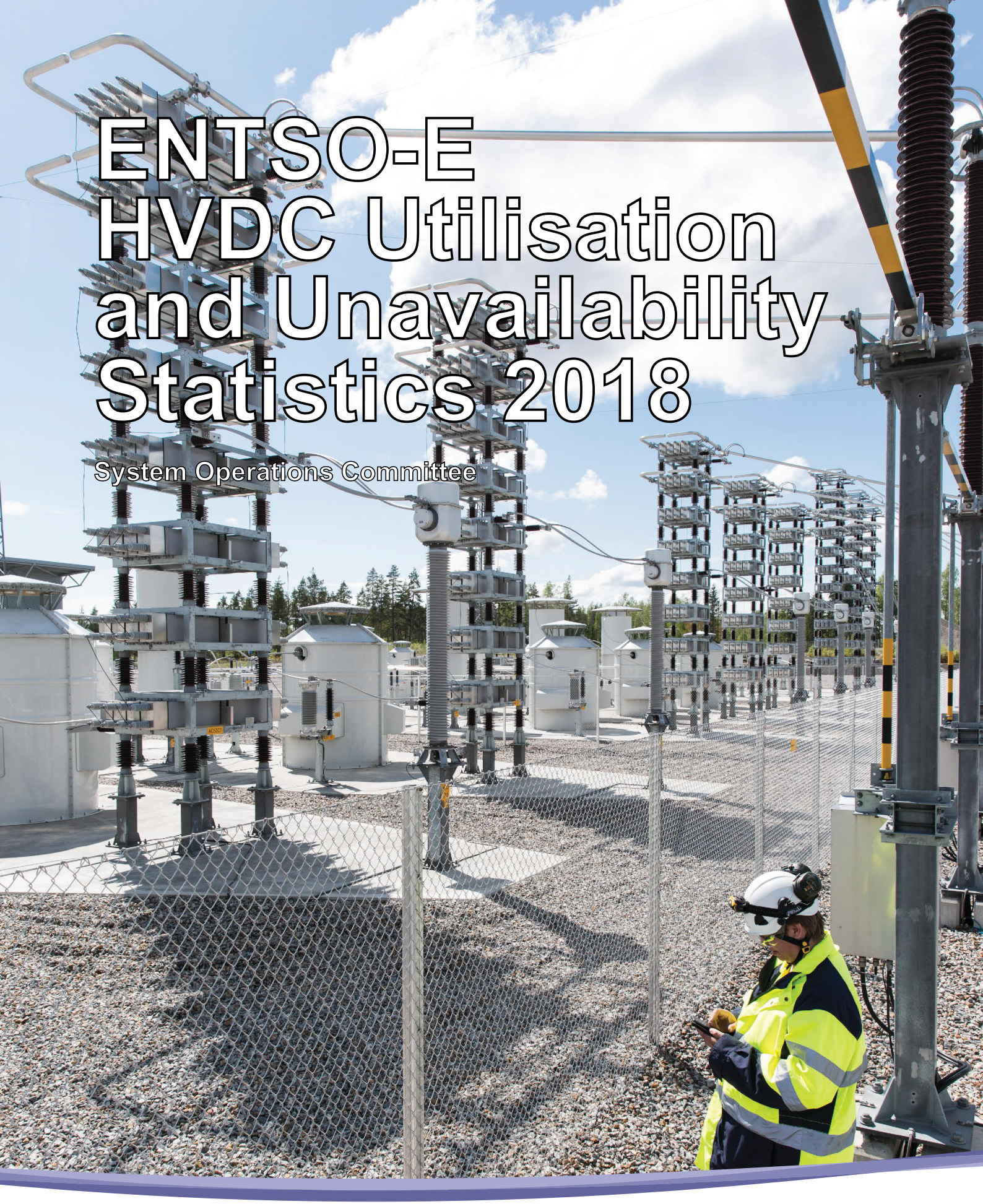

ENTSO-E HVDC Utilisation and Unavailability Statistics 2018

System Operations Committee

European Network of Transmission System Operators for Electricity

entsoe

ENTSO-E HVDC Utilisation and Unavailability Statistics 2018

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Report rendered October 9, 2019

Executive Summary

The HVDC links are important components for a stable operation of the Nordic and Baltic power system while supporting the commercial power trade in the European energy markets. Furthermore, the HVDC links can provide other important functions like voltage and emergency power support to the HVAC grid. Hence, the advantages of keeping the HVDC links in operation as much as possible are indisputable. The ENTSO-E HVDC Utilisation and Unavailability Statistics 2018 report aims to provide an overview of the Nordic and Baltic HVDC links as well as a detailed view of each individual link. The executive summary concludes the most important parts of the report into one chapter.

In 2018, 53.7 TWh of electric energy was transmitted through the Nordic and Baltic HVDC links. This is approximately 57 % of the total technical capacity (E_{max}) and correlates well with the percentage utilisation from previous years.

The total number of disturbance outages registered was 42, preventing 1.8 TWh of potential energy transmission, or 1.9 % of the total technical capacity (E_{max}). Maintenance outages amounted to 4.3 TWh, or 5.4 % of the total technical capacity (E_{max}), and limitations reduced the transmission capacity by 2.9 TWh (3.0 %) of the total technical HVDC transmission capacity. The total amount of unavailable technical capacity (E_U) compared to the total technical capacity (E_{max}) has increased by 1 % per year since 2015 and was in 2018 at its highest point since 2012. The change is mostly due to an increase in unplanned maintenance outages (E_{UM}). The unavailable technical capacity (E_U) includes disturbance outages (E_D), limitations (E_L), unplanned (E_{UM}) and planned maintenance outages (E_{PM}) and other outages (E_{OO}). The amount unavailable technical capacity (E_U) due to limitations did not deviate significantly compared to recent years. However, a significant amount of them were due to seasonal causes as a result of a hot summer in 2018.

The most significant events in 2018 occurred for Baltic Cable, Kontek, NordBalt, NorNed and Skagerak 1–3. Baltic Cable had two larger disturbances caused by a cable and a transformer failure, Kontek had an oil leak from a land cable, NordBalt had its DC underground cable joints replaced, NorNed had a cable fault and Skagerak 1–3 had their electrode masts regalvanized and electrode lines replaced.

The use of Estlink 1 continued to be small in 2018. Only 11 % of the available technical capacity (E_A) was used to transmission in 2018. The use of Estlink 2 increased compared to 2017 and was 51 %. The percentage of unavailable annual hours increased to 8 % for Estlink 1 due to a major AC phase reactor fault, and the value for Estlink 2 continued to be very low, approximately 1 %. The number of disturbances were lower than average in both Estlink 1 and Estlink 2.

The use of Fenno-Skan 1 continued to be very high in 2018. Even 95 % of the available capacity (E_A) was used for transmission of which 97 % was import to Finland. Fenno-Skan 1 was available almost all the time in 2018. The percentage of unavailable annual hours was insignificant, as it was during 2016–2017. Technical capacity not used (E_{TCNU}) for Fenno-Skan 2 remained at the same level as during the previous year. It was 40 % in 2017 and 39 % in 2018. 53 % of the total available capacity (E_A) was used for import to Finland and 7 % export to Sweden in 2018. The number of disturbances were lower than the 5-year average in both Fenno-Skan 1 and Fenno-Skan 2.

The utilisation of Konti-Skan 1 has decreased by 6 % since 2016, when it was 58 %, while the utilisation of Konti-Skan 2 has not changed significantly. The unavailable technical capacity (E_U) has not changed significantly since 2016.

LitPol Link has been utilised more since 2016 and was 53 % of the total technical capacity (E_{max}) in 2018. Furthermore, the unavailable technical capacity (E_U) has decreased annually since 2016.

Storebaelt and SwePol utilisations have not changed remarkably during the recent years, and were utilised for transmission for 64 % and 66 % percent of the total technical capacity (E_{max}) during 2018.

Annual utilization of Vyborg Link has increased every year during last 5 years. It was 67 % in 2018. 100 % of transmission is import to Finland from Russia. There were no outages in 2018 but the connection was limited 12 % of annual hours, which is 5 times more than normally.

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1 Introduction and Background

This report presents the availability and utilisation of HVDC links connected to the Nordic and Baltic power system in 2018, with an emphasis on disturbance outages. This includes an overview of availability and utilisation for the HVDC links, information about disturbances and unavailability and individual presentations of the performance of each HVDC link.

The first version of the HVDC statistics for utilization and unavailability was published in 2011 as an addition to the Nordic Grid Disturbance and Fault Statistics of year 2010. At that time, the report covered only the Nordic power systems and presented 14 HVDC links. For the statistical year 2012, the HVAC Grid Disturbance Report and HVDC statistics were separated into two reports, which is the format of the reports today. For the statistical year 2014, the Baltic TSOs joined. Additionally, two HVDC links were added for the statistical year 2014: Estlink 2 and Skagerak 4. For the statistical year 2016, LitPol Link and NordBalt were added to the report.

The total HVDC transmission capacity connected to the Nordic and Baltic power systems in 2018 is 10.2 GW, which makes the annual transmission capacity 89.1 TWh. Most of the HVDC links connect the Nordic synchronous system to other systems. The HVDC links and their defined export direction in the report are shown in Figure 1.1. Each HVDC link has a defined export direction only in order to distinguish a direction of power flow.

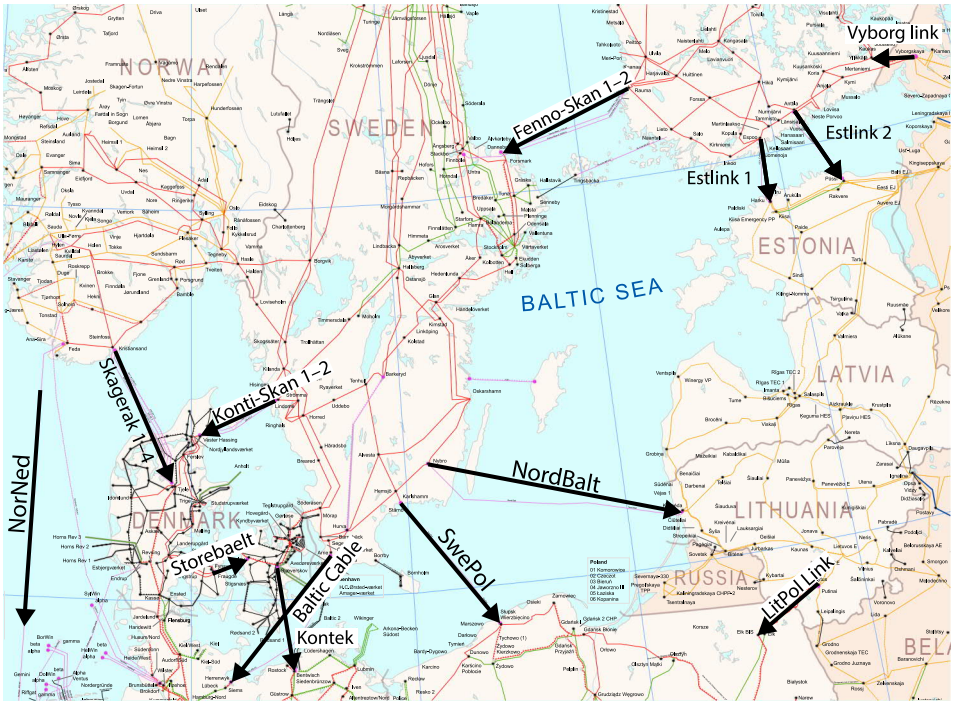

Figure 1.1: Part of Interconnected network of Northern Europe [1] map showing the HVDC links. To distinguish the direction of power flow, each link has a defined export direction in this report. This direction is indicated by the arrows.

The HVDC links are important components for a stable operation of the Nordic and Baltic power system while supporting the commercial power trade in the European energy markets. Furthermore, the HVDC links can provide other important functions like voltage and emergency power support to the HVAC grid. Hence, the advantages of keeping the HVDC links in operation as much as possible are indisputable.

To achieve as much uptime as possible, the number and length of disturbance outages must be kept at minimum. This requires high-quality hardware components, thorough installation routines, and efficient fault analysis combined with preventive maintenance. However, planned outages and limitations due to maintenance work are necessary but should be planned and conducted as efficiently as possible.

Therefore, mapping the available capacity, including the reasons for unavailability, is of vital interest for the utilisation of this infrastructure. Furthermore, the utilisation of the links directly correlates with the commercial value of the energy trade.

2 Scope

The DISTAC HVDC statistics presents a macro view of the availability and utilization of each HVDC link, including disturbance, maintenance and other outage events as well as limitations. Limitations originating from maintenance work done in the AC grid are also included if they affect the power transfer of an HVDC connection. Furthermore, disturbance outages are more thoroughly examined than other events.

The DISTAC HVDC statistics has a different scope than the CIGRE HVDC statistics, which focuses more on outages, faults and disturbances of the HVDC links. This means that CIGRE is more detailed regarding what happens at the HVDC station, and includes transients, commutation failures, thyristor failures and so on. In general, DISTAC has the macro view and CIGRE has the micro view. But most of the data is the same for both reports.

2.1 Contact persons

Each country is represented by at least one contact person, responsible for the statistical information of the corresponding country. The contact person can provide additional information concerning the HVDC availability and utilisation statistics. The relevant contact information is given in Appendix B.

3 Methods, definitions and calculations

This Chapter explains the availability and utilisation categories of the HVDC statistics. For a more thorough explanation of theory, calculations and definitions, read the *HVDC Guideline for Utilisation and Unavailability Statistics* [2].

The technical capacity (E_{max}) of the HVDC link is the maximum energy that can be physically transmitted through the HVDC link to the converter station on the importing side, excluding all HVDC link losses, during a year.

To analyse the availability and utilisation of an HVDC link in detail, the technical capacity is divided into two categories: **available technical capacity (E_A)** and **unavailable technical capacity (E_U)**. The **available technical capacity (E_A)** is further divided into categories of technical capacity that has been utilised, that is, **imported energy (E_I)** and **exported energy (E_E)**, and into technical capacity that has not been utilised, that is, **technical capacity not used (E_{TCNU})**. The **unavailable technical capacity (E_U)** is divided into categories of technical capacity that could not be utilised. They are: **limitations (E_{Lim}), disturbance outages (E_D), unplanned maintenance (E_{UM}), planned maintenance (E_{PM})** and **other outages (E_{OO})**. These categories are visually presented in Figure 3.1.

As stated above, the **available technical capacity (E_A)** is the part of the **technical capacity (E_{max})** that has or could have been utilised.

- **Technical capacity not used (E_{TCNU})** is the amount of energy that has not been imported or exported or been unavailable due to limitations or outages.
- **Imported energy (E_I)** is the energy transferred from the HVDC link to the importing AC side. The direction of import is defined for each HVDC link and can be viewed in Table 4.1 or in the respective subChapter for the link in Chapter 5.3. It does not include **import losses (L_I)**, that is, the energy losses in any of the HVDC link components during import. It should be noted that these values are measurements and therefore considered factual.
- **Exported energy (E_E)** and **export losses (L_E)** is defined like the imported energy, but with an opposite point of view.

The **unavailable technical capacity (E_U)** is the part of the **technical capacity (E_{max})** that could not be utilised. It consists of limitations and outages, where an outage is when a component is fully disconnected from the system and the transfer capacity is reduced to zero. Limitations and the different types of outages are explained as:

- A **limitation (E_{Lim})** is a condition when the transmission capacity of an HVDC link is limited, that is, the power transmission capacity of the link is less than the rated power. The limitation is always motivated from a technical perspective, but not always concerning the link itself. The most common causes of limitations are:
  - faults on any HVDC link component that do not cause a total outage;
  - faults, congestions or outages in the AC grid causing a limitation in the transmission capacity of the link;
  - seasonal variations on the transmission capacity of the HVDC link.
- **Disturbance outages (E_D)** is technical capacity lost due to a fault on the HVDC link or in the AC grid causing a total outage of the link. This could be a forced outage or an automatic trip.
- **Unplanned maintenance outages (E_{UM})** is technical capacity lost due to emergency or otherwise urgent repair work or maintenance on the HVDC link, often with minimal warning time. Repair work or replacements due to a disturbance outage is also unplanned maintenance, even if the work lasts for a long time. Unplanned maintenance might affect the intraday power market if it cannot be postponed to more suitable times.
- **Planned maintenance outages (E_{PM})** is technical capacity lost due to maintenance work on the HVDC link. The work must be done to retain an entity's ability to perform its required function. Examples for planned maintenance are annual and preventive maintenance, replacement and updating of components.
- **Other outages (E_{OO})** is technical capacity lost due to any other reason except those mentioned above. This could be, for example, when the markets do not need the transmission capacity of the link and the link is disconnected.

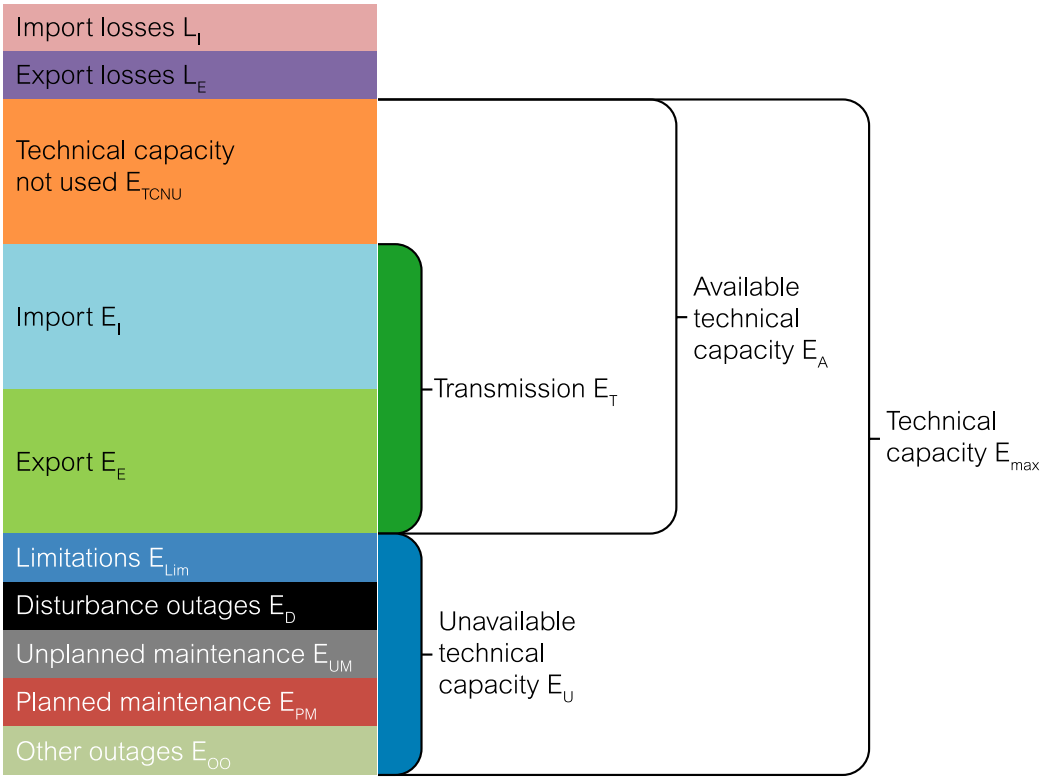

Figure 3.1: The availability and utilisation categories used in the HVDC statistics. Every value is an energy value and represents a part of the technical capacity. The technical capacity is divided into two smaller categories**: available technical capacity (E_A)** and **unavailable technical capacity (E_U)**. The available technical capacity is further divided into categories of technical capacity that has been utilised, that is, **imported energy (E_I)** and **exported energy (E_E)**, and into technical capacity that has not been utilised, that is, **technical capacity not used (E_{TCNU})**. The unavailable technical capacity is divided into categories of technical capacity that could not be utilised. They are: **limitations (E_{Lim}), disturbance outages (E_D), unplanned maintenance (E_{UM}), planned maintenance (E_{PM})** and **other outages (E_{OO})**.

4 Technical details of the HVDC links

Table 4.1 presents the main properties of the HVDC links while Table 4.2 presents the technical properties of the HVDC lines. The defined export directions are also presented in Figure 1.1.

Schematic presentations of the HVDC links and their converter stations, both for line-commutated converters (LCC) and voltage source converters (VSC) are presented in Appendix A.

Table 4.1: Main properties of the HVDC links

Link	Commissioning year	Market connection	Type of HVDC converter	Rated power, monopolar (MW)	Parallel monopolar capacity (MW)	Bipolar capacity (MW)	Defined export direction
Baltic Cable	1994	Yes	LCC	600			South
Estlink 1	2006	Yes	VSC	350	1000		South
Estlink 2	2014	Yes	LCC	650			South
Fenno-Skan 1	1989	Yes	LCC	400	1200	1200	West
Fenno-Skan 2	2011	Yes	LCC	800			West
Kontek	1995	Yes	LCC	600			South
Konti-Skan 1[2]	2008	Yes	LCC	370	680/740		West
Konti-Skan 2[2]	1988	Yes	LCC	370			West
LitPol Link	2015	Yes	LCC	500			West
NordBalt	2016	Yes	VSC	700			South
NorNed	2008	Yes	LCC	700			South
Skagerak 1	1976–	Yes	LCC	236			South
Skagerak 2	1977	Yes	LCC	236	1000	1000	South
Skagerak 3	1993	Yes	LCC	478			South
Skagerak 4	2014	Yes	VSC	682			South
Storebaelt	2010	Yes	LCC	600			East
SwePol	2000	Yes	LCC	600			South
Vyborg Link[1]	1981, 1982, 1984, 2000	Partly	LCC	1400			West
Total				10272	3940	2200	

[1] Each commissioning increased capacity by 350 MW. However, the total commercial capacity of Vyborg Link is 1300 MW. Fingrid Oyj, the Finnish transmission system operator, allocates 100 MW for reserves.
[2] Konti-Skan is rated differently depending of direction of flow. West to east, that is import, 740 MW (370+370) and east to west, that is export, 680 MW (340+340).

Table 4.2: Technical details of the HVDC lines

Link	Total length of the link (km)	Length of mass cable (km)	Length of PEX cable (km)	Length of DC overhead line (km)	Length of DC back-to-back connection (km)
Baltic Cable	262	250		12	
Estlink 1	105		210 (2 × 105 km)		
Estlink 2	171	157		14	
Fenno-Skan 1	233	200		33	
Fenno-Skan 2	299	196		103	
Kontek	160		160		
Konti-Skan 1	150	89		61	
Konti-Skan 2	150	89		61	
LitPol Link	< 1				< 1
NordBalt	450		2 × 450		
NorNed	580	580			
Skagerak 1	212.5	133.6		78.5	
Skagerak 2	211.4	132.9		78.5	
Skagerak 3	212.9	134.4		78.5	
Skagerak 4	226	226			
Storebaelt	57	57			
SwePol	254	254			
Vyborg Link	< 1				< 1

5 Results

This Chapter presents the utilisation and unavailability of all the HVDC links as well as individual presentations of each HVDC link connected to the Nordic and Baltic power system.

Section 5.1 provides an overview of the HVDC links for the year 2018 and Section 5.2 provides an overview of the years 2012–2018. Section 5.3 presents the availability and utilisation of each HVDC link for the year 2018 as well as an annual overview of the utilisation and a trend of the utilisation and the number of outages for the years 2012–2018.

5.1 Overview of 2018

In 2018, 53.7 TWh of electric energy was transmitted through the Nordic and Baltic HVDC links. The total number of disturbance outages registered was 42, preventing 1.8 TWh of potential energy transmission, or 1.9 % of the total technical capacity (E_{max}).

Maintenance outages amounted to 4.3 TWh, or 4.4 % of the total technical capacity (E_{max}), and limitations reduced the transmission capacity by 2.9 TWh (3.0 %) of the total technical HVDC transmission capacity.

Figure 5.1 presents the overview of the availability and utilisation of HVDC statistics at an aggregated level, thus allowing to compare links with each other. It should be noted that the usages of the links show big variations. Most links are market dependent, some are mostly used only in one direction, and some are used for technical reasons to control power flow for system stability according to agreements.

Appendix C shows the overviews of the HVDC links using the same values as Figure 5.1 but ranked according to the highest unavailable technical capacity, according to the highest transmission, and according to the highest technical capacity not used.

