33.3	16.7	0.0	50.0	0.0
Sweden	-	-	-	-	-

Table 6.12: Percentage allocation of cable faults by cause over 2015–2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	0.0	60.0	20.0	20.0	0.0
Latvia	0.0	40.0	0.0	60.0	0.0
Lithuania	0.0	0.0	0.0	100.0	0.0
Denmark	0.0	11.4	22.9	60.0	5.7
Finland	10.0	10.0	30.0	50.0	0.0
Iceland	50.0	0.0	0.0	50.0	0.0
Norway	23.8	16.7	2.4	52.4	4.8
Sweden	2.8	0.0	13.9	66.7	16.7

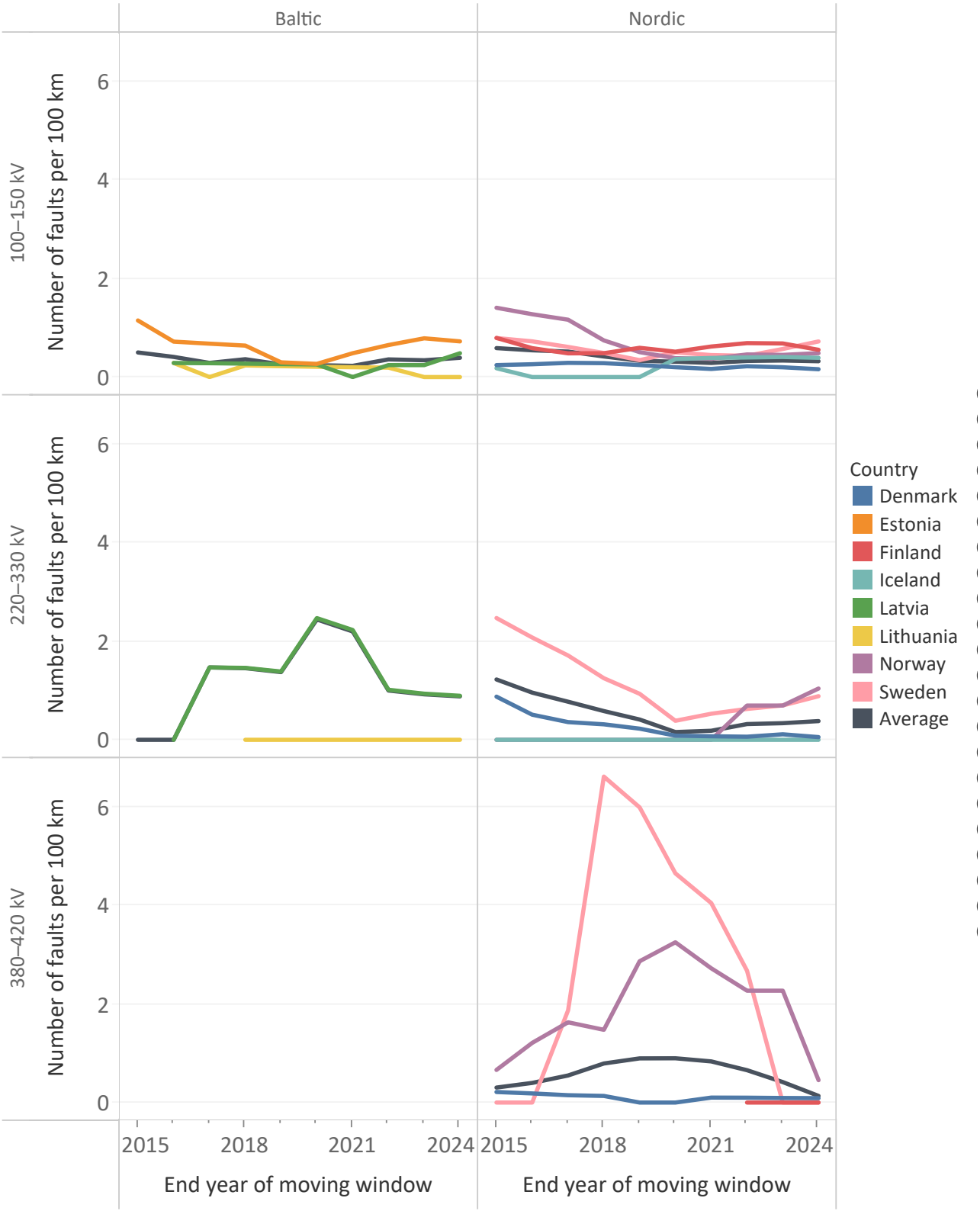

Figure 6.1: 5-year moving average of cable faults per 100 km. Estonia and Lithuania do not own 220–330 kV cables. Estonia, Iceland and Latvia do not own 380–420 kV cables. Finnish TSO Fingrid does not own 100–400 kV AC-cables.

6.4 Faults on overhead lines

This section presents overhead line faults in 2024 and for 2015–2024.

Table 6.13 presents the length of overhead lines and the number of faults in 2024, and the 10-year annual average of the number of faults for 2015–2024. Table 6.14 presents the number of faults per 100 km of overhead line in 2024 and the annual averages for 2015–2024.

Table 6.15 presents the number of faults and the number of permanent faults for 2024 and their 10-year respective average values for 2015–2024.

Table 6.16 shows the percentage allocation of overhead line faults by cause in 2024. Table 6.17 presents the respective percentages over 2015–2024.

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 2024, and the annual average number of faults for 2015–2024, grouped by voltage level.

Region	Country	100–150 kV			220–330 kV			380–420 kV		
		km in 2024	Number of faults in 2024	10-year ann. avg of faults	km in 2024	Number of faults in 2024	10-year ann. avg of faults	km in 2024	Number of faults in 2024	10-year ann. avg of faults
Baltic	Estonia	3 342	71	59.1	1 851	6	9.5	0	0	0.0
	Latvia	3 730	108	85.9	1 720	18	9.3	0	0	0.0
	Lithuania	4 969	79	92.3	2 011	7	8.5	103	0	0.6
	Total	12 041	258	237.3	5 582	31	27.3	103	0	0.6
Nordic	Denmark	2 933	34	25.6	25	0	0.2	1 377	1	4.8
	Finland	8 701	179	317.9	1 032	12	11.8	5 634	15	8.1
	Iceland	1 383	7	15.9	1 112	1	4.6	0	0	0.0
	Norway	10 999	104	83.7	4 095	18	29.2	4 766	59	45.4
	Sweden	1	0	157.3	3 773	26	27.2	11 374	33	32.4
	Total	24 017	324	600.4	10 037	57	73.0	23 151	108	90.7
Baltic & Nordic total		36 057	582	837.7	15 619	88	100.3	23 253	108	91.3

Table 6.14: Number of overhead line faults per 100 km in 2024 and the annual average for 2015–2024, grouped by voltage level.

