European Network of Transmission System Operators for Electricity

entsoe

HVAC NORDIC AND BALTIC GRID DISTURBANCE STATISTICS 2023

11 December 2024

From: Regional Group Nordic

HVAC NORDIC AND BALTIC GRID DISTURBANCE STATISTICS 2023

Report rendered 11 December 2024

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 35 countries, are responsible for the secure and coordinated operation of Europe's electricity system, the largest interconnected electrical grid in the world. In addition to its core, historical role in technical cooperation, ENTSO-E is also the common voice of TSOs.

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

Our mission

ENTSO-E and its members, as the European TSO community, fulfil a common mission: Ensuring the security of the 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 HVAC NORDIC AND BALTIC GRID DISTURBANCE STATISTICS 2023 gives both an overview of the grid disturbances, faults, and energy not supplied (ENS) in the Nordic and Baltic 100–420 kV alternating current grids, as well as a deeper dive into the statistics of individual components used in the grids.

The year 2023 was good; disturbances had much smaller effect on the end-users compared to average years. ENS was only 72 % in Baltic and only 69 % in Nordic countries of the corresponding ten-year annual averages.

Year 2023 compared to ten-year annual averages:

- The number of faults was little higher in Baltic and at the same level in Nordic.
- The number of disturbances that caused ENS was 26 % smaller in Baltic and at the same level in Nordic.

The grid components that caused the largest share of ENS in 2023 was overhead lines in Latvia 98 %, Iceland 72 %, Estonia 70 %, Lithuania 67 %, Sweden 51 %, Finland 48 %, Norway 39 %. In Denmark control equipment was the largest, 62 %.

The dominant causes of the overhead line faults were environmental causes in Norway 89 %, Finland 88 %, Iceland 79 %, Latvia 66 % and in Sweden 44 %. In Denmark and in Lithuania most common were external causes, 56 % in Denmark and 50 % in Lithuania. In Estonia most common causes were environmental 35 % and unknown 38 %. A big share of unknown are normally environmental causes. Unknown causes include also causes not particularly examined and reported.

Policies for examining the cause of line faults are listed in Appendix B on page 52.

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 2023 and the corresponding annual averages for the 10-year period 2014–2023.

	Number of faults		No. of disturbances		Ratio		ENS (MWh)	
Country	2023	Annual avg. 2014–2023	2023	Annual avg. 2014–2023	2023	2014–2023	2023	Annual avg. 2014–2023
Estonia	203	163	171	154	1.2	1.1	55	63
Latvia	149	141	136	126	1.1	1.1	30	51
Lithuania	146	156	138	145	1.1	1.1	23	37
Baltic total	498	460	445	426	1.1	1.1	109	152
Denmark	83	72	75	66	1.1	1.1	92	42
Finland	485	439	478	422	1.0	1.0	91	240
Iceland	51	69	47	47	1.1	1.5	808	854
Norway	325	336	295	299	1.1	1.1	338	1104
Sweden	392	440	385	422	1.0	1.0	1129	1322
Nordic total	1336	1356	1280	1255	1.0	1.1	2459	3562
Baltic & Nordic total	1834	1816	1725	1681	1.1	1.1	2568	3714

Table of contents

ENTSO-E | Rue de Spa, 8 | 1000 Brussels | info@entsoe.eu | www.entsoe.eu | @entso_e

List of Figures

List of Tables

Glossary

Disturbance See grid disturbance.
DSO Distribution System Operator.
End-user "Buyers of electrical energy who do not resell all the energy" [1, p. 11].
Energy not supplied "The estimated energy which would have been supplied to end-users if no interruption and no transmission restrictions had occurred" [1, p. 12].
ENS Energy not supplied.
ENTSO-E European Network of Transmission System Operators for Electricity.
Fault "The inability of a component to perform its required function" [1, p. 3–4].
Fault cause "Cause relating to design, production, installation, operation or maintenance which results in a fault" [1, p. 7].
Grid disturbance "Outages, forced or unintended disconnection or failed re-connection (of a component) as a result of faults in the power grid" [1, p. 5].
HVAC High-voltage alternating current. As explained in Section 1.3, this report encompasses HVAC components in the 100–420 kV voltage range.
HVDC High-voltage direct current.
kV Kilovolt.
MWh Megawatt hour.
Nominal voltage "Value of the voltage by which the electrical installation or part of the electrical installation is designated and identified" [2].
ppm Parts per million.
Primary cause (of a fault) "Event or circumstance which leads to a fault" [1, p. 7].
Primary fault "A fault which initiates a grid disturbance" [1, p. 4].
RGN Regional Group Nordic.
Secondary fault A fault that aggravates a grid disturbance [1, p. 3–4].
SGU Significant Grid User.
Statistical area The area inside a country's borders. The statistical area is further limited to central components, as shown in Figure 1.2.
Statistical voltage level This report groups the voltage levels into three statistical voltage levels. The statistical voltage levels are 100–150 kV, 220–330 kV and 380–420 kV.
SVC Static var compensator.
TSO Transmission System Operator.
TWh Terawatt hour.

This page is intentionally left blank.

ENTSO-E | Rue de Spa, 8 | 1000 Brussels | info@entsoe.eu | www.entsoe.eu | @entso_e

1 Introduction

1.1 Description of the report

The HVAC NORDIC AND BALTIC GRID DISTURBANCE STATISTICS 2023 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 2023. 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 2023.

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

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

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

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

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

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.

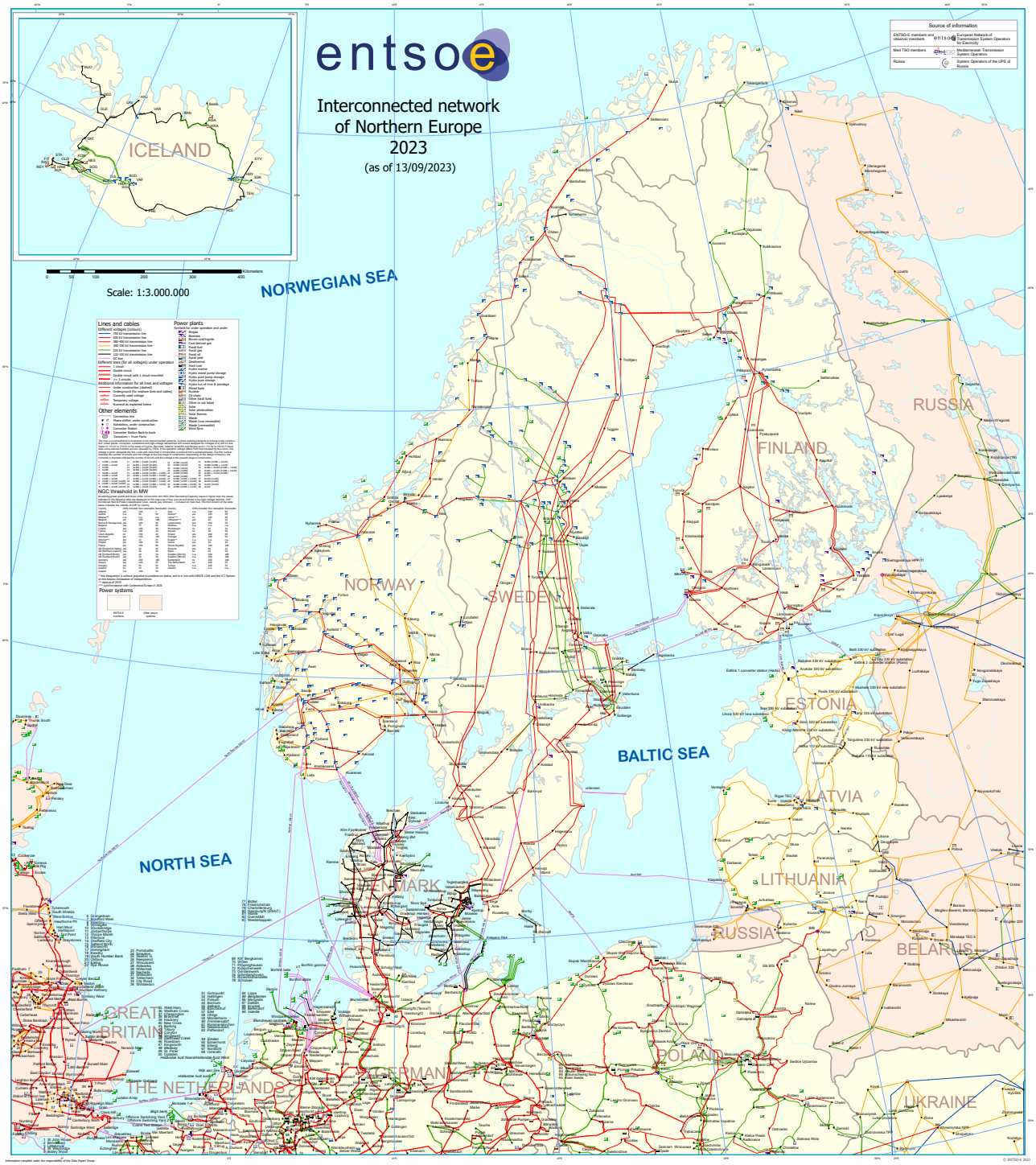

Figure 1.1: The Nordic and Baltic main grids [3] in 2023. All of Denmark is included in the disturbance data of this report although only the grid of eastern Denmark belongs to the Nordic synchronous area.

ENTSO-E | Rue de Spa, 8 | 1000 Brussels | info@entsoe.eu | www.entsoe.eu | @entso_e

1.3 The scope and limitations of the statistics

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

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

The statistics do not comprise:

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

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

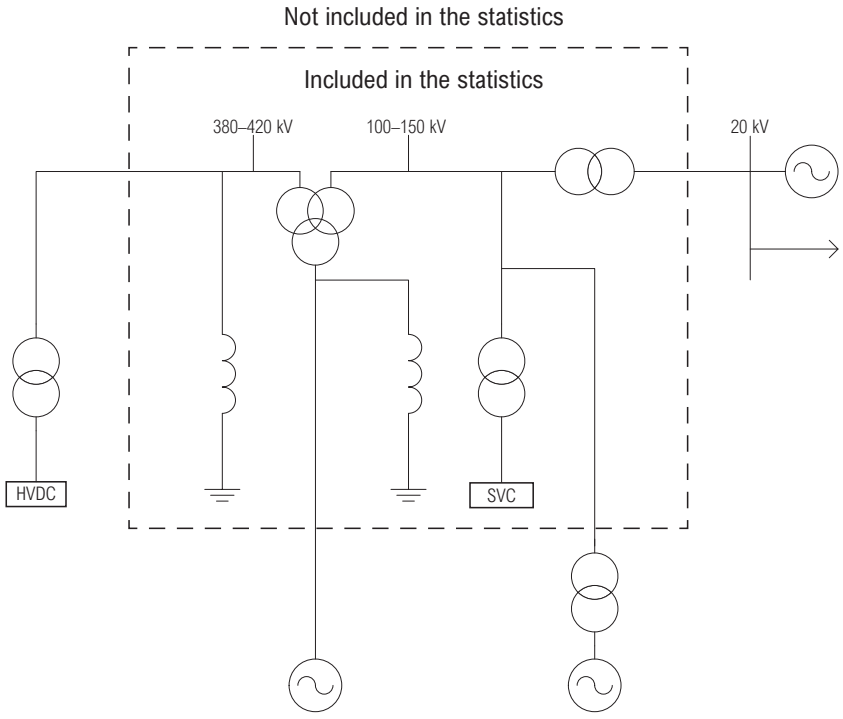

Figure 1.2: A graphical representation of the included grid components in the statistics.

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

1.4 Available data in the report

Many figures and tables present data for 2023 or for 2014–2023. Some figures use data from longer periods. For example, moving average figures for component faults in Chapter 6 use data from 2005. However, not all participating TSO's have data since 2005. In these cases, the figures and tables show all the available data.

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

1.5 Contact persons

Each country is represented by at least one contact person, responsible for his/her country's statistical information. The contact person can provide additional information concerning the ENTSO-E Nordic and Baltic disturbance statistics. The relevant contact information is given in Appendix C.

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

1.6 Fault causes

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

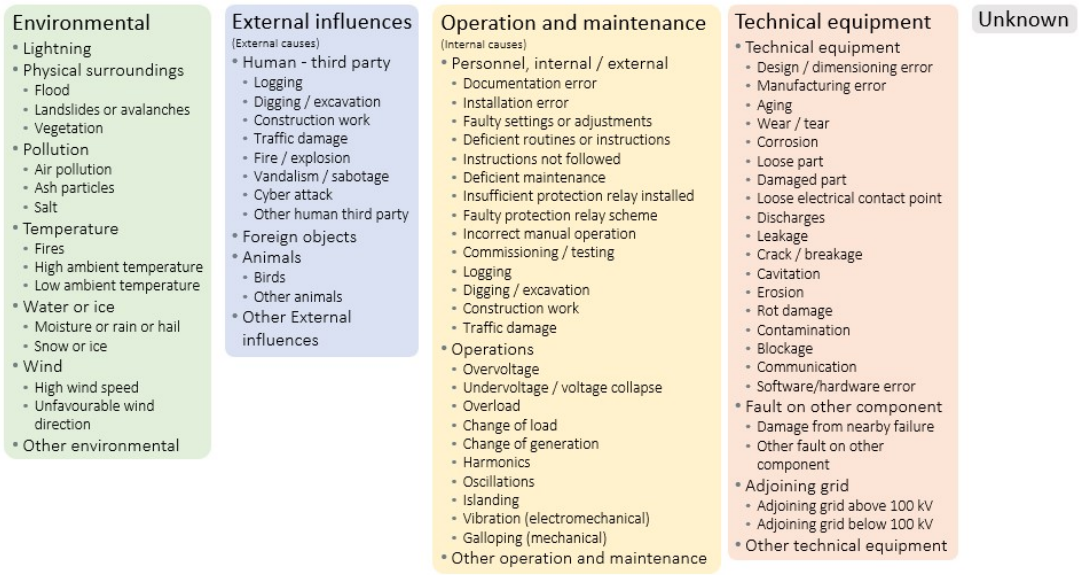

Figure 1.3: The cause scheme with 5 top-level categories: environmental causes, external influences, operation and maintenance, technical equipment, and unknown.

ENTSO-E | Rue de Spa, 8 | 1000 Brussels | info@entsoe.eu | www.entsoe.eu | @entso_e

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. The network statistics of each country cover data from several grid owners (TSOs and DSOs).