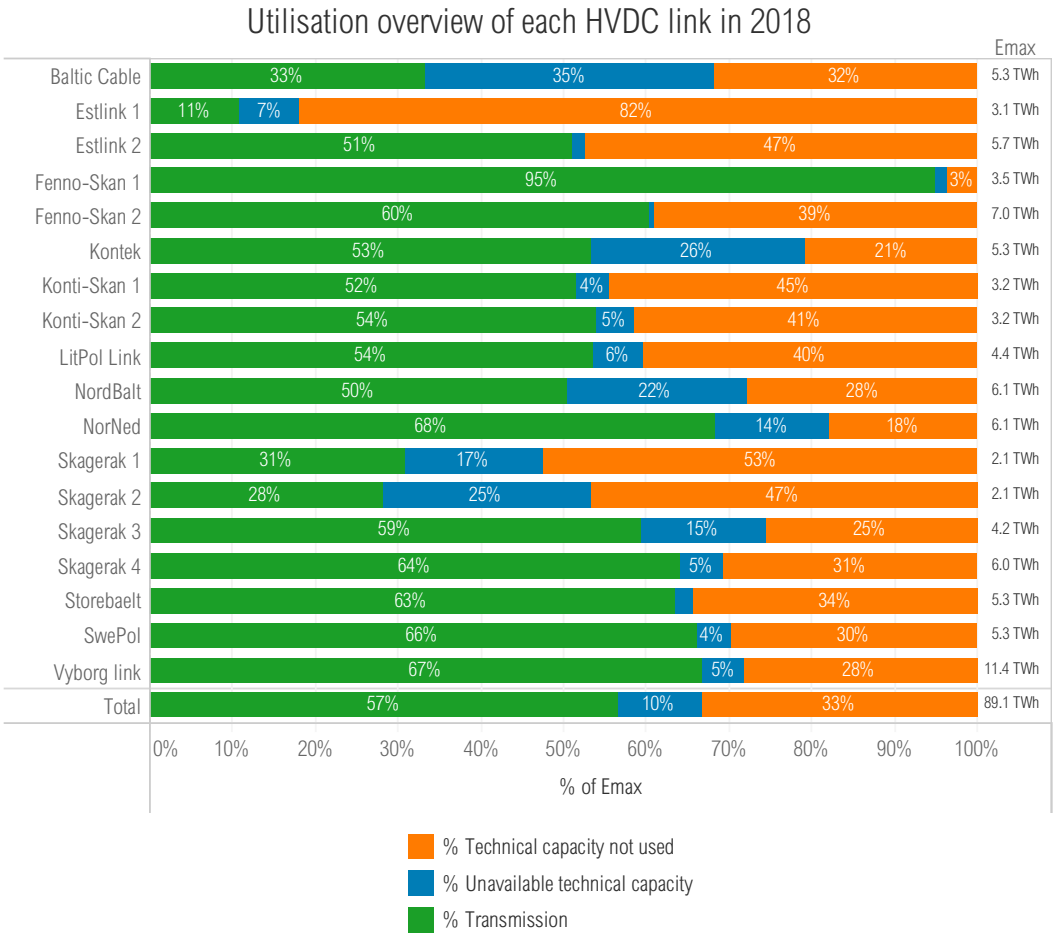

Figure 5.1: Overview of the availability and utilisation of each HVDC link in 2018. The unavailable technical capacity (E_U) is the amount of technical capacity (E_{max}) not available due to limitations or outages. Transmission (E_T) is the amount of technical capacity (E_{max}) imported and exported through the HVDC link. Technical capacity not used (E_{TCNU}) is the amount of energy that has not been imported or exported or been unavailable due to limitations or outages. More detailed explanations can be read in Chapter 3.

Figure 5.2 presents the percentage unavailable technical capacity (E_U) of the annual technical capacity (E_{max}) due to the disturbance outages. Figure 5.3 presents the number of all disturbance, maintenance and other outages. The most notable explanations for the unavailability in 2018 were the following:

- Baltic Cable had 4 disturbance outages during 2018, of which two were more severe. The former of them was caused by a cable failure in March and the latter was caused by a transformer failure in December.
- Estlink 1 had one major disturbance outage in November that was caused by a major fault in the AC phase reactors.
- Kontek had an oil leak from a land cable in May that was finally repaired in September.
- NordBalt planned maintenance was caused by a longer maintenance operation to replace the DC underground cable joints.
- NorNed disturbance outage was caused by a cable fault in March, which was repaired in April;
- Skagerak 1,2 and 3 had their electrode masts regalvanized and electrode lines replaced, which caused the high amount of planned maintenance in 2018. Additionally, Skagerak 2 had a disturbance outage caused by a transformer failure.
- The limitations on Skagerak 4 were mainly related to the electrode current when Skagerak 3 was out due to maintenance.

- Vyborg Link limitation in July was caused by annual maintenance. Normally, maintenance work causes only limitations because the 350 MW units are not worked on simultaneously.

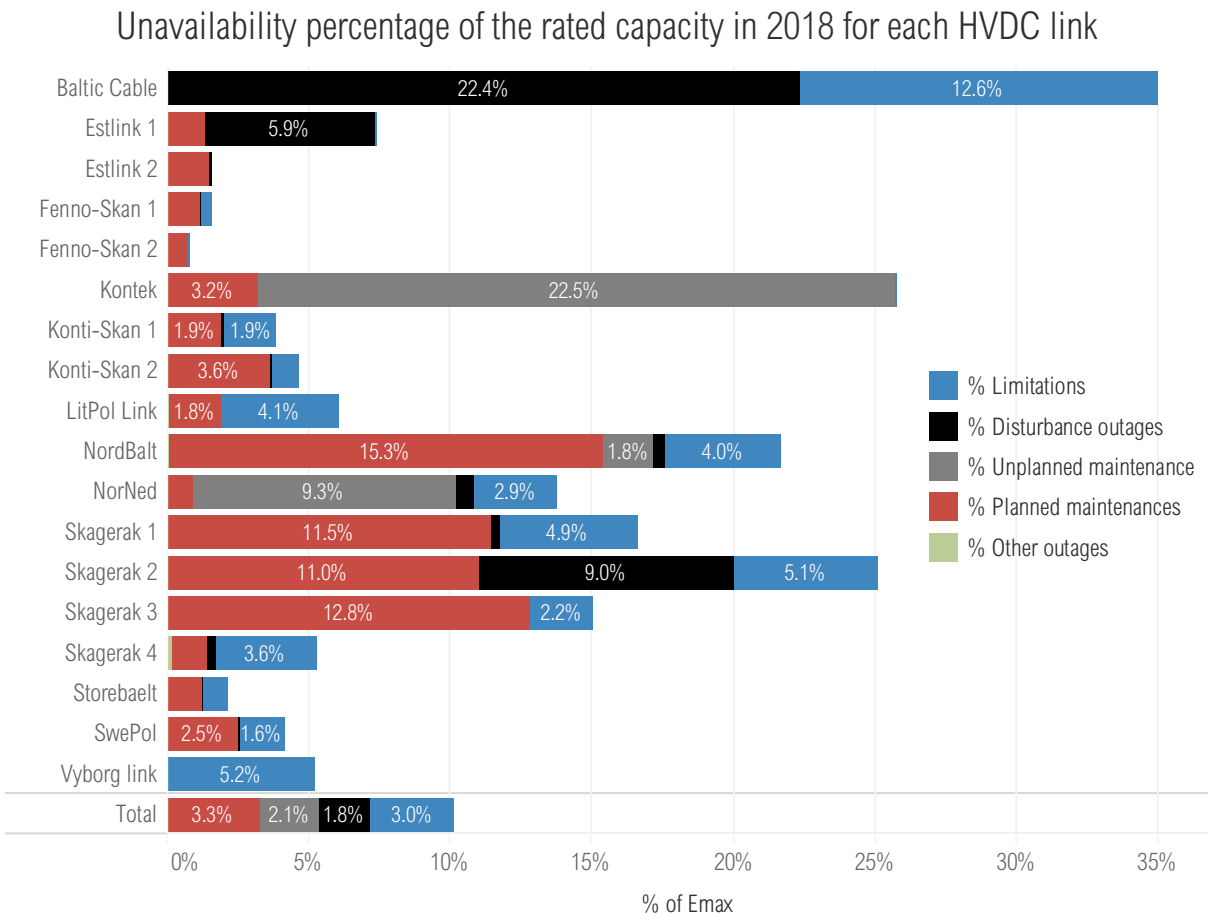

Figure 5.2: Percentage distribution of unavailable technical capacity (E_U) due to limitations, disturbance outages, unplanned and planned maintenance and other outages for each link in 2018. Several HVDC links were more limited in 2018 than previous years due to high outdoor temperatures during summer.

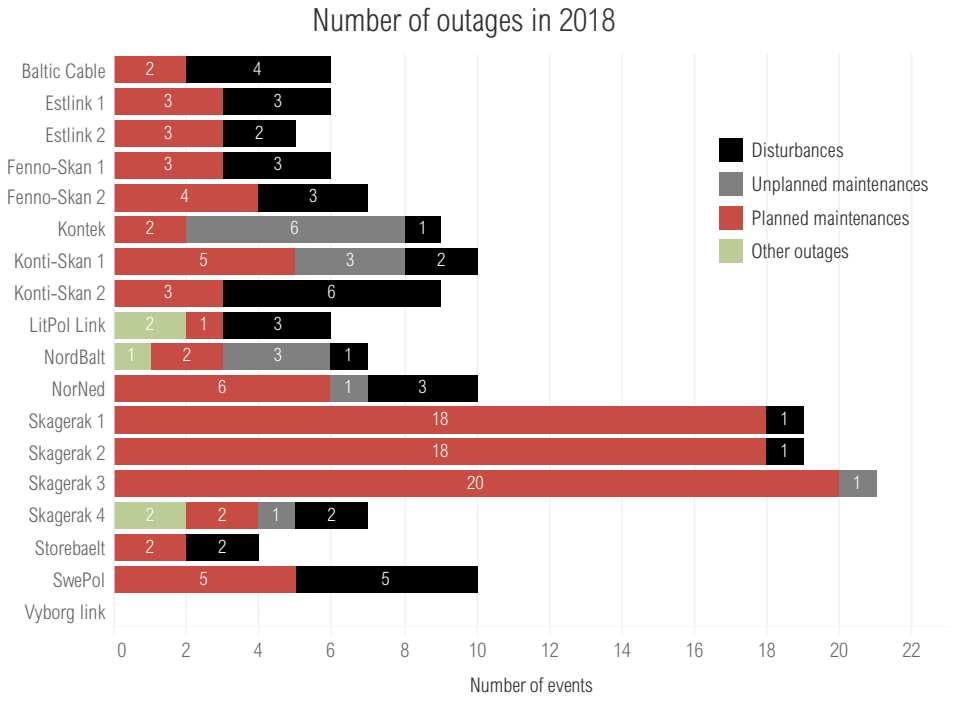

Figure 5.3: The number of disturbance, unplanned maintenance, planned maintenance and other outages for each link in 2018.

5.2 Overview of years 2012–2018

Because the HVDC links are an important component in the Nordic and Baltic power systems, it is also very interesting to see how the links have been utilised during the past years. Figure 5.4 presents the annual utilisation (%) of all HVDC links and Figure 5.5 presents the annual utilisation with all utilisation categories. Figure 5.6 presents the percentage of hours a link has been affected by either a limitation, unplanned or planned maintenance or disturbance or other outages.

As can be seen, the technical capacity not used (E_{TCNU}), the transmission (E_T) and the unavailable technical capacity (E_U) has not changed significantly since 2012. However, the total technical capacity (E_{max}) of all HVDC links has increased, as can be seen in Figure 5.5.

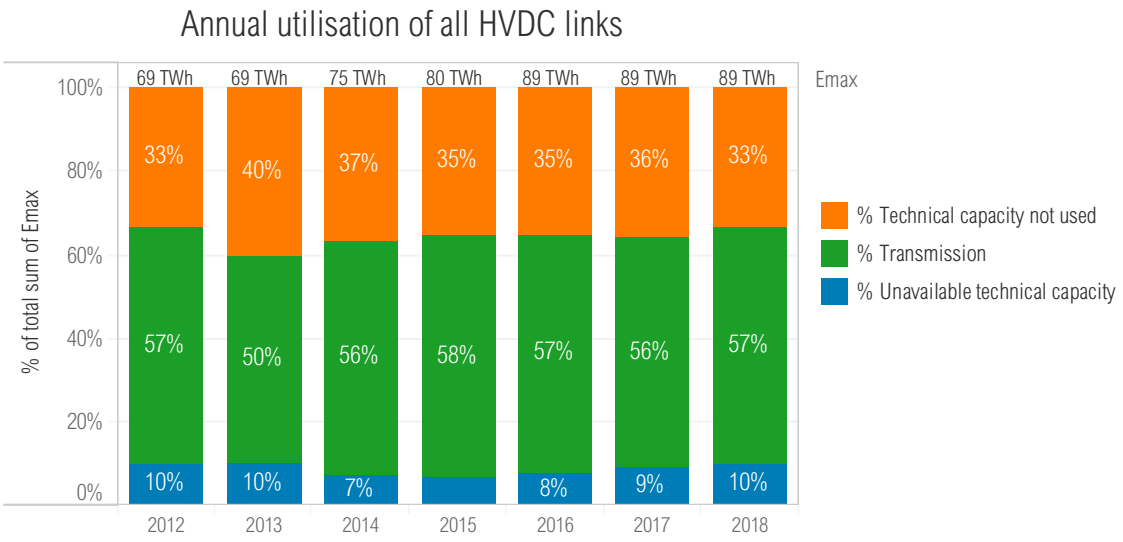

Figure 5.4: The annual utilisation of all HVDC links since 2012. The unavailable technical capacity (E_U) is the amount of technical capacity (E_{max}) not available due to limitations or outages. Transmission (E_T) is the amount of technical capacity (E_{max}) imported and exported through the HVDC links. Technical capacity not used (E_{TCNU}) is the amount of energy that has not been imported or exported or been unavailable due to limitations or outages. More detailed explanations can be read in Chapter 3. As can be seen, the technical capacity not used (E_{TCNU}), the transmission (E_T) and the unavailable technical capacity (E_U) has not changed significantly since 2012.

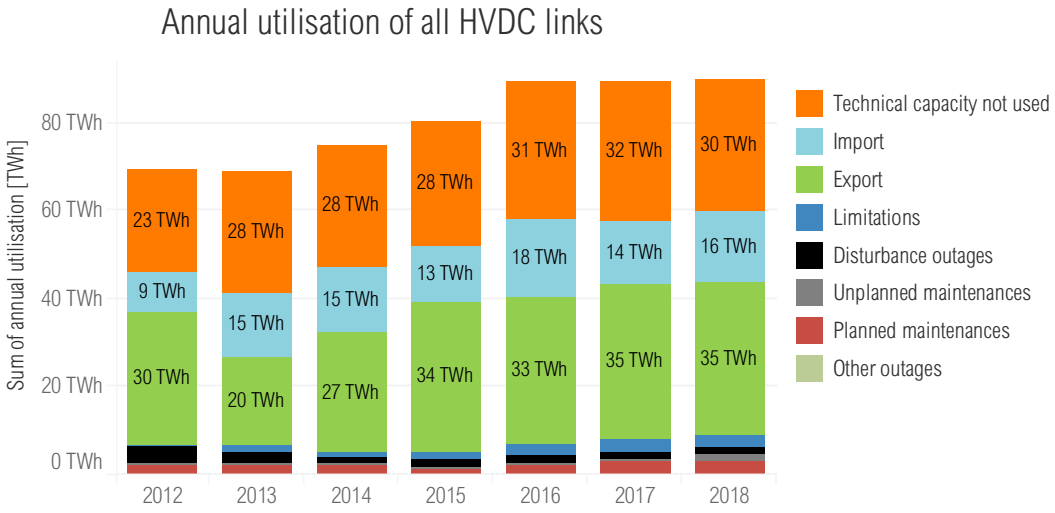

Figure 5.5: Annual utilisation of all HVDC links presented in megawatt hours (MWh). Technical capacity not used (E_{TCNU}) is the amount of energy that has not been imported or exported or been unavailable due to limitations or outages. Transmission (E_T) is the amount of technical capacity (E_{max}) imported and exported through the HVDC links. Limitations, disturbance outages, unplanned and planned maintenance outages and other outages form together the unavailable technical capacity (E_U). More detailed explanations can be read in Chapter 3. From 2012, there are 14 HVDC links included. As of 2014, Estlink 2 and Skagerak 4 were added. In 2016, LitPol Link and NordBalt were added. The maximum technical capacity (E_{max}) is marginally higher in 2012 and 2016 because they are leap years.

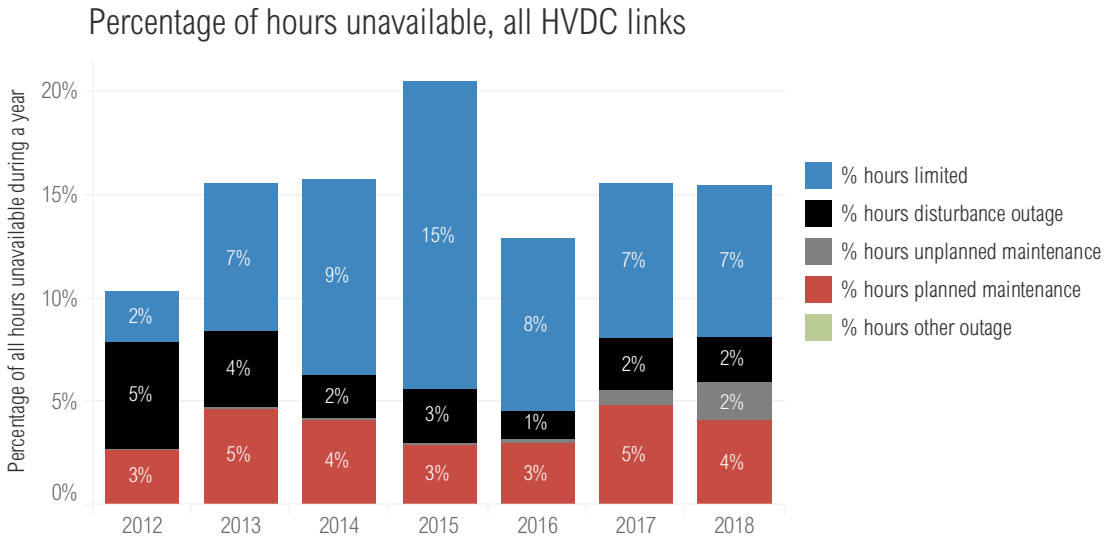

Figure 5.6: The percentage of hours all HVDC links have been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage. The percentage is calculated by counting the number of hours with an limitation or outage and dividing it by the total number of hours in a year. Therefore, the result may show more than 100 % if one hour is affected by multiple types of outages or limitations.

5.3 Individual presentations of each HVDC link

This Section presents the performance of each HVDC link. The categories used in the following presentations of each separate HVDC link are presented and defined in Chapter 3.

Note that the sums in the tables for each link may show a technical capacity E_{max} higher than the E_{max} stated in the diagram. This is due to power flow higher than rated technical power capacity of the links. Other times, when power flow is below the rated technical capacity (and there is no limitation reported), the difference is registered in the category "technical capacity not used".

5.3.1 Baltic Cable

Figure 5.7 presents the availability and utilisation of Baltic Cable for 2018 and Table 5.1 presents the numerical values behind it. Baltic Cable is connected between southern Sweden (bidding zone SE4) and Germany (bidding zone DE-TenneT). The operations started in 1994 and the transmission capacity is 600 MW.

In 2018, Baltic Cable had an available technical capacity of 66 %. The technical capacity not used was 34 %. Totally, 1.3 TWh (24 % of the technical capacity) was exported from Sweden to Germany and 454 GWh (8 % of the technical capacity) was imported to Sweden.

The annual maintenance of Baltic Cable lasted 2 days in May. Additionally, Baltic Cable had 4 disturbance outages during 2018, of which two were more severe. The former of them was caused by a cable failure in March and the latter was caused by a transformer failure in December.

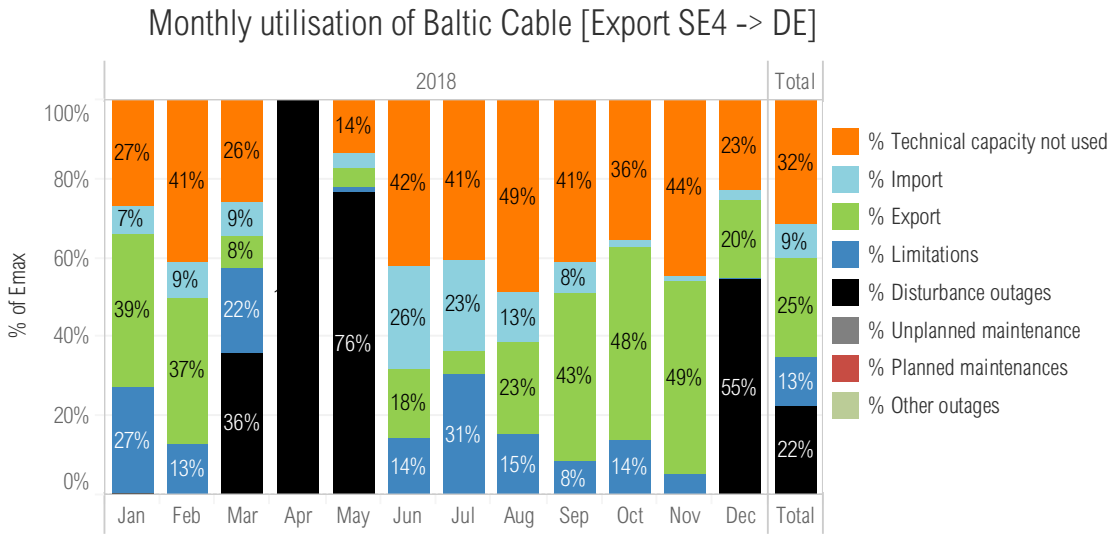

Figure 5.7: Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Baltic Cable in 2018.

Table 5.1: Monthly distribution of the technical capacity (E_{max}) for The Baltic Cable in 2018. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Baltic Cable [Export SE4 -> DE] — 2018

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Import losses, GWh	0.7	0.8	0.8	-	0.3	2.5	2.2	1.2	0.7	0.2	0.2	0.2	9.8
Export losses, GWh	5.6	5.8	2.1	-	0.8	2.6	2.8	3.9	4.2	6.2	6.7	2.3	43.0
Technical capacity not used, GWh	119.1	166.3	114.3	-	60.6	181.3	182.4	217.2	178.0	159.5	192.0	102.2	1672.9
Import, GWh	33.0	37.0	39.5	-	15.4	112.9	101.2	56.0	33.4	8.7	6.7	10.3	454.2
Export, GWh	173.9	149.0	36.7	-	22.2	76.6	25.1	104.7	184.1	217.2	212.2	88.9	1290.7
Limitations, GWh	120.5	51.8	95.9	-	6.8	61.3	137.8	68.5	36.5	62.6	21.6	1.1	664.4
Disturbance outages, GWh	1.2	-	159.5	432.0	341.4	-	-	-	-	-	0.6	244.4	1179.1
Unplanned maintenances, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenances, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	447.7	404.2	446.0	432.0	446.5	432.2	446.4	446.4	432.0	447.9	433.1	447.0	5261.3

Figure 5.8 presents the annual utilization of Baltic Cable according to all the categories of technical capacity (E_{max}) for the years 2012–2018. The availability and unavailability categories are explained further in Section 3. Figure 5.9 presents the percentage of hours of a year Baltic Cable has been affected by either a limitation, an unplanned or planned maintenance outage, a disturbance outage or an other outage annually during the years 2012–2018. Figure 5.10 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2018.