Region	Country	100–150 kV		220–330 kV		380–420 kV	
		Number of faults / 100 km in 2024	10-year ann. avg no. of faults / 100 km	Number of faults / 100 km in 2024	10-year ann. avg no. of faults / 100 km	Number of faults / 100 km in 2024	10-year ann. avg no. of faults / 100 km
Baltic	Estonia	2.12	1.74	0.32	0.52	0.00	0.00
	Latvia	2.90	2.26	1.05	0.60	0.00	0.00
	Lithuania	1.59	1.85	0.35	0.46	0.00	0.65
	Total	2.14	1.95	0.56	0.52	0.00	0.65
Nordic	Denmark	1.16	0.89	0.00	0.56	0.07	0.35
	Finland	2.06	2.02	1.16	0.78	0.27	0.14
	Iceland	0.51	1.24	0.09	0.49	0.00	0.00
	Norway	0.95	0.77	0.44	0.66	1.24	1.09
	Sweden	0.00	1.17	0.69	0.73	0.29	0.32
	Total	1.35	1.36	0.57	0.69	0.47	0.43
Baltic & Nordic total		1.61	1.48	0.56	0.63	0.46	0.43

Table 6.15: Number of overhead lines faults and permanent faults in 2024 and their 10-year annual average values for 2015–2024, grouped by voltage level.

		100–150 kV				220–330 kV				380–420 kV			
		Faults		Permanent faults		Faults		Permanent faults		Faults		Permanent faults	
Region	Country	Number in 2024	10-year ann. avg	Number in 2024	10-year ann. avg	Number in 2024	10-year ann. avg	Number in 2024	10-year ann. avg	Number in 2024	10-year ann. avg	Number in 2024	10-year ann. avg
Baltic	Estonia	71	59.1	23	13.0	6	9.5	4	3.1	0	0.0	0	0.0
	Latvia	108	85.9	35	35.2	18	9.3	3	1.4	0	0.0	0	0.0
	Lithuania	79	92.3	8	12.8	7	8.5	0	1.3	0	0.6	0	0.4
	Total	258	237.3	66	61.0	31	27.3	7	5.8	0	0.6	0	0.4
Nordic	Denmark	34	25.6	2	2.6	0	0.2	0	0.0	1	4.8	0	1.0
	Finland	179	317.9	1	25.6	12	11.8	0	1.4	15	8.1	1	0.9
	Iceland	7	15.9	1	2.4	1	4.6	0	1.2	0	0.0	0	0.0
	Norway	104	83.7	29	21.6	18	29.2	1	3.2	59	45.4	1	2.0
	Sweden	0	157.3	0	6.7	26	27.2	0	1.4	33	32.4	1	2.0
	Total	324	600.4	33	58.9	57	73.0	1	7.2	108	90.7	3	5.9
Baltic & Nordic total		582	837.7	99	119.9	88	100.3	8	13.0	108	91.3	3	6.3

Table 6.16: Percentage allocation of overhead line faults by cause in 2024.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	59.7	14.3	5.2	3.9	16.9
Latvia	40.5	38.1	0.0	5.6	15.9
Lithuania	23.3	30.2	7.0	5.8	33.7
Denmark	8.6	71.4	2.9	14.3	2.9
Finland	91.3	1.9	5.8	1.0	0.0
Iceland	100.0	0.0	0.0	0.0	0.0
Norway	93.9	2.2	0.0	3.3	0.6
Sweden	62.7	10.2	5.1	0.0	22.0

Table 6.17: Percentage allocation of overhead line faults by cause over 2015–2024.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	43.6	20.3	10.3	7.7	18.1
Latvia	47.9	28.9	1.1	2.0	20.2
Lithuania	17.9	37.5	3.1	3.7	37.8
Denmark	25.8	50.3	6.2	8.8	8.8
Finland	63.6	2.2	2.0	12.1	20.1
Iceland	89.3	2.9	0.5	6.8	0.5
Norway	90.3	1.8	1.8	4.0	2.1
Sweden	48.4	2.6	3.2	4.3	41.6

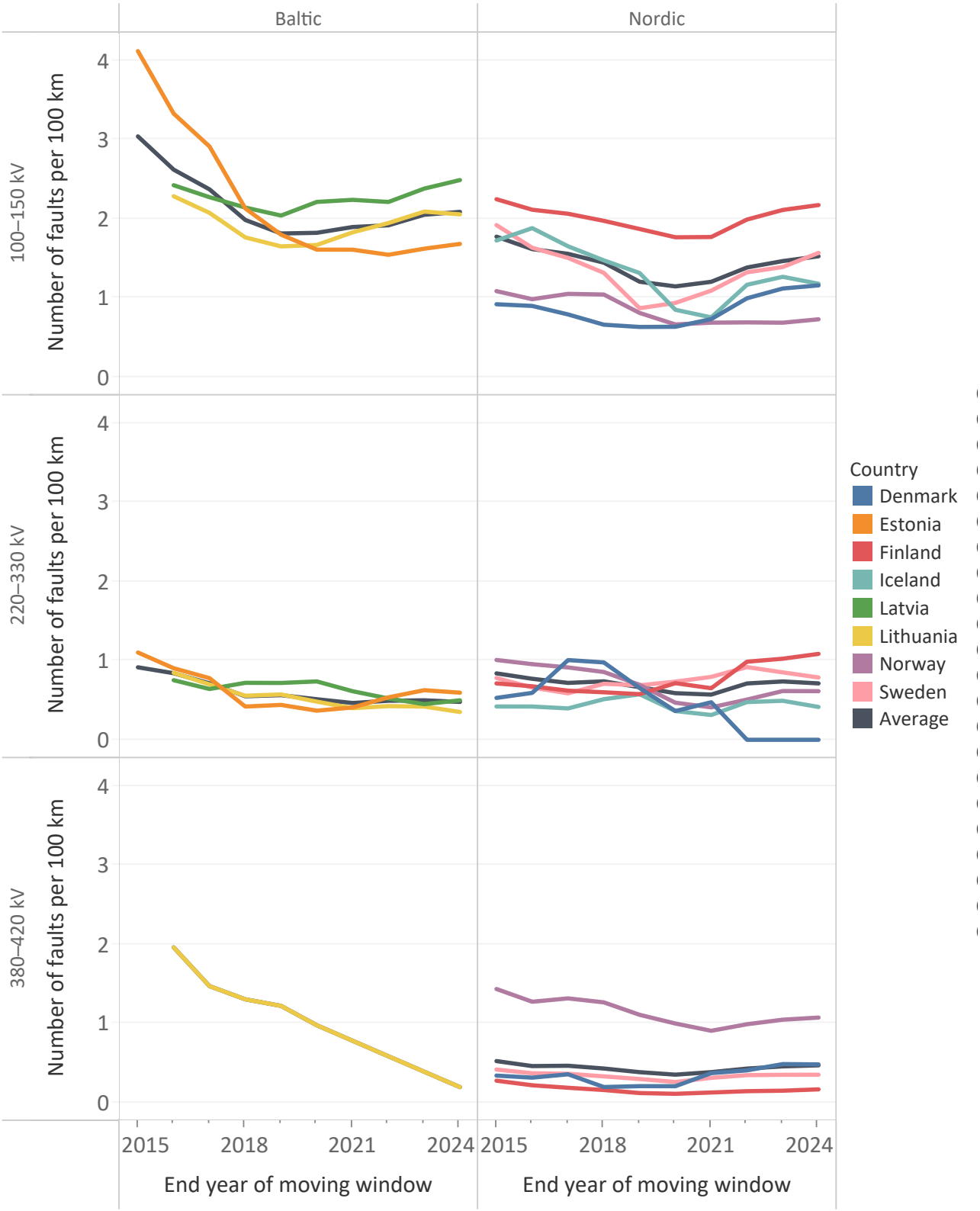

Figure 6.2: 5-year moving average of overhead line faults per 100 km. Estonia, Iceland and Latvia do not own 380–420 kV transmission grids.