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. 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[1]	87 %	100 %	100 %
Iceland	100 %	100 %	–
Latvia	100 %	100 %	–
Lithuania	100 %	100 %	100 %
Norway	100 %	100 %	100 %
Sweden[1]	76 %	99 %	100 %

[1] Fault and grid asset data from all distribution companies for voltage levels 100–150 kV was not available in Finland and Sweden.

2 Summary

In 2023, 1725 grid disturbances occurred in the Nordic and Baltic 100–420 kV grids, which is little above the 10-year annual average of 1681 disturbances. The energy not supplied (ENS) due to faults in the Nordic grids amounted to 2459 MWh and 109 MWh in the Baltic. There were 2568 MWh of ENS in the Nordic and Baltic grids, which is only 69 % of the 10-year annual average. Out of all 1725 disturbances, 341 caused ENS in 2023.

The following sections present the summaries for each Nordic and Baltic country including the most significant issues in 2023.

2.1 Summary of Denmark

In Denmark, the ENS caused by grid disturbances was 92 MWh in 2023 (10-year annual average 42 MWh). There were 75 grid disturbances (10-year annual average 66) and 9 of them caused ENS.

In 2023, 74 % of the total ENS was caused by substation faults, and 21 % by faults in adjoining grids. The most significant reasons for ENS caused by disturbances were operation and maintenance (73 %) and technical equipment (27 %). Disturbances were caused most by external influences (35 %) and technical equipment (29 %).

Secondary faults in Denmark accounted for 10 % of all faults in 2023 and caused 27 % of the total ENS. Secondary faults were caused by operation and maintenance (100 %).

The three most significant disturbances in 2023 were the following:

- Due to a relay setting faulty being active, a transformer tripped. At the same time, there was planned maintenance in the substation, which is why the redundant transformer was disconnected. The resulting ENS was 37.2 MWh.
- A bird caused a two-phased fault on a 60 kV busbar. The two transformers in the substation tripped 280 and 380 ms respectively thereafter due to induced voltages in the signals to the transformers mechanical protection. The resulting ENS was 19.5 MWh.
- An overhead line tripped caused by birds. A secondary fault caused outage of a complete substation due to an installation error. The resulting ENS was 10.2 MWh.

2.2 Summary of Estonia

In Estonia there were 171 grid disturbances (10-year annual average 154) and 14 of them caused ENS. The ENS caused by grid disturbances was 55 MWh in 2023 (10-year annual average 63 MWh).

In 2023, 70 % of the total ENS was caused by overhead line faults, and 30 % by substation faults. The most significant reasons for ENS were caused by disturbances were external influences 57 %, environmental causes 32 %. Disturbances were caused most by technical equipment (27 %) and operation and maintenance (23 %).

Secondary faults in Estonia accounted for 8,4 % of all faults in 2023 and didn‘t cause ENS. Secondary faults were primarily caused by operation and maintenance (41 %) and technical equipment (35 %).

The three most significant disturbances in the 110–330 kV grid in 2023 were:

- Two-phase earth fault on 110 kV overhead line. The tree fell on the line by the heavy storm. ENS 5.95 MWh.
- One-phase earth fault on 110 kV overhead line. The optical ground wire was covered with frost. ENS 11.87 MWh.
- Two-phase earth fault on 110 kV parallel overhead lines. 220 kV crossing overhead line wire fell on the 110 kV overhead lines during dismantling. ENS 29.75 MWh.

2.3 Summary of Finland

In Finland, there were 478 grid disturbances (10-year annual average 422) and 58 of them caused ENS. The ENS caused by grid disturbances was 91 MWh in 2023 (10-year annual average 240 MWh).

In 2023, 48 % of the total ENS was caused by overhead line faults, and 52 % by substation faults. The most significant reasons for ENS caused by disturbances were technical equipment (45 %) and environmental causes (37 %). Disturbances were caused most by environmental causes (79 %) and technical equipment (9 %).

Secondary faults in Finland accounted for 1 % of all faults in 2023 and caused 12 % of the total ENS. Secondary faults were primarily caused by technical equipment (86 %). The reasons of ENS of the secondary faults were also technical equipment (100 %).

The five most significant disturbances in the 110–400 kV grid in 2023 were:

- One-phase earth fault on the 110 kV earth connector, which was broken. ENS 13.7 MWh.
- Traffic accident on 110 kV substation. A truck hit equipment. ENS 11.1 MWh.
- One-phase earth fault on 110 kV overhead line. A surge arrester was broken. ENS 10.7 MWh.
- One-phase earth fault on 110 kV instrument transformer, which was broken. ENS 10.5 MWh
- One-phase earth fault on 110 kV overhead line. The line was covered with frost. ENS 10.5 MWh.

2.4 Summary of Iceland

In Iceland, the ENS caused by grid disturbances was 808 MWh in 2023 (10-year annual average 854 MWh). There were 51 grid disturbances (10-year annual average 47) and 31 of them caused ENS.

In 2023, 72 % of the total ENS was caused by overhead line faults, 1 % by substation faults, and 28 % of adjoining grid faults. The most significant reason for ENS caused disturbances were weather (32 %) and technical equipment (51 %).

Secondary faults in Iceland accounted for 7,8 % of all faults in 2023 and caused no ENS. Secondary faults were all caused by technical equipment.

The most significant disturbances in 2023 were the following:

- On 16th of January, one 132 kV overhead line SN1 tripped due to a failure in surge arrester. The total ENS was 127 MWh MWh.
- On 17th of August, one 220 kV overhead line BU1 tripped due to an overload because planned maintenance of two 220 kV lines in the area. The total ENS was 182 MWh MWh.
- On 10th of October, one 220 kV overhead line TR1 tripped because of earth failure, and it caused chain reaction on other lines in the area. The total ENS was 209 MWh MWh.

2.5 Summary of Latvia

In Latvia, the ENS caused by grid disturbances was 30 MWh in 2023 (10-year annual average 51 MWh). There were 136 grid disturbances (10-year annual average 126) and 12 of them caused ENS.

In 2023, 98 % of the total ENS was caused by overhead line faults, and 2 % by adjoining grid faults.

The most significant reasons for ENS caused by disturbances were environmental causes (100 %). Disturbances were caused most by environmental causes (53 %) and technical equipment causes (22 %). Secondary faults in Latvia accounted for 9 % of all faults in 2023 and did not cause ENS. Secondary faults were primarily caused by operation and maintenance (23 %) and technical equipment (77 %). The most significant disturbances in 2023 were the following:

- Series of faults in one day period due to autumn storm caused outage of 13 OHL and 8 substations, and it resulted with 22 MWh of overall ENS.

- External short-circuit on 330 kV power transformer middle faze bushing caused its explosion which resulted in fire and damage to other equipment (6 elements) from blast. Repair works took only one month due to existing spare parts and available repair team.
- Inappropriate disconnection of one 330 kV OHL in state where other OHL remain in operation with overcompensated reactive power (40 %) caused voltage drop (U=0,83pu), then disconnection of reactor, then voltage jump (U=1,18pu) and disconnection of other 330 kV OHL.

2.6 Summary of Lithuania

In Lithuania, the ENS caused by grid disturbances was 23 MWh in 2023 (10-year annual average 37 MWh). There were 138 grid disturbances (10-year annual average 145) and 12 of them caused ENS.

In 2023, 67 % of the total ENS was caused by overhead line faults, 9 % by control equipment faults, and 24 % by substation faults The most significant reasons for ENS caused by disturbances were external influences (33 %) and technical equipment (42 %). Disturbances were caused most by external influences (41 %) and technical equipment (18 %).

Secondary faults in Lithuania accounted for 5,5 % of all faults in 2023 and caused approximately 8,6 % of the total ENS. Secondary faults were primarily caused by technical equipment (38 %) and operation and maintenance (63 %).

The most significant disturbances in 2023 were the following:

- On 28 February 2023, a third-party crane with its boom raised came into the 110 kV overhead line, causing a disturbance outage. As a result, the Cukrus substation lost connection to the grid, with an ENS of 5.89 MWh.
- On 26 August 2023, a 110 kV radial overhead line was disconnected due to high winds, which caused a few trees to fall on the lines. ENS was 4.46 MWh MWh.
- On 10 October 2023, multiple 110 kV overhead lines were disconnected due to very high winds which caused trees to fall on the lines. ENS was 5.07 MWh MWh.

2.7 Summary of Norway

There were no grid disturbances with national consequences in 2023. Energy not supplied (ENS) caused by grid disturbances over 100 kV was the lowest in 10 years (338 MWh), and the number of disturbances was the third lowest in the same period (295).

In 2023, 39 % of the total ENS was caused by overhead line faults, 23 % by substation faults and 35 % by system faults. The high share of ENS caused by system faults was due to one disturbance causing islanding with production deficit leading to interruption of a large end-user. The most significant reasons for ENS caused by grid disturbances were environmental causes including lightning (53 %) and technical equipment (22 %).

The disturbance with the highest number of end-users affected and interrupted power was a short circuit on a 420 kV overhead line on the west coast of Norway in November during strong winds. This fault led to interruption of 75,000 end users with approx. 285 MW interrupted power. Earlier on the same day, the end-users in the northern part of this area experienced an interruption following a short circuit on another 420 kV overhead line, also during strong winds. The network supplying this area was operated N-0 in this period due to required maintenance on the alternative supply.

2.8 Summary of Sweden

In Sweden, the ENS caused by grid disturbances was 1129 MWh in 2023 (10-year annual average 1322 MWh). There were 385 grid disturbances (10-year annual average 422) and 156 of them caused ENS.

In 2023, 55 % of the total ENS was caused by overhead line faults, and 39 % by substation faults. The most significant reasons for ENS caused by disturbances were environmental causes (42 %) and unknown (28 %). Disturbances were caused most by environmental causes (32 %), unknown causes (32 %) and technical equipment (24 %).

Secondary faults in Sweden accounted for 2 % of all faults in 2023 and did not cause any ENS. Secondary faults were caused by technical equipment (57 %) and environmental causes (43 %).

In 2023, there were no notable grid disturbances that distinguished themselves from others. However, a few disturbances occurred on overhead lines, particularly on transmission towers. These disturbances were primarily caused by damaged parts resulting from strong winds and the natural wear and tear associated with an aging transmission network.

3 Disturbances

3.1 Overview

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

Table 3.1 presents the number of grid disturbances in 2023 by country and the annual averages for 2014–2023, and Figure 3.1 shows the annual number of disturbances for 2014–2023, 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 note the difference between a grid disturbance and a fault. A grid disturbance is initiated by a fault, called the primary fault, and may be followed by consequential faults, called secondary faults. Only secondary faults that extend or aggravate a disturbance are included in this report.

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

Table 3.1: The number of disturbances and disturbances causing ENS in 2023, and their annual averages for 2014–2023 in the 100–420 kV grids.

	Disturbances		Disturbances causing ENS	
Country	Number 2023	Annual average 2014–2023	Number 2023	Annual average 2014–2023
Estonia	171	154.4	14	21.4
Latvia	136	125.9	12	13.9
Lithuania	138	145.3	12	16.1
Baltic total	445	425.6	38	51.4
Denmark	75	65.9	9	5.9
Finland	478	421.5	58	71.6
Iceland	47	47.0	13	19.4
Norway	295	298.7	67	76.6
Sweden	385	422.2	156	149.2
Nordic total	1280	1255.3	303	322.7
Baltic & Nordic total	1725	1680.9	341	374.1

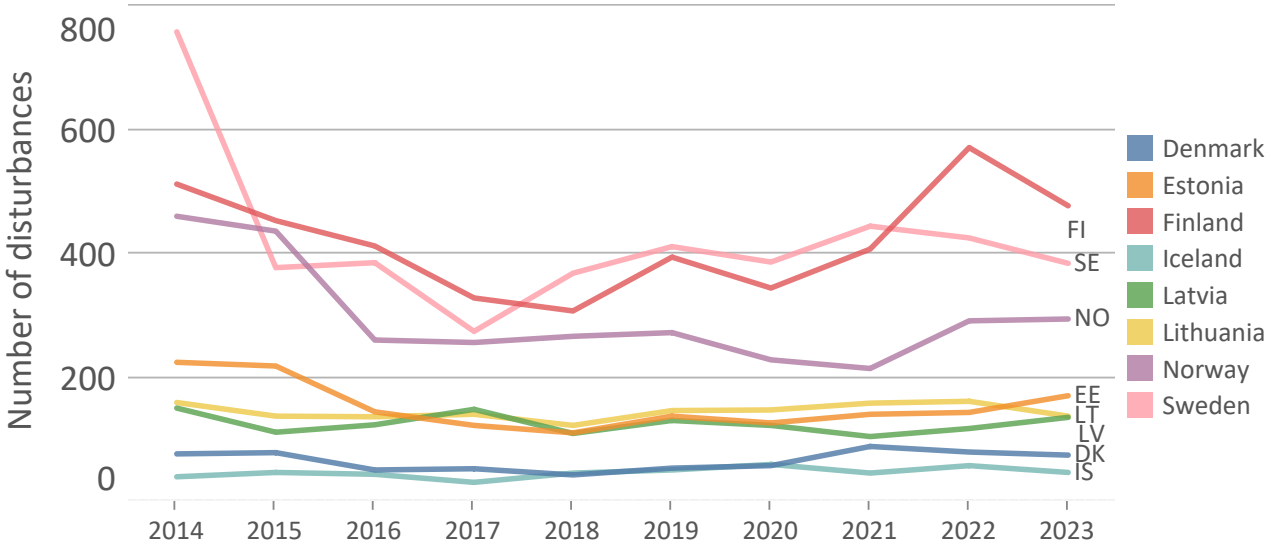

Figure 3.1: Annual number of grid disturbances in the 100–420 kV grids.

ENTSO-E | Rue de Spa, 8 | 1000 Brussels | info@entsoe.eu | www.entsoe.eu | @entso_e

3.2 Disturbances by month

Table 3.2 presents the percentage allocation of grid disturbances in the 100–420 kV grids by month in 2023. Table 3.3 presents percentage allocation by month over 2014–2023.