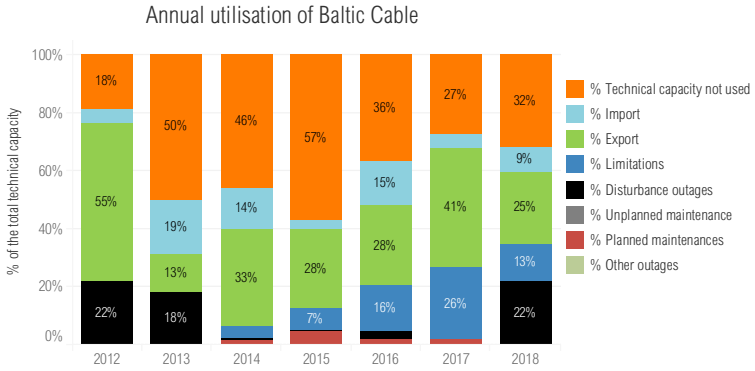

Figure 5.8: Annual utilisation of Baltic Cable according to the utilisation and unavailability categories for the years 2012–2018. The utilisation and unavailability categories are described in more detail in Section 3.

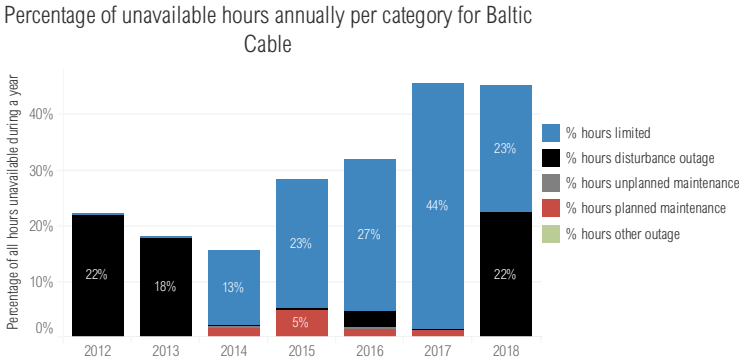

Figure 5.9: Percentage of hours Baltic Cable has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2018. The percentage is calculated by counting the number of hours with an limitation or outage and dividing it by the total number of hours in a year. Therefore, the result may show more than 100 % if one hour is affected by more than one kind of limitation or outage.

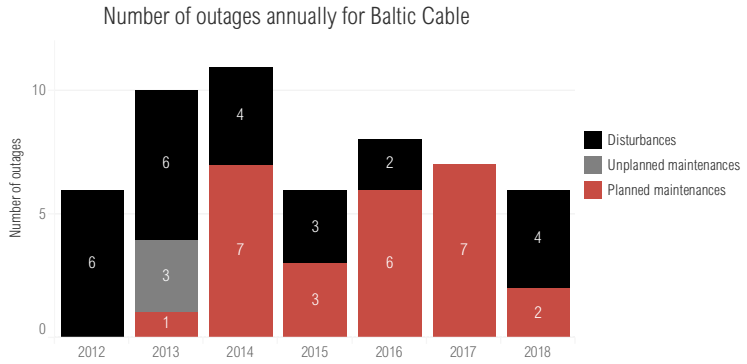

Figure 5.10: The annual number of disturbances, unplanned and planned maintenance outages and other outages Baltic Cable for the years 2012–2018. Baltic cable had no other outages during the years 2012–2018.

5.3.2 Estlink 1

Figure 5.11 presents the availability and utilisation of Estlink 1 for 2018 and Table 5.2 presents the numerical values behind it. Estlink 1 has been in operation since 2006 and is the first HVDC connection between Finland and Estonia. In Finland, it is connected to Espoo substation (bidding zone FI) and in Estonia, it is connected to Harku substation (bidding zone EE). The transmission capacity of Estlink 1 is 350 MW.

In 2018, Estlink 1 had an available technical capacity of 93 %. The technical capacity not used was 82 % due to that Estlink 2 is prioritised because of its lower transmission losses and because Estlink 1 is often used in Automatic Frequency Control Mode. Totally, 204 GWh (7 % of the technical capacity) was exported from Finland to Estonia and 126 GWh (4 % of the technical capacity) was imported to Finland.

The annual maintenance of Estlink 1 lasted four days in June. Additionally, there were two minor disturbances during 2018 and one major in November, which was caused by a major fault in the AC phase reactors.

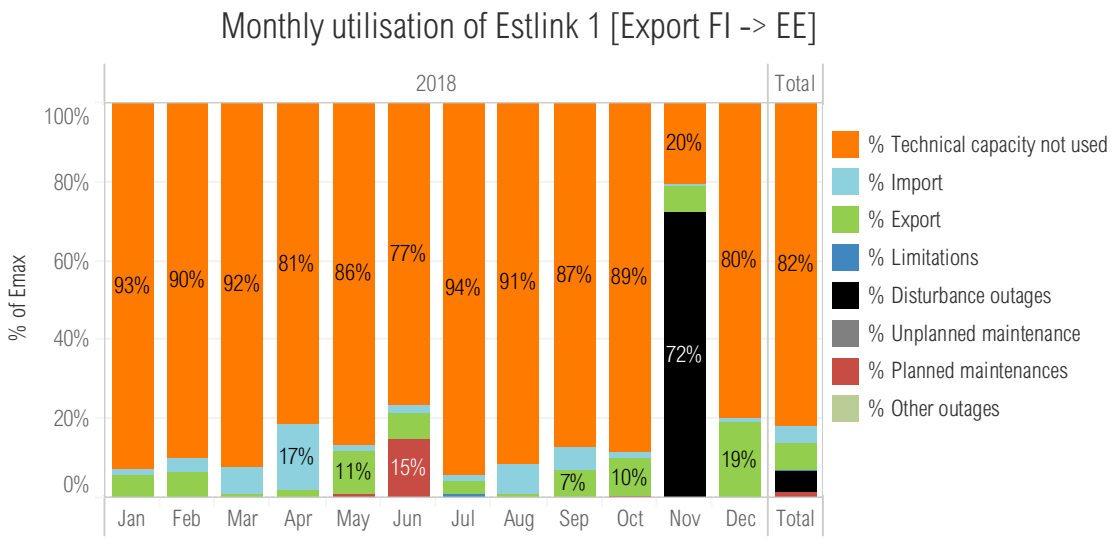

Figure 5.11: Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Estlink 1 in 2018.

Table 5.2: Monthly distribution of the technical capacity (E_{max}) for Estlink 1 in 2018. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Estlink 1 [Export FI -> EE]	2018												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Import losses, GWh	1.5	1.5	2.1	3.1	1.4	1.3	1.7	2.7	1.8	1.3	0.3	1.2	19.8
Export losses, GWh	1.8	1.7	1.2	1.1	2.6	1.9	1.8	1.1	2.0	2.4	1.1	3.5	22.1
Technical capacity not used, GWh	241.1	211.5	240.4	204.6	225.0	193.5	245.1	237.7	219.7	230.8	51.4	208.4	2509.2
Import, GWh	4.5	8.3	17.0	42.6	4.4	4.5	4.1	20.0	14.2	2.9	1.2	2.6	126.4
Export, GWh	14.7	15.4	3.0	4.8	28.5	16.3	8.4	2.7	18.1	24.9	17.3	49.3	203.5
Limitations, GWh	-	-	-	-	-	-	2.7	-	-	-	-	-	2.7
Disturbance outages, GWh	-	-	-	-	-	-	-	-	-	-	182.2	-	182.2
Unplanned maintenances, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenances, GWh	-	-	-	-	2.4	37.8	-	-	-	1.8	-	-	42.0
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	260.4	235.2	260.4	252.0	260.4	252.0	260.4	260.4	252.0	260.4	252.0	260.4	3066.0

Figure 5.12 presents the annual utilization of Estlink 1 according to all the categories of technical capacity (E_{max}) for the years 2012–2018. The availability and unavailability categories are explained further in Section 3. Figure 5.13 presents the percentage of hours of a year Estlink 1 has been affected by either a limitation, an unplanned or planned maintenance outage, a disturbance outage or an other outage annually during the years 2012–2018. Figure 5.14 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2018.

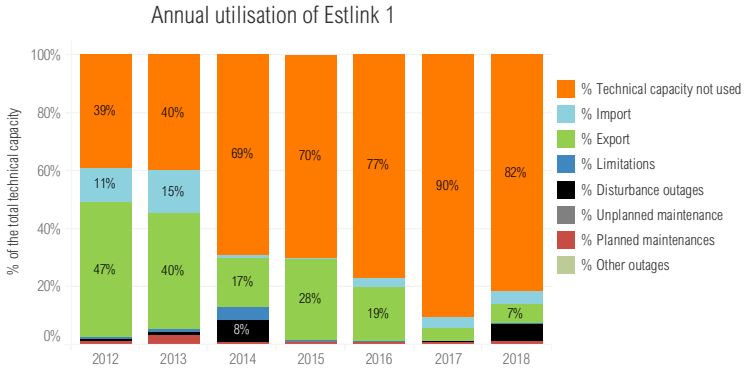

Figure 5.12: Annual utilisation of Estlink 1 according to the utilisation and unavailability categories for the years 2012–2018. The utilisation and unavailability categories are described in more detail in Section 3.

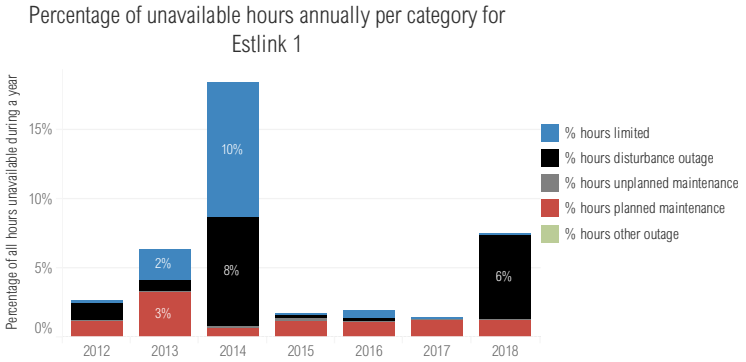

Figure 5.13: Percentage of hours Estlink 1 has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2018. The percentage is calculated by counting the number of hours with an limitation or outage and dividing it by the total number of hours in a year. Therefore, the result may show more than 100 % if one hour is affected by more than one kind of limitation or outage.

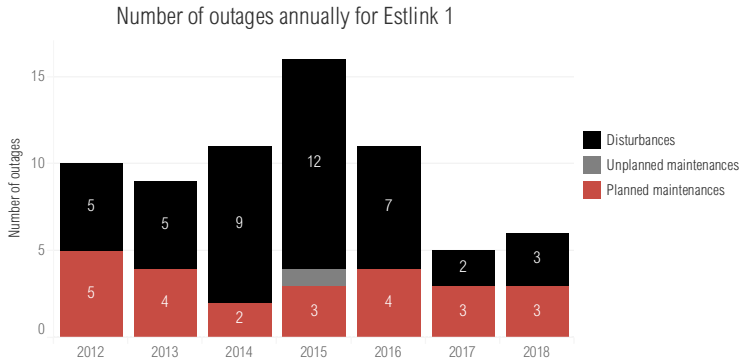

Figure 5.14: The annual number of disturbances, unplanned and planned maintenance outages and other outages Estlink 1 for the years 2012–2018. Estlink 1 had no other outages during the years 2012–2018.

5.3.3 Estlink 2

Figure 5.15 presents the availability and utilisation of Estlink 2 for 2018 and Table 5.3 presents the numerical values behind it. Estlink 2 was commissioned in Feb 2014 and is the second HVDC connection between Finland and Estonia. In Finland, it is connected to Anttila substation (bidding zone FI) and in Estonia, it is connected to Püssi substation (bidding zone EE). The transmission capacity of Estlink 2 is 650 MW.

In 2018, Estlink 2 had an available technical capacity of 98 %. The technical capacity not used was 47 %. Totally, 2.2 TWh (38 % of the technical capacity) was exported from Finland to Estonia and 746 GWh (13 % of the technical capacity) was imported to Finland.

The annual maintenance of Estlink 2 lasted four days in April. Normally, there is annual maintenance for HVDC links but for Estlink 2 the maintenance happens every second year. Additionally, there were two disturbances during 2018 with only minor impact.

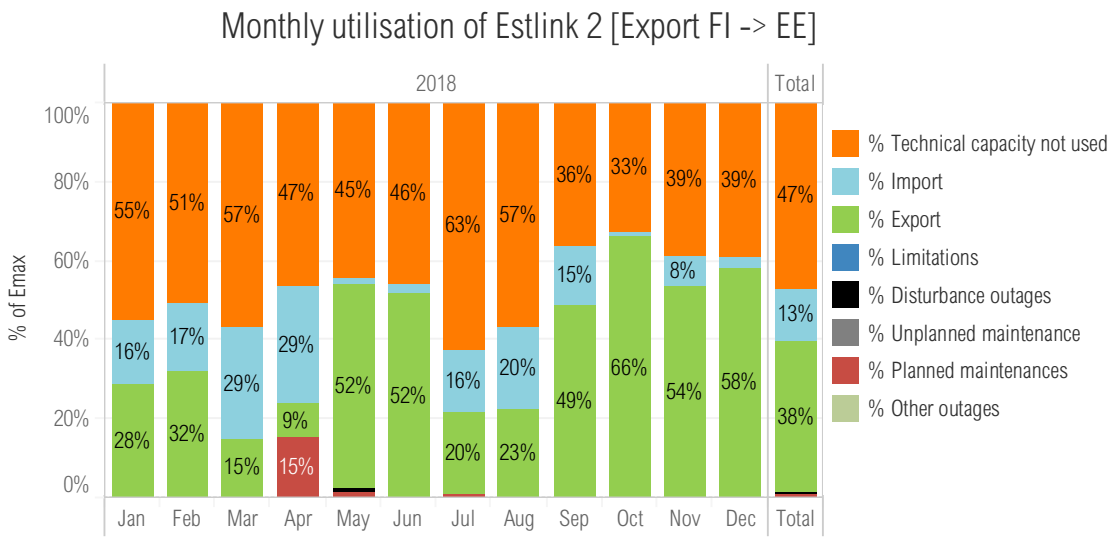

Figure 5.15: Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Estlink 2 in 2018.

Table 5.3: Monthly distribution of the technical capacity (E_{max}) for Estlink 2 in 2018. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Estlink 2 [Export FI -> EE]	2018												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Import losses, GWh	1.4	1.4	2.6	2.6	0.1	0.2	1.4	1.9	1.3	0.1	0.7	0.3	14.2
Export losses, GWh	2.7	2.8	1.3	0.8	5.0	4.8	1.9	2.0	4.7	6.6	5.3	5.8	43.7
Technical capacity not used, GWh	266.3	220.9	274.9	218.2	215.9	214.5	302.7	276.4	170.6	159.4	181.9	190.0	2691.6
Import, GWh	79.6	75.6	138.0	137.8	6.9	11.4	77.3	97.9	68.1	4.9	35.5	12.8	745.5
Export, GWh	137.8	140.4	70.8	40.7	249.9	242.2	98.4	109.4	229.3	319.3	250.7	280.8	2169.7
Limitations, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Disturbance outages, GWh	-	-	-	-	3.2	-	-	-	-	-	-	-	3.2
Unplanned maintenances, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenances, GWh	-	-	-	71.3	7.8	-	5.2	-	-	-	-	-	84.3
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	483.6	436.8	483.6	468.1	483.6	468.0	483.6	483.6	468.0	483.6	468.1	483.6	5694.4

Figure 5.16 presents the annual utilization of Estlink 2 according to all the categories of technical capacity (E_{max}) for the years 2014–2018. The availability and unavailability categories are explained further in Section 3. Figure 5.17 presents the percentage of hours of a year Estlink 2 has been affected by either a limitation, an unplanned or planned maintenance outage, a disturbance outage or an other outage annually during the years 2014–2018. Figure 5.18 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2014–2018.

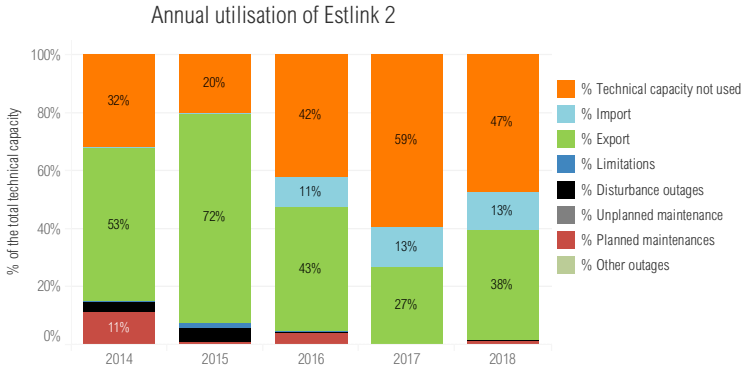

Figure 5.16: Annual utilisation of Estlink 2 according to the utilisation and unavailability categories for the years 2014–2018. The utilisation and unavailability categories are described in more detail in Section 3.

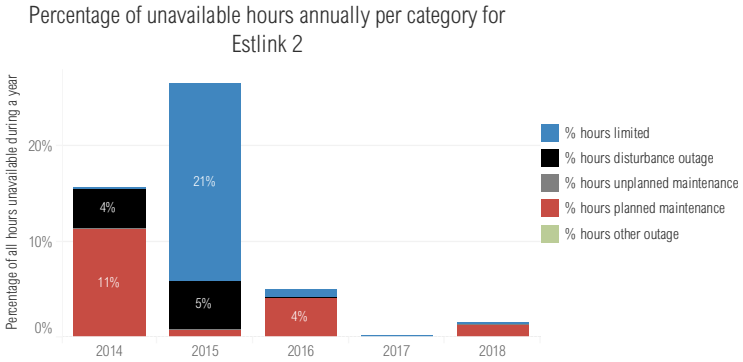

Figure 5.17: Percentage of hours Estlink 2 has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2014–2018. The percentage is calculated by counting the number of hours with an limitation or outage and dividing it by the total number of hours in a year. Therefore, the result may show more than 100 % if one hour is affected by more than one kind of limitation or outage.

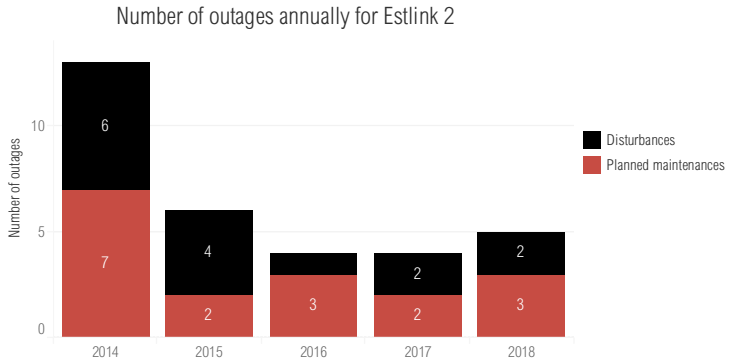

Figure 5.18: The annual number of disturbances, unplanned and planned maintenance outages and other outages Estlink 2 for the years 2014–2018. Estlink 2 had no other outages during the years 2014–2018.

5.3.4 Fenno-Skan 1

Figure 5.19 presents the availability and utilisation of Fenno-Skan 1 for 2018 and Table 5.4 presents the numerical values behind it. Fenno-Skan 1 has been in operation since 1989 and is the first HVDC connection between Finland and Sweden. In Finland (bidding zone FI), Fenno-Skan 1 is connected to Rauma and in Sweden to Dannebo (bidding zone SE3). The transmission capacity used to be 500 MW during summer and 550 MW during winter but was permanently decreased to 400 MW in 1.7.2014 after detailed DC cable investigations were completed. The investigations were started after a cable fault 12 February 2013.

In 2018, Fenno-Skan 1 had an available technical capacity of 98 %. The technical capacity not used was 3 %. Totally, 114 GWh (3 % of the technical capacity) was exported from Finland to Sweden and 3.2 TWh (92 % of the technical capacity) was imported to Finland.

The annual maintenance of Fenno-Skan 1 lasted three days in September. Additionally, there where three disturbance outages during 2018 with only minor impact.

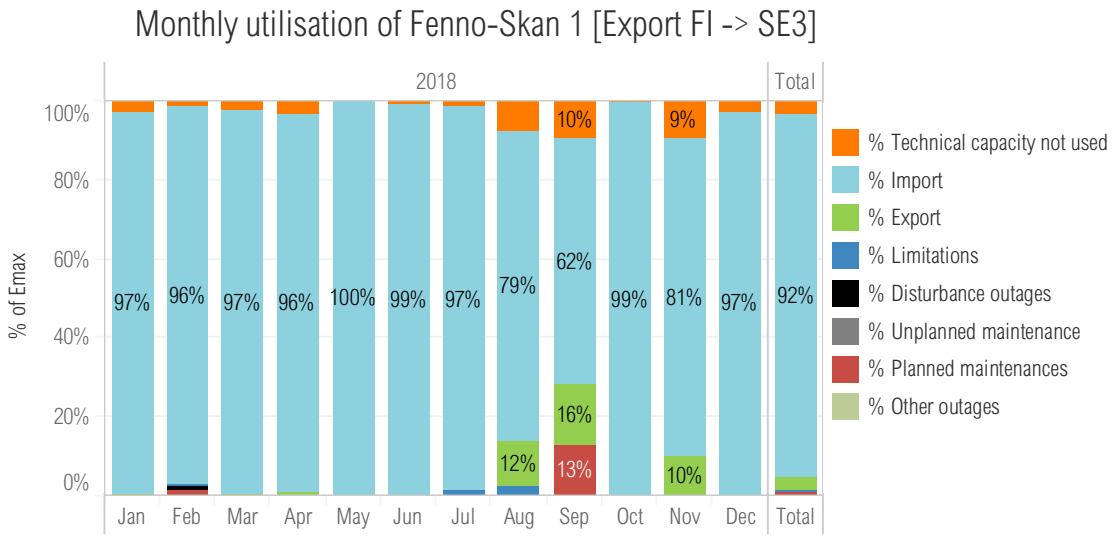

Figure 5.19: Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Fenno-Skan 1 in 2018.

Table 5.4: Monthly distribution of the technical capacity (E_{max}) for Fenno-Skan 1 in 2018. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Fenno-Skan 1 [Export FI -> SE3]	2018												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Import losses, GWh	7.8	7.1	8.2	7.5	8.0	7.6	7.7	6.3	4.9	7.9	6.4	8.0	87.3
Export losses, GWh	-	-	-	0.2	-	-	-	1.1	1.2	-	0.9	-	3.5
Technical capacity not used, GWh	8.6	3.4	7.0	9.0	-	2.2	4.0	22.6	27.4	1.9	27.3	8.8	122.0
Import, GWh	288.5	258.5	289.9	276.0	298.3	286.8	290.7	234.6	179.2	297.1	232.3	289.6	3221.5
Export, GWh	1.1	-	0.9	3.4	-	-	-	34.4	45.0	-	28.9	-	113.6
Limitations, GWh	-	1.0	-	-	-	-	3.8	6.2	-	-	-	-	11.1
Disturbance outages, GWh	-	2.8	-	-	-	-	-	0.3	-	-	-	-	3.1
Unplanned maintenances, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenances, GWh	-	3.6	-	-	-	-	-	-	36.7	-	-	-	40.3
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	298.2	269.3	297.7	288.4	298.3	288.9	298.5	298.1	288.2	299.0	288.5	298.4	3511.5

Figure 5.20 presents the annual utilization of Fenno-Skan 1 according to all the categories of technical capacity (E_{max}) for the years 2012–2018. The availability and unavailability categories are explained further in Section 3. Figure 5.21 presents the percentage of hours of a year Fenno-Skan 1 has been affected by either a limitation, an unplanned or planned maintenance outage, a disturbance outage or an other outage annually during the years 2012–2018. Figure 5.22 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2018.

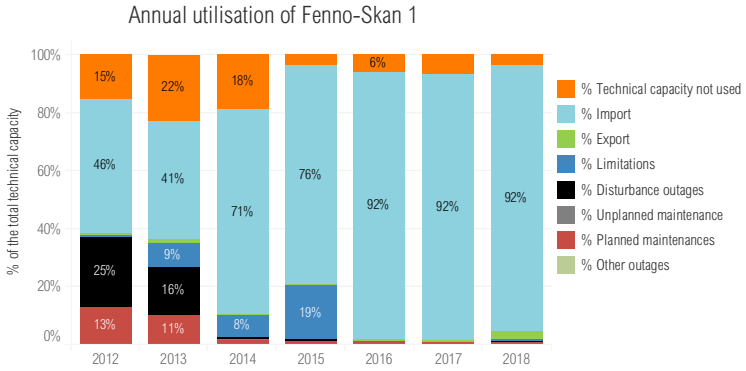

Figure 5.20: Annual utilisation of Fenno-Skan 1 according to the utilisation and unavailability categories for the years 2012–2018. The utilisation and unavailability categories are described in more detail in Section 3.