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6.5 Faults in circuit breakers

This section presents circuit breaker faults in 2024 and for 2015–2024.

Table 6.18 presents the number of circuit breakers and the number of faults in 2024, and the 10-year annual average of the number of faults for 2015–2024. Table 6.19 presents the number of faults per 100 devices in 2024 and the annual averages for 2015–2024.

Table 6.20 presents the percentage allocation of circuit breaker faults by cause in 2024. Table 6.21 presents the respective percentages over 2015–2024.

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 2024, and the annual average number of faults for 2015–2024, grouped by voltage level.

Region	Country	100–150 kV			220–330 kV			380–420 kV		
		Number of devices in 2024	Number of faults in 2024	10-year ann. avg of faults	Number of devices in 2024	Number of faults in 2024	10-year ann. avg of faults	Number of devices in 2024	Number of faults in 2024	10-year ann. avg of faults
Baltic	Estonia	719	7	7.0	143	7	4.2	0	0	0.0
	Latvia	635	0	2.4	110	0	0.1	0	0	0.0
	Lithuania	906	1	3.4	160	0	0.5	11	0	0.1
	Total	2 260	8	12.8	413	7	4.8	11	0	0.1
Nordic	Denmark	1 022	0	1.7	38	0	0.1	308	0	0.4
	Finland	958	1	3.9	63	1	0.1	446	2	0.4
	Iceland	173	1	2.2	107	0	0.8	0	0	0.0
	Norway	2 693	4	7.0	684	2	3.7	630	4	2.6
	Sweden	0	0	3.2	214	1	1.4	688	1	3.7
	Total	4 846	6	18.0	1 106	4	6.1	2 072	7	7.1
Baltic & Nordic total		7 106	14	30.8	1 519	11	10.9	2 083	7	7.2

Table 6.19: Number of circuit breaker faults per 100 devices in 2024 and the annual average for 2015–2024, grouped by voltage level.

Region	Country	100–150 kV		220–330 kV		380–420 kV	
		Number of faults / 100 devices in 2024	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2024	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2024	10-year ann. avg no. of faults / 100 devices
Baltic	Estonia	0.974	1.09	4.895	3.29	0.000	0.00
	Latvia	0.000	0.39	0.000	0.10	0.000	0.00
	Lithuania	0.110	0.39	0.000	0.42	0.000	1.43
	Total	0.354	0.60	1.695	1.37	0.000	1.43
Nordic	Denmark	0.000	0.18	0.000	0.35	0.000	0.16
	Finland	0.104	0.15	1.587	0.14	0.448	0.11
	Iceland	0.578	1.40	0.000	0.91	0.000	0.00
	Norway	0.149	0.28	0.292	0.52	0.635	0.52
	Sweden	0.000	0.14	0.467	0.43	0.145	0.56
	Total	0.124	0.21	0.362	0.50	0.338	0.40
Baltic & Nordic total		0.197	0.29	0.724	0.69	0.336	0.40

Table 6.20: Percentage allocation of circuit breakers faults by cause in 2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	0.0	0.0	0.0	78.6	21.4
Latvia	-	-	-	-	-
Lithuania	0.0	0.0	0.0	100.0	0.0
Denmark	-	-	-	-	-
Finland	0.0	0.0	50.0	50.0	0.0
Iceland	0.0	0.0	0.0	100.0	0.0
Norway	0.0	0.0	70.0	20.0	10.0
Sweden	0.0	0.0	0.0	100.0	0.0

Table 6.21: Percentage allocation of circuit breaker faults over 2015–2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	1.8	1.8	7.1	78.6	10.7
Latvia	0.0	4.0	8.0	88.0	0.0
Lithuania	0.0	0.0	37.5	57.5	5.0
Denmark	0.0	0.0	86.4	13.6	0.0
Finland	4.5	2.3	34.1	43.2	15.9
Iceland	6.7	0.0	3.3	90.0	0.0
Norway	4.5	3.0	34.6	39.1	18.8
Sweden	10.8	0.0	13.3	67.5	8.4

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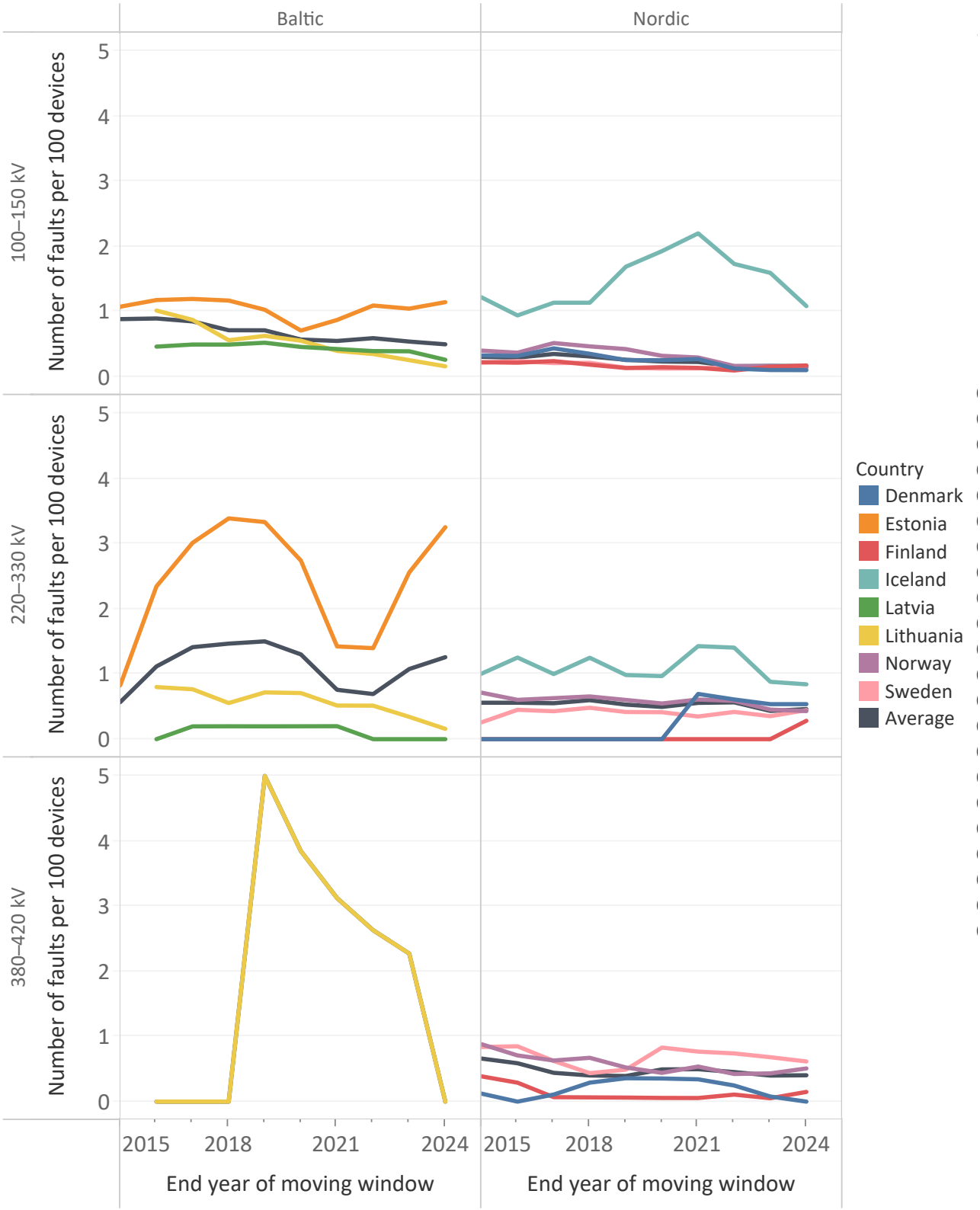

Figure 6.3: 5-year moving average of circuit breaker faults per 100 devices. Estonia, Iceland and Latvia do not own 380–420 kV transmission grids.