Table 3.2: Percentage allocation of grid disturbances in the 100–420 kV grids by month in 2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Estonia	7%	6%	4%	6%	11%	11%	13%	16%	7%	0%	9%	10%
Latvia	7%	4%	2%	2%	3%	5%	7%	36%	4%	15%	5%	8%
Lithuania	4%	5%	5%	4%	8%	12%	16%	25%	7%	9%	4%	1%
Denmark	7%	8%	7%	3%	3%	12%	9%	9%	17%	7%	9%	9%
Finland	8%	4%	3%	7%	9%	18%	20%	14%	8%	3%	4%	3%
Iceland	9%	17%	9%	4%	9%	13%	6%	4%	6%	11%	11%	2%
Norway	6%	15%	5%	4%	7%	10%	10%	9%	8%	11%	5%	8%
Sweden	4%	2%	5%	4%	6%	14%	21%	22%	5%	7%	5%	6%

Table 3.3: Percentage allocation of grid disturbances in the 100–420 kV grids by month over 2014–2023. 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%	4%	5%	7%	11%	12%	16%	17%	7%	6%	4%	5%
Latvia	5%	3%	7%	5%	7%	13%	12%	23%	7%	7%	4%	7%
Lithuania	4%	2%	7%	5%	9%	12%	17%	26%	5%	4%	4%	3%
Denmark	9%	7%	6%	6%	7%	8%	8%	11%	10%	8%	8%	13%
Finland	7%	3%	3%	6%	10%	13%	22%	14%	6%	4%	3%	7%
Iceland	10%	19%	13%	5%	6%	6%	6%	3%	7%	8%	5%	12%
Norway	16%	10%	8%	3%	4%	8%	11%	8%	6%	7%	8%	10%
Sweden	5%	4%	4%	4%	7%	14%	22%	19%	7%	5%	4%	5%

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 2023. Table 3.5 shows the respective percentages over 2014–2023.

Table 3.6 presents the percentage allocation of grid disturbances that caused ENS by cause in terms of the primary fault in 2023. Table 3.7 shows the respective percentages over 2014–2023.

Table 3.4: Grid disturbances (%) by cause for 2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	19%	11%	23%	27%	20%
Latvia	53%	12%	3%	22%	10%
Lithuania	18%	41%	7%	18%	17%
Denmark	16%	35%	19%	29%	1%
Finland	79%	4%	6%	9%	2%
Iceland	32%	2%	15%	51%	0%
Norway	53%	3%	18%	22%	4%
Sweden	32%	3%	8%	24%	32%

Table 3.5: Percentage allocation of grid disturbances by cause over 2014–2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	25%	10%	15%	39%	11%
Latvia	37%	23%	5%	19%	17%
Lithuania	13%	29%	8%	22%	28%
Denmark	18%	24%	20%	32%	7%
Finland	54%	2%	6%	20%	18%
Iceland	39%	1%	11%	46%	3%
Norway	53%	2%	16%	24%	5%
Sweden	38%	2%	8%	23%	29%

ENTSO-E | Rue de Spa, 8 | 1000 Brussels | info@entsoe.eu | www.entsoe.eu | @entso_e

Table 3.6: Percentage allocation of grid disturbances that caused ENS by cause in 2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	14%	21%	29%	14%	21%
Latvia	92%	0%	0%	8%	0%
Lithuania	8%	33%	17%	42%	0%
Denmark	0%	22%	44%	33%	0%
Finland	55%	5%	19%	16%	5%
Iceland	46%	8%	8%	38%	0%
Norway	48%	4%	19%	24%	4%
Sweden	32%	3%	11%	24%	30%

Table 3.7: Percentage allocation of grid disturbances that caused ENS by cause over 2014–2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	12%	13%	25%	41%	10%
Latvia	41%	26%	12%	17%	4%
Lithuania	12%	45%	24%	16%	3%
Denmark	12%	3%	51%	32%	2%
Finland	32%	3%	10%	22%	33%
Iceland	52%	2%	11%	34%	1%
Norway	50%	2%	22%	22%	3%
Sweden	39%	2%	9%	22%	28%

4 Energy not supplied

This chapter presents energy not supplied (ENS) caused by grid disturbances. The presentation includes the amount of ENS in 2023 by country and the annual averages for 2014–2023. 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 2023 by country and the annual averages for 2014–2023.

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 2023 and the annual averages for 2014–2023.

	ENS (MWh)	
Country	2023	Annual average 2014–2023
Estonia	55.4	63.4
Latvia	30.4	51.2
Lithuania	23.2	37.5
Baltic total	109.0	152.0
Denmark	92.1	41.6
Finland	91.3	240.2
Iceland	807.6	853.7
Norway	338.2	1104.4
Sweden	1129.5	1322.2
Nordic total	2458.6	3562.1
Baltic & Nordic total	2567.6	3714.1

ENTSO-E | Rue de Spa, 8 | 1000 Brussels | info@entsoe.eu | www.entsoe.eu | @entso_e

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 2023 and the corresponding annual averages for 2014–2023. Ppm (parts per million) represents ENS (MWh) as a proportional value of the consumed energy (TWh).

	Consumption	ENS	ENS / consumption (ppm)	
Country	(TWh) 2023	(MWh) 2023	2023	Annual average 2014–2023
Estonia	8.2	55.4	6.8	7.5
Latvia	6.9	30.4	4.4	7.3
Lithuania	11.8	23.2	2.0	3.2
Baltic total	26.9	109.0	4.1	5.6
Denmark	36.1	92.1	2.6	1.2
Finland	79.8	91.3	1.1	2.9
Iceland	19.3	807.6	41.7	46.3
Norway	134.5	338.2	2.5	8.4
Sweden	134.6	1129.5	8.4	9.6
Nordic total	404.4	2458.6	6.1	8.8
Baltic & Nordic total	431.2	2567.6	6.0	8.6

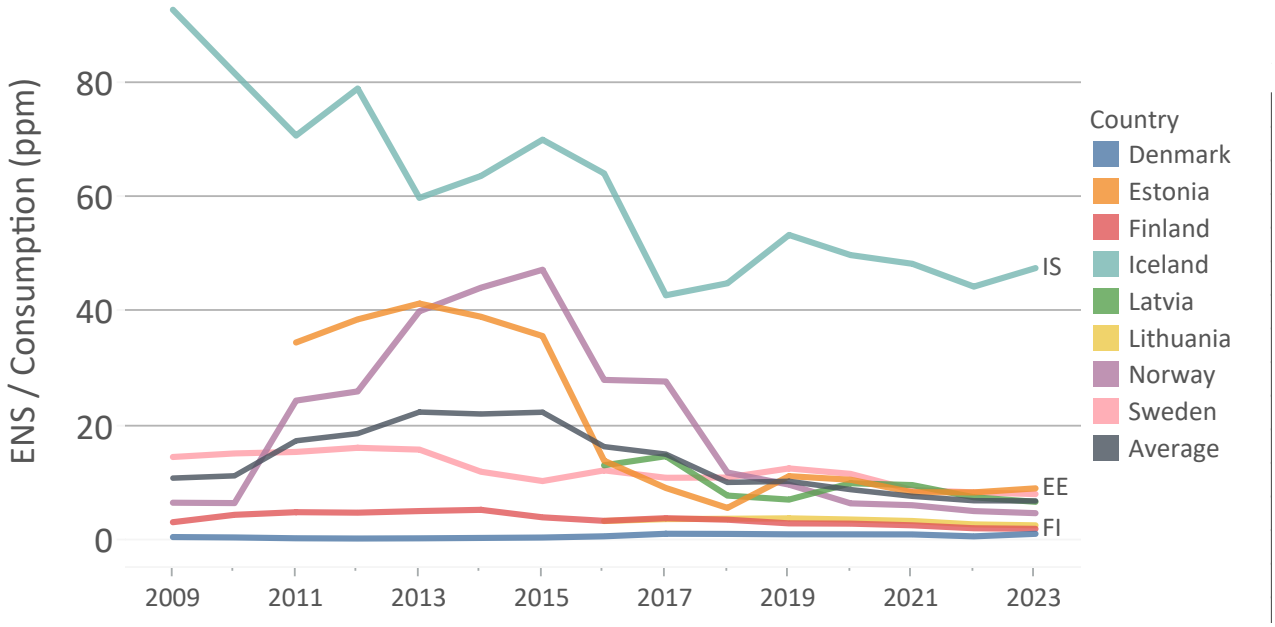

Figure 4.1: 5-year moving average for the amount of ENS divided by consumption (ppm) since 2000. Estonia has data since 2007 and since Latvia and Lithuania have data since 2012. Ppm (parts per million) represents ENS (MWh) as a proportional value of the consumed energy (TWh).

4.3 Energy not supplied by month

This section presents ENS due to disturbances that occurred in the 100–420 kV grids by month. Table 4.3 shows the percentage allocation of ENS by month in 2023 and Table 4.4 presents the respective percentage values over 2014–2023.

Table 4.3: ENS (%) by month in 2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Estonia	0%	54%	2%	1%	2%	0%	0%	11%	4%	0%	2%	23%
Latvia	1%	0%	0%	0%	0%	1%	0%	26%	0%	71%	1%	0%
Lithuania	2%	27%	0%	9%	2%	0%	0%	37%	0%	22%	1%	0%
Denmark	0%	0%	21%	0%	0%	0%	6%	0%	21%	1%	10%	40%
Finland	3%	15%	1%	14%	4%	27%	4%	5%	12%	0%	12%	3%
Iceland	16%	0%	0%	0%	0%	1%	0%	23%	27%	26%	6%	0%
Norway	8%	4%	0%	4%	38%	3%	5%	7%	4%	3%	22%	1%
Sweden	0%	2%	3%	4%	11%	22%	9%	21%	9%	8%	3%	8%

Table 4.4: Percentage allocation of ENS by month over 2014–2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Estonia	11%	12%	3%	9%	7%	4%	4%	5%	12%	22%	6%	4%
Latvia	2%	0%	3%	0%	5%	33%	10%	13%	11%	10%	4%	9%
Lithuania	6%	9%	13%	5%	7%	24%	17%	8%	2%	5%	3%	2%
Denmark	11%	10%	8%	4%	2%	3%	2%	9%	12%	20%	4%	15%
Finland	5%	2%	10%	6%	4%	9%	18%	17%	4%	5%	5%	16%
Iceland	17%	25%	6%	1%	2%	7%	3%	3%	3%	5%	2%	25%
Norway	17%	19%	8%	4%	2%	11%	5%	5%	6%	4%	14%	6%
Sweden	6%	6%	3%	3%	7%	15%	22%	16%	6%	6%	5%	4%

ENTSO-E | Rue de Spa, 8 | 1000 Brussels | info@entsoe.eu | www.entsoe.eu | @entso_e

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 2023. Table 4.6 shows the respective percentages over 2014–2023.

Table 4.5: ENS (%) by cause in 2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	33%	57%	5%	1%	3%
Latvia	98%	0%	1%	1%	0%
Lithuania	18%	47%	11%	25%	0%
Denmark	0%	0%	73%	27%	0%
Finland	37%	1%	16%	45%	1%
Iceland	33%	23%	1%	44%	0%
Norway	31%	3%	40%	24%	2%
Sweden	42%	4%	3%	22%	28%

Table 4.6: Percentage allocation of ENS by cause over 2014–2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	4%	13%	10%	72%	1%
Latvia	18%	17%	53%	11%	1%
Lithuania	11%	39%	14%	35%	1%
Denmark	10%	0%	62%	28%	0%
Finland	24%	3%	8%	53%	11%
Iceland	40%	3%	13%	44%	0%
Norway	40%	2%	12%	42%	3%
Sweden	32%	5%	6%	37%	20%

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 2023 and for 2014–2023, while Table 4.8 presents ENS for faults only.

Table 4.7: ENS in 2023 and its annual average for 2014–2023, and the annual average amount of ENS by voltage level for 2014–2023.

	ENS (MWh)		Average annual ENS (MWh) by voltage level over 2014–2023			
Country	2023	Annual average 2014–2023	100–150 kV	220–330 kV	380–420 kV	Other[1]
Estonia	55.4	71.3	50.7	5.5	0.0	15.1
Latvia	30.4	51.2	33.5	17.5	0.0	0.2
Lithuania	23.2	37.5	36.1	0.3	0.0	1.1
Baltic total	109.0	160.0	120.3	23.3	0.0	16.4
Denmark	92.1	41.8	37.6	0.0	1.0	3.2
Finland	91.3	255.5	219.6	0.8	0.0	35.1
Iceland	807.6	950.4	316.1	397.7	0.0	236.6
Norway	338.2	1204.3	671.5	224.2	181.2	27.5
Sweden	1129.5	1344.3	1033.5	130.6	52.8	127.4
Nordic total	2458.6	3696.3	2278.3	753.3	235.0	429.7
Baltic & Nordic total	2567.6	3856.4	2398.6	776.6	235.0	446.2

[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 2023.

Country	100–150 kV	220–330 kV	380–420 kV
Estonia	53,6	1,7	0,0
Latvia	30,4	0,0	0,0
Lithuania	15,6	2,1	0,0
Denmark	72,6	0,0	0,0
Finland	91,2	0,0	0,0
Iceland	191,9	391,9	0,0
Norway	128,2	37,8	54,6
Sweden	832,9	231,2	0,0
Baltic & Nordic	1416,3	664,7	54,6

4.6 Energy not supplied by component

Table 4.9 presents the percentage allocation of ENS by component in 2023, and Table 4.10 shows the respective percentages over 2014–2023. The ENS is allocated to the component where each fault occurred. The total amount of ENS in 2023 and the annual average values for 2014–2023 are in Table 4.7.

Table 4.9: ENS (%) by component in 2023. 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%	70%	70%	0%	3%	0%	24%	1%	0%	3%	0%	0%	30%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Latvia	0%	98%	98%	0%	0%	0%	2%	0%	0%	0%	0%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Lithuania	0%	67%	67%	0%	0%	0%	9%	0%	0%	0%	0%	0%	9%	0%	0%	0%	0%	0%	0%	24%	0%	24%
Denmark	0%	5%	5%	6%	0%	0%	62%	0%	6%	0%	0%	0%	74%	0%	0%	0%	0%	0%	0%	21%	0%	21%
Finland	0%	48%	48%	0%	0%	12%	6%	15%	12%	0%	0%	7%	52%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Iceland	0%	72%	72%	0%	0%	0%	0%	0%	0%	1%	0%	0%	1%	0%	0%	0%	0%	0%	0%	28%	0%	28%
Norway	0%	39%	39%	0%	2%	0%	14%	0%	1%	2%	0%	3%	23%	3%	0%	0%	0%	0%	3%	0%	35%	35%
Sweden	5%	51%	55%	0%	10%	0%	1%	23%	0%	2%	1%	1%	39%	0%	0%	0%	0%	0%	0%	6%	0%	6%

Table 4.10: Percentage allocation of ENS by component over 2014–2023. 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%	15%	15%	0%	11%	0%	22%	3%	1%	2%	0%	18%	56%	0%	0%	5%	0%	0%	5%	24%	0%	24%
Latvia	0%	35%	35%	1%	0%	0%	55%	5%	1%	3%	0%	0%	65%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Lithuania	1%	51%	51%	3%	5%	0%	26%	8%	2%	0%	1%	0%	46%	0%	0%	0%	0%	0%	0%	3%	0%	3%
Denmark	4%	3%	7%	43%	7%	0%	21%	2%	6%	5%	0%	0%	85%	0%	0%	0%	0%	0%	0%	8%	0%	8%
Finland	0%	58%	58%	2%	4%	0%	7%	2%	6%	5%	0%	1%	26%	0%	1%	0%	0%	0%	1%	14%	1%	15%
Iceland	1%	25%	26%	0%	5%	0%	13%	0%	2%	16%	1%	9%	47%	0%	0%	0%	0%	0%	0%	19%	8%	28%
Norway	4%	36%	39%	6%	4%	2%	23%	8%	8%	1%	1%	5%	58%	0%	0%	0%	0%	0%	0%	0%	2%	2%
Sweden	1%	47%	49%	3%	4%	1%	8%	4%	6%	6%	3%	5%	40%	1%	0%	1%	0%	0%	2%	10%	0%	10%

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 2023.