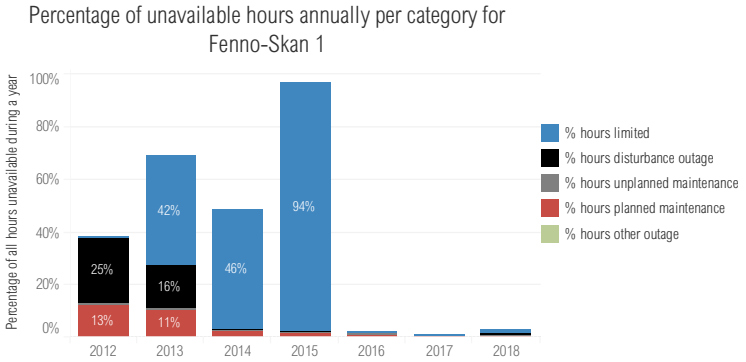

Figure 5.21: Percentage of hours Fenno-Skan 1 has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2018. The percentage is calculated by counting the number of hours with an limitation or outage and dividing it by the total number of hours in a year. Therefore, the result may show more than 100 % if one hour is affected by more than one kind of limitation or outage.

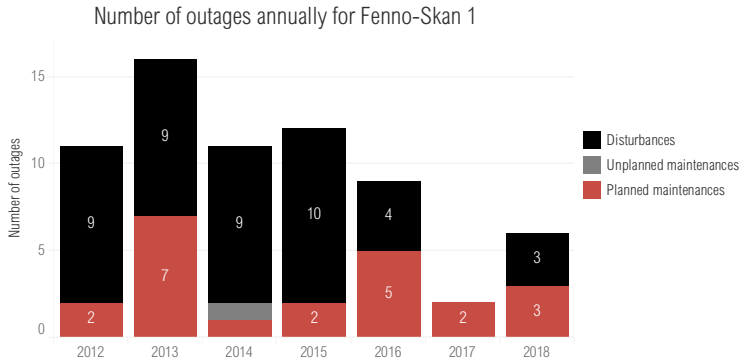

Figure 5.22: The annual number of disturbances, unplanned and planned maintenance outages and other outages Fenno-Skan 1 during 2012–2018. Fenno-Skan 1 had no other outages during the years 2012–2018.

5.3.5 Fenno-Skan 2

Figure 5.23 presents the availability and utilisation of Fenno-Skan 2 for 2018 and Table 5.5 presents the numerical values behind it. Fenno-Skan 2 has been in operation since 2011 and is the second HVDC connection between Finland and Sweden. In Finland (bidding zone FI) Fenno-Skan 2 is connected to Rauma and in Sweden to Finnböle (bidding zone SE3). The transmission capacity of Fenno-Skan 2 is 800 MW.

In 2018, Fenno-Skan 2 had an available technical capacity of 99 %. The technical capacity not used was 39 %. Totally, 494 GWh (7 % of the technical capacity) was exported from Finland to Sweden and 3.7 TWh (53 % of the technical capacity) was imported to Finland.

The annual maintenance of Fenno-Skan 2 lasted two days in September. Normally, there is annual maintenance for HVDC links but for Fenno-Skan 2 the maintenance happens every second year. Additionally, there where three disturbance outages during 2018 with only minor impact.

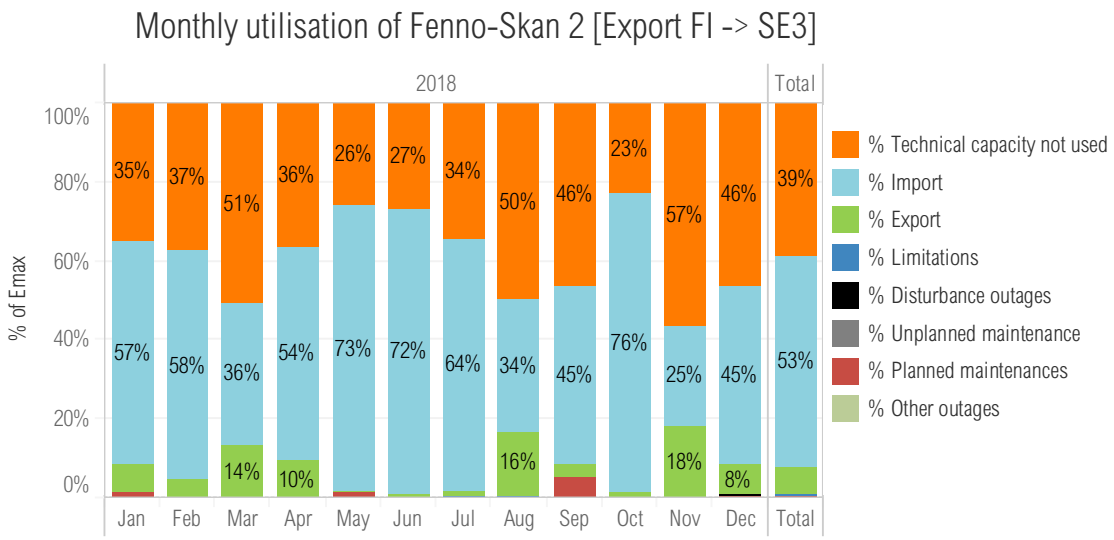

Figure 5.23: Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Fenno-Skan 2 in 2018.

Table 5.5: Monthly distribution of the technical capacity (E_{max}) for Fenno-Skan 2 in 2018. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Fenno-Skan 2 [Export FI -> SE3]	2018												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Import losses, GWh	7.4	6.4	4.3	6.5	9.3	9.6	7.5	3.9	5.5	9.7	2.7	5.5	78.3
Export losses, GWh	0.7	0.4	1.4	0.9	-	0.1	0.2	1.9	0.4	0.1	1.9	0.8	8.8
Technical capacity not used, GWh	206.6	199.7	300.4	209.8	152.7	153.5	204.9	297.3	266.9	137.1	326.1	275.0	2729.9
Import, GWh	336.6	312.8	213.3	311.3	432.5	417.6	378.1	199.5	259.6	451.1	146.3	269.7	3728.5
Export, GWh	44.2	25.1	80.8	55.1	2.2	5.1	10.6	94.7	18.5	7.9	103.6	46.1	493.9
Limitations, GWh	-	-	-	-	-	-	1.7	3.8	-	-	-	-	5.5
Disturbance outages, GWh	-	-	-	-	-	-	-	-	-	-	-	0.4	0.4
Unplanned maintenances, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenances, GWh	7.9	-	-	-	8.0	-	-	-	31.0	-	-	4.0	50.9
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	595.4	537.7	594.5	576.1	595.3	576.1	595.3	595.2	576.1	596.1	576.0	595.2	7009.0

Figure 5.24 presents the annual utilization of Fenno-Skan 2 according to all the categories of technical capacity (E_{max}) for the years 2012–2018. The availability and unavailability categories are explained further in Section 3. Figure 5.25 presents the percentage of hours of a year Fenno-Skan 2 has been affected by either a limitation, an unplanned or planned maintenance outage, a disturbance outage or an other outage annually during the years 2012–2018. Figure 5.26 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2018.

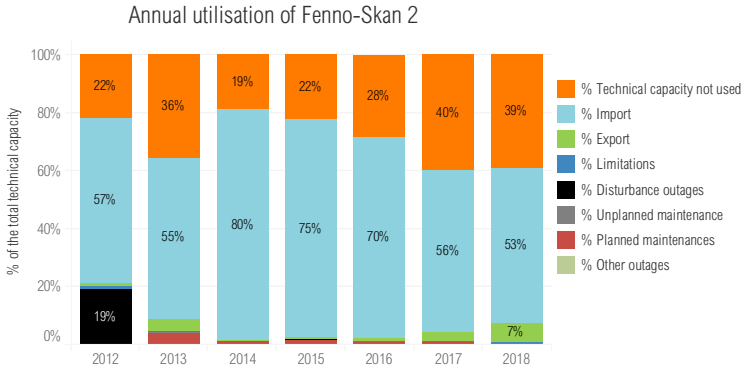

Figure 5.24: Annual utilisation of Fenno-Skan 2 according to the utilisation and unavailability categories for the years 2012–2018. The utilisation and unavailability categories are described in more detail in Section 3.

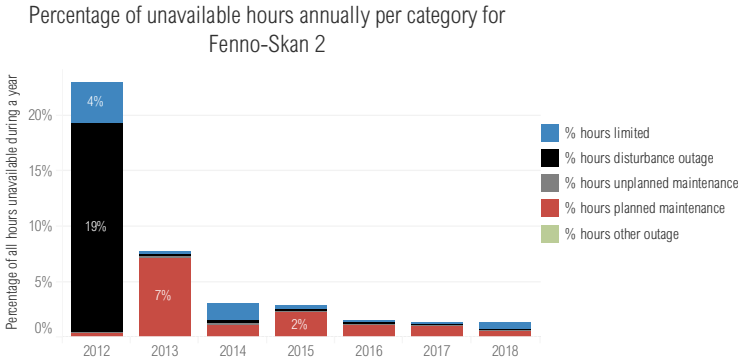

Figure 5.25: Percentage of hours Fenno-Skan 2 has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2018. The percentage is calculated by counting the number of hours with an limitation or outage and dividing it by the total number of hours in a year. Therefore, the result may show more than 100 % if one hour is affected by more than one kind of limitation or outage.

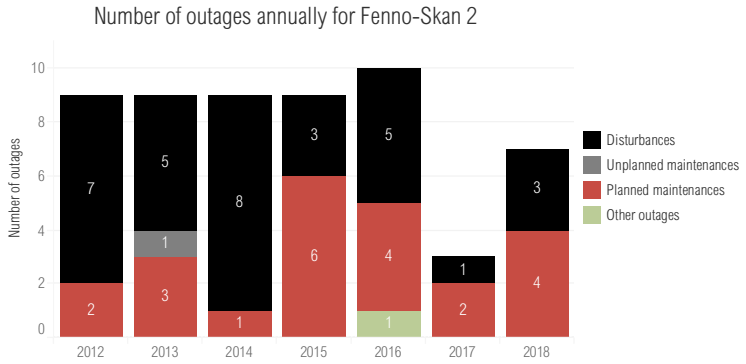

Figure 5.26: The annual number of disturbances, unplanned and planned maintenance outages and other outages Fenno-Skan 2 for the years 2012–2018.

5.3.6 Kontek

Figure 5.27 presents the availability and utilisation of Kontek for 2018 and Table 5.6 presents the numerical values behind it. Kontek has been in operation since 1995 In Denmark it is connected to Bjaeverskov (bidding zone DK2) and in Germany to Bentwisch (bidding zone DE-50Hertz). The transmission capacity of Kontek is 600 MW.

In 2018, Kontek had an available technical capacity of 74 %. The technical capacity not used was 21 %. Totally, 1.4 TWh (26 % of the technical capacity) was exported from Denmark to Germany and 1.4 TWh (27 % of the technical capacity) was imported to Denmark.

The annual maintenance of Kontek lasted ten days in May in 2018. The maintenance outage was prolonged due to reparations of a detected oil leak from a land cable and was finally repaired in the end of September. Additionally, Kontek had one minor disturbance outage during 2018.

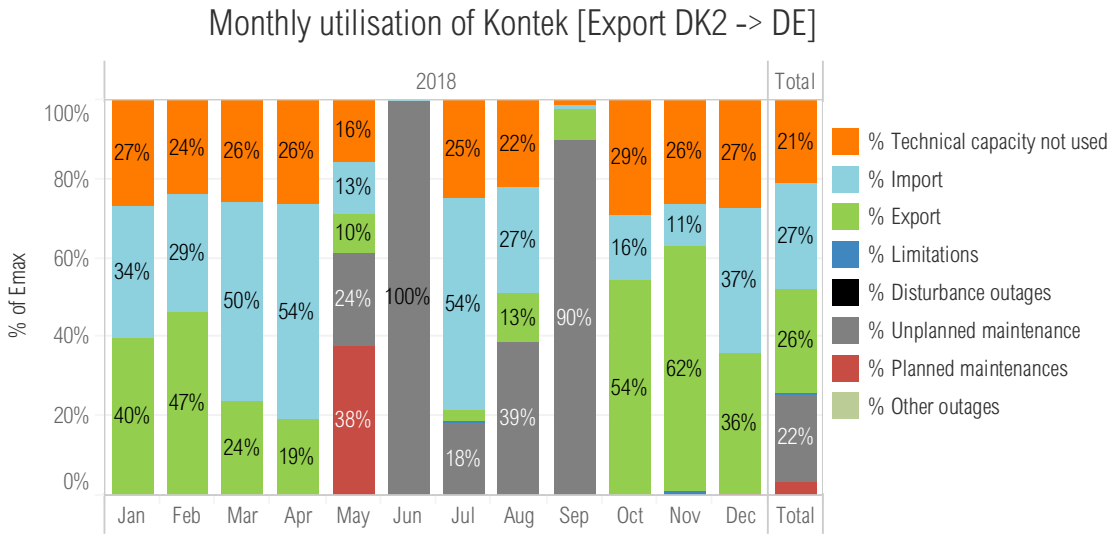

Figure 5.27: Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Kontek in 2018.

Table 5.6: Monthly distribution of the technical capacity (E_{max}) for Kontek in 2018. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Kontek [Export DK2 -> DE]

2018	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Import losses, GWh	3.0	2.4	4.4	4.7	1.1	-	5.0	2.5	0.1	1.4	0.9	3.4	28.8
Export losses, GWh	3.7	4.0	2.2	1.7	0.9	-	0.3	1.1	0.7	5.1	5.6	3.3	28.7
Technical capacity not used, GWh	119.3	96.4	115.1	113.1	71.5	-	110.4	97.2	6.7	131.1	113.0	121.0	1095.0
Import, GWh	149.8	118.8	223.1	235.4	56.1	-	239.1	120.4	3.7	72.7	45.5	165.0	1429.6
Export, GWh	177.3	188.0	107.5	83.4	44.6	-	13.4	56.0	32.3	242.9	269.1	159.2	1373.9
Limitations, GWh	-	-	-	-	-	-	1.3	-	-	0.3	4.3	-	5.9
Disturbance outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Unplanned maintenances, GWh	-	-	-	-	105.6	432.0	82.2	172.8	389.3	-	-	-	1181.9
Planned maintenances, GWh	-	-	-	-	168.6	-	-	-	-	-	-	1.2	169.8
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	446.4	403.2	445.8	432.0	446.4	432.0	446.4	446.4	432.0	447.0	432.0	446.4	5256.0

Figure 5.28 presents the annual utilization of Kontek according to all the categories of technical capacity (E_{max}) for the years 2012–2018. The availability and unavailability categories are explained further in Section 3. Figure 5.29 presents the percentage of hours of a year Kontek has been affected by either a limitation, an unplanned or planned maintenance outage, a disturbance outage or an other outage annually during the years 2012–2018. Figure 5.30 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2018.

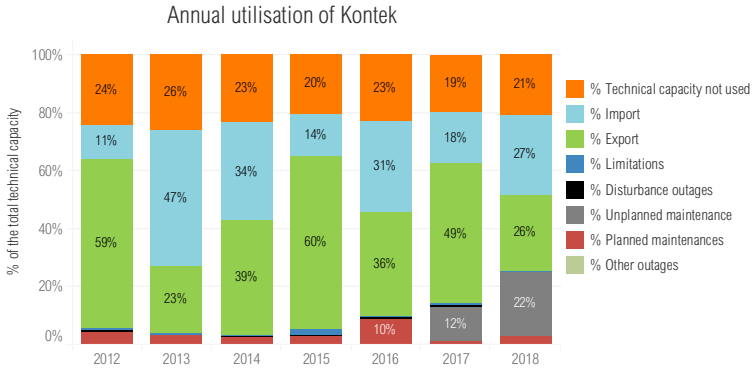

Figure 5.28: Annual utilisation of Kontek according to the utilisation and unavailability categories for the years 2012–2018. The utilisation and unavailability categories are described in more detail in Section 3.

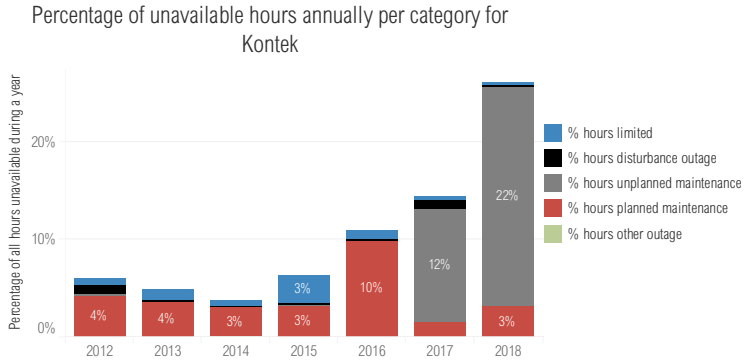

Figure 5.29: Percentage of hours Kontek has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2018. The percentage is calculated by counting the number of hours with an limitation or outage and dividing it by the total number of hours in a year. Therefore, the result may show more than 100 % if one hour is affected by more than one kind of limitation or outage.

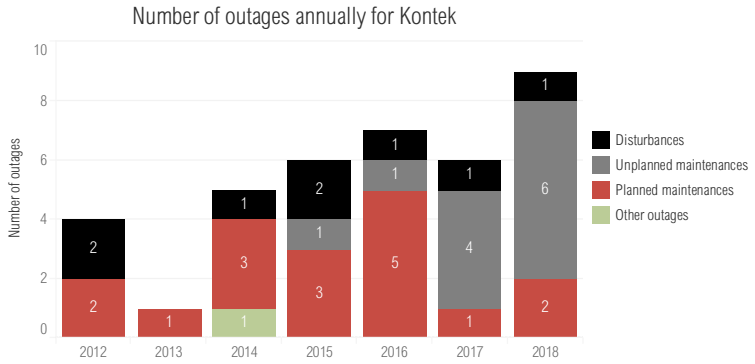

Figure 5.30: The annual number of disturbances, unplanned and planned maintenance outages and other outages Kontek for the years 2012–2018.

5.3.7 Konti-Skan 1

Figure 5.31 presents the availability and utilisation of Konti-Skan 1 for 2018 and Table 5.7 presents the numerical values behind it. In south-western Sweden it is connected to Lindome (bidding zone SE3) and in Denmark to Vester Hassing (bidding zone DK1). It has a transmission capacity of 370 MW from west to east and 340 MW from east to west and it has been in operation since 1965. The upgraded converter stations were commissioned in 2008.

In 2018, Konti-Skan 1 had an available technical capacity of 96 % and the technical capacity not used was 44 %. Totally, 0.9 TWh (27 % of the technical capacity) was exported from Sweden to Denmark and 0.8 TWh (25 % of the technical capacity) was imported to Sweden.

The annual maintenance of Konti-Skan 1 lasted six days in September. Additionally, Konti-Skan 1 had 2 disturbance outages, 3 unplanned maintenance outages and 5 planned maintenance outages during 2018 with only minor impact.

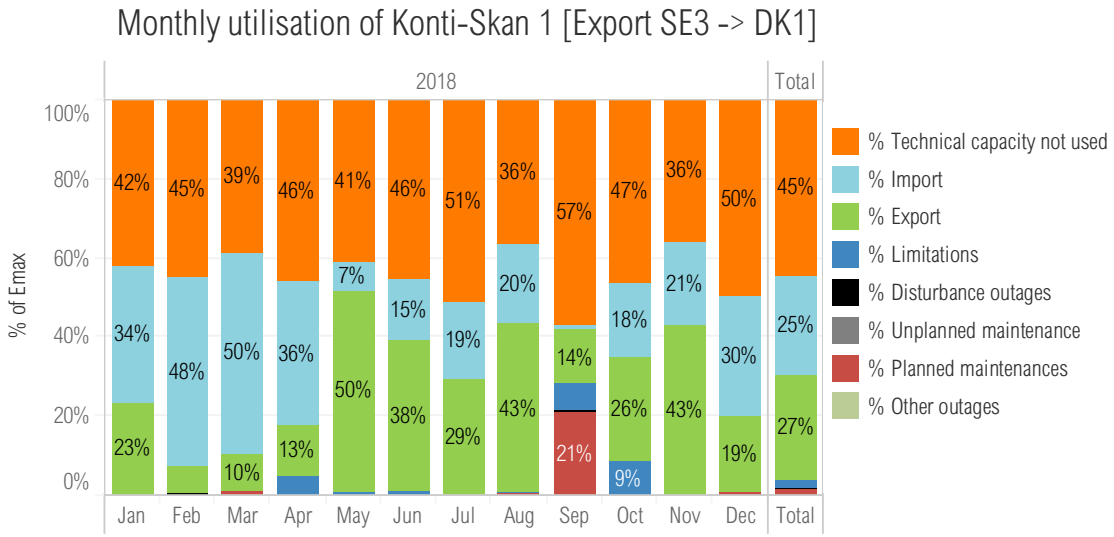

Figure 5.31: Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Konti-Skan 1 in 2018.

Table 5.7: Monthly distribution of the technical capacity (E_{max}) for Konti-Skan 1 in 2018. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Konti-Skan 1 [Export SE3 -> DK1]

2018	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Import losses, GWh	2.6	3.2	3.8	2.3	0.6	1.1	1.5	1.6	0.1	1.4	1.6	2.3	22.1
Export losses, GWh	1.3	0.4	0.6	0.7	2.8	2.0	1.7	2.4	0.9	1.4	2.3	1.0	17.5
Technical capacity not used, GWh	115.4	111.4	107.2	122.4	113.6	121.3	141.4	100.1	151.5	128.6	95.3	137.6	1445.7
Import, GWh	94.9	120.0	138.7	96.4	20.0	40.5	52.9	55.0	2.5	50.8	56.6	82.9	811.0
Export, GWh	64.6	16.2	26.9	34.4	138.9	101.9	81.0	118.2	37.7	72.7	114.5	52.6	859.5
Limitations, GWh	-	-	-	13.2	2.8	2.8	-	1.3	17.7	23.6	-	-	61.3
Disturbance outages, GWh	-	0.4	-	-	-	-	-	-	0.4	-	-	-	0.7
Unplanned maintenances, GWh	0.4	0.7	-	-	-	-	-	-	-	-	-	-	1.1
Planned maintenances, GWh	-	-	2.2	-	-	-	-	0.7	56.6	-	-	2.2	61.7
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	275.3	248.6	274.9	266.4	275.3	266.4	275.3	275.3	266.4	275.7	266.4	275.3	3241.2

Figure 5.32 presents the annual utilization of Konti-Skan 1 according to all the categories of technical capacity (E_{max}) for the years 2012–2018. The availability and unavailability categories are explained further in Section 3. Figure 5.33 presents the percentage of hours of a year Konti-Skan 1 has been affected by either a limitation, an unplanned or planned maintenance outage, a disturbance outage or an other outage annually during the years 2012–2018. Figure 5.34 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2018.

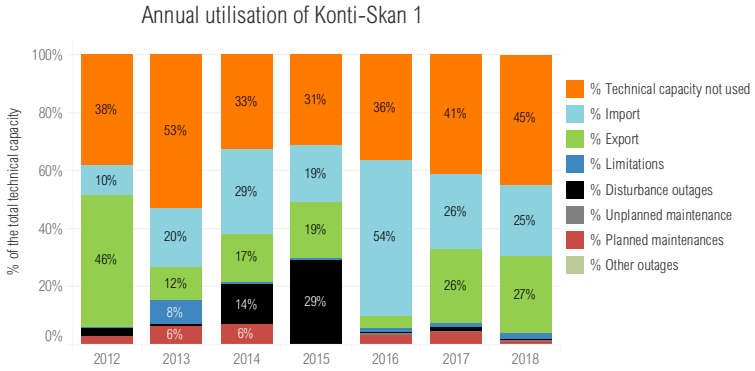

Figure 5.32: Annual utilisation of Konti-Skan 1 according to the utilisation and unavailability categories for the years 2012–2018. The utilisation and unavailability categories are described in more detail in Section 3.