6.6 Faults in control equipment

This section presents control equipment faults in 2024 and for 2015–2024. 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. Number of control equipment are in this report equal to number of circuit breakers per voltage level.

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 2024, and the 10-year annual average of the number of faults for 2015–2024. Table 6.23 presents the number of faults per 100 devices in 2024 and the annual averages for 2015–2024.

Table 6.24 presents the percentage allocation of control equipment faults by cause in 2024. Table 6.25 presents the respective percentages over 2015–2024.

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 2024, and the annual average number of faults for 2015–2024, grouped by voltage level.

Region	Country	100–150 kV			220–330 kV			380–420 kV		
		Number of devices in 2024	Number of faults in 2024	10-year ann. avg of faults	Number of devices in 2024	Number of faults in 2024	10-year ann. avg of faults	Number of devices in 2024	Number of faults in 2024	10-year ann. avg of faults
Baltic	Estonia	719	17	14.9	143	7	3.4	0	0	0.0
	Latvia	673	8	16.1	110	3	2.5	0	0	0.0
	Lithuania	906	7	10.0	160	7	4.3	11	1	0.1
	Total	2 298	32	41.0	413	17	10.2	11	1	0.1
Nordic	Denmark	1 022	4	6.4	38	0	0.3	308	5	2.1
	Finland	958	10	15.9	63	0	4.3	446	1	3.5
	Iceland	173	1	4.7	107	2	3.3	0	0	0.0
	Norway	2 693	31	28.7	684	15	20.2	630	20	16.2
	Sweden	0	0	17.9	214	8	10.4	688	10	18.2
	Total	4 846	46	73.6	1 106	25	38.5	2 072	36	40.0
Baltic & Nordic total		7 144	78	114.6	1 519	42	48.7	2 083	37	40.1

Table 6.23: Number of control equipment faults per 100 devices in 2024 and the annual average for 2015–2024, grouped by voltage level.

Region	Country	100–150 kV		220–330 kV		380–420 kV	
		Number of faults / 100 devices in 2024	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2024	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2024	10-year ann. avg no. of faults / 100 devices
Baltic	Estonia	2.364	2.32	4.895	2.66	0.000	0.00
	Latvia	1.189	2.53	2.727	2.43	0.000	0.00
	Lithuania	0.773	1.15	4.375	3.62	9.091	1.43
	Total	1.393	1.91	4.116	2.92	9.091	1.43
Nordic	Denmark	0.391	0.67	0.000	1.05	1.623	0.85
	Finland	1.044	0.63	0.000	5.87	0.224	0.97
	Iceland	0.578	3.00	1.869	3.75	0.000	0.00
	Norway	1.151	1.14	2.193	2.83	3.175	3.21
	Sweden	0.000	0.77	3.738	3.20	1.453	2.75
	Total	0.949	0.87	2.260	3.14	1.737	2.25
Baltic & Nordic total		1.092	1.08	2.765	3.09	1.776	2.25

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Table 6.24: Percentage allocation of control equipment faults by cause in 2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	0.0	0.0	58.3	25.0	16.7
Latvia	0.0	0.0	45.5	54.5	0.0
Lithuania	0.0	6.7	73.3	20.0	0.0
Denmark	0.0	0.0	77.8	22.2	0.0
Finland	18.2	0.0	72.7	9.1	0.0
Iceland	0.0	0.0	100.0	0.0	0.0
Norway	3.0	1.5	48.5	33.3	13.6
Sweden	0.0	0.0	44.4	50.0	5.6

Table 6.25: Percentage allocation of control equipment faults by cause over 2015–2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	3.8	0.0	44.8	35.5	15.8
Latvia	0.5	0.0	46.7	47.3	5.4
Lithuania	0.0	0.7	46.5	27.1	25.7
Denmark	4.5	3.4	63.6	27.3	1.1
Finland	8.0	0.0	67.9	19.4	4.6
Iceland	0.0	0.0	41.3	58.8	0.0
Norway	4.6	2.9	48.7	38.1	5.7
Sweden	5.4	0.2	33.1	50.8	10.5