	Faults in 2023			Secondary faults in 2023	
Country	Number	causing ENS	ENS (MWh)	Number	ENS (MWh)
Estonia	203	15	55.4	17	0.0
Latvia	149	12	30.4	13	0.5
Lithuania	146	12	23.2	8	2.0
Baltic total	498	39	109.0	38	2.6
Denmark	83	9	92.1	8	24.8
Finland	485	59	91.3	7	10.5
Iceland	51	13	807.6	4	0.0
Norway	325	73	338.2	30	132.3
Sweden	392	156	1129.5	7	0.0
Nordic total	1336	310	2458.6	56	167.6
Baltic & Nordic total	1834	349	2567.6	94	170.2

ENTSO-E | Rue de Spa, 8 | 1000 Brussels | info@entsoe.eu | www.entsoe.eu | @entso_e

5.2 Statistics of secondary faults

Table 5.2 presents the percentage allocation of secondary faults by cause in 2023, and Table 5.3 shows the respective values over 2017–2023. Table 5.4 presents the annual number of secondary faults for 2017–2023.

Table 5.5 presents the percentage allocation of ENS due to secondary faults in 2023, and Table 5.6 shows the respective values over 2017–2023. Table 5.7 presents the annual amounts of ENS caused by the secondary faults for 2017–2023.

Data about secondary faults have been collected since 2017.

Table 5.2: Percentage allocation of secondary faults by cause in 2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	12%	0%	41%	35%	12%
Latvia	0%	0%	23%	77%	0%
Lithuania	0%	0%	63%	38%	0%
Denmark	0%	0%	100%	0%	0%
Finland	0%	0%	14%	86%	0%
Iceland	0%	0%	50%	50%	0%
Norway	30%	0%	37%	30%	3%
Sweden	43%	0%	0%	57%	0%

Table 5.3: Percentage allocation of secondary faults by cause over 2017–2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	8%	5%	32%	46%	9%
Latvia	0%	0%	38%	59%	4%
Lithuania	1%	0%	31%	37%	31%
Denmark	0%	3%	77%	21%	0%
Finland	18%	5%	41%	27%	9%
Iceland	13%	0%	17%	71%	0%
Norway	27%	1%	27%	40%	5%
Sweden	8%	1%	4%	78%	8%

Table 5.4: Annual number of secondary faults for 2017–2023.

Country	2017	2018	2019	2020	2021	2022	2023	Annual average
Estonia	9	8	7	15	4	5	17	9,3
Latvia	20	20	23	9	16	13	13	9,7
Lithuania	13	19	18	6	0	4	8	16,3
Denmark	9	3	6	5	3	5	8	5,6
Finland	13	9	6	18	16	19	7	12,6
Iceland	8	18	26	22	14	11	4	14,7
Norway	30	34	26	28	36	31	30	30,7
Sweden	10	7	14	9	27	9	7	11,9
Baltic & Nordic	112	118	126	112	116	97	94	110,7

Table 5.5: Percentage allocation of ENS due to secondary faults by cause in 2023. 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%
Latvia	0%	0%	56%	44%	0%
Lithuania	0%	0%	100%	0%	0%
Denmark	0%	0%	100%	0%	0%
Finland	0%	0%	0%	100%	0%
Iceland	0%	0%	0%	0%	0%
Norway	5%	0%	91%	3%	0%
Sweden	0%	0%	0%	0%	0%

Table 5.6: Percentage allocation of ENS due to secondary faults by cause over 2017–2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	0%	1%	19%	79%	0%
Latvia	0%	0%	95%	5%	0%
Lithuania	0%	0%	3%	97%	0%
Denmark	0%	0%	96%	4%	0%
Finland	24%	1%	9%	58%	8%
Iceland	4%	0%	0%	96%	0%
Norway	20%	22%	25%	33%	0%
Sweden	0%	0%	0%	84%	16%

Table 5.7: Annual amount of ENS (MWh) due to secondary faults for 2017–2023.

Country	2017	2018	2019	2020	2021	2022	2023	Annual average
Estonia	0,1	0,3	0,1	0,1	1,2	0,0	0,0	0,0
Latvia	16,0	34,1	2,2	163,3	8,6	6,5	0,5	4,7
Lithuania	50,0	25,2	0,5	24,1	0,0	7,0	2,1	2,2
Denmark	4,0	0,3	4,7	0,0	0,0	16,4	24,8	1,0
Finland	6,0	48,2	12,6	12,9	15,3	7,7	10,5	2,3
Iceland	0,0	0,0	0,2	84,1	4,7	13,8	0,0	2,1
Norway	58,8	131,3	71,3	167,2	130,9	60,1	132,3	15,3
Sweden	32,0	0,0	8,4	0,0	10,2	0,0	0,0	1,0
Baltic & Nordic	166,9	239,3	100,0	451,7	170,9	111,6	170,2	28,8

6 Faults in power system components

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

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

6.1 Overview of faults

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

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

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

Table 6.1 presents the number of faults and the energy not supplied (ENS) caused by them in 2023 and for 2014–2023. Table 6.2 shows the number of faults and number of grid disturbances in 2023, their annual averages for 2014–2023, and the faults to disturbance ratio over 2014–2023.

Table 6.3 shows the percentage allocation of faults per component in 2023, and Table 6.4 shows the respective percentages over 2014–2023. 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 2023 and their annual averages for 2014–2023.

	Number of faults		No. of faults with ENS		ENS (MWh)	
Country	2023	Annual avg. 2014–2023	2023	Annual avg. 2014–2023	2023	Annual avg. 2014–2023
Estonia	203	163.3	15	21.6	55.4	63.4
Latvia	149	141.1	12	14.7	30.4	51.2
Lithuania	146	155.6	12	16.3	23.2	37.5
Baltic total	498	460.0	39	52.6	109.0	152.0
Denmark	83	72.4	9	6.6	92.1	41.6
Finland	485	438.7	59	110.9	91.3	240.2
Iceland	51	68.6	13	21.3	807.6	853.7
Norway	325	336.0	73	85.7	338.2	1104.4
Sweden	392	439.8	156	174.5	1129.5	1322.2
Nordic total	1336	1355.5	310	399.0	2458.6	3562.1
Baltic & Nordic total	1834	1815.5	349	451.6	2567.6	3714.1

Table 6.2: The number of faults and the number of grid disturbances in 2023, their annual averages for 2014–2023, and the fault to disturbance ratio in 2023 and over 2014–2023.

	Number of faults		No. of disturbances		Ratio	
Country	2023	Annual avg. 2014–2023	2023	Annual avg. 2014–2023	2023	Annual avg. 2014–2023
Estonia	203	163.3	171	154.4	1.2	1.1
Latvia	149	141.1	136	125.9	1.1	1.1
Lithuania	146	155.6	138	145.3	1.1	1.1
Baltic total	498	460.0	445	425.6	1.1	1.1
Denmark	83	72.4	75	65.9	1.1	1.1
Finland	485	438.7	478	421.5	1.0	1.0
Iceland	51	68.6	47	47.0	1.1	1.5
Norway	325	336.0	295	298.7	1.1	1.1
Sweden	392	439.8	385	422.2	1.0	1.0
Nordic total	1336	1355.5	1280	1255.3	1.0	1.1
Baltic & Nordic total	1834	1815.5	1725	1680.9	1.1	1.1

Table 6.3: Percentage allocation of faults by component in 2023. 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%	36%	37%	1%	7%	1%	18%	4%	4%	5%	0%	0%	40%	3%	0%	0%	0%	6%	9%	13%	0%	13%
Latvia	0%	73%	73%	0%	1%	0%	11%	0%	2%	2%	0%	1%	17%	0%	0%	0%	0%	0%	0%	10%	0%	10%
Lithuania	0%	77%	77%	0%	0%	0%	6%	1%	1%	0%	0%	2%	10%	0%	0%	0%	0%	0%	0%	11%	1%	12%
Denmark	4%	47%	51%	5%	0%	0%	16%	4%	2%	7%	0%	0%	34%	0%	0%	0%	0%	5%	5%	11%	0%	11%
Finland	0%	86%	86%	0%	2%	0%	5%	1%	0%	1%	0%	2%	12%	0%	1%	1%	0%	0%	1%	0%	0%	1%
Iceland	0%	37%	37%	16%	2%	0%	0%	0%	0%	10%	0%	0%	27%	0%	0%	0%	0%	0%	0%	27%	8%	35%
Norway	1%	55%	55%	0%	4%	3%	20%	1%	1%	2%	1%	2%	34%	1%	0%	2%	4%	1%	7%	0%	3%	3%
Sweden	1%	68%	69%	0%	1%	0%	4%	4%	1%	3%	2%	2%	18%	1%	2%	1%	0%	0%	3%	9%	1%	10%

Table 6.4: Percentage allocation of faults by component over 2014–2023. 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%	45%	45%	2%	6%	1%	11%	5%	3%	7%	0%	4%	40%	1%	0%	1%	0%	1%	3%	11%	0%	11%
Latvia	0%	67%	67%	1%	2%	0%	14%	1%	2%	3%	0%	0%	23%	0%	0%	0%	0%	0%	0%	9%	0%	9%
Lithuania	0%	68%	68%	1%	3%	1%	10%	1%	1%	1%	1%	1%	18%	0%	0%	0%	0%	0%	0%	14%	0%	14%
Denmark	6%	42%	48%	5%	3%	0%	13%	1%	2%	8%	1%	3%	36%	2%	0%	0%	1%	3%	6%	9%	0%	9%
Finland	0%	82%	83%	0%	1%	0%	6%	0%	1%	2%	0%	2%	13%	0%	1%	0%	0%	0%	2%	3%	0%	3%
Iceland	0%	32%	32%	1%	4%	0%	12%	1%	0%	5%	0%	4%	28%	0%	0%	1%	0%	0%	1%	23%	16%	38%
Norway	1%	51%	53%	1%	4%	2%	20%	1%	2%	2%	1%	5%	38%	0%	0%	1%	5%	1%	7%	0%	2%	2%
Sweden	1%	61%	61%	1%	2%	1%	11%	3%	1%	4%	0%	2%	25%	1%	1%	0%	1%	0%	4%	9%	1%	10%

ENTSO-E | Rue de Spa, 8 | 1000 Brussels | info@entsoe.eu | www.entsoe.eu | @entso_e

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 2023. Table 6.6 shows the respective percentages over 2014–2023.

Table 6.7 presents the percentage allocation of faults that caused ENS by cause in 2023. Table 6.8 shows the respective percentages over 2014–2023.

Table 6.5: Percentage allocation of the number of faults by cause in 2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	18%	9%	23%	31%	19%
Latvia	48%	11%	5%	27%	9%
Lithuania	17%	38%	10%	19%	16%
Denmark	14%	31%	27%	27%	1%
Finland	78%	4%	6%	10%	2%
Iceland	29%	2%	18%	51%	0%
Norway	51%	2%	19%	23%	4%
Sweden	32%	3%	8%	25%	32%

Table 6.6: Percentage allocation of the number of faults by cause over 2014–2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	24%	9%	16%	40%	11%
Latvia	33%	20%	9%	23%	15%
Lithuania	12%	27%	9%	23%	29%
Denmark	17%	22%	23%	32%	6%
Finland	53%	2%	7%	20%	18%
Iceland	31%	1%	9%	58%	1%
Norway	51%	2%	17%	26%	4%
Sweden	36%	2%	8%	26%	28%

Table 6.7: Percentage allocation of the number of faults that caused ENS by cause in 2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	20%	20%	27%	13%	20%
Latvia	75%	0%	8%	17%	0%
Lithuania	8%	33%	25%	33%	0%
Denmark	0%	0%	78%	22%	0%
Finland	54%	5%	19%	17%	5%
Iceland	46%	8%	8%	38%	0%
Norway	45%	4%	26%	22%	3%
Sweden	32%	3%	11%	24%	30%

Table 6.8: Percentage allocation of the number of faults that caused ENS by cause over 2014–2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	12%	13%	25%	40%	10%
Latvia	31%	15%	29%	22%	3%
Lithuania	11%	42%	26%	18%	3%
Denmark	11%	0%	55%	33%	2%
Finland	32%	2%	8%	15%	43%
Iceland	50%	1%	10%	38%	0%
Norway	48%	3%	23%	24%	3%
Sweden	36%	2%	10%	27%	26%

ENTSO-E | Rue de Spa, 8 | 1000 Brussels | info@entsoe.eu | www.entsoe.eu | @entso_e

6.3 Faults in cables

This section presents cable faults in 2023 and for 2014–2023.

Table 6.9 presents the length of cables and the number of faults in 2023, and the 10-year annual average of the number of faults for 2014–2023. Table 6.10 presents the number of faults per 100 km of cable in 2023 and the annual averages for 2014–2023.

Table 6.11 shows the percentage allocation of cable faults by cause in 2023. Table 6.12 presents the respective percentages over 2014–2023.

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 2023, and the annual average number of faults for 2014–2023, grouped by voltage level.