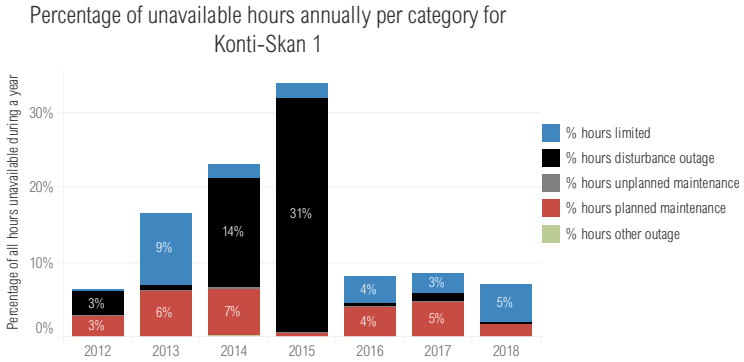

Figure 5.33: Percentage of hours Konti-Skan 1 has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2018. The percentage is calculated by counting the number of hours with an limitation or outage and dividing it by the total number of hours in a year. Therefore, the result may show more than 100 % if one hour is affected by more than one kind of limitation or outage.

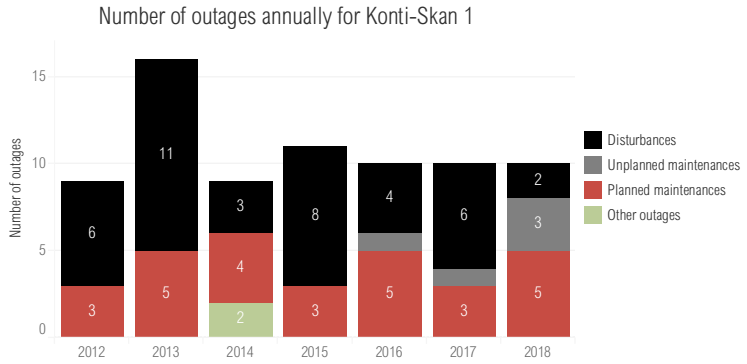

Figure 5.34: The annual number of disturbances, unplanned and planned maintenance outages and other outages for Konti-Skan 1 for the years 2012–2018.

5.3.8 Konti-Skan 2

Figure 5.35 presents the availability and utilisation of Konti-Skan 2 for 2018 and Table 5.8 presents the numerical values behind it. Konti-Skan 2 is connected between Sweden and Denmark in parallel to Konti-Skan 1. It has a transmission capacity of 370 MW from west to east and 340 MW from east to west and it has been in operation since 1988.

In 2018, Konti-Skan 2 had an available technical capacity of 95 % and the technical capacity not used was 41 %. Totally, 0.9 TWh (27 % of the technical capacity) was exported from Sweden to Denmark and 0.9 TWh (27 % of the technical capacity) was imported to Sweden.

The annual maintenance of Konti-Skan 2 lasted 12 days in September. Additionally, Konti-Skan 2 had 6 disturbance outages and 3 planned maintenance outages during 2018 with only minor impact.

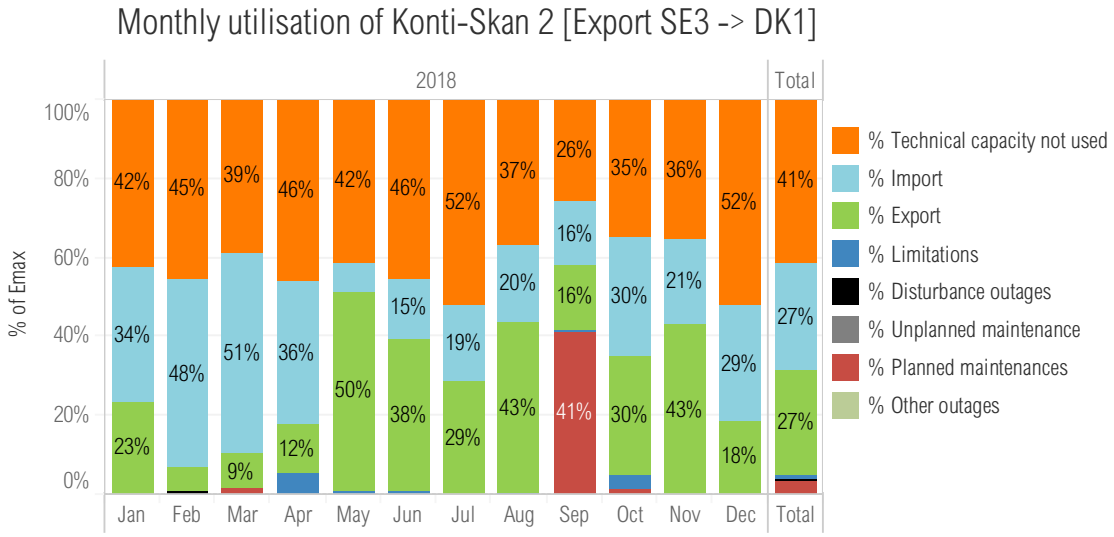

Figure 5.35: Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Konti-Skan 2 in 2018.

Table 5.8: Monthly distribution of the technical capacity (E_{max}) for Konti-Skan 2 in 2018. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Konti-Skan 2 [Export SE3 -> DK1] — 2018

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Import losses, GWh	2.4	3.1	3.7	2.2	0.5	1.0	1.3	1.5	1.5	2.5	1.5	2.1	23.3
Export losses, GWh	1.6	0.3	0.6	0.8	3.5	2.4	1.9	3.2	1.2	2.0	2.8	1.2	21.4
Technical capacity not used, GWh	116.8	113.1	106.1	122.7	114.9	121.7	143.9	101.0	69.0	96.4	94.6	143.3	1343.5
Import, GWh	94.2	118.9	139.2	97.1	19.0	40.1	52.1	54.5	43.3	83.0	56.5	81.1	879.0
Export, GWh	64.3	14.8	25.9	33.1	138.7	101.9	79.3	118.7	42.6	82.9	115.3	50.9	868.3
Limitations, GWh	-	-	-	13.5	2.7	2.7	-	1.1	1.2	10.1	-	-	31.4
Disturbance outages, GWh	-	1.8	-	-	-	-	-	-	-	-	-	-	1.8
Unplanned maintenances, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenances, GWh	-	-	3.7	-	-	-	-	-	110.3	3.3	-	-	117.2
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	275.3	248.6	274.9	266.4	275.3	266.4	275.3	275.3	266.4	275.7	266.4	275.3	3241.2

Figure 5.36 presents the annual utilization of Konti-Skan 2 according to all the categories of technical capacity (E_{max}) for the years 2012–2018. The availability and unavailability categories are explained further in Section 3. Figure 5.37 presents the percentage of hours of a year Konti-Skan 2 has been affected by either a limitation, an unplanned or planned maintenance outage, a disturbance outage or an other outage annually during the years 2012–2018. Figure 5.38 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2018.

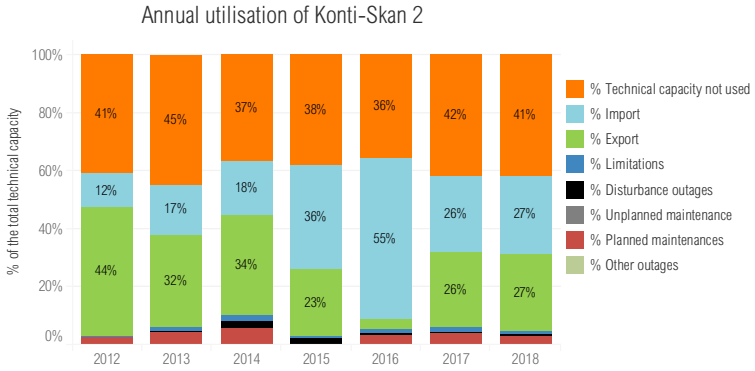

Figure 5.36: Annual utilisation of Konti-Skan 2 according to the utilisation and unavailability categories for the years 2012–2018. The utilisation and unavailability categories are described in more detail in Section 3.

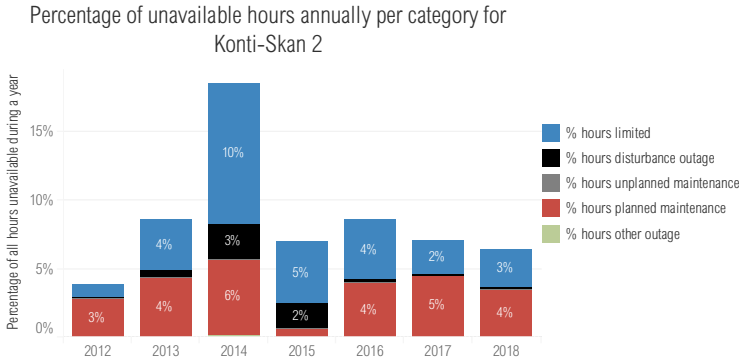

Figure 5.37: Percentage of hours Konti-Skan 2 has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2018. The percentage is calculated by counting the number of hours with an limitation or outage and dividing it by the total number of hours in a year. Therefore, the result may show more than 100 % if one hour is affected by more than one kind of limitation or outage.

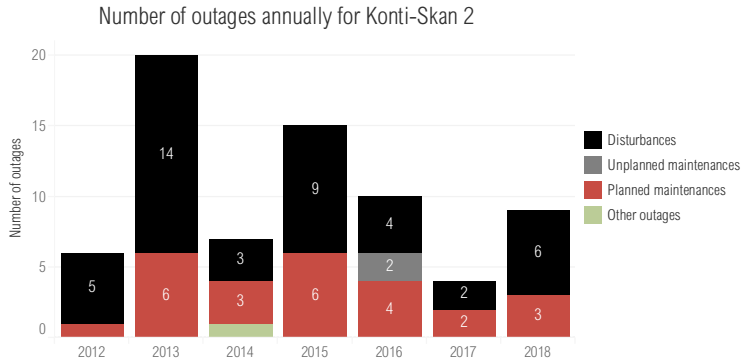

Figure 5.38: The annual number of disturbances, unplanned and planned maintenance outages and other outages Konti-Skan 2 for the years 2012–2018.

5.3.9 LitPol Link

Figure 5.39 presents the availability and utilisation of LitPol Link for 2018 and Table 4.1 presents the numerical values behind it. LitPol Link has been in operation since the end of 2015. In Lithuania, it is connected to Alytus (bidding zone LT) and in Poland to Ełk (bidding zone PL). The transmission capacity of LitPol Link is 500 MW.

In 2018, LitPol Link had had an available technical capacity of 93 %. The technical capacity not used was 40 %. Totally, 1.6 TWh (37 % of the technical capacity) as exported from Lithuania to Poland and 0.7 TWh (16 % of the technical capacity) was imported to Lithuania.

The annual maintenance lasted six days in September. Additionally, there were 3 disturbance outages on LitPol Link in 2018 with only minor impact.

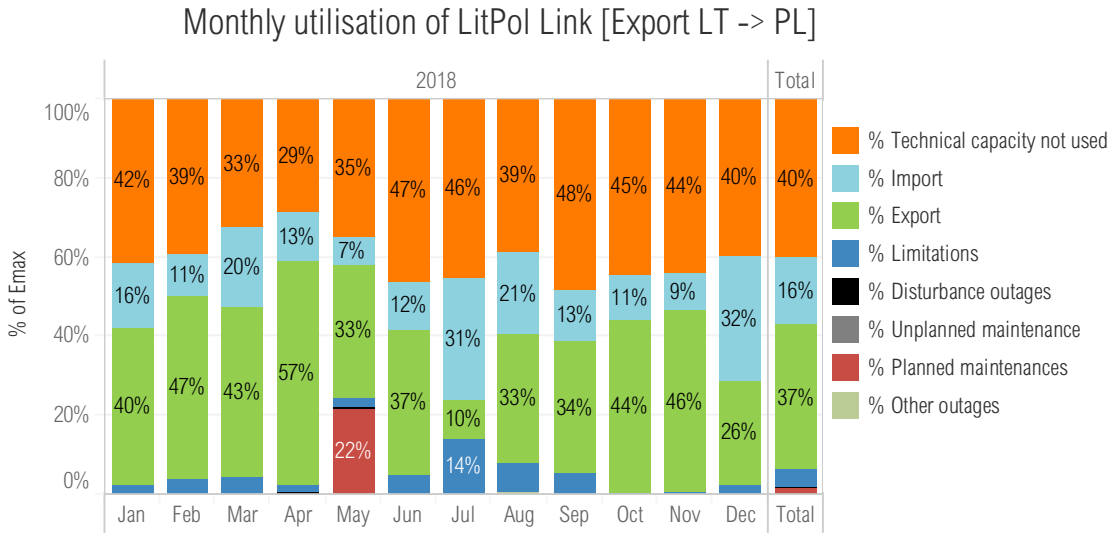

Figure 5.39: Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for LitPol Link in 2018.

Table 5.9: Monthly distribution of the technical capacity (E_{max}) for LitPol Link in 2018. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of LitPol Link [Export LT -> PL]	2018												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Import losses, GWh	1.3	1.0	1.6	0.8	0.6	1.2	2.1	1.4	0.9	0.9	0.8	1.9	14.5
Export losses, GWh	2.0	2.1	2.2	3.0	1.9	1.7	0.2	1.7	1.8	2.2	2.1	1.5	22.4
Technical capacity not used, GWh	155.2	131.5	121.9	102.7	130.4	167.4	169.3	143.6	174.0	166.4	159.2	147.7	1769.2
Import, GWh	60.7	35.4	74.1	45.2	26.8	43.4	113.6	77.7	46.1	42.3	33.7	118.4	717.3
Export, GWh	147.2	156.7	159.7	203.7	123.7	131.7	37.9	122.1	121.6	161.9	165.8	96.2	1628.1
Limitations, GWh	8.9	12.4	16.3	7.4	9.9	17.5	51.3	26.2	18.3	1.3	1.3	9.8	180.6
Disturbance outages, GWh	-	-	-	1.0	0.8	-	-	-	-	-	-	-	1.8
Unplanned maintenances, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenances, GWh	-	-	-	-	80.5	-	-	-	-	-	-	-	80.5
Other outages, GWh	-	-	-	-	-	-	-	2.4	-	-	-	-	2.4
Total, GWh	372.0	336.0	372.0	360.0	372.0	360.0	372.0	372.0	360.0	372.0	360.0	372.0	4380.0

Figure 5.40 presents the annual utilization of LitPol Link according to all the categories of technical capacity (E_{max}) for the years 2016–2018. The availability and unavailability categories are explained further in Section 3. Figure 5.41 presents the percentage of hours of a year LitPol Link has been affected by either a limitation, an unplanned or planned maintenance outage, a disturbance outage or an other outage annually during the years 2016–2018. Figure 5.42 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2016–2018.

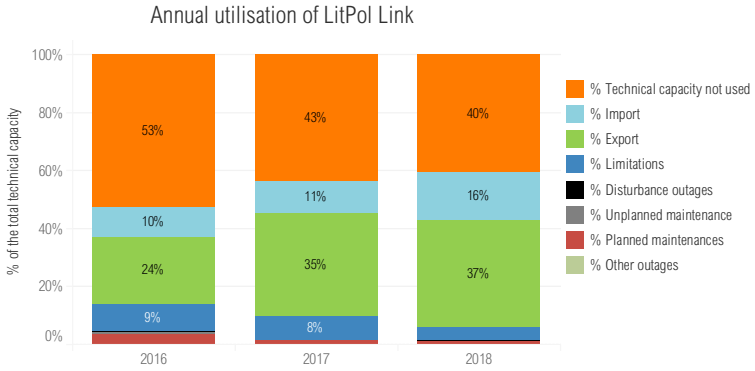

Figure 5.40: Annual utilisation of LitPol Link according to the utilisation and unavailability categories for the years 2016–2018. The utilisation and unavailability categories are described in more detail in Section 3.

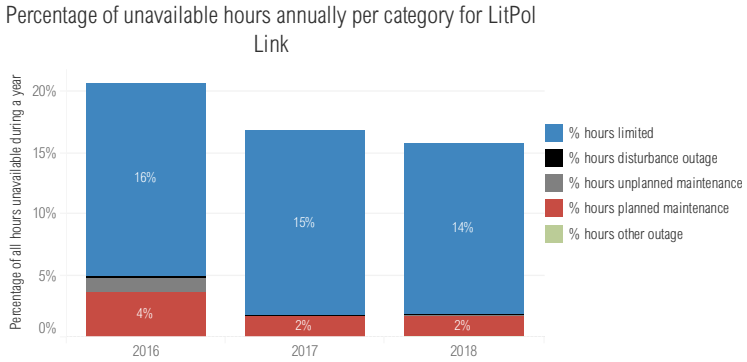

Figure 5.41: Percentage of hours LitPol Link has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2016–2018. The percentage is calculated by counting the number of hours with an limitation or outage and dividing it by the total number of hours in a year. Therefore, the result may show more than 100 % if one hour is affected by more than one kind of limitation or outage.

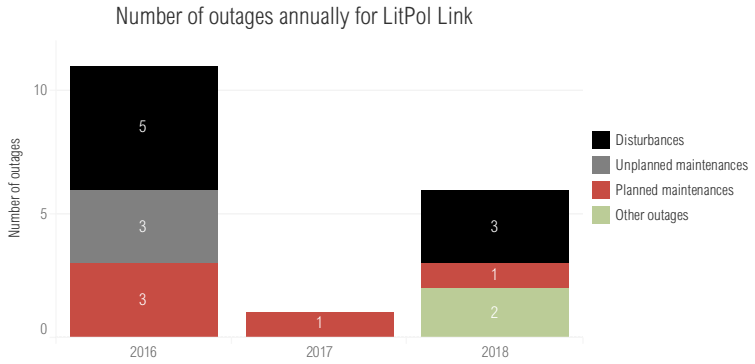

Figure 5.42: The annual number of disturbances, unplanned and planned maintenance outages and other outages LitPol Link for the years 2016–2018.

5.3.10 NordBalt

Figure 5.43 presents the availability and utilisation of NordBalt for 2018 and Table 5.10 presents the numerical values behind it. NordBalt has been in operation since 2016. In Sweden, it is connected to Nybro (bidding zone SE4) and in Lithuania to Klaipeda (bidding zone LT). The transmission capacity of NordBalt is 700 MW at the receiving end.

In 2018, NordBalt had had an available technical capacity of 79 %. The technical capacity not used was 28 %. Totally, 2.9 TWh (47 % of the technical capacity) was exported from Sweden to Lithuania and 0.2 TWh (4 % of the technical capacity) was imported to Sweden.

The annual maintenance of NordBalt lasted 55 days from August to October. The maintenance was longer than usually because its DC underground cable joints were replaced. Additionally, NordBalt had 1 disturbance, 3 unplanned maintenances and 2 planned maintenances in 2018. The disturbance outage in January was caused by a fault in the cable joint on the onshore cable.

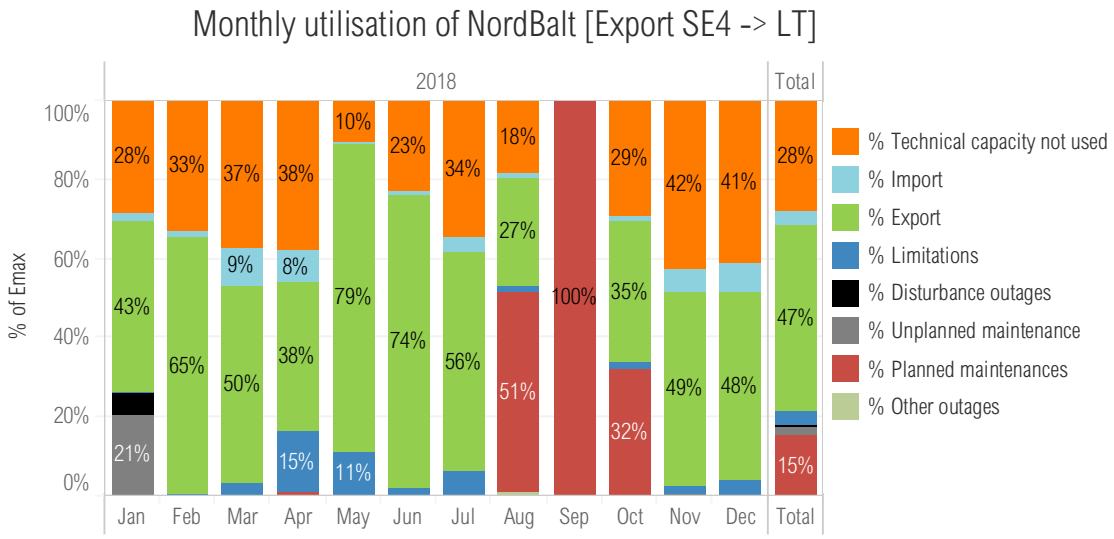

Figure 5.43: Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for NordBalt in 2018.

Table 5.10: Monthly distribution of the technical capacity (E_{max}) for NordBalt in 2018. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of NordBalt [Export SE4 -> LT]	2018												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Import losses, GWh	0.4	0.3	1.6	1.4	-	0.2	0.7	0.4	-	0.4	1.1	1.3	7.8
Export losses, GWh	9.9	13.3	11.1	7.3	17.5	16.8	12.7	6.0	-	7.9	10.4	11.0	124.0
Technical capacity not used, GWh	145.8	154.2	195.2	189.3	54.6	115.7	178.5	93.5	-	152.3	214.1	215.1	1708.3
Import, GWh	12.7	8.7	47.7	42.8	0.1	5.0	19.7	9.7	-	7.5	30.4	35.7	220.0
Export, GWh	225.2	305.0	259.4	189.7	409.3	374.1	289.9	141.1	-	184.5	247.5	249.3	2875.1
Limitations, GWh	3.5	0.6	18.4	77.3	56.8	9.2	32.7	7.7	-	10.6	10.3	20.7	248.0
Disturbance outages, GWh	25.6	-	-	-	-	-	-	-	-	-	-	-	25.6
Unplanned maintenances, GWh	107.9	1.9	-	-	-	-	-	-	-	-	1.7	-	111.5
Planned maintenances, GWh	-	-	-	4.9	-	-	-	263.9	504.0	165.9	-	-	938.7
Other outages, GWh	-	-	-	-	-	-	-	4.9	-	-	-	-	4.9
Total, GWh	520.8	470.4	520.8	504.0	520.8	504.0	520.8	520.8	504.0	520.8	504.0	520.8	6132.0

Figure 5.44 presents the annual utilization of NordBalt according to all the categories of technical capacity (E_{max}) for the years 2016–2018. The availability and unavailability categories are explained further in Section 3. Figure 5.45 presents the percentage of hours of a year NordBalt has been affected by either a limitation, an unplanned or planned maintenance outage, a disturbance outage or an other outage annually during the years 2016–2018. Figure 5.46 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2016–2018.

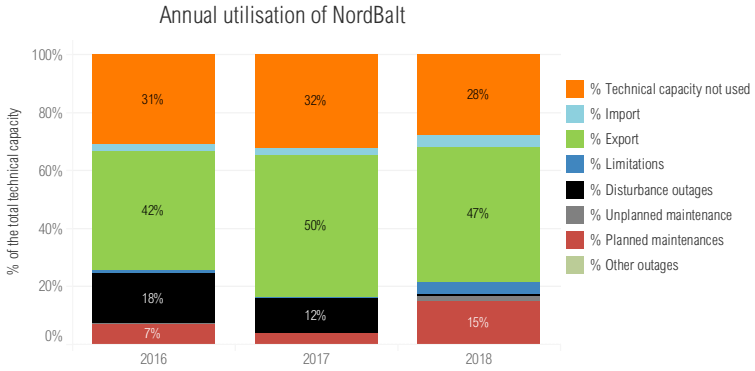

Figure 5.44: Annual utilisation of NordBalt according to the utilisation and unavailability categories for the years 2016–2018. The utilisation and unavailability categories are described in more detail in Section 3.