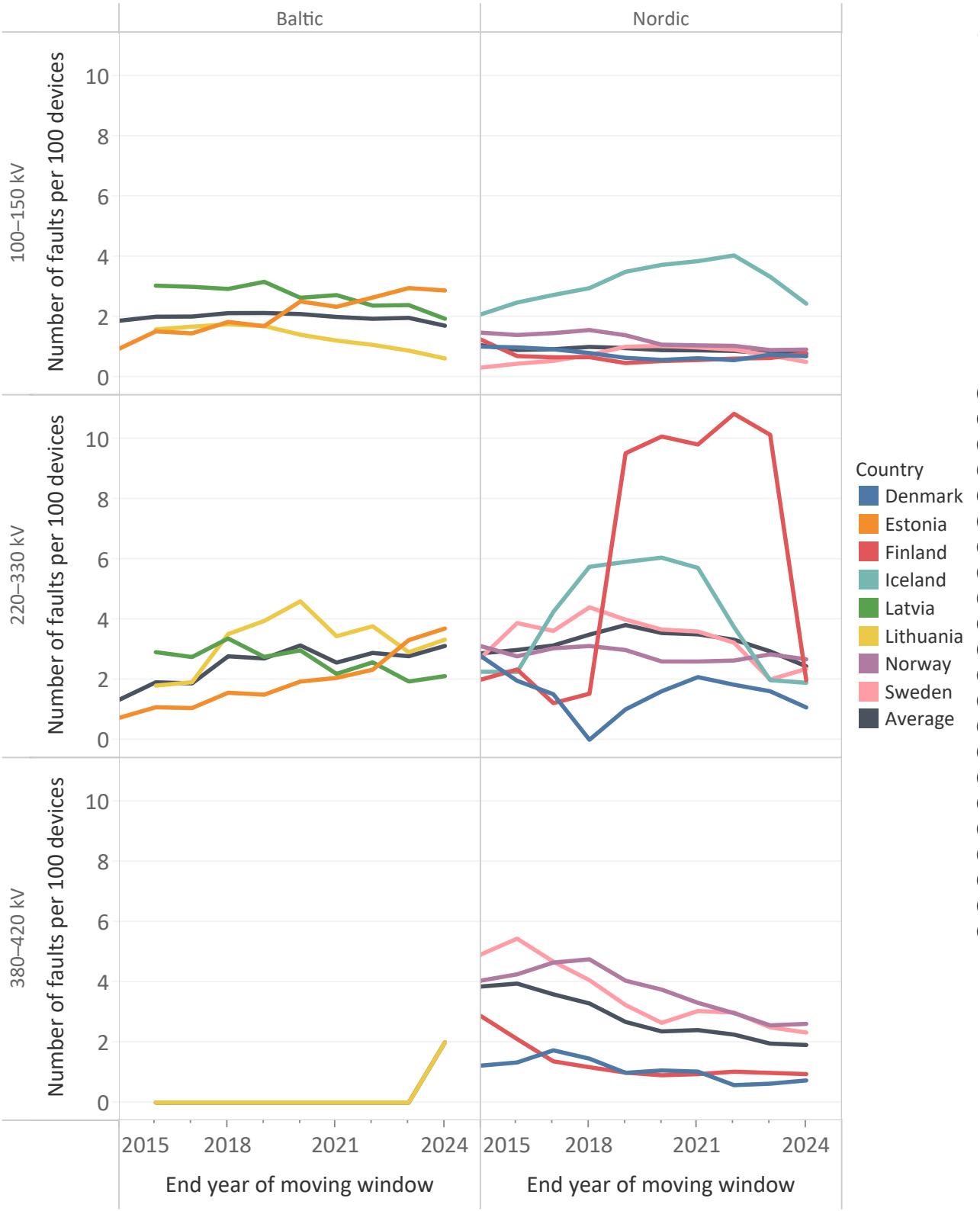

Figure 6.4: 5-year moving average of control equipment faults per 100 devices. Estonia, Iceland and Latvia do not own 380–420 kV transmission grids.

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6.7 Faults in instrument transformers

This section presents instrument transformer faults in 2024 and for 2015–2024.

Table 6.26 presents the number of instrument transformers and the number of faults in 2024, and the 10-year annual average of the number of faults for 2015–2024. Table 6.27 presents the number of faults per 100 devices in 2024 and the annual averages for 2015–2024.

Table 6.28 presents the percentage allocation of instrument transformer faults by cause in 2024. Table 6.29 presents the respective percentages over 2015–2024.

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 2024, and the annual average number of faults for 2015–2024, grouped by voltage level. The number of instrument transformers in Sweden is not accurate due to missing data from some regional grid owners.

Region	Country	100–150 kV			220–330 kV			380–420 kV		
		Number of devices in 2024	Number of faults in 2024	10-year ann. avg of faults	Number of devices in 2024	Number of faults in 2024	10-year ann. avg of faults	Number of devices in 2024	Number of faults in 2024	10-year ann. avg of faults
Baltic	Estonia	3 323	10	3.7	1 150	1	1.6	0	0	0.0
	Latvia	2 388	6	3.3	468	0	0.1	0	0	0.0
	Lithuania	3 465	1	1.4	649	0	0.1	66	0	0.0
	Total	9 176	17	8.4	2 267	1	1.8	66	0	0.0
Nordic	Denmark	3 640	2	1.0	243	0	0.0	1 535	1	0.7
	Finland	4 049	1	2.3	336	0	0.0	2 259	0	0.4
	Iceland	597	1	0.2	450	1	0.2	0	0	0.0
	Norway	7 768	3	3.0	2 805	1	2.4	930	2	1.3
	Sweden	9	0	3.4	1 478	0	0.3	3 508	1	0.9
	Total	16 063	7	9.9	5 312	2	2.9	8 232	4	3.3
Baltic & Nordic total		25 239	24	18.3	7 579	3	4.7	8 298	4	3.3

Table 6.27: Number of instrument transformer faults per 100 devices in 2024 and the annual average for 2015–2024, grouped by voltage level.

Region	Country	100–150 kV		220–330 kV		380–420 kV	
		Number of faults / 100 devices in 2024	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2024	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2024	10-year ann. avg no. of faults / 100 devices
Baltic	Estonia	0.301	0.15	0.087	0.22	0.000	0.00
	Latvia	0.251	0.17	0.000	0.03	0.000	0.00
	Lithuania	0.029	0.05	0.000	0.02	0.000	0.00
	Total	0.185	0.12	0.044	0.11	0.000	0.00
Nordic	Denmark	0.055	0.03	0.000	0.00	0.065	0.07
	Finland	0.025	0.03	0.000	0.00	0.000	0.02
	Iceland	0.168	0.04	0.222	0.05	0.000	0.00
	Norway	0.039	0.04	0.036	0.09	0.215	0.14
	Sweden	0.000	0.06	0.000	0.02	0.029	0.03
	Total	0.044	0.04	0.038	0.06	0.049	0.05
Baltic & Nordic total		0.095	0.06	0.040	0.07	0.048	0.05

Table 6.28: Percentage allocation of instrument transformer faults by cause in 2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	0.0	0.0	18.2	81.8	0.0
Latvia	0.0	0.0	0.0	100.0	0.0
Lithuania	0.0	0.0	0.0	100.0	0.0
Denmark	0.0	0.0	33.3	66.7	0.0
Finland	0.0	0.0	0.0	100.0	0.0
Iceland	0.0	0.0	0.0	100.0	0.0
Norway	16.7	0.0	66.7	16.7	0.0
Sweden	0.0	0.0	0.0	100.0	0.0

Table 6.29: Percentage allocation of instrument transformer faults by cause over 2015–2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	0.0	0.0	13.2	83.0	3.8
Latvia	0.0	0.0	0.0	100.0	0.0
Lithuania	0.0	0.0	26.7	73.3	0.0
Denmark	0.0	5.9	29.4	58.8	5.9
Finland	14.8	0.0	11.1	66.7	7.4
Iceland	25.0	0.0	0.0	75.0	0.0
Norway	10.4	3.0	28.4	53.7	4.5
Sweden	13.0	0.0	6.5	76.1	4.3