Country	100–150 kV			220–330 kV			380–420 kV		
	km in 2023	Number of faults in 2023	10-year ann. avg of faults	km in 2023	Number of faults in 2023	10-year ann. avg of faults	km in 2023	Number of faults in 2023	10-year ann. avg of faults
Estonia	112	1	0.6	0	0	0.0	0	0	0.0
Latvia	83	0	0.2	22	0	0.2	0	0	0.0
Lithuania	116	0	0.1	0	0	0.0	0	0	0.0
Denmark	1 852	2	3.5	366	1	0.4	222	0	0.2
Finland	377	2	1.1	0	0	0.0	0	0	0.0
Iceland	111	0	0.2	10	0	0.0	0	0	0.0
Norway	633	2	3.4	115	0	0.4	44	0	0.8
Sweden	486	4	2.4	115	0	1.3	20	0	0.4
Baltic & Nordic	3 770	11	11.5	629	1	2.3	286	0	1.4

Table 6.10: Number of cable faults per 100 km in 2023 and the annual average for 2014–2023, grouped by voltage level.

Country	100–150 kV		220–330 kV		380–420 kV	
	Number of faults / 100 km in 2023	10-year ann. avg no. of faults / 100 km	Number of faults / 100 km in 2023	10-year ann. avg no. of faults / 100 km	Number of faults / 100 km in 2023	10-year ann. avg no. of faults / 100 km
Estonia	0.89	0.73	0.00	0.00	0.00	0.00
Latvia	0.00	0.26	0.00	1.14	0.00	0.00
Lithuania	0.00	0.10	0.00	0.00	0.00	0.00
Denmark	0.11	0.23	0.27	0.16	0.00	0.11
Finland	0.53	0.56	0.00	0.00	0.00	0.00
Iceland	0.00	0.18	0.00	0.00	0.00	0.00
Norway	0.32	0.59	0.00	0.36	0.00	1.89
Sweden	0.82	0.53	0.00	1.01	0.00	2.25
Baltic & Nordic	0.29	0.37	0.16	0.46	0.00	0.57

Table 6.11: Percentage allocation of cable faults by cause in 2023. Proportionately higher percentage values are highlighted in yellow and red.

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

Table 6.12: Percentage allocation of cable faults by cause over 2014–2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	0%	67%	17%	17%	0%
Latvia	0%	25%	0%	75%	0%
Lithuania	0%	0%	0%	100%	0%
Denmark	0%	12%	20%	63%	5%
Finland	9%	9%	27%	55%	0%
Iceland	50%	0%	0%	50%	0%
Norway	24%	13%	2%	57%	4%
Sweden	5%	0%	12%	66%	17%

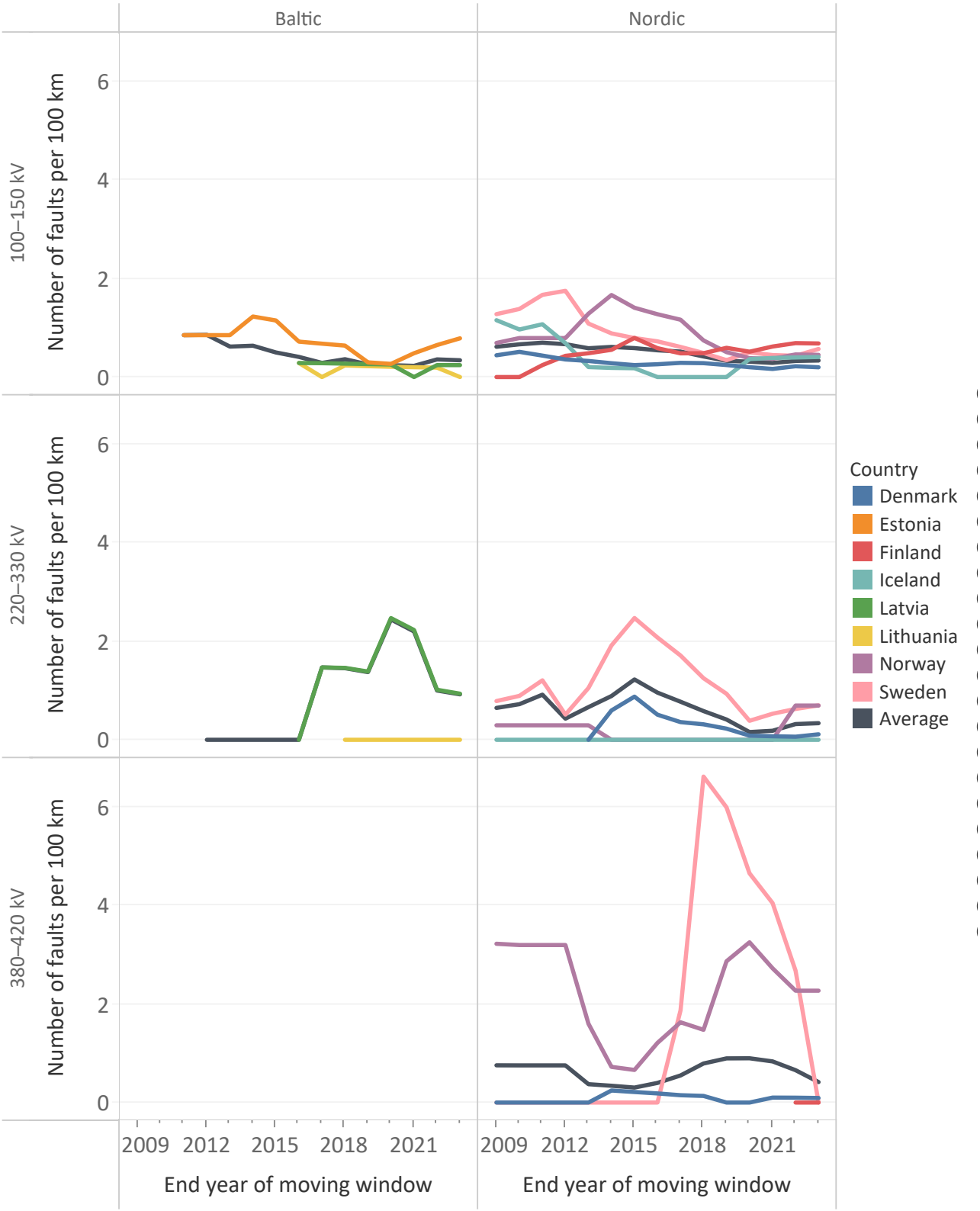

Figure 6.1: 5-year moving average of cable faults per 100 km. Estonia has data since 2007, and Latvia and Lithuania have data since 2012. Estonia, Finland and Lithuania do not own 220–330 kV cables. Estonia, Finland, Iceland and Latvia do not own 380–420 kV cables.

6.4 Faults on overhead lines

This section presents overhead line faults in 2023 and for 2014–2023.

Table 6.13 presents the length of overhead lines and the number of faults in 2023, and the 10-year annual average of the number of faults for 2014–2023. Table 6.14 presents the number of faults per 100 km of overhead line in 2023 and the annual averages for 2014–2023.

Table 6.15 presents the number of faults and the number of permanent faults for 2023 and their 10-year respective average values for 2014–2023.

Table 6.16 shows the percentage allocation of overhead line faults by cause in 2023. Table 6.17 presents the respective percentages over 2014–2023.

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 2023, and the annual average number of faults for 2014–2023, grouped by voltage level.

Country	100–150 kV			220–330 kV			380–420 kV		
	km in 2023	Number of faults in 2023	10-year ann. avg of faults	km in 2023	Number of faults in 2023	10-year ann. avg of faults	km in 2023	Number of faults in 2023	10-year ann. avg of faults
Estonia	3 361	63	63.9	1 634	11	9.6	0	0	0.0
Latvia	3 730	102	86.0	1 720	7	8.7	0	0	0.0
Lithuania	4 970	107	96.0	1 894	6	8.9	103	0	0.6
Denmark	2 697	32	25.6	0	0	0.3	1 472	7	4.7
Finland	17 181	399	339.5	1 061	10	12.5	5 411	7	8.6
Iceland	1 383	12	17.3	1 112	7	4.6	0	0	0.0
Norway	11 168	85	93.4	3 977	40	34.0	4 654	53	45.6
Sweden	15 680	216	203.2	3 312	24	28.9	8 540	26	34.0
Baltic & Nordic	60 170	1 016	924.9	14 710	105	107.5	20 180	93	93.5

Table 6.14: Number of overhead line faults per 100 km in 2023 and the annual average for 2014–2023, grouped by voltage level.

Country	100–150 kV		220–330 kV		380–420 kV	
	Number of faults / 100 km in 2023	10-year ann. avg no. of faults / 100 km	Number of faults / 100 km in 2023	10-year ann. avg no. of faults / 100 km	Number of faults / 100 km in 2023	10-year ann. avg no. of faults / 100 km
Estonia	1.87	1.88	0.67	0.52	0.00	0.00
Latvia	2.73	2.26	0.41	0.57	0.00	0.00
Lithuania	2.15	1.93	0.32	0.49	0.00	0.73
Denmark	1.19	0.88	0.00	0.77	0.48	0.34
Finland	2.32	2.04	0.94	0.76	0.13	0.15
Iceland	0.87	1.37	0.63	0.50	0.00	0.00
Norway	0.76	0.86	1.01	0.75	1.14	1.14
Sweden	1.38	1.35	0.72	0.77	0.30	0.34
Baltic & Nordic	1.69	1.57	0.71	0.67	0.46	0.44

ENTSO-E | Rue de Spa, 8 | 1000 Brussels | info@entsoe.eu | www.entsoe.eu | @entso_e

Table 6.15: Number of overhead lines faults and permanent faults in 2023 and their 10-year annual average values for 2014–2023, grouped by voltage level.

Country	100–150 kV				220–330 kV				380–420 kV			
	Faults		Permanent faults		Faults		Permanent faults		Faults		Permanent faults	
	Number in 2023	10-year ann. avg	Number in 2023	10-year ann. avg	Number in 2023	10-year ann. avg	Number in 2023	10-year ann. avg	Number in 2023	10-year ann. avg	Number in 2023	10-year ann. avg
Estonia	63	63.9	18	13.0	11	9.6	7	2.8	0	0.0	0	0.0
Latvia	102	86.0	50	34.7	7	8.7	1	1.2	0	0.0	0	0.0
Lithuania	107	96.0	11	13.4	6	8.9	0	1.5	0	0.6	0	0.4
Denmark	32	25.6	4	2.7	0	0.3	0	0.0	7	4.7	2	1.0
Finland	399	339.5	24	27.5	10	12.5	0	1.4	7	8.6	0	1.2
Iceland	12	17.3	7	2.3	7	4.6	4	1.2	0	0.0	0	0.0
Norway	85	93.4	19	20.6	40	34.0	4	3.3	53	45.6	3	2.0
Sweden	216	203.2	11	7.2	24	28.9	2	1.8	26	34.0	3	2.3
Baltic & Nordic	1 016	924.9	144	121.4	105	107.5	18	13.2	93	93.5	8	6.9

Table 6.16: Percentage allocation of overhead line faults by cause in 2023.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	35%	20%	4%	3%	38%
Latvia	66%	13%	3%	6%	12%
Lithuania	22%	50%	4%	4%	20%
Denmark	28%	56%	5%	8%	3%
Finland	88%	4%	1%	5%	1%
Iceland	79%	5%	0%	16%	0%
Norway	89%	3%	3%	3%	2%
Sweden	44%	4%	6%	8%	39%

Table 6.17: Percentage allocation of overhead line faults by cause over 2014–2023.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	49%	18%	10%	8%	15%
Latvia	49%	27%	1%	1%	21%
Lithuania	17%	39%	3%	3%	38%
Denmark	30%	46%	6%	8%	10%
Finland	62%	2%	2%	15%	19%
Iceland	89%	3%	0%	6%	1%
Norway	91%	2%	2%	4%	2%
Sweden	53%	2%	3%	4%	38%

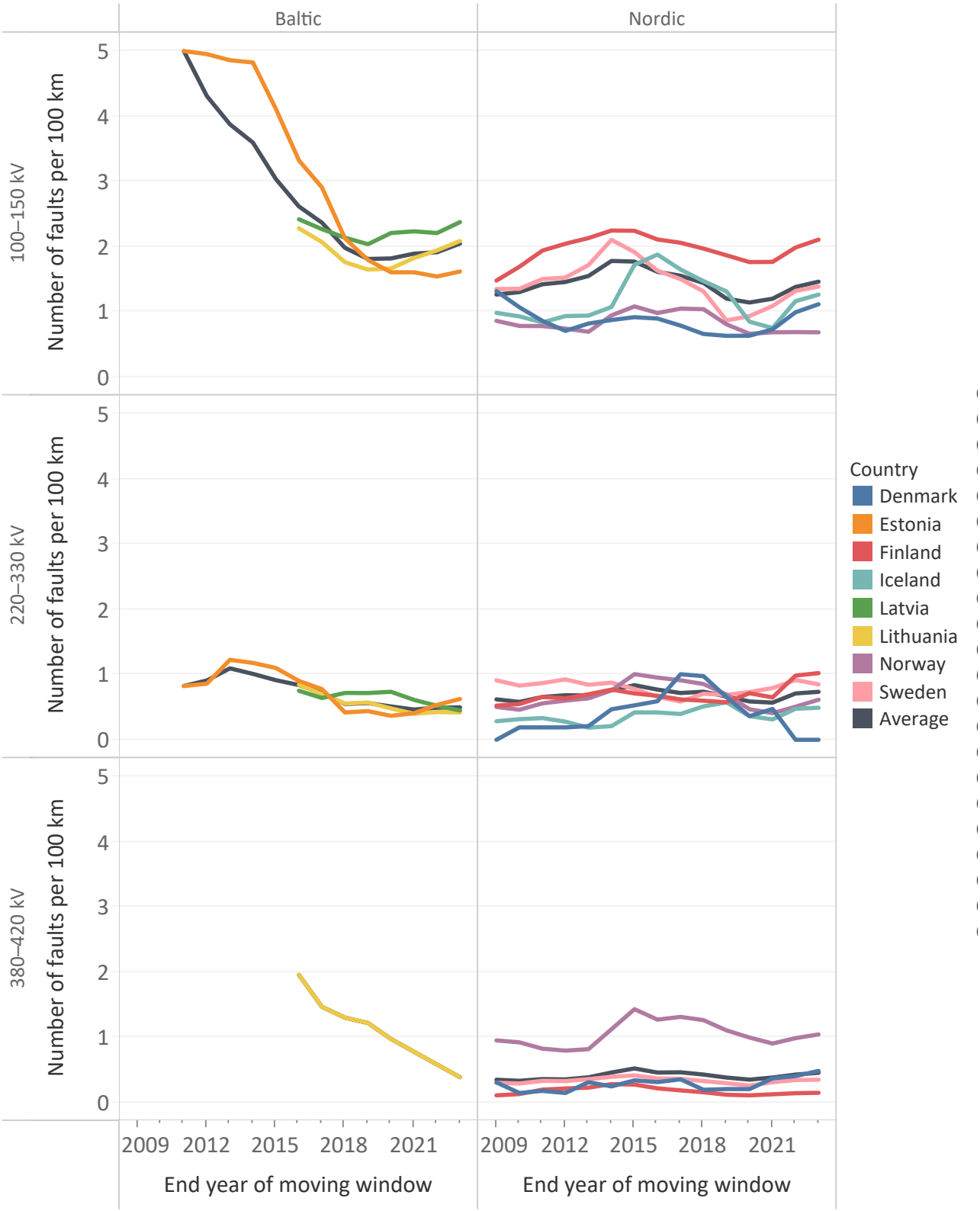

Figure 6.2: 5-year moving average of overhead line faults per 100 km. Estonia has data since 2007, and Latvia and Lithuania have data since 2012. Estonia, Iceland and Latvia do not own 380–420 kV transmission grids.