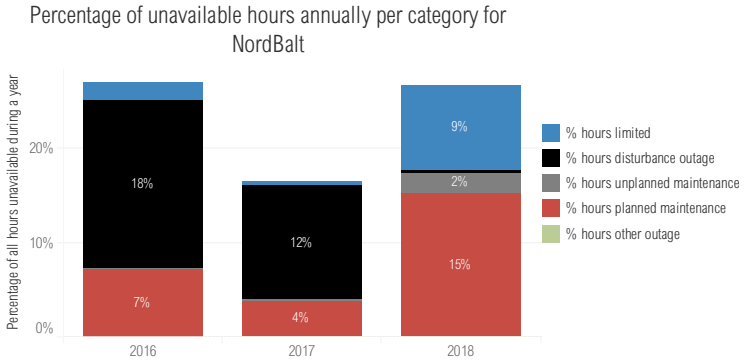

Figure 5.45: Percentage of hours NordBalt has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2016–2018. The percentage is calculated by counting the number of hours with an limitation or outage and dividing it by the total number of hours in a year. Therefore, the result may show more than 100 % if one hour is affected by more than one kind of limitation or outage.

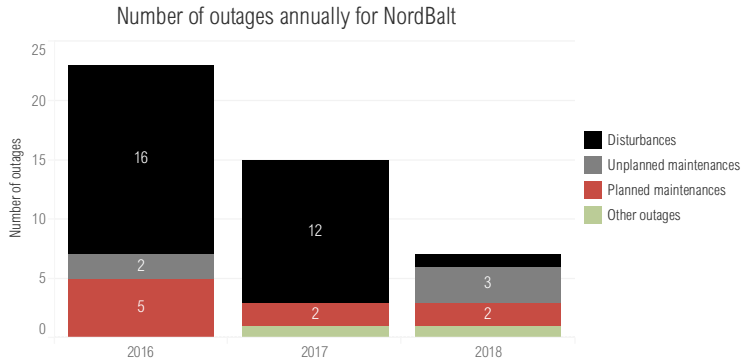

Figure 5.46: The annual number of disturbances, unplanned and planned maintenance outages and other outages NordBalt for the years 2016–2018.

5.3.11 NorNed

Figure 5.47 presents the availability and utilisation of NorNed for 2018 and Table 5.11 presents the numerical values behind it. NorNed has been in operation since 2008, and is, with a length of 580 km, the longest HVDC link connected to the Nordic power system. In Norway on the south-western coast (bidding zone NO2) it is connected to Feda substation and in Netherlands to Eemshaven (bidding zone APX NL). The transmission capacity of NorNed is 700 MW.

In 2018, NorNed had had an available technical capacity of 93 %. The technical capacity not used was 25 %. Totally, 3.9 TWh (63 % of the technical capacity) was exported from Norway to the Netherlands and 0.3 TWh (5 % of the technical capacity) was imported to Norway.

There was no annual maintenance done on NorNed in 2018. Instead, there were 6 smaller planned maintenance outages. Additionally, NorNed had 3 disturbance outages during 2018, of which the most severe happened in March. The disturbance was caused by a cable fault and was repaired in the end of April.

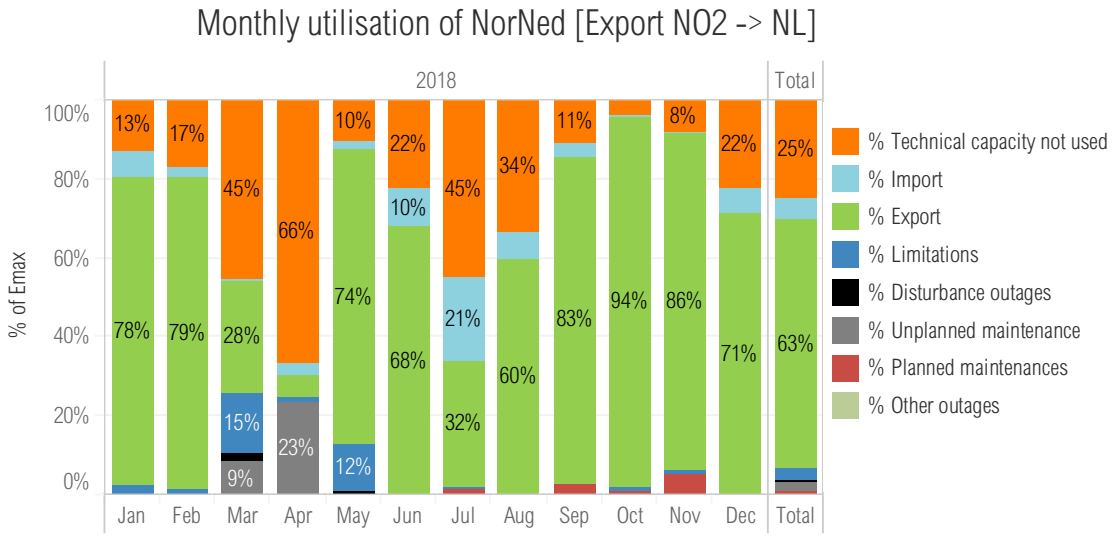

Figure 5.47: Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for NorNed in 2018.

Table 5.11: Monthly distribution of the technical capacity (E_{max}) for NorNed in 2018. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of NorNed [Export NO2 -> NL]	2018												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Import losses, GWh	1.3	0.3	0.1	0.7	0.4	1.8	3.5	1.2	0.7	-	-	1.2	11.1
Export losses, GWh	15.7	14.3	5.0	0.7	13.4	12.9	4.8	11.1	16.4	19.3	16.1	13.9	143.7
Technical capacity not used, GWh	68.5	82.0	236.8	334.7	54.4	112.9	234.3	174.8	54.5	20.2	40.9	117.1	1531.0
Import, GWh	33.7	9.9	3.4	18.1	11.6	49.3	108.8	33.9	19.2	0.1	0.7	33.0	321.5
Export, GWh	407.5	372.3	146.3	24.7	388.6	343.0	167.0	312.2	418.0	492.2	431.9	371.5	3875.3
Limitations, GWh	12.8	7.7	80.0	8.1	61.7	-	0.4	-	-	3.0	5.2	-	179.0
Disturbance outages, GWh	-	-	10.4	-	5.6	-	-	-	-	-	-	-	16.0
Unplanned maintenances, GWh	-	-	44.4	118.4	-	-	-	-	-	-	-	-	162.8
Planned maintenances, GWh	-	-	-	-	-	-	10.4	-	14.0	5.7	25.8	-	56.0
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	522.4	471.9	521.2	504.0	521.8	505.2	520.9	521.0	505.8	521.2	504.5	521.5	6141.5

Figure 5.48 presents the annual utilization of NorNed according to all the categories of technical capacity (E_{max}) for the years 2012–2018. The availability and unavailability categories are explained further in Section 3. Figure 5.49 presents the percentage of hours of a year NorNed has been affected by either a limitation, an unplanned or planned maintenance outage, a disturbance outage or an other outage annually during the years 2012–2018. Figure 5.50 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2018.

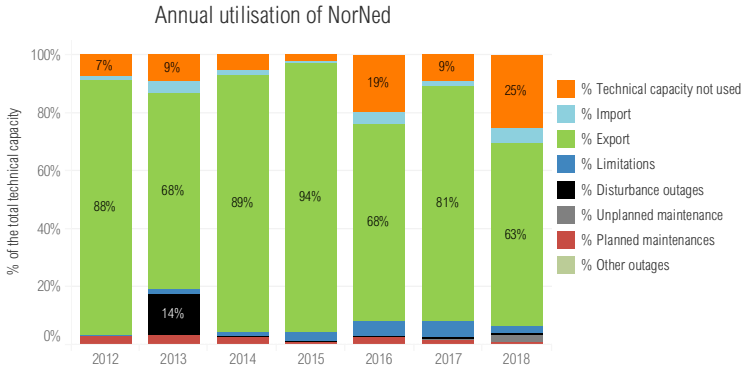

Figure 5.48: Annual utilisation of NorNed according to the utilisation and unavailability categories for the years 2012–2018. The utilisation and unavailability categories are described in more detail in Section 3.

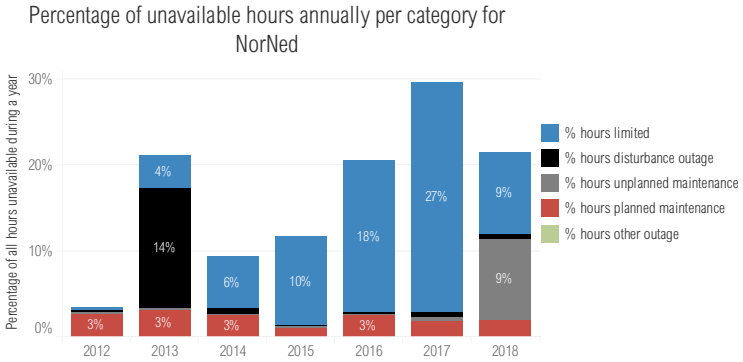

Figure 5.49: Percentage of hours NorNed has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2018. The percentage is calculated by counting the number of hours with an limitation or outage and dividing it by the total number of hours in a year. Therefore, the result may show more than 100 % if one hour is affected by more than one kind of limitation or outage.

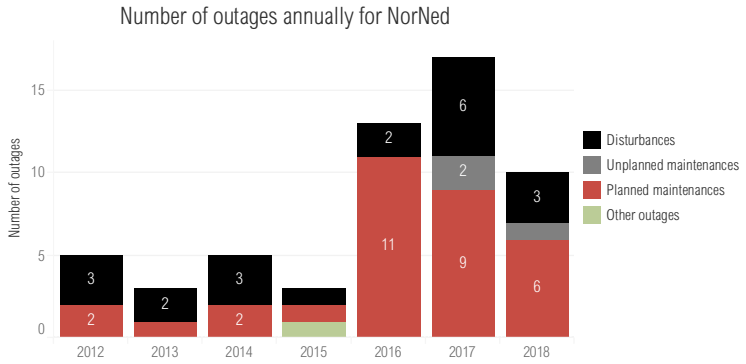

Figure 5.50: The annual number of disturbances, unplanned and planned maintenance outages and other outages NorNed for the years 2012–2018.

5.3.12 Skagerak 1

Figure 5.51 presents the availability and utilisation of Skagerak 1 for 2018 and Table 5.12 presents the numerical values behind it. Skagerak 1 and Skagerak 2 have been in operation since 1976 and are the oldest HVDC links in operation in the Nordic countries. In Norway, the links are connected to Kristiansand on the southern coast (bidding zone NO2) and in Denmark to Tjele (bidding zone DK1), approximately 15 km east of the town of Viborg in the northern part of Jutland. The transmission capacity is 236 MW at the receiving end.

In 2018, Skagerak 1 had an available technical capacity of 84 %. The technical capacity not used was 53 %. Totally, 0.4 TWh (19 % of the technical capacity) was exported from Norway to the Denmark and 0.2 TWh (12 % of the technical capacity) was imported to Norway.

Skagerak 1,2 and 3 have an ongoing process of regalvanizing their electrode masts and replacing their electrode lines, which caused the high amount of planned maintenance in 2018. This regalvanizing work was completed during 2018. Additionally, Skagerak 1 had 1 minor disturbance outage in December during 2018.

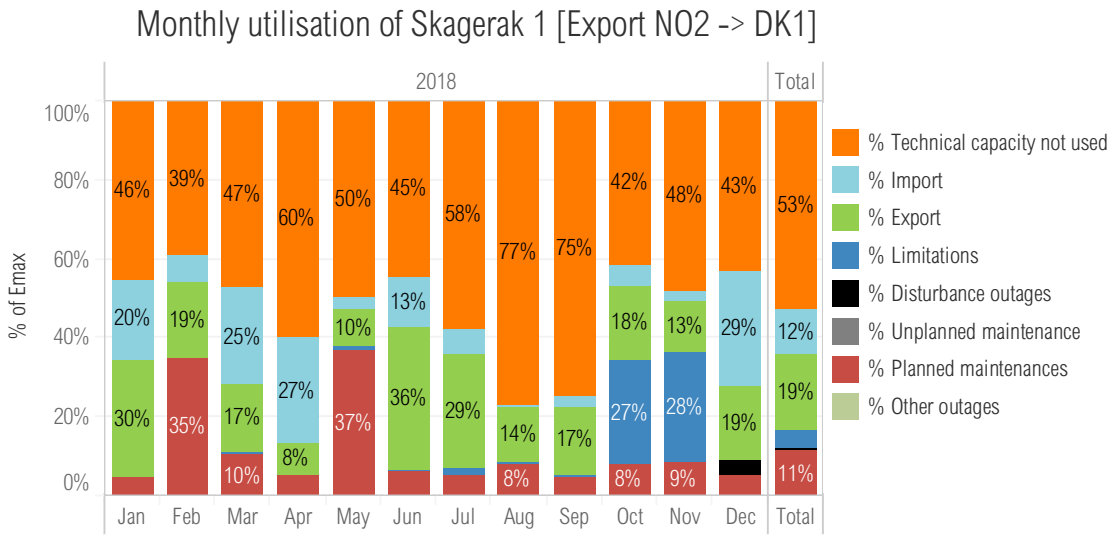

Figure 5.51: Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Skagerak 1 in 2018.

Table 5.12: Monthly distribution of the technical capacity (E_{max}) for Skagerak 1 in 2018. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Skagerak 1 [Export NO2 -> DK1] — 2018

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Import losses, GWh	1.8	0.6	2.4	2.5	0.3	1.0	0.5	-	0.2	0.3	0.1	2.5	12.2
Export losses, GWh	2.5	1.3	1.3	0.7	0.8	3.1	2.4	0.8	1.0	1.1	0.7	1.5	17.1
Technical capacity not used, GWh	80.1	62.1	82.8	101.7	87.8	76.0	101.8	135.4	127.1	73.3	82.4	75.7	1086.1
Import, GWh	34.8	11.1	43.5	45.8	4.9	21.8	10.6	1.0	4.9	9.4	4.2	51.1	243.2
Export, GWh	52.4	30.2	29.7	13.6	16.7	60.9	50.4	24.4	28.6	32.0	22.0	33.0	393.9
Limitations, GWh	-	-	1.2	-	1.2	0.2	3.8	0.2	0.4	46.7	46.8	-	100.5
Disturbance outages, GWh	-	-	-	-	-	-	-	-	-	-	-	6.8	6.8
Unplanned maintenances, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenances, GWh	8.3	55.2	18.4	8.7	65.0	11.0	9.0	14.6	9.0	14.2	14.6	9.0	236.9
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	175.6	158.6	175.6	169.9	175.6	169.9	175.6	175.6	169.9	175.6	169.9	175.6	2067.4

Figure 5.52 presents the annual utilization of Skagerak 1 according to all the categories of technical capacity (E_{max}) for the years 2012–2018. The availability and unavailability categories are explained further in Section 3. Figure 5.53 presents the percentage of hours of a year Skagerak 1 has been affected by either a limitation, an unplanned or planned maintenance outage, a disturbance outage or an other outage annually during the years 2012–2018. Figure 5.54 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2018.

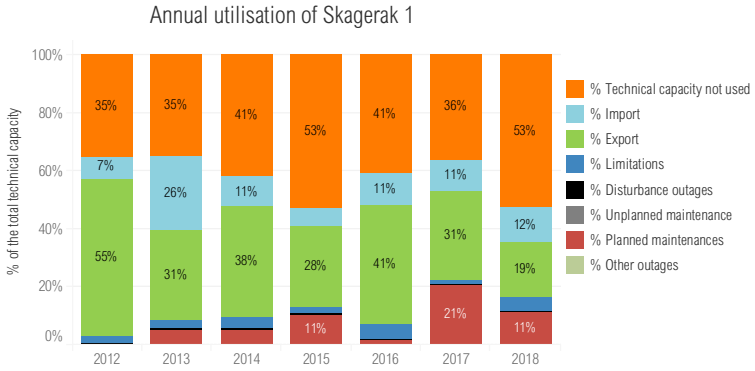

Figure 5.52: Annual utilisation of Skagerak 1 according to the utilisation and unavailability categories for the years 2012–2018. The utilisation and unavailability categories are described in more detail in Section 3.

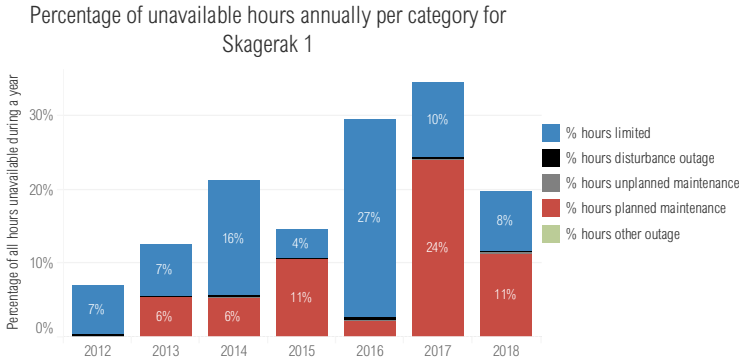

Figure 5.53: Percentage of hours Skagerak 1 has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2018. The percentage is calculated by counting the number of hours with an limitation or outage and dividing it by the total number of hours in a year. Therefore, the result may show more than 100 % if one hour is affected by more than one kind of limitation or outage.

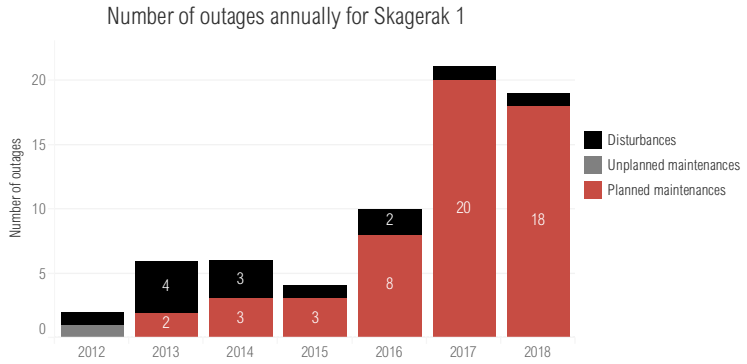

Figure 5.54: The annual number of disturbances, unplanned and planned maintenance outages and other outages Skagerak 1 for the years 2012–2018. Skagerak 1 had no other outages during the years 2012–2018.

5.3.13 Skagerak 2

Figure 5.55 presents the availability and utilisation of Skagerak 2 for 2018 and Table 5.13 presents the numerical values behind it. Skagerak 1 and Skagerak 2 have been in operation since 1976 and are the oldest HVDC links in operation in the Nordic countries. In Norway, the links are connected to Kristiansand on the southern coast (bidding zone NO2) and in Denmark to Tjele (bidding zone DK1), approximately 15 km east of the town of Viborg in the northern part of Jutland. The transmission capacity of Skagerak 2 is 236 MW at the receiving end.

In 2018, Skagerak 2 had an available technical capacity of 75 %. The technical capacity not used was 47 %. Totally, 0.4 TWh (18 % of the technical capacity) was exported from Norway to the Denmark and 0.2 TWh (10 % of the technical capacity) was imported to Norway.

Skagerak 1,2 and 3 have an ongoing process of regalvanizing their electrode masts and replacing their electrode lines, which caused the high amount of planned maintenance in 2018. This regalvanizing work was completed during 2018. Additionally, Skagerak 2 had 1 disturbance outage in April during 2018. The disturbance outage was caused by a transformer failure and lasted until May.

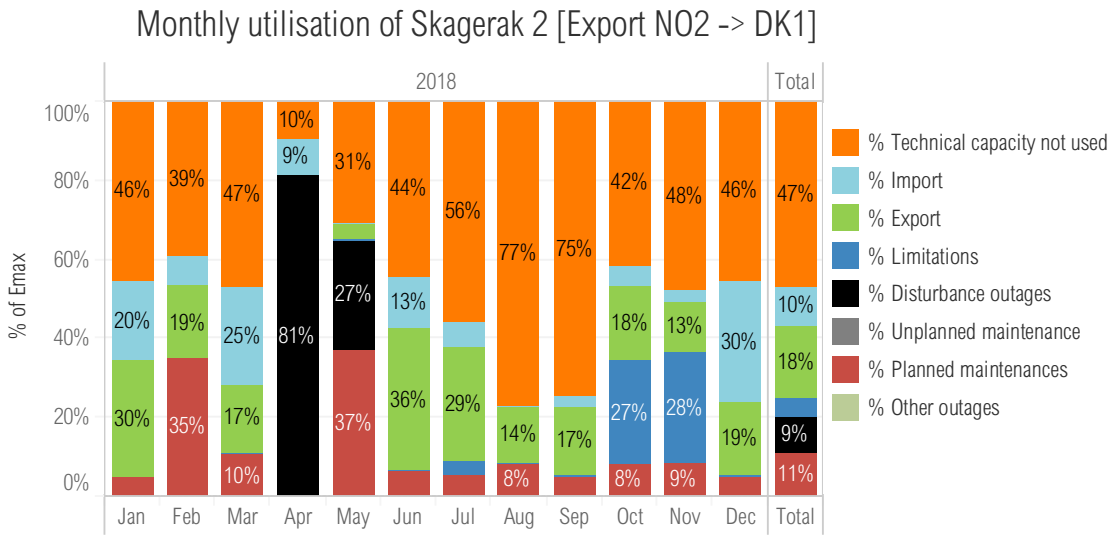

Figure 5.55: Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Skagerak 2 in 2018.

Table 5.13: Monthly distribution of the technical capacity (E_{max}) for Skagerak 2 in 2018. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Skagerak 2 [Export NO2 -> DK1]	2018												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Import losses, GWh	1.8	0.6	2.0	0.8	-	1.2	0.5	-	0.2	0.4	0.1	2.7	10.3
Export losses, GWh	2.5	1.4	1.5	-	0.2	2.7	2.4	0.8	0.9	1.1	0.7	1.5	15.7
Technical capacity not used, GWh	80.0	62.3	82.6	16.6	53.9	75.4	98.6	135.0	127.0	73.3	81.7	80.1	966.4
Import, GWh	34.9	11.1	43.7	15.1	0.3	22.0	10.7	1.0	4.9	9.4	4.2	53.4	210.6
Export, GWh	52.4	30.0	29.7	-	7.1	61.4	50.7	24.5	28.7	32.0	22.1	33.0	371.7
Limitations, GWh	-	-	1.2	-	1.2	0.4	6.7	0.5	0.4	46.7	47.3	0.3	104.6
Disturbance outages, GWh	-	-	-	138.3	48.1	-	-	-	-	-	-	-	186.4
Unplanned maintenances, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenances, GWh	8.3	55.2	18.4	-	65.0	10.7	9.0	14.6	8.9	14.2	14.6	8.9	227.8
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	175.6	158.6	175.6	169.9	175.6	169.9	175.6	175.6	169.9	175.6	169.9	175.6	2067.4

Figure 5.56 presents the annual utilization of Skagerak 2 according to all the categories of technical capacity (E_{max}) for the years 2012–2018. The availability and unavailability categories are explained further in Section 3. Figure 5.57 presents the percentage of hours of a year Skagerak 2 has been affected by either a limitation, an unplanned or planned maintenance outage, a disturbance outage or an other outage annually during the years 2012–2018. Figure 5.58 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2018.

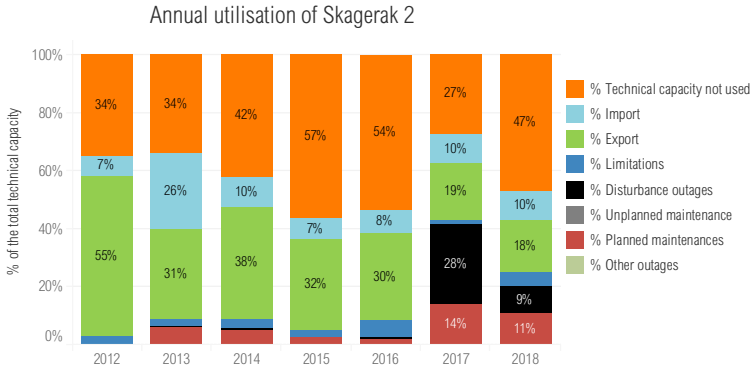

Figure 5.56: Annual utilisation of Skagerak 2 according to the utilisation and unavailability categories for the years 2012–2018. The utilisation and unavailability categories are described in more detail in Section 3.