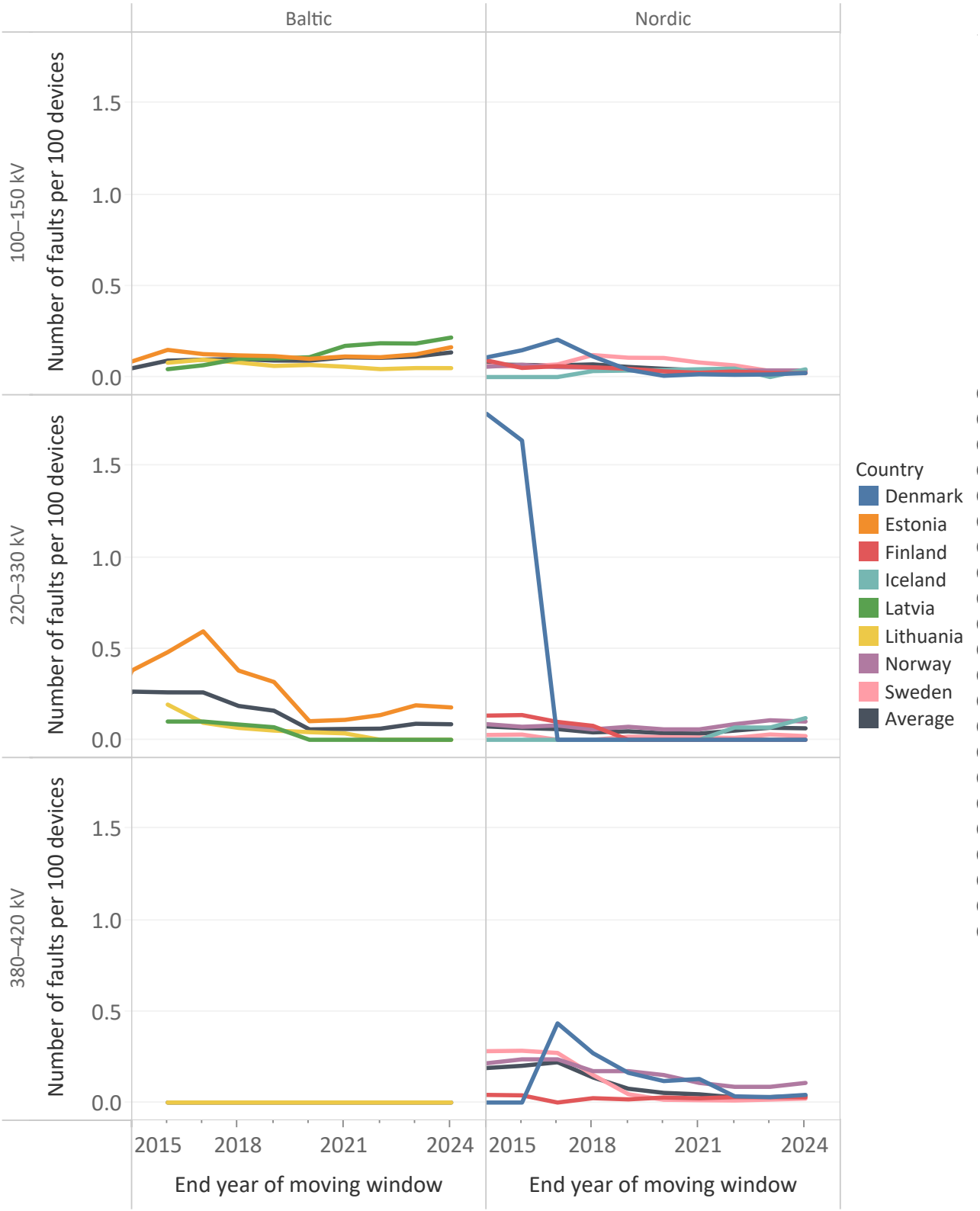

Figure 6.5: 5-year moving average of instrument transformer faults per 100 devices. Estonia, Iceland and Latvia do not own 380–420 kV transmission grids. Denmark's high values during 2012–2016 are caused by one fault in 2012.

6.8 Faults in power transformers

This section presents power transformer faults in 2024 and for 2015–2024. 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 2024, and the 10-year annual average of the number of faults for 2015–2024. Table 6.31 presents the number of faults per 100 devices in 2024 and the annual averages for 2015–2024.

Table 6.32 shows the percentage allocation of power transformer faults by cause in 2024. Table 6.33 presents the respective percentages over 2015–2024.

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 2024, and the annual average number of faults for 2015–2024, grouped by voltage level.

Region	Country	100–150 kV			220–330 kV			380–420 kV		
		Number of devices in 2024	Number of faults in 2024	10-year ann. avg of faults	Number of devices in 2024	Number of faults in 2024	10-year ann. avg of faults	Number of devices in 2024	Number of faults in 2024	10-year ann. avg of faults
Baltic	Estonia	175	4	7.8	24	4	3.6	0	0	0.0
	Latvia	247	2	2.6	27	0	1.2	0	0	0.0
	Lithuania	377	2	0.3	24	1	0.7	3	0	0.0
	Total	799	8	10.7	75	5	5.5	3	0	0.0
Nordic	Denmark	130	9	4.5	10	0	0.2	67	3	1.7
	Finland	13	1	6.1	13	0	0.7	79	2	0.8
	Iceland	19	0	2.3	18	2	1.3	0	0	0.0
	Norway	757	11	4.5	164	0	1.6	141	3	1.6
	Sweden	0	0	8.9	1	0	1.2	22	1	1.1
	Total	919	21	26.3	206	2	5.0	309	9	5.2
Baltic & Nordic total		1 718	29	37.0	281	7	10.5	312	9	5.2

Table 6.31: Number of power transformer faults per 100 devices in 2024 and the annual average for 2015–2024, grouped by voltage level.

Region	Country	100–150 kV		220–330 kV		380–420 kV	
		Number of faults / 100 devices in 2024	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2024	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2024	10-year ann. avg no. of faults / 100 devices
Baltic	Estonia	2.286	3.87	16.667	14.40	0.000	0.00
	Latvia	0.810	1.05	0.000	4.60	0.000	0.00
	Lithuania	0.531	0.08	4.167	2.93	0.000	0.00
	Total	1.001	1.28	6.667	7.33	0.000	0.00
Nordic	Denmark	6.923	1.97	0.000	1.98	4.478	3.85
	Finland	7.692	0.59	0.000	3.10	2.532	1.11
	Iceland	0.000	9.09	11.111	8.50	0.000	0.00
	Norway	1.453	0.61	0.000	1.11	2.128	2.01
	Sweden	0.000	1.18	0.000	1.25	4.545	1.50
	Total	2.285	0.94	0.971	1.73	2.913	1.93
Baltic & Nordic total		1.688	1.02	2.491	2.89	2.885	1.92

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Table 6.32: Percentage allocation of power transformer faults by cause in 2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	0.0	0.0	25.0	75.0	0.0
Latvia	0.0	0.0	50.0	50.0	0.0
Lithuania	0.0	0.0	100.0	0.0	0.0
Denmark	0.0	8.3	33.3	58.3	0.0
Finland	33.3	0.0	66.7	0.0	0.0
Iceland	0.0	0.0	0.0	100.0	0.0
Norway	28.6	21.4	0.0	35.7	14.3
Sweden	0.0	0.0	100.0	0.0	0.0

Table 6.33: Percentage allocation of power transformer faults by cause over 2015–2024. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	3.5	2.6	23.7	59.6	10.5
Latvia	0.0	21.1	42.1	31.6	5.3
Lithuania	0.0	20.0	40.0	30.0	10.0
Denmark	14.1	4.7	35.9	43.8	1.6
Finland	21.1	2.6	15.8	40.8	19.7
Iceland	8.3	0.0	13.9	77.8	0.0
Norway	20.8	10.4	19.5	37.7	11.7
Sweden	11.6	7.1	25.0	24.1	32.1