6.5 Faults in circuit breakers

This section presents circuit breaker faults in 2023 and for 2014–2023.

Table 6.18 presents the number of circuit breakers and the number of faults in 2023, and the 10-year annual average of the number of faults for 2014–2023. Table 6.19 presents the number of faults per 100 devices in 2023 and the annual averages for 2014–2023.

Table 6.20 presents the percentage allocation of circuit breaker faults by cause in 2023. Table 6.21 presents the respective percentages over 2014–2023.

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 2023, and the annual average number of faults for 2014–2023, grouped by voltage level.

Country	100–150 kV			220–330 kV			380–420 kV		
	Number of devices in 2023	Number of faults in 2023	10-year ann. avg of faults	Number of devices in 2023	Number of faults in 2023	10-year ann. avg of faults	Number of devices in 2023	Number of faults in 2023	10-year ann. avg of faults
Estonia	671	4	6.9	134	10	3.7	0	0	0.0
Latvia	635	1	2.7	110	0	0.1	0	0	0.0
Lithuania	899	0	3.5	114	0	0.5	11	0	0.1
Denmark	1 010	0	2.0	38	0	0.1	291	0	0.4
Finland	3 056	10	4.5	79	0	0.0	425	0	0.2
Iceland	173	1	2.1	107	0	0.9	0	0	0.0
Norway	2 693	5	7.5	684	1	4.0	630	6	2.5
Sweden	2 923	2	4.3	362	1	1.4	790	2	3.7
Baltic & Nordic	12 060	23	33.5	1 628	12	10.7	2 147	8	6.9

Table 6.19: Number of circuit breaker faults per 100 devices in 2023 and the annual average for 2014–2023, grouped by voltage level.

Country	100–150 kV		220–330 kV		380–420 kV	
	Number of faults / 100 devices in 2023	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2023	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2023	10-year ann. avg no. of faults / 100 devices
Estonia	0.60	1.10	7.46	2.95	0.00	0.00
Latvia	0.16	0.44	0.00	0.10	0.00	0.00
Lithuania	0.00	0.41	0.00	0.44	0.00	1.69
Denmark	0.00	0.22	0.00	0.39	0.00	0.17
Finland	0.33	0.17	0.00	0.00	0.00	0.06
Iceland	0.58	1.34	0.00	1.05	0.00	0.00
Norway	0.19	0.31	0.15	0.56	0.95	0.53
Sweden	0.07	0.17	0.28	0.42	0.25	0.57
Baltic & Nordic	0.19	0.31	0.74	0.68	0.37	0.41

Table 6.20: Percentage allocation of circuit breakers faults by cause in 2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	14%	7%	0%	71%	7%
Latvia	0%	0%	0%	100%	0%
Lithuania	0%	0%	0%	0%	0%
Denmark	0%	0%	0%	0%	0%
Finland	0%	0%	40%	30%	30%
Iceland	0%	0%	0%	100%	0%
Norway	8%	0%	33%	50%	8%
Sweden	40%	0%	0%	20%	40%

Table 6.21: Percentage allocation of circuit breaker faults over 2014–2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	2%	2%	9%	78%	8%
Latvia	0%	4%	7%	89%	0%
Lithuania	0%	0%	39%	56%	5%
Denmark	0%	0%	84%	16%	0%
Finland	6%	2%	30%	36%	26%
Iceland	7%	0%	3%	90%	0%
Norway	6%	3%	31%	42%	17%
Sweden	16%	0%	14%	63%	7%

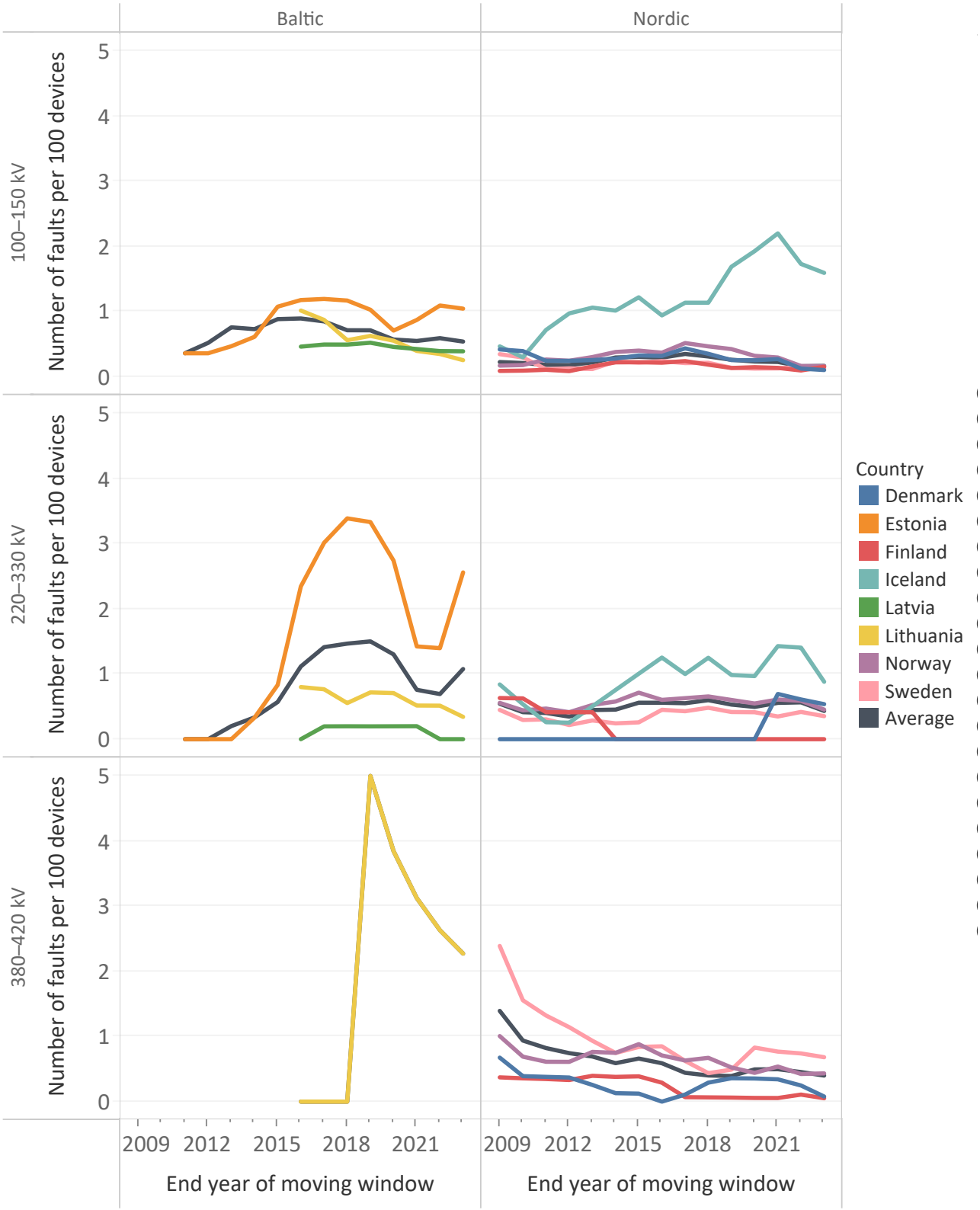

Figure 6.3: 5-year moving average of circuit breaker faults per 100 devices. Estonia has data since 2007, and Latvia and Lithuania have data since 2012. Estonia, Iceland and Latvia do not own 380–420 kV transmission grids.

6.6 Faults in control equipment

This section presents control equipment faults in 2023 and for 2014–2023. Protection devices are considered as part of the control equipment in this report. Control equipment embedded in other components are not included in this category as they are deemed to be a part of the other component.

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

Table 6.22 presents the number of control equipment and the number of faults in 2023, and the 10-year annual average of the number of faults for 2014–2023. Table 6.23 presents the number of faults per 100 devices in 2023 and the annual averages for 2014–2023.

Table 6.24 presents the percentage allocation of control equipment faults by cause in 2023. Table 6.25 presents the respective percentages over 2014–2023.

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 2023, and the annual average number of faults for 2014–2023, grouped by voltage level. Control equipment embedded in other components are not included in this category as they are deemed to be a part of the other component.

Country	100–150 kV			220–330 kV			380–420 kV		
	Number of devices in 2023	Number of faults in 2023	10-year ann. avg of faults	Number of devices in 2023	Number of faults in 2023	10-year ann. avg of faults	Number of devices in 2023	Number of faults in 2023	10-year ann. avg of faults
Estonia	671	26	15.2	134	10	3.1	0	0	0.0
Latvia	673	15	16.7	110	2	2.7	0	0	0.0
Lithuania	899	4	11.3	114	5	3.6	11	0	0.0
Denmark	1 010	12	7.0	38	0	0.3	291	1	2.3
Finland	3 056	21	17.3	79	0	4.3	425	4	3.7
Iceland	173	0	4.9	107	0	3.2	0	0	0.0
Norway	2 693	27	29.7	684	27	21.4	630	11	16.3
Sweden	2 923	11	18.2	362	3	10.7	790	2	20.9
Baltic & Nordic	12 098	116	120.3	1 628	47	49.3	2 147	18	43.2

Table 6.23: Number of control equipment faults per 100 devices in 2023 and the annual average for 2014–2023, grouped by voltage level. Control equipment embedded in other components are not included in this category as they are deemed to be a part of the other component.

Country	100–150 kV		220–330 kV		380–420 kV	
	Number of faults / 100 devices in 2023	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2023	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2023	10-year ann. avg no. of faults / 100 devices
Estonia	3.87	2.43	7.46	2.50	0.00	0.00
Latvia	2.23	2.65	1.82	2.64	0.00	0.00
Lithuania	0.44	1.31	4.39	3.20	0.00	0.00
Denmark	1.19	0.77	0.00	1.16	0.34	1.00
Finland	0.69	0.65	0.00	5.68	0.94	1.07
Iceland	0.00	3.12	0.00	3.75	0.00	0.00
Norway	1.00	1.21	3.95	2.98	1.75	3.47
Sweden	0.38	0.73	0.83	3.19	0.25	3.22
Baltic & Nordic	0.96	1.11	2.89	3.12	0.84	2.54

Table 6.24: Percentage allocation of control equipment faults by cause in 2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	19%	0%	56%	11%	14%
Latvia	0%	0%	24%	76%	0%
Lithuania	0%	0%	67%	33%	0%
Denmark	0%	0%	92%	8%	0%
Finland	4%	0%	64%	32%	0%
Iceland	0%	0%	0%	0%	0%
Norway	5%	0%	42%	48%	6%
Sweden	13%	0%	25%	50%	13%

Table 6.25: Percentage allocation of control equipment faults by cause over 2014–2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	4%	0%	41%	40%	15%
Latvia	1%	0%	48%	46%	5%
Lithuania	0%	6%	44%	24%	26%
Denmark	6%	3%	57%	31%	2%
Finland	7%	0%	68%	21%	4%
Iceland	0%	0%	38%	62%	0%
Norway	5%	3%	49%	39%	4%
Sweden	6%	0%	32%	53%	10%

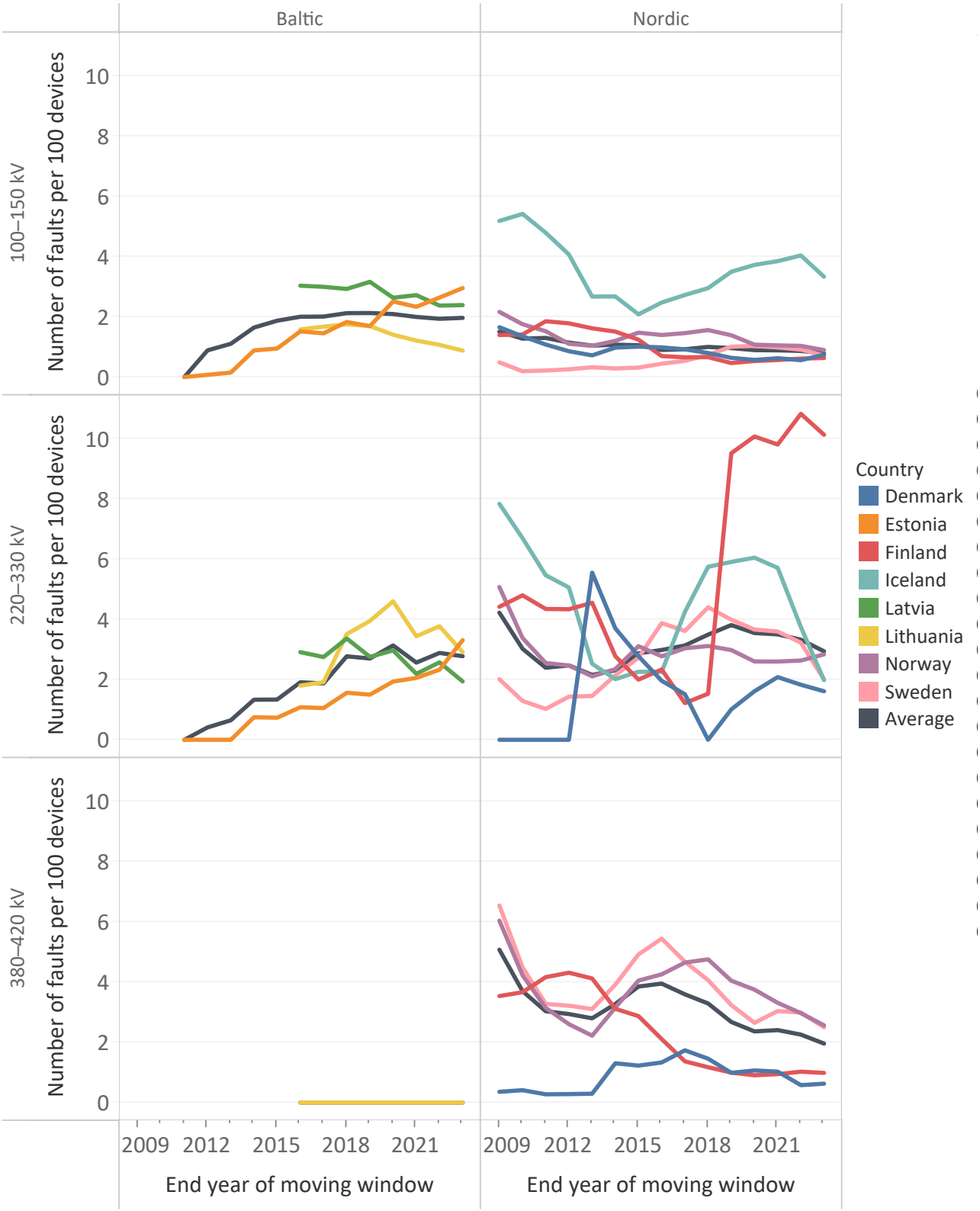

Figure 6.4: 5-year moving average of control equipment faults per 100 devices. Estonia has data since 2007, and Latvia and Lithuania have data since 2012. Estonia, Iceland and Latvia do not own 380–420 kV transmission grids. Control equipment embedded in other components are not included in this category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

6.7 Faults in instrument transformers

This section presents instrument transformer faults in 2023 and for 2014–2023.