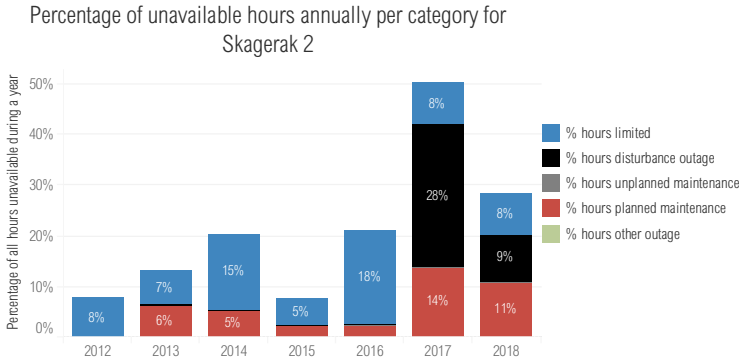

Figure 5.57: Percentage of hours Skagerak 2 has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2018. The percentage is calculated by counting the number of hours with an limitation or outage and dividing it by the total number of hours in a year. Therefore, the result may show more than 100 % if one hour is affected by more than one kind of limitation or outage.

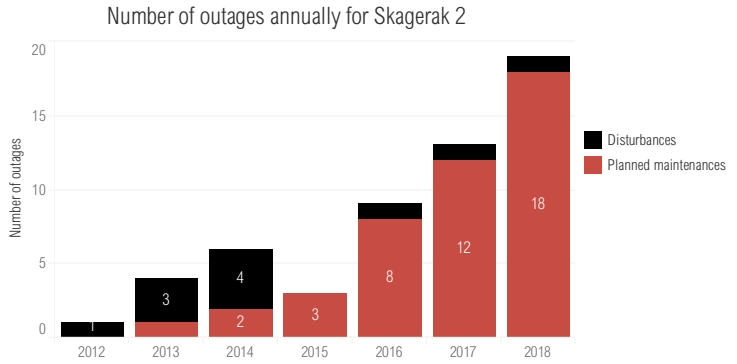

Figure 5.58: The annual number of disturbances, unplanned and planned maintenance outages and other outages Skagerak 2 for the years 2012–2018. Skagerak 2 had no other outages during the years 2012–2018.

5.3.14 Skagerak 3

Figure 5.59 presents the availability and utilisation of Skagerak 3 for 2018 and Table 5.14 presents the numerical values behind it. Skagerak 3 has been in operation since 1993. In Norway, it is connected to Kristiansand (bidding zone NO2) and in Denmark to Tjele (bidding zone DK1). The transmission capacity of Skagerak 3 is 478 MW at the receiving end.

In 2018, Skagerak 3 had an available technical capacity of 79.6 %. The technical capacity not used was 23.0 %. Totally, 1.6 TWh (37.5 % of the technical capacity) was exported from Norway to Denmark and 0.9 TWh (19.1 % of the technical capacity) was imported to Norway.

Skagerak 1,2 and 3 have an ongoing process of regalvanizing their electrode masts and replacing their electrode lines, which caused the high amount of planned maintenance in 2018. This regalvanizing work was completed during 2018. Additionally, Skagerak 3 had no disturbance outages during 2018.

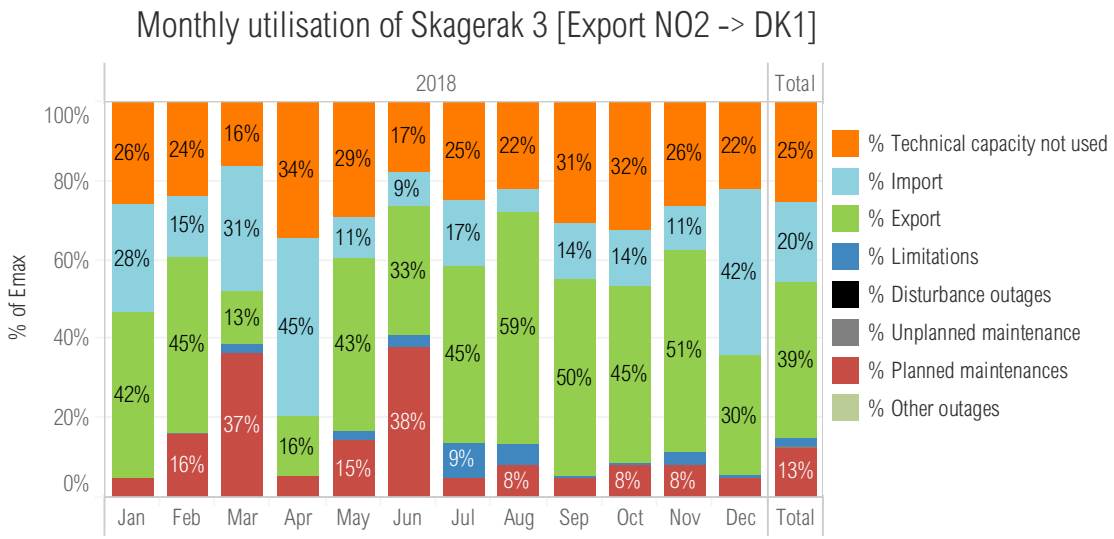

Figure 5.59: Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Skagerak 3 in 2018.

Table 5.14: Monthly distribution of the technical capacity (E_{max}) for Skagerak 3 in 2018. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Skagerak 3 [Export NO2 -> DK1]

	2018												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Import losses, GWh	2.7	1.2	2.9	3.7	0.9	0.8	1.5	0.5	1.2	1.3	1.0	4.0	21.9
Export losses, GWh	3.5	3.3	1.1	1.1	3.6	2.7	3.7	4.9	4.0	3.9	4.1	2.6	38.6
Technical capacity not used, GWh	91.1	77.3	58.6	118.6	104.2	60.1	88.9	78.2	105.9	115.4	90.3	77.7	1066.5
Import, GWh	97.9	48.3	111.7	154.6	37.7	30.4	59.2	20.8	48.7	49.4	38.0	149.5	846.2
Export, GWh	150.0	143.6	47.4	53.6	153.8	112.8	158.7	208.7	170.8	160.7	177.0	108.1	1645.0
Limitations, GWh	-	-	7.9	-	8.1	10.1	31.2	19.3	1.5	1.5	10.3	3.0	92.9
Disturbance outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Unplanned maintenances, GWh	-	0.5	-	-	-	-	-	-	-	-	-	-	0.5
Planned maintenances, GWh	16.6	51.5	130.0	17.4	51.9	130.7	17.6	28.7	17.3	28.7	28.6	17.3	536.3
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	355.7	321.2	355.6	344.2	355.6	344.2	355.6	355.7	344.2	355.7	344.2	355.7	4187.5

Figure 5.60 presents the annual utilization of Skagerak 3 according to all the categories of technical capacity (E_{max}) for the years 2012–2018. The availability and unavailability categories are explained further in Section 3. Figure 5.61 presents the percentage of hours of a year Skagerak 3 has been affected by either a limitation, an unplanned or planned maintenance outage, a disturbance outage or an other outage annually during the years 2012–2018. Figure 5.62 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2018.

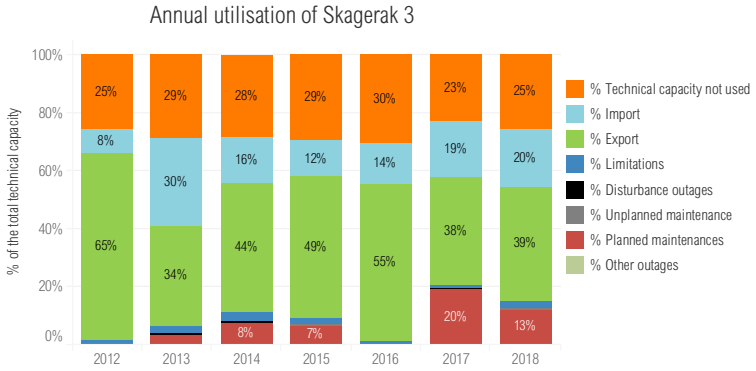

Figure 5.60: Annual utilisation of Skagerak 3 according to the utilisation and unavailability categories for the years 2012–2018. The utilisation and unavailability categories are described in more detail in Section 3.

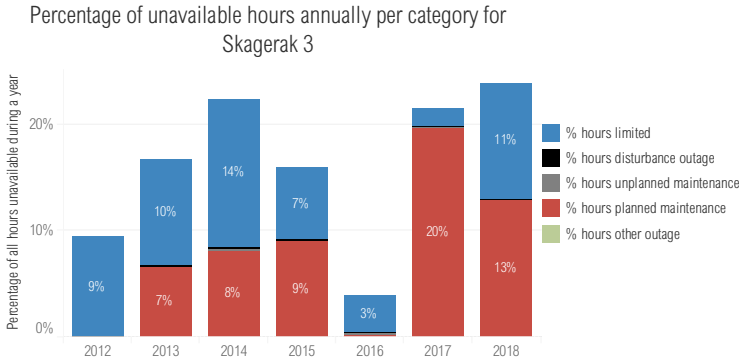

Figure 5.61: Percentage of hours Skagerak 3 has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2018. The percentage is calculated by counting the number of hours with an limitation or outage and dividing it by the total number of hours in a year. Therefore, the result may show more than 100 % if one hour is affected by more than one kind of limitation or outage.

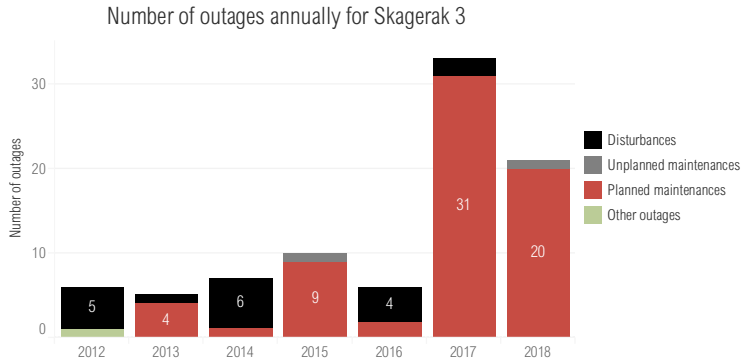

Figure 5.62: The annual number of disturbances, unplanned and planned maintenance outages and other outages Skagerak 3 for the years 2012–2018.

5.3.15 Skagerak 4

Figure 5.63 presents the availability and utilisation of Skagerak 4 for 2018 and Table 5.15 presents the numerical values behind it. Skagerak 4 has been in commercial operation since 29 December 2014. In Norway, it is connected to Kristiansand (bidding zone NO2) and in Denmark to Tjele (bidding zone DK1). The transmission capacity is 682 MW at the receiving end.

In 2018, Skagerak 4 had an available technical capacity of 95 %. The technical capacity not used was 31 %. Totally, 2.5 TWh (42 % of the technical capacity) was exported from Norway to the Denmark and 1.3 TWh (22 % of the technical capacity) was imported to Norway.

The annual maintenance of Skagerak 4 lasted four days in October. Additionally, Skagerak 4 had 2 disturbance outages, 1 unplanned maintenance outage and 1 planned maintenance outage during 2018 with only minor impact. The limitations on Skagerak 4 were mainly related to the electrode current when Skagerak 3 was out due to maintenance.

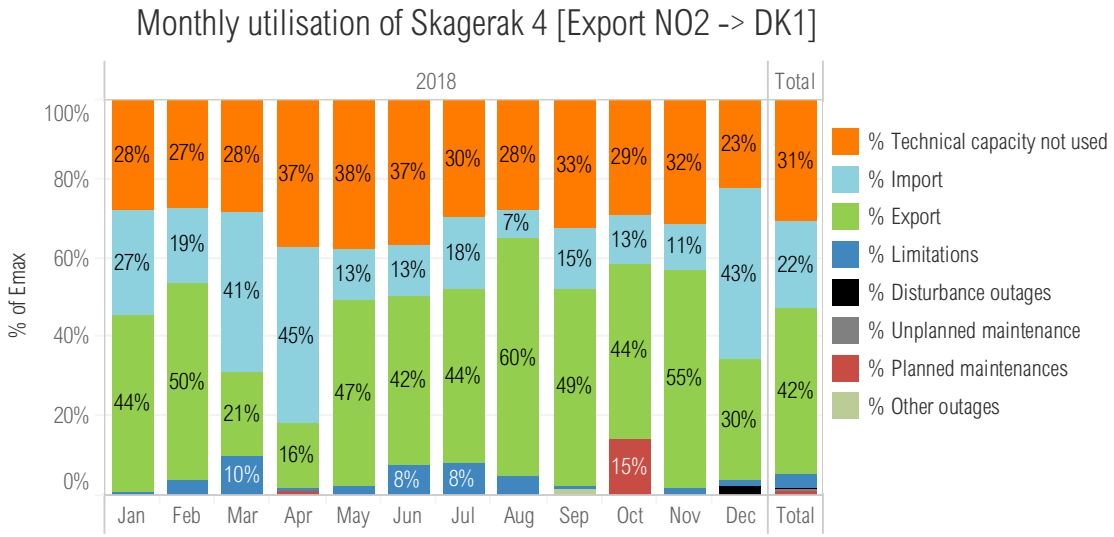

Figure 5.63: Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Skagerak 4 in 2018.

Table 5.15: Monthly distribution of the technical capacity (E_{max}) for Skagerak 4 in 2018. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Skagerak 4 [Export NO2 -> DK1]	2018												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Import losses, GWh	3.4	2.1	4.9	5.6	1.6	1.6	2.2	0.9	1.8	1.6	1.4	5.4	32.4
Export losses, GWh	4.3	4.3	2.0	1.6	4.6	3.9	4.2	5.8	4.6	4.3	5.1	3.0	47.7
Technical capacity not used, GWh	140.5	125.9	143.6	182.6	191.3	180.7	150.5	141.9	160.0	147.3	156.2	114.5	1835.0
Import, GWh	137.2	85.9	206.3	220.1	65.3	63.7	91.4	35.8	75.8	64.5	54.6	219.3	1319.9
Export, GWh	224.2	228.5	105.8	79.1	238.8	208.1	224.9	305.1	242.9	222.0	271.3	154.2	2504.9
Limitations, GWh	5.4	17.5	51.7	3.8	12.1	38.5	40.5	24.6	4.7	-	8.9	6.1	213.9
Disturbance outages, GWh	-	-	-	-	-	-	-	-	-	-	-	13.3	13.3
Unplanned maintenances, GWh	-	0.6	-	-	-	-	-	-	-	-	-	-	0.6
Planned maintenances, GWh	-	-	-	5.4	-	-	-	-	-	73.6	-	-	79.1
Other outages, GWh	-	-	-	-	-	-	-	-	7.6	-	-	-	7.6
Total, GWh	507.4	458.3	507.4	491.0	507.4	491.0	507.4	507.4	491.0	507.4	491.0	507.4	5974.3

Figure 5.64 presents the annual utilization of Skagerak 4 according to all the categories of technical capacity (E_{max}) for the years 2015–2018. The availability and unavailability categories are explained further in Section 3. Figure 5.65 presents the percentage of hours of a year Skagerak 4 has been affected by either a limitation, an unplanned or planned maintenance outage, a disturbance outage or an other outage annually during the years 2015–2018. Figure 5.66 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2015–2018.

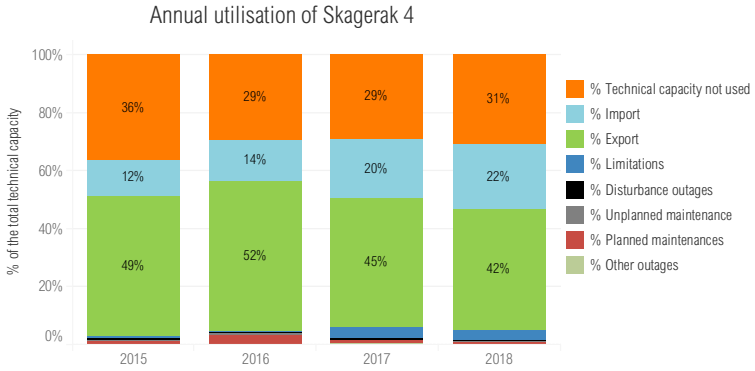

Figure 5.64: Annual utilisation of Skagerak 4 according to the utilisation and unavailability categories for the years 2015–2018. The utilisation and unavailability categories are described in more detail in Section 3.

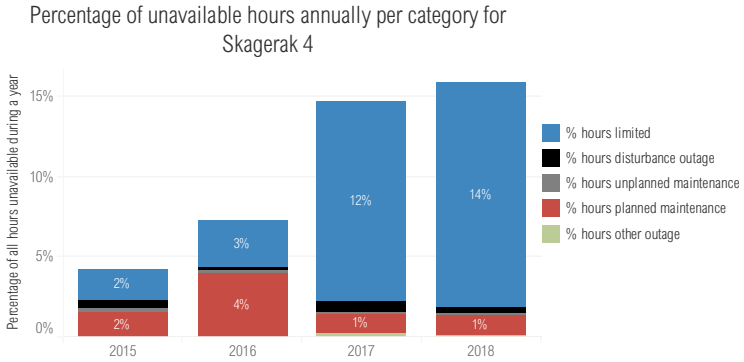

Figure 5.65: Percentage of hours Skagerak 4 has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2015–2018. The percentage is calculated by counting the number of hours with an limitation or outage and dividing it by the total number of hours in a year. Therefore, the result may show more than 100 % if one hour is affected by more than one kind of limitation or outage.

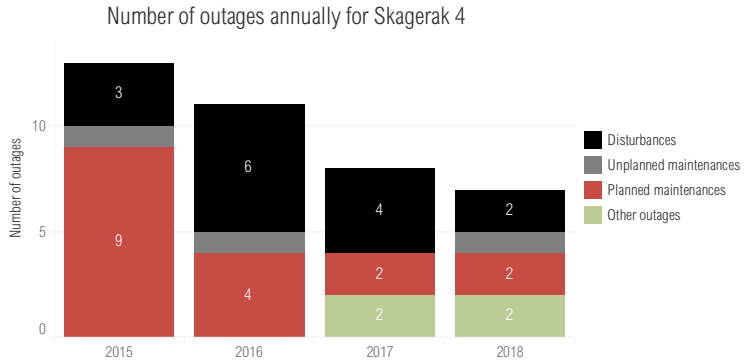

Figure 5.66: The annual number of disturbances, unplanned and planned maintenance outages and other outages Skagerak 4 for the years 2015–2018.

5.3.16 Storebaelt

Figure 5.67 presents the availability and utilisation of Storebaelt for 2018 and Table 5.16 presents the numerical values behind it. Storebaelt has been in operation since 2010. It connects the western part of the Danish system, which belongs to the Continental European synchronous system (Jutland and the island of Fynen), with the eastern part, belonging to the Nordic synchronous system (Zealand). The link is connected to Fraugde on Fynen (bidding zone DK1) and to Herslev on Zealand (bidding zone DK2). The transmission capacity is 600 MW.

In 2018, Storebaelt had an available technical capacity of 98 %. The technical capacity not used was 35 %. Totally, 3.2 TWh (61 % of the technical capacity) was exported from Jutland to Zealand and 0.1 TWh (3 % of the technical capacity) was imported to Jutland.

The annual maintenance of Storebaelt lasted 4 days in April. Additionally, Storebaelt had 2 disturbance outages and 1 planned maintenance outage during 2018 with only minor impact.

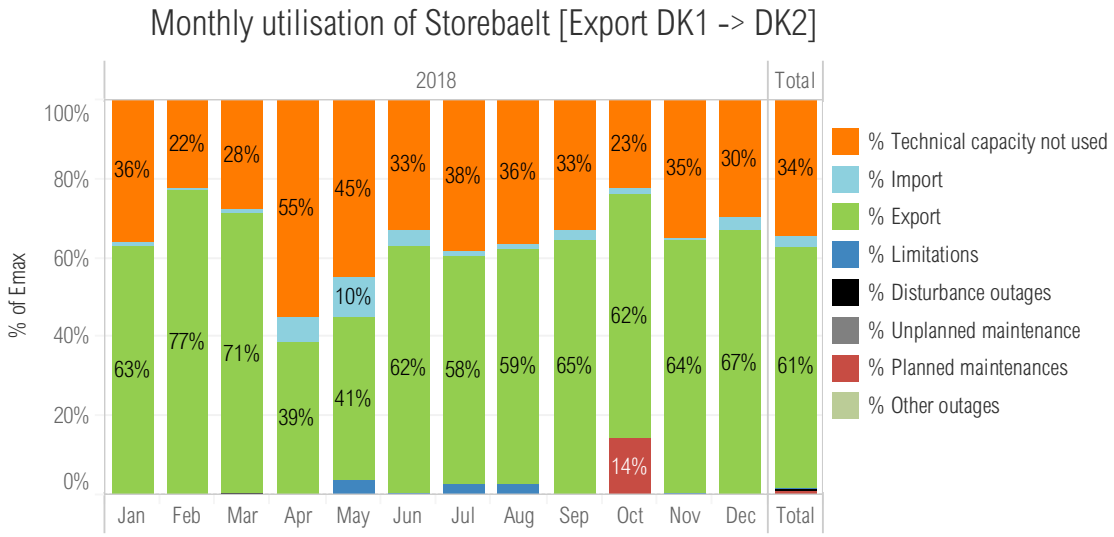

Figure 5.67: Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Storebaelt in 2018.

Table 5.16: Monthly distribution of the technical capacity (E_{max}) for Storebaelt in 2018. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of Storebaelt [Export DK1 -> DK2]	2018												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Import losses, GWh	0.1	-	0.1	0.5	0.7	0.3	0.1	0.1	0.2	0.1	-	0.2	2.5
Export losses, GWh	4.8	5.4	5.5	2.8	3.1	4.7	4.3	4.6	4.9	4.8	4.8	5.2	54.7
Technical capacity not used, GWh	159.5	89.9	123.6	237.9	200.2	141.8	170.3	161.3	141.8	101.0	151.7	133.3	1812.3
Import, GWh	4.6	2.0	3.5	26.4	45.6	17.5	7.0	7.6	10.4	6.0	2.1	13.4	146.0
Export, GWh	282.4	311.3	316.4	166.8	184.4	269.9	256.7	264.7	279.8	275.9	277.2	299.6	3185.1
Limitations, GWh	-	-	-	0.8	16.2	2.8	12.4	12.9	-	-	1.1	-	46.2
Disturbance outages, GWh	-	-	1.0	-	-	-	-	-	-	-	-	-	1.0
Unplanned maintenances, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenances, GWh	-	-	1.2	-	-	-	-	-	-	64.2	-	-	65.4
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	446.4	403.2	445.8	432.0	446.4	432.0	446.4	446.4	432.0	447.0	432.0	446.4	5256.0

Figure 5.68 presents the annual utilization of Storebaelt according to all the categories of technical capacity (E_{max}) for the years 2012–2018. The availability and unavailability categories are explained further in Section 3. Figure 5.69 presents the percentage of hours of a year Storebaelt has been affected by either a limitation, an unplanned or planned maintenance outage, a disturbance outage or an other outage annually during the years 2012–2018. Figure 5.70 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2018.

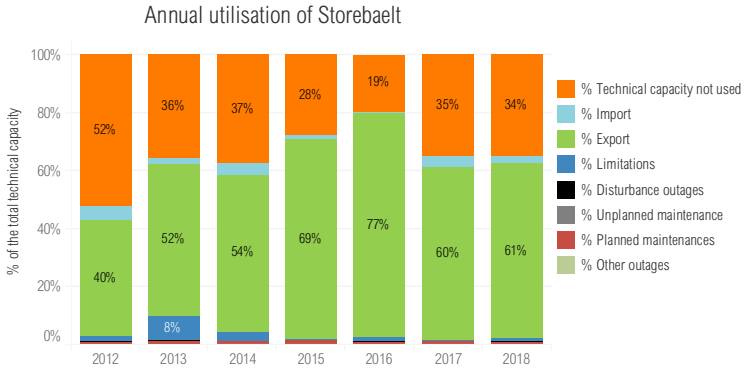

Figure 5.68: Annual utilisation of Storebaelt according to the utilisation and unavailability categories for the years 2012–2018. The utilisation and unavailability categories are described in more detail in Section 3.