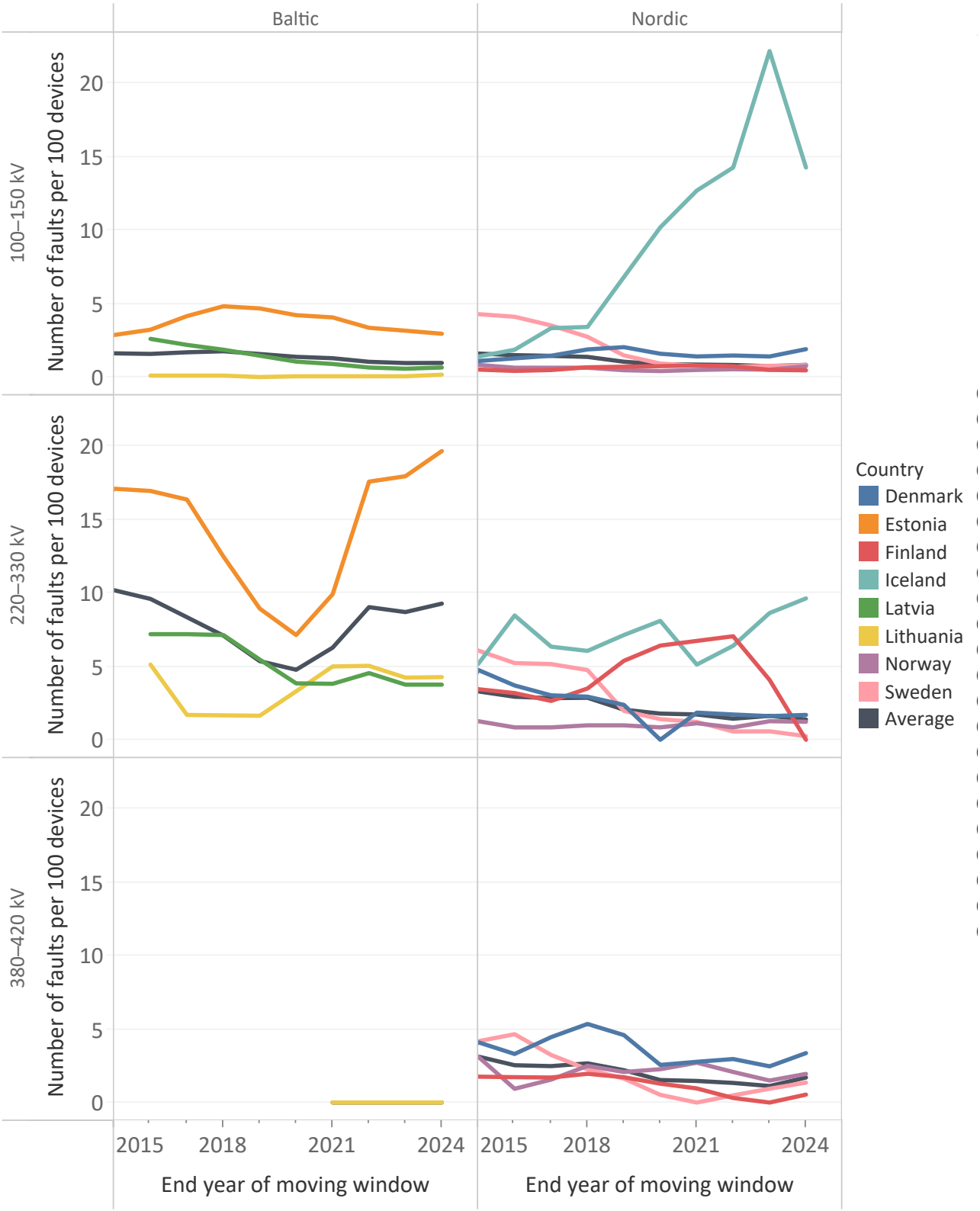

Figure 6.6: 5-year moving average of power transformer faults per 100 devices. Estonia, Iceland, Latvia and Lithuania do not own 380–420 kV power transformers in their transmission grids.

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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), and synchronous compensators. The statistics include the number of devices and their faults, number of faults per 100 devices and ENS in 2024 and their annual averages for 2015–2024.

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 2024, the number of faults per 100 devices, the amount of ENS due to reactor faults in 2024 and their annual averages for 2015–2024.

	Devices	Faults	Faults per 100 devices		ENS (MWh)	
Country	2024	2024	2024	Annual avg. 2015–2024	2024	Annual avg. 2015–2024
Estonia	26	8	31	10.8	0.0	0.0
Latvia	17	0	0	3.5	0.0	0.0
Lithuania	2	0	0	0.0	0.0	0.0
Baltic total	45	8	18	7.5	0.0	0.0
Denmark	116	0	0	1.2	0.0	0.0
Finland	198	2	1	0.3	0.0	1.1
Iceland	22	0	0	0.0	0.0	0.0
Norway	167	2	1	0.9	0.0	1.1
Sweden	53	2	4	1.2	0.0	12.9
Nordic total	556	6	1	0.9	0.0	15.1
Baltic & Nordic total	601	14	2	1.3	0.0	15.2

[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 2024, the number of faults per 100 devices, the amount of ENS due to series capacitor faults in 2024 and their annual averages for 2015–2024.

	Devices	Faults	Faults per 100 devices		ENS (MWh)	
Country	2024	2024	2024	Annual avg. 2015–2024	2024	Annual avg. 2015–2024
Estonia	0	0	0.0	0.0	0.0	0.0
Latvia	0	0	0.0	0.0	0.0	0.0
Lithuania	0	0	0.0	0.0	0.0	0.0
Baltic total	0	0	0.0	0.0	0.0	0.0
Denmark	0	0	0.0	0.0	0.0	0.0
Finland	13	5	38.5	47.8	0.0	1.9
Iceland	1	0	0.0	11.1	0.0	0.0
Norway	3	0	0.0	0.0	0.0	0.0
Sweden	10	11	110.0	57.8	0.0	0.0
Nordic total	27	16	59.3	45.4	0.0	1.9
Baltic & Nordic total	27	16	59.3	43.5	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 2024, the number of faults per 100 devices, the amount of ENS due to shunt capacitor faults in 2024 and their annual average for 2015–2024.

	Devices	Faults	Faults per 100 devices		ENS (MWh)	
Country	2024	2024	2024	Annual average 2015–2024	2024	Annual average 2015–2024
Estonia	10	0	0.0	11.3	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	8.3	0.0	3.0
Denmark	59	6	10.2	2.2	0.0	0.0
Finland[1]	17	1	5.9	4.5	0.0	0.0
Iceland	13	0	0.0	4.3	0.0	0.0
Norway	43	1	2.3	8.4	0.0	0.0
Sweden[1]	32	0	0.0	0.8	0.0	15.2
Nordic total	164	8	4.9	2.6	0.0	15.2
Baltic & Nordic total	178	8	4.5	2.8	0.0	18.2

[1] 2024 values for Finland and Sweden include only transmission system operators' (TSO) networks.

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 2024, the number of faults per 100 devices, the amount of ENS due to SVC faults in 2024 and their annual averages for 2015–2024.

	Devices	Faults	Faults per 100 devices		ENS (MWh)	
Country	2024	2024	2024	Annual avg. 2015–2024	2024	Annual avg. 2015–2024
Estonia	0	0	0.0	0.0	0.0	0.0
Latvia	0	0	0.0	0.0	0.0	0.0
Lithuania	11	0	0.0	2.7	0.0	0.0
Baltic total	11	0	0.0	2.6	0.0	0.0
Denmark	1	0	0.0	50.0	0.0	0.0
Finland	1	2	200.0	21.4	0.0	0.0
Iceland	2	0	0.0	11.1	0.0	0.0
Norway	17	8	47.1	85.1	0.0	0.0
Sweden	1	1	100.0	155.1	0.0	0.0
Nordic total	22	11	50.0	78.0	0.0	0.0
Baltic & Nordic total	33	11	33.3	54.3	0.0	0.0

References

[1] ENTSO-E, "ENTSO-E Grid Disturbance Definitions for the Power System above 100 kV, Version 5." https://eepublicdownloads.entsoe.eu/clean-documents/SOC%20documents/ENTSO-E_Grid_Disturbance_Definitions_for_the_Power_System_above_100_kV_-_to_be_published_version__1_.pdf, June 2021.