Table 6.26 presents the number of instrument transformers and the number of faults in 2023, and the 10-year annual average of the number of faults for 2014–2023. Table 6.27 presents the number of faults per 100 devices in 2023 and the annual averages for 2014–2023.

Table 6.28 presents the percentage allocation of instrument transformer faults by cause in 2023. Table 6.29 presents the respective percentages over 2014–2023.

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 2023, and the annual average number of faults for 2014–2023, grouped by voltage level. The number of instrument transformers in Sweden is not accurate due to missing data from some regional grid owners.

Country	100–150 kV			220–330 kV			380–420 kV		
	Number of devices in 2023	Number of faults in 2023	10-year ann. avg of faults	Number of devices in 2023	Number of faults in 2023	10-year ann. avg of faults	Number of devices in 2023	Number of faults in 2023	10-year ann. avg of faults
Estonia	3 361	5	2.8	1 120	3	1.5	0	0	0.0
Latvia	2 388	3	2.8	468	0	0.1	0	0	0.0
Lithuania	3 377	2	1.4	666	0	0.1	66	0	0.0
Denmark	6 497	2	1.1	243	0	0.0	1 533	0	0.6
Finland	11 117	1	2.4	348	0	0.1	2 174	1	0.4
Iceland	597	0	0.1	450	0	0.1	0	0	0.0
Norway	7 768	1	3.4	2 805	3	2.3	930	0	1.2
Sweden	12 872	2	3.7	2 576	2	0.3	4 141	1	1.6
Baltic & Nordic	47 977	16	17.7	8 676	8	4.5	8 844	2	3.8

Table 6.27: Number of instrument transformer faults per 100 devices in 2023 and the annual average for 2014–2023, grouped by voltage level.

Country	100–150 kV		220–330 kV		380–420 kV	
	Number of faults / 100 devices in 2023	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2023	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2023	10-year ann. avg no. of faults / 100 devices
Estonia	0.15	0.12	0.27	0.24	0.00	0.00
Latvia	0.13	0.16	0.00	0.03	0.00	0.00
Lithuania	0.06	0.06	0.00	0.02	0.00	0.00
Denmark	0.03	0.03	0.00	0.00	0.00	0.07
Finland	0.01	0.03	0.00	0.03	0.05	0.03
Iceland	0.00	0.02	0.00	0.03	0.00	0.00
Norway	0.01	0.04	0.11	0.08	0.00	0.13
Sweden	0.02	0.06	0.08	0.02	0.02	0.06
Baltic & Nordic	0.03	0.05	0.09	0.07	0.02	0.06

Table 6.28: Percentage allocation of instrument transformer faults by cause in 2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	0%	0%	25%	75%	0%
Latvia	0%	0%	0%	100%	0%
Lithuania	0%	0%	50%	50%	0%
Denmark	0%	0%	50%	50%	0%
Finland	0%	0%	0%	100%	0%
Iceland	0%	0%	0%	0%	0%
Norway	0%	25%	25%	25%	25%
Sweden	0%	0%	0%	100%	0%

Table 6.29: Percentage allocation of instrument transformer faults by cause over 2014–2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	0%	0%	12%	84%	5%
Latvia	0%	0%	0%	100%	0%
Lithuania	0%	0%	27%	73%	0%
Denmark	0%	6%	24%	65%	6%
Finland	17%	0%	10%	66%	7%
Iceland	50%	0%	0%	50%	0%
Norway	13%	3%	22%	58%	4%
Sweden	11%	0%	5%	79%	5%

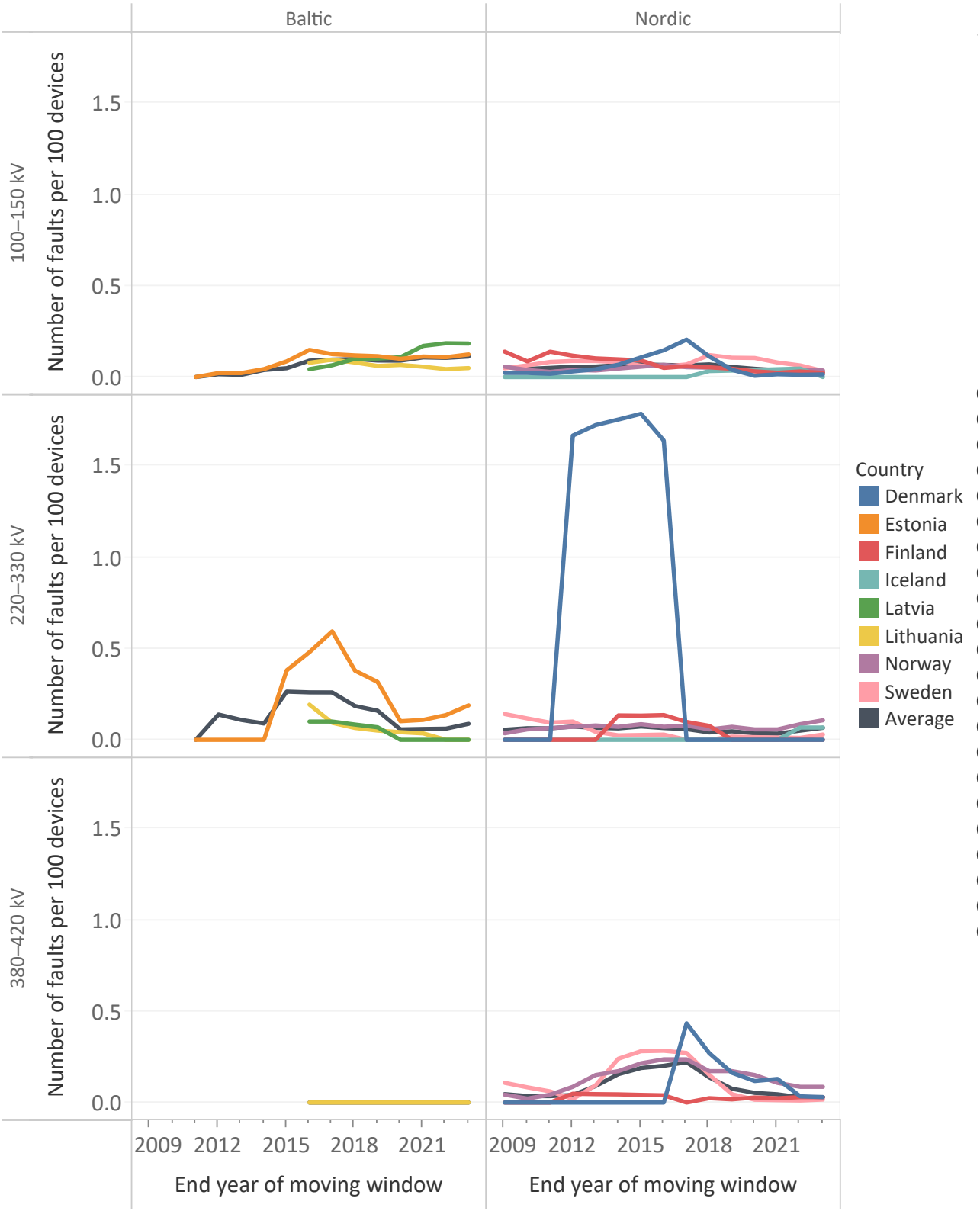

Figure 6.5: 5-year moving average of instrument transformer faults per 100 devices. Estonia has data since 2007, and Latvia and Lithuania have data since 2012. Estonia, Iceland and Latvia do not own 380–420 kV transmission grids. Denmark's high values during 2012–2016 are caused by one fault in 2012.

6.8 Faults in power transformers

This section presents power transformer faults in 2023 and for 2014–2023. 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 2023, and the 10-year annual average of the number of faults for 2014–2023. Table 6.31 presents the number of faults per 100 devices in 2023 and the annual averages for 2014–2023.

Table 6.32 shows the percentage allocation of power transformer faults by cause in 2023. Table 6.33 presents the respective percentages over 2014–2023.

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 2023, and the annual average number of faults for 2014–2023, grouped by voltage level.

Country	100–150 kV			220–330 kV			380–420 kV		
	Number of devices in 2023	Number of faults in 2023	10-year ann. avg of faults	Number of devices in 2023	Number of faults in 2023	10-year ann. avg of faults	Number of devices in 2023	Number of faults in 2023	10-year ann. avg of faults
Estonia	179	8	8.3	29	3	3.8	0	0	0.0
Latvia	247	2	3.0	27	1	1.4	0	0	0.0
Lithuania	378	0	0.3	24	0	0.7	3	0	0.0
Denmark	244	5	3.9	12	0	0.2	48	1	1.5
Finland	1 358	4	6.6	28	0	0.9	93	0	0.7
Iceland	19	3	2.3	18	2	1.1	0	0	0.0
Norway	757	2	4.2	142	5	1.6	80	1	1.4
Sweden	913	8	14.4	106	1	2.9	94	2	1.2
Baltic & Nordic	4 095	32	43.0	386	12	12.6	318	4	4.8

Table 6.31: Number of power transformer faults per 100 devices in 2023 and the annual average for 2014–2023, grouped by voltage level.

Country	100–150 kV		220–330 kV		380–420 kV	
	Number of faults / 100 devices in 2023	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2023	10-year ann. avg no. of faults / 100 devices	Number of faults / 100 devices in 2023	10-year ann. avg no. of faults / 100 devices
Estonia	4.47	4.03	10.34	15.32	0.00	0.00
Latvia	0.81	1.22	3.70	5.41	0.00	0.00
Lithuania	0.00	0.08	0.00	2.94	0.00	0.00
Denmark	2.05	1.64	0.00	2.08	2.08	3.65
Finland	0.29	0.57	0.00	3.73	0.00	0.99
Iceland	15.79	8.30	11.11	7.48	0.00	0.00
Norway	0.26	0.57	3.52	1.13	1.25	1.94
Sweden	0.88	1.74	0.94	2.72	2.13	1.54
Baltic & Nordic	0.78	1.12	3.11	3.39	1.26	1.83

ENTSO-E | Rue de Spa, 8 | 1000 Brussels | info@entsoe.eu | www.entsoe.eu | @entso_e

Table 6.32: Percentage allocation of power transformer faults by cause in 2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	0%	0%	36%	36%	27%
Latvia	0%	33%	0%	33%	33%
Lithuania	0%	0%	0%	0%	0%
Denmark	0%	33%	50%	17%	0%
Finland	0%	25%	0%	75%	0%
Iceland	0%	0%	20%	80%	0%
Norway	0%	13%	38%	50%	0%
Sweden	0%	18%	27%	18%	36%

Table 6.33: Percentage allocation of power transformer faults by cause over 2014–2023. Proportionately higher percentage values are highlighted in yellow and red.

Country	Environmental causes	External influences	Operation and maintenance	Technical equipment	Unknown
Estonia	3%	2%	21%	63%	10%
Latvia	0%	27%	36%	32%	5%
Lithuania	0%	20%	20%	50%	10%
Denmark	20%	4%	36%	39%	2%
Finland	18%	2%	16%	45%	18%
Iceland	9%	0%	15%	76%	0%
Norway	22%	7%	22%	39%	10%
Sweden	24%	5%	21%	24%	26%

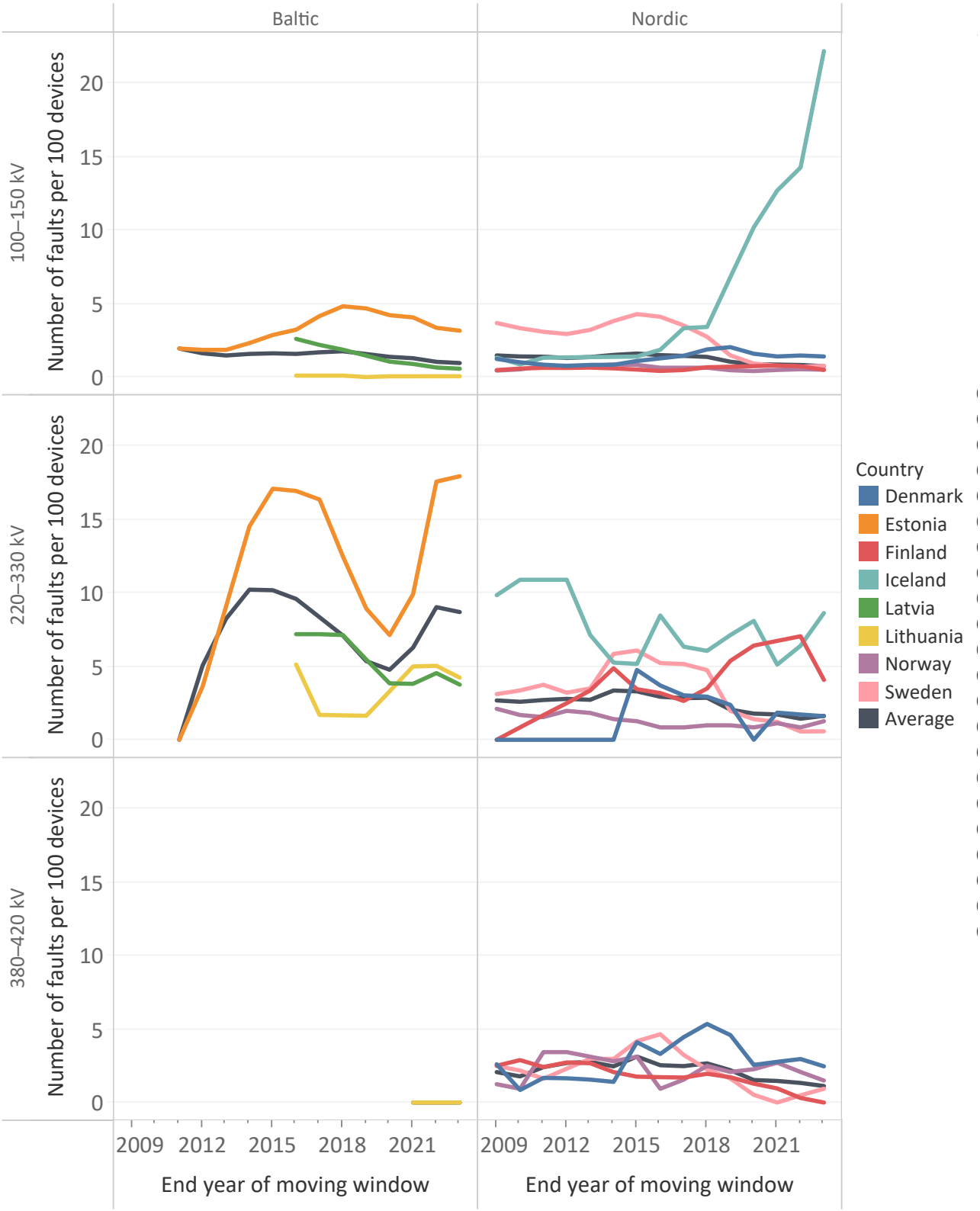

Figure 6.6: 5-year moving average of power transformer faults per 100 devices. Estonia has data since 2007, and Latvia and Lithuania have data since 2012. Estonia, Iceland, Latvia and Lithuania do not own 380–420 kV power transformers in their transmission grids.

ENTSO-E | Rue de Spa, 8 | 1000 Brussels | info@entsoe.eu | www.entsoe.eu | @entso_e

6.9 Faults in compensation devices

The following sections present fault statistics for compensation devices. The following compensation devices are presented in this section: reactors, series capacitors, shunt capacitors and Static var compensators (SVCs). The statistics include the number of devices and their faults, number of faults per 100 devices and ENS in 2023 and their annual averages for 2014–2023.

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 2023, the number of faults per 100 devices, the amount of ENS due to reactor faults in 2023 and their annual averages for 2014–2023.

	Devices	Faults	Faults per 100 devices		ENS (MWh)	
Country	2023	2023	2023	Annual avg. 2014–2023	2023	Annual avg. 2014–2023
Estonia	26	7	27	8.1	0.1	0.0
Latvia	17	0	0	4.1	0.0	0.0
Lithuania	2	0	0	0.0	0.0	0.0
Baltic total	45	7	16	6.0	0.1	0.0
Denmark	115	0	0	1.5	0.0	0.0
Finland	226	0	0	0.2	0.0	1.1
Iceland	240	0	0	0.0	0.0	0.0
Norway	167	2	1	2.3	11.4	1.1
Sweden	751	2	0	1.4	0.0	12.9
Nordic total	1499	4	0	1.2	11.4	15.1
Baltic & Nordic total	1544	11	1	1.5	11.5	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 2023, the number of faults per 100 devices, the amount of ENS due to series capacitor faults in 2023 and their annual averages for 2014–2023.

	Devices	Faults	Faults per 100 devices		ENS (MWh)	
Country	2023	2023	2023	Annual avg. 2014–2023	2023	Annual avg. 2014–2023
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	4	30.8	47.7	0.0	1.9
Iceland	1	0	0.0	12.5	0.0	0.0
Norway	3	0	0.0	3.3	0.0	0.0
Sweden	13	7	53.9	47.5	0.0	0.0
Nordic total	30	11	36.7	41.4	0.0	1.9
Baltic & Nordic total	30	11	36.7	39.6	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 2023, the number of faults per 100 devices, the amount of ENS due to shunt capacitor faults in 2023 and their annual average for 2014–2023.

	Devices	Faults	Faults per 100 devices		ENS (MWh)	
Country	2023	2023	2023	Annual average 2014–2023	2023	Annual average 2014–2023
Estonia	10	0	0.0	12.1	0.0	3.3
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	9.0	0.0	3.3
Denmark	77	0	0.0	0.8	0.0	0.0
Finland	20	3	15.0	4.3	0.0	0.0
Iceland	13	0	0.0	4.3	0.0	0.0
Norway	43	5	11.6	2.3	0.0	0.0
Sweden	545	3	0.6	0.8	0.0	15.2
Nordic total	698	11	1.6	1.7	0.0	15.2
Baltic & Nordic total	712	11	1.5	1.9	0.0	18.5

ENTSO-E | Rue de Spa, 8 | 1000 Brussels | info@entsoe.eu | www.entsoe.eu | @entso_e

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 2023, the number of faults per 100 devices, the amount of ENS due to SVC faults in 2023 and their annual averages for 2014–2023.

	Devices	Faults	Faults per 100 devices		ENS (MWh)	
Country	2023	2023	2023	Annual avg. 2014–2023	2023	Annual avg. 2014–2023
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	0	0.0	11.1	0.0	0.0
Iceland	2	0	0.0	12.5	0.0	0.0
Norway	17	14	82.4	72.4	0.0	0.0
Sweden	3	0	0.0	169.8	0.0	0.0
Nordic total	24	14	58.3	70.2	0.0	0.0
Baltic & Nordic total	35	14	40.0	51.6	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] IEC 60050-826:2004: Electrical installations, 2020.

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

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

Appendices

A Calculation of energy not supplied

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

Denmark

In Denmark, the ENS of the transmission grid is calculated as the transformer load just before the grid disturbance or interruption multiplied by the outage duration. Transformer load covers load/consumption and generation at lower/medium voltage.

Estonia

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

Finland

In Finland, ENS in the transmission grid is counted for those faults that caused an outage at the point of supply, which is the high voltage side of the transformer. ENS is calculated individually for all connection points and is linked to the fault that caused the outage. ENS is counted by multiplying the outage duration and the power before the fault. Outage duration is the time that the point of supply is dead or the time until the delivery of power to the customer can be arranged via another grid connection.

Iceland

In Iceland, ENS is computed per the delivery from the transmission grid. It is calculated at the points of supply in the 220 kV or 132 kV systems. ENS is linked to the fault that caused the outage. In the data of the ENTSO-E Nordic and Baltic statistics, ENS that was caused by the generation or distribution systems has been left out. However, distribution systems register ENS caused by outages in the transmission and distribution systems with end-user impact. Mutual rules for registration of faults and ENS in all grids are used in Iceland.

Latvia

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

Lithuania

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

ENTSO-E | Rue de Spa, 8 | 1000 Brussels | info@entsoe.eu | www.entsoe.eu | @entso_e

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.

C Contact persons

Denmark:
Energinet
Tonne Kjærsvej 65
DK-7000 Fredericia, Denmark
Anders Bratløv
Tel. +45 51 38 01 31
E-mail: anv@energinet.dk
Jakob Cordes Nørskov
Tel. +45 26 36 40 50
E-mail: JNV@energinet.dk

Estonia:
Elering AS
Kadaka tee 42
Tallinn, Estonia
Irene Puusaar
Tel. +372 508 4372
E-mail: irene.puusaar@elering.ee
Kaur Krusell
Tel. +372 564 86011
E-mail: kaur.krusell@elering.ee

Finland:
Fingrid Oyj
Läkkisepäntie 21, P.O. Box 530
FI-00101 Helsinki, Finland
Markku Piironen
Tel. +358 30 395 4172
Mobile +358 40 351 1718
E-mail: markku.piironen@fingrid.fi

Iceland:
Landsnet
Gylfaflöt 9, IS-.32
Reykjavik, Iceland
Kjartan Sigurjónsson
Tel. +354 825 2393
E-mail: kjartans@landsnet.is

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

Lithuania:
Litgrid AB
Karlo Gustavo Emilio Manerheimo st. 8,
LT-05131, Vilnius
Valdas Tarvydas
Tel. +370 6867 7626
E-mail: valdas.tarvydas@litgrid.eu

Norway:
Statnett SF
Nydalen allé 33, PB 4904 Nydalen
NO-0423 Oslo
Jørn Heggset
Tel. +47 71 66 92 53
E-mail: jorn.heggset@statnett.no

Sweden:
Svenska kraftnät
Sturegatan 1, P.O. Box 1200
SE-172 24 Sundbyberg
Jonathan Kristensson
Tel: +46 10 475 81 69
Mobile: +46 72 512 22 80
E-mail: Jonathan.Kristensson@svk.se
Tsega Muzollo
Mobile: +46 72 444 50 62
E-mail: tsega.muzollo@svk.se

Publisher:
ENTSO-E AISBL
Rue de Spa 8
1000 Brussels, Belgium
Tel. +32 2 741 09 50
info@entsoe.eu
www.entsoe.eu

D Contact persons for the distribution network statistics

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

Denmark:
Green Power Denmark
Vodroffsvej 59
1900 Frederiksberg C
Jens Zoëga Hansen
Tel. +45 20 90 77 85
E-mail: jzh@greenpowerdenmark.dk

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

Finland:
Energiateollisuus ry,
Finnish Energy Industries
P.O. Box 100, FI-00101 Helsinki
Visiting address:
Eteläranta 10, Helsinki
Jonna Pasi
Tel. +358 44 510 6238
E-mail: jonna.pasi@energia.fi

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

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

Lithuania:
Litgrid AB
Karlo Gustavo Emilio Manerheimo st. 8,
LT-05131, Vilnius
Valdas Tarvydas
Tel. +370 6867 7626
E-mail: valdas.tarvydas@litgrid.eu

Norway:
Statnett SF
Nydalen allé 33,
PB 4904 Nydalen, NO-0423 Oslo
Jørn Heggset
Tel. +47 71 66 92 53
E-mail: jorn.heggset@statnett.no

Sweden:
Energiföretagen Sverige
SE-101 53 Stockholm
Matz Tapper
Tel. +46 8 677 27 26
E-mail: matz.tapper@energiforetagen.se

E ENS, consumption and line length 2014–2023

Figure E.1 presents the annual amount of ENS, consumption and total length of lines for 2014–2023. The total line length is the sum of the lengths of overhead lines and cables in the 100–420 kV grids.

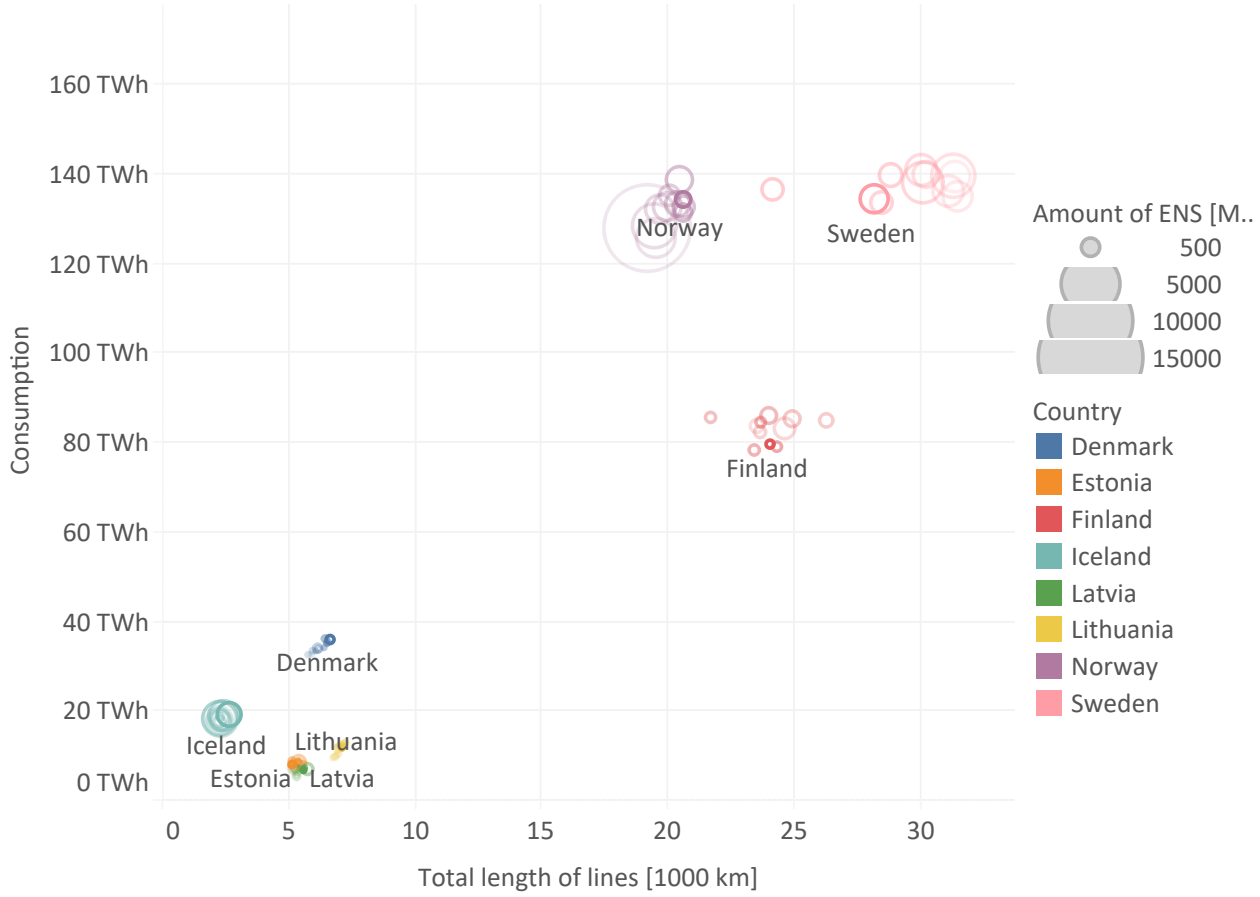

Figure E.1: The annual amount of ENS (circle size), length of lines (x-axis) and consumption (y-axis) for 2014–2023. The most recent statistical year 2023 is shown with the darkest colour. Each previous year is shown in a lighter colour.

ENTSO-E | Rue de Spa, 8 | 1000 Brussels | info@entsoe.eu | www.entsoe.eu | @entso_e