[2] ENTSO-E, "The Interconnected network of Northern Europe 2024." https://eepublicdownloads.entsoe.eu/clean-documents/Publications/maps/2024/ENTSOE_Grid_Map_Northern_Europe.pdf. [Online; accessed 20.11.2024].

[3] 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. The transformer load is estimated from measurements from transformers and production units in the distribution grid. The production contains both real measurements and aggregated units. The aggregated units are estimated from similar units located nearby.

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.

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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 '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, 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 Lightning faults

Most of the Baltic and Nordic electricity networks consists of overhead lines. The lengths of overhead lines per voltage levels in 2024 Table 6.13.

- 100–150 kV: 36 057 km
- 220–330 kV: 15 619 km
- 380–420 kV: 23 253 km

Lightning and other environmental causes are the most common cause in overhead lines in a normal year for most countries. Table 6.16 presents the percentage allocation of overhead line faults by cause in 2024.

This Appendix D presents the numbers and shares of lightning faults of all environmental causes and the shares of lightning faults of all faults. Table D.1 presents the data for year 2024 and Table D.2 annual averages for 2021–2024.

Table D.1: Number of lightning faults, all environmental faults, all faults, and ratios for 2024.

Country	Lightning faults	All environ. faults	All faults	Ratio (light./environ.)	Ratio (light./all)
Estonia	27	49	195	55%	14%
Latvia	11	51	160	22%	7%
Lithuania	11	20	127	55%	9%
Baltic total	49	120	482	41%	10%
Denmark	1	3	70	33%	1%
Finland	91	192	240	47%	38%
Iceland	1	8	21	13%	5%
Norway	71	184	339	39%	21%
Sweden	35	38	97	92%	36%
Nordic total	199	425	767	47%	26%
Baltic & Nordic total	248	545	1249	46%	20%

[1] Ratios are calculated as lightning faults divided by the respective total (environmental or all faults).

Table D.2: Annual averages 2021–2024 of lightning faults, all environmental faults, all faults, and ratios.

Country	Lightning faults	All environ. faults	All faults	Ratio (light./environ.)	Ratio (light./all)
Estonia	16	33	173	48%	9%
Latvia	13	53	140	24%	9%
Lithuania	10	23	152	44%	7%
Baltic total	39	109	465	36%	8%
Denmark	4	14	83	31%	5%
Finland	86	266	438	32%	20%
Iceland	1	20	56	6%	2%
Norway	59	158	310	37%	19%
Sweden	114	124	353	92%	32%
Nordic total	264	581	1239	45%	21%
Baltic & Nordic total	303	690	1704	44%	18%

[1] Annual averages are calculated over the period 2021–2024.
[2] Ratios follow the same definition as in Table D.1.

E ENS, consumption and line length 2015–2024

Figure E.1 presents the annual amount of ENS, consumption and total length of lines for 2015–2024. The total line length is the sum of the lengths of overhead lines and cables in the 100–420 kV grids.

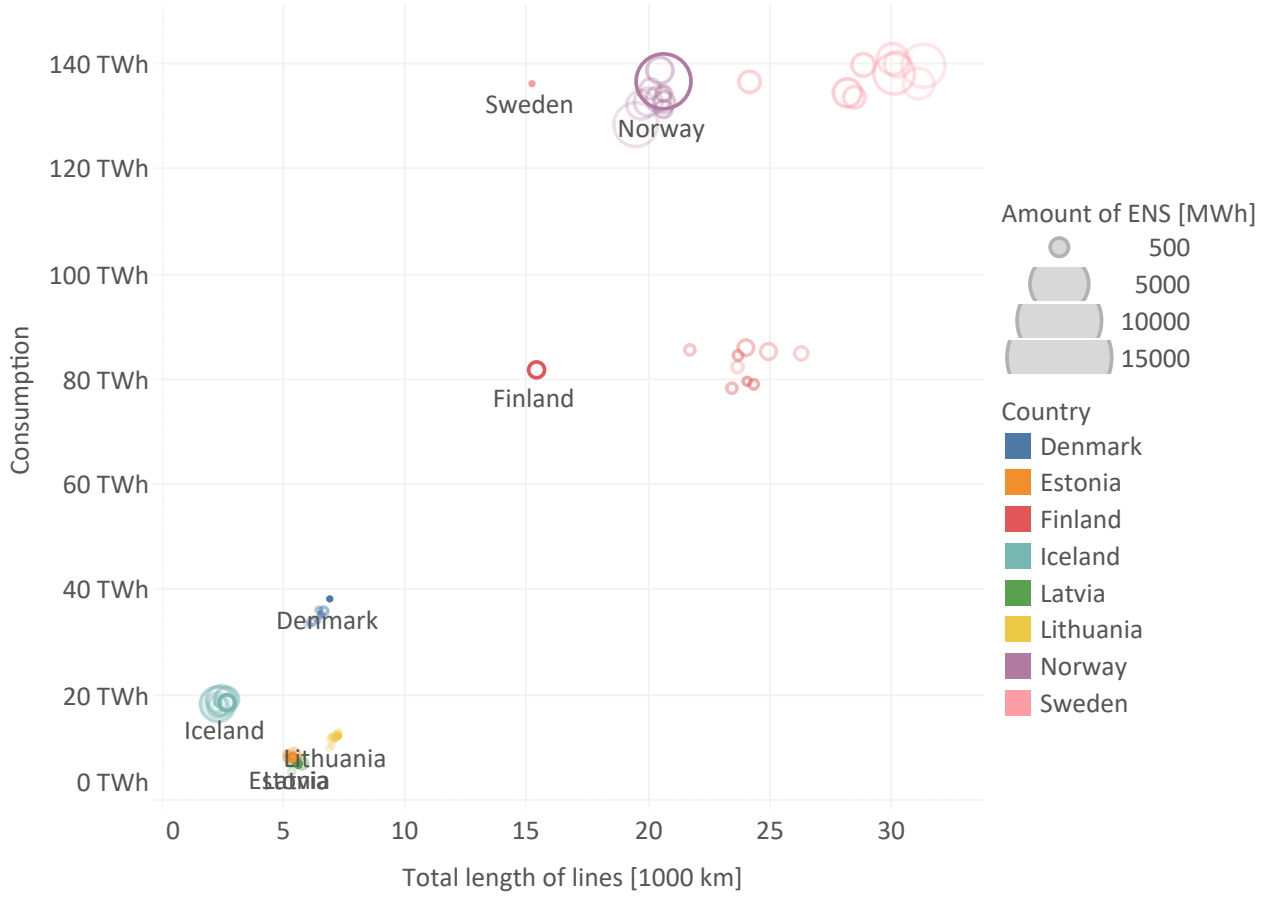

Figure E.1: The annual amount of ENS (circle size), length of lines (x-axis) and consumption (y-axis) for 2015–2024. The most recent statistical year 2024 is shown with the darkest colour. Each previous year is shown in a lighter colour.

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