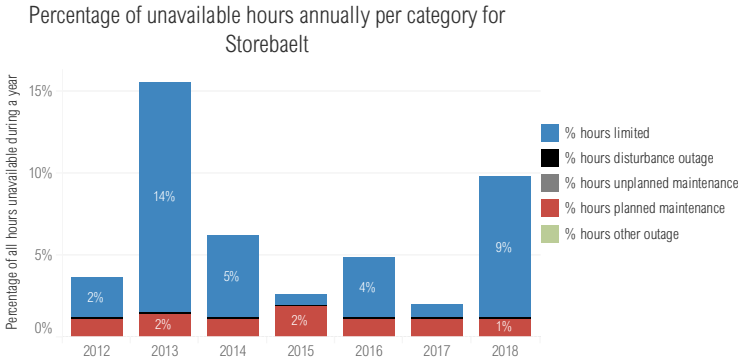

Figure 5.69: Percentage of hours Storebaelt has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2018. The percentage is calculated by counting the number of hours with an limitation or outage and dividing it by the total number of hours in a year. Therefore, the result may show more than 100 % if one hour is affected by more than one kind of limitation or outage.

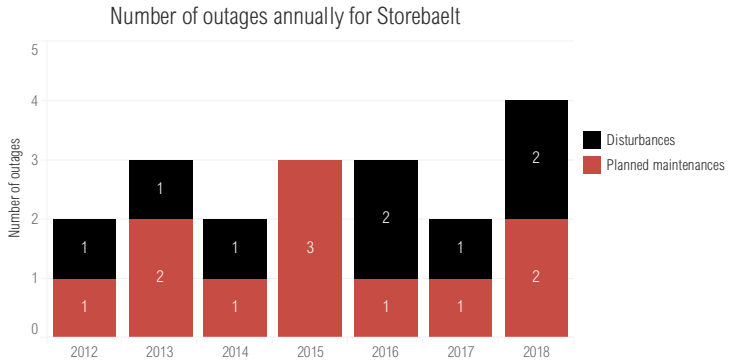

Figure 5.70: The annual number of disturbances, unplanned and planned maintenance outages and other outages Storebaelt for the years 2012–2018. Storebaelt had no other outages during the years 2012–2018.

5.3.17 SwePol

Figure 5.71 presents the availability and utilisation of SwePol for 2018 and Table 5.17 presents the numerical values behind it. SwePol Link has been in operation since 2000 and it connects the Swedish and Polish transmission grids. In south-eastern Sweden (bidding zone SE4) it is connected to Stärnö and in Poland (bidding zone PL) to Slupsk. The transmission capacity is 600 MW.

In 2018, SwePol had an available technical capacity of 96 %. The technical capacity not used was 30 %. Totally, 3.1 TWh (59 % of the technical capacity) was exported from Sweden to Poland and 0.4 TWh (7 % of the technical capacity) was imported to Sweden.

The annual maintenance of SwePol lasted six days in September. Additionally, SwePol had 5 disturbance outages and 4 planned maintenance outages during 2018 with only minor impact.

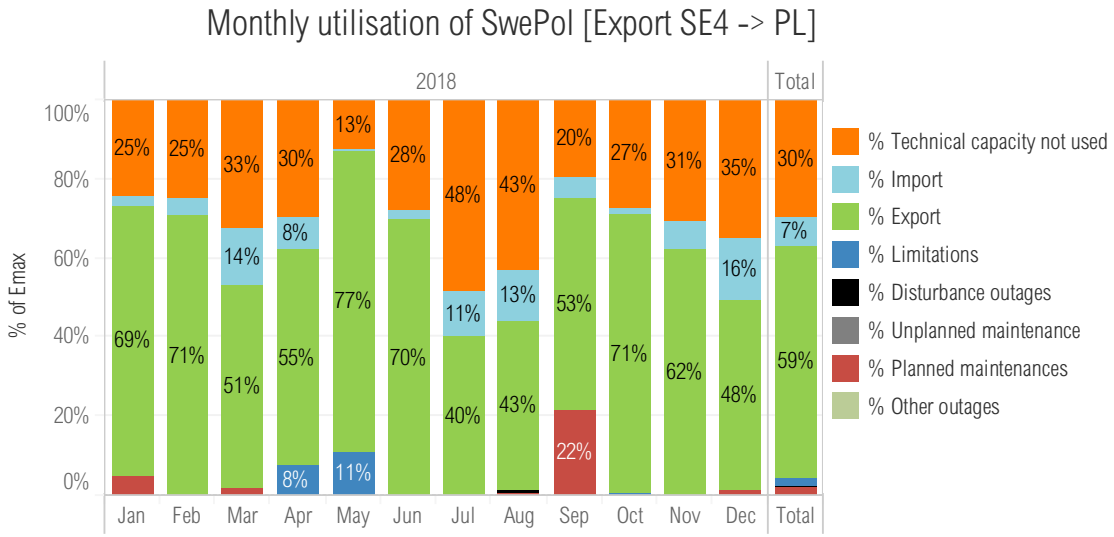

Figure 5.71: Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for SwePol in 2018.

Table 5.17: Monthly distribution of the technical capacity (E_{max}) for SwePol in 2018. Note that import and export losses are not included in the technical capacity (E_{max}), as is shown in Figure 3.1.

Monthly utilisation of SwePol [Export SE4 -> PL]

2018	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Import losses, GWh	0.2	0.4	1.5	0.7	-	0.3	1.1	1.3	0.5	0.2	0.7	1.7	8.5
Export losses, GWh	8.9	8.3	6.5	6.5	9.6	8.7	5.0	5.2	6.6	8.9	7.7	6.0	87.9
Technical capacity not used, GWh	109.8	99.9	145.9	128.9	56.3	118.9	215.1	192.6	85.7	122.5	131.9	155.9	1563.4
Import, GWh	10.0	17.3	63.8	34.1	0.1	11.4	51.3	57.2	22.2	6.7	31.1	70.8	376.1
Export, GWh	306.2	286.0	227.8	235.9	341.8	301.7	180.0	190.2	231.0	315.8	269.1	213.1	3098.4
Limitations, GWh	-	-	-	33.1	48.3	-	-	-	-	2.0	-	-	83.4
Disturbance outages, GWh	-	-	-	-	-	-	-	4.6	-	-	-	-	4.6
Unplanned maintenances, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenances, GWh	20.4	-	8.4	-	-	-	-	1.8	93.0	-	-	6.6	130.1
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	446.4	403.2	445.8	432.0	446.4	432.0	446.4	446.4	432.0	447.0	432.0	446.4	5256.0

Figure 5.72 presents the annual utilization of SwePol according to all the categories of technical capacity (E_{max}) for the years 2012–2018. The availability and unavailability categories are explained further in Section 3. Figure 5.73 presents the percentage of hours of a year SwePol has been affected by either a limitation, an unplanned or planned maintenance outage, a disturbance outage or an other outage annually during the years 2012–2018. Figure 5.74 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2018.

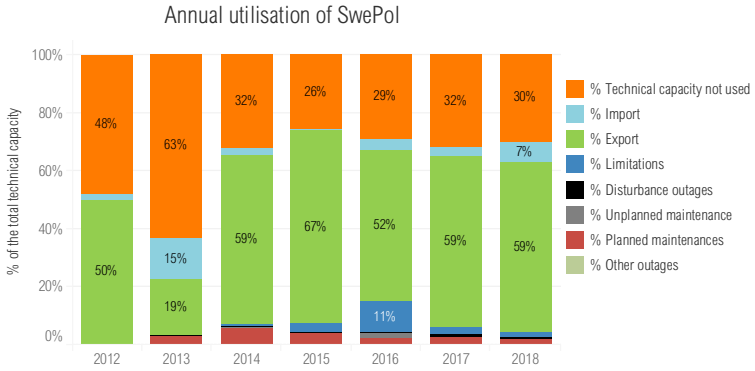

Figure 5.72: Annual utilisation of SwePol according to the utilisation and unavailability categories for the years 2012–2018. The utilisation and unavailability categories are described in more detail in Section 3.

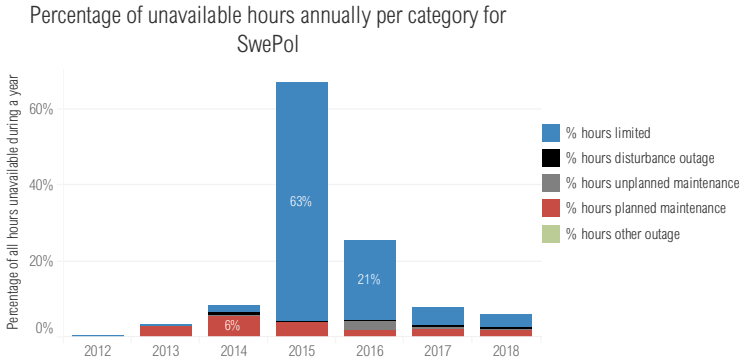

Figure 5.73: Percentage of hours SwePol has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2018. The percentage is calculated by counting the number of hours with an limitation or outage and dividing it by the total number of hours in a year. Therefore, the result may show more than 100 % if one hour is affected by more than one kind of limitation or outage.

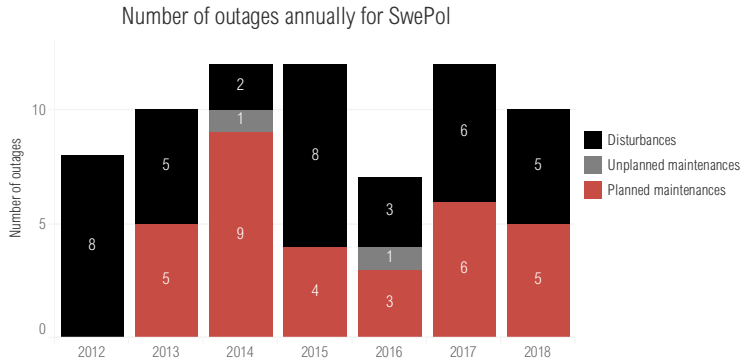

Figure 5.74: The annual number of disturbances, unplanned and planned maintenance outages and other outages SwePol for the years 2012–2018. SwePol had no other outages during the years 2012–2018.

5.3.18 Vyborg Link

Figure 5.73 presents the availability and utilisation of the Vyborg Link for 2018 and. The Vyborg Link is a back-to-back HVDC connection between Russia and Finland. The HVDC substation is situated in Vyborg, Russia. The 400 kV lines from Vyborg are connected to substations Yllikkälä and Kymi in southern Finland. The commissioning years were 1981, 1982, 1984, and 2000. Each commissioning included a capacity of 350 MW. The total technical capacity today is 4 × 350 MW and the commercial transmission capacity is 1.3 GW. Fingrid Oyj, the Finnish transmission system operator, allocates 100 MW for reserves. Earlier, the direction of transmission has been only to Finland but during September 2014, one 350 MW unit was successfully tested to be able to export electricity to Russia. The possibility of commercial trade from Finland to Russia started on 1 December 2014.

In 2018, the Vyborg Link had an available technical capacity of 95 %. The technical capacity not used was 28 %. Totally, 5.8 TWh (67 % of the technical capacity) was exported from Russia to Finland and none was imported to Russia.

The annual maintenance of Vyborg Link lasted 30 days in July. Normally, maintenance work on Vyborg Link causes only limitations because the 350 MW units are not worked on simultaneously. In 2018, available transmission capacity during the annual maintenance was limited to 400 MW and caused therefore no planned maintenance outage. Vyborg Link had no disturbance, maintenance or other outages during 2018.

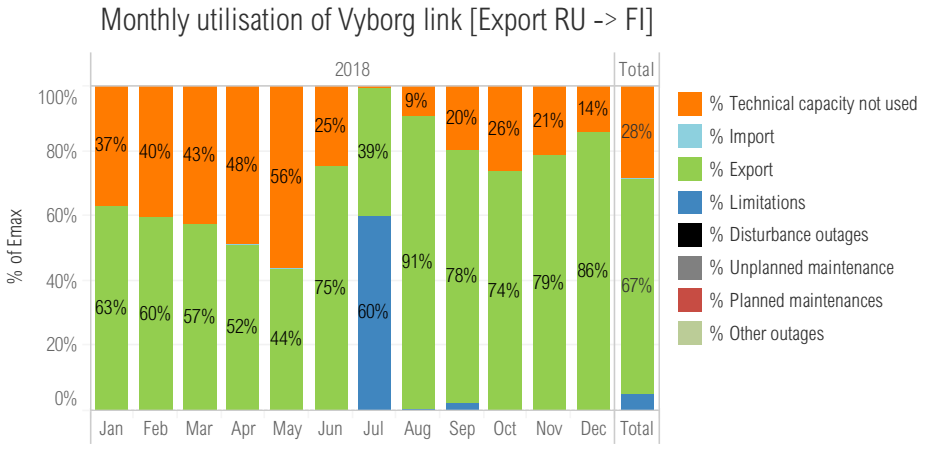

Figure 5.75: Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Vyborg Link in 2018.

Table 5.18: Monthly distribution of the technical capacity (E_{max}) for Vyborg Link in 2018. Measurements from the other side of the Vyborg Link is unknown and therefore losses are based on assumptions. Therefore, transmission losses have been omitted from this table.

Monthly utilisation of Vyborg link [Export RU -> FI]	2018												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Technical capacity not used, GWh	375.6	367.1	425.5	459.2	548.5	238.6	7.1	90.6	187.6	263.6	209.8	143.3	3316.6
Import, GWh	-	-	-	-	0.1	-	-	-	-	-	-	-	0.1
Export, GWh	640.1	541.4	571.8	489.3	430.0	734.6	380.3	928.0	737.7	740.8	771.0	885.7	7850.7
Limitations, GWh	-	-	-	-	-	-	580.1	6.5	23.9	-	-	-	610.5
Disturbance outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Unplanned maintenance., GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Planned maintenance, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Other outages, GWh	-	-	-	-	-	-	-	-	-	-	-	-	-
Total, GWh	1015.7	908.5	997.3	948.5	978.5	973.2	967.5	1025.2	949.2	1004.4	980.8	1029.1	11777.9

Figure 5.76 presents the annual utilization of Vyborg Link according to all the categories of technical capacity (E_{max}) for the years 2012–2018. The availability and unavailability categories are explained further in Section 3. Figure 5.77 presents the percentage of hours of a year Vyborg Link has been affected by either a limitation, an unplanned or planned maintenance outage, a disturbance outage or an other outage annually during the years 2012–2018. Figure 5.78 presents the annual number of disturbance outages, unplanned and planned maintenance and other outages during the years 2012–2018.

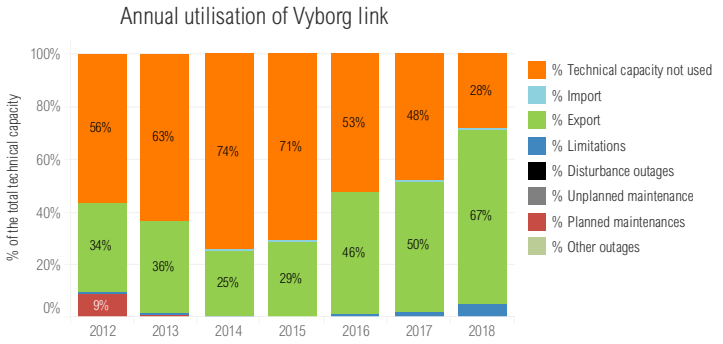

Figure 5.76: Annual utilisation of Vyborg Link according to the utilisation and unavailability categories for the years 2012–2018. The utilisation and unavailability categories are described in more detail in Section 3.

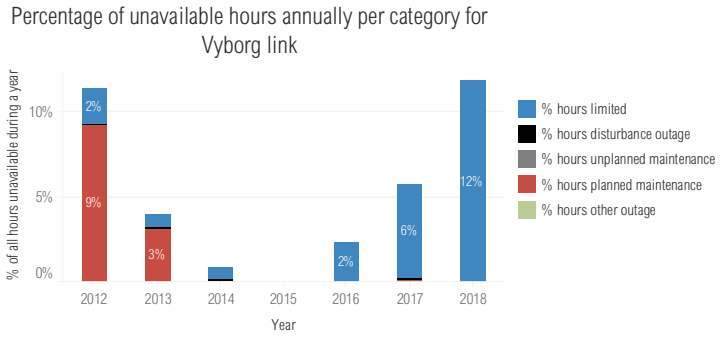

Figure 5.77: Percentage of hours Vyborg Link has been affected by either a limitation, unplanned or planned maintenance or a disturbance or other outage annually for the years 2012–2018. The percentage is calculated by counting the number of hours with an limitation or outage and dividing it by the total number of hours in a year. Therefore, the result may show more than 100 % if one hour is affected by more than one kind of limitation or outage.

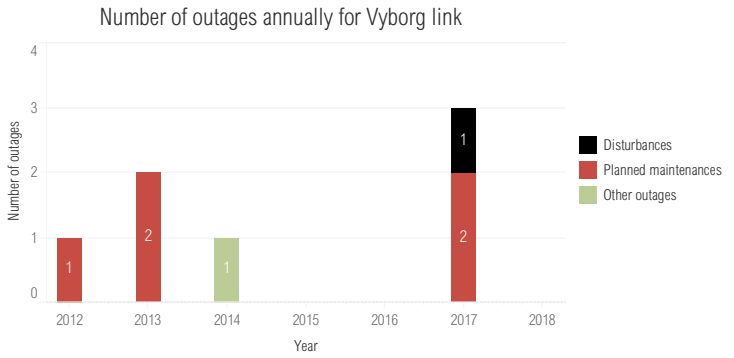

Figure 5.78: The annual number of disturbances, unplanned and planned maintenance outages and other outages Vyborg Link for the years 2012–2018.

References

[1] ENTSO-E, "The ENTSO-E Interconnected System Grid Map." https://www.entsoe.eu/publications/order-maps-and-publications/electronic-grid-maps/Pages/default.aspx.

[2] DISTAC, "Guideline for HVDC Utilisation and Unavailability Statistics." Not yet published.

Appendices

A Schematic presentation of HVDC links

Figure A.1 shows a schematic presentation of an HVDC link with line commutated converters (LCC) and Figure A.3 shows a similar presentation of a link with voltage source converters (VSC). Figure A.2 and Figure A.4, show the converter stations for HVDC links having line commutated converters and voltage source converters, respectively. All the figures also show definitions for the origin of an event. The origin of each event is used for categorizing a disturbance or a limitation for statistical purposes. The figures also show how the terms 'local' and 'remote' are defined and the locations of the circuit breakers and measurement points for transferred energy on a link.

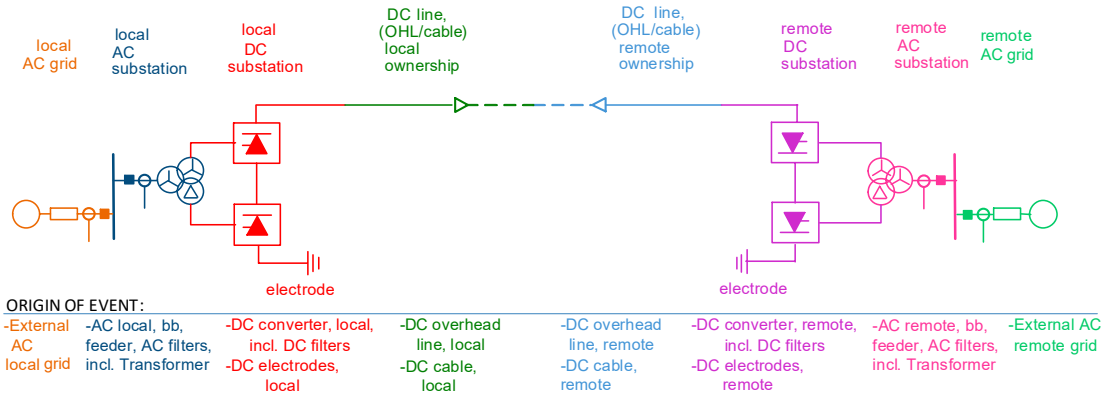

Figure A.1: A schematic presentation of an HVDC link with line commutated converters (LCC)

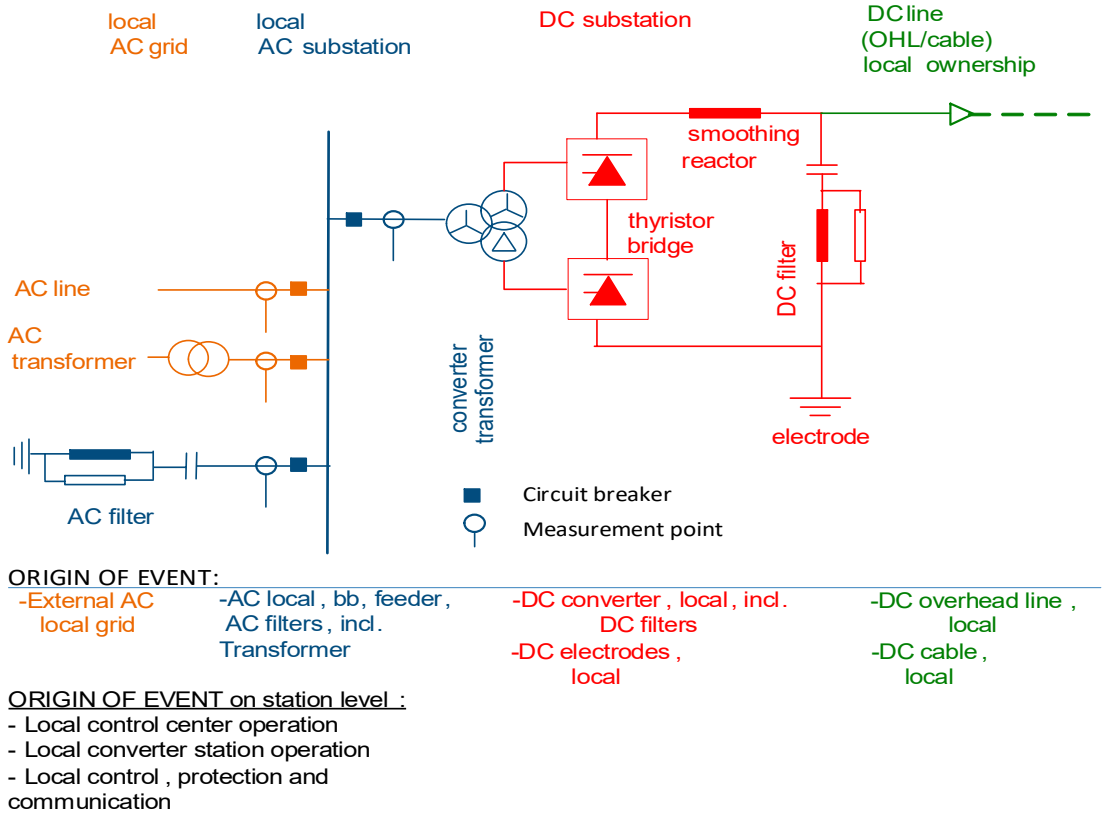

Figure A.2: A converter station of a line commutated converter HVDC link with the connection to the AC grid

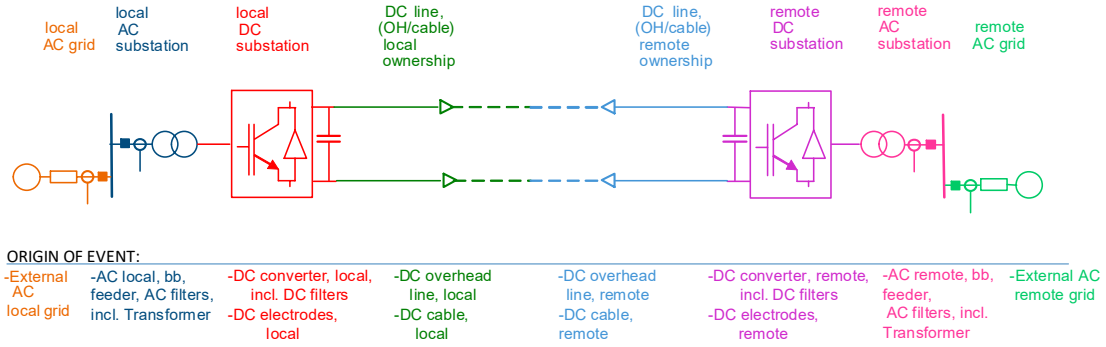

Figure A.3: A schematic presentation of an HVDC link with voltage source converters (VSC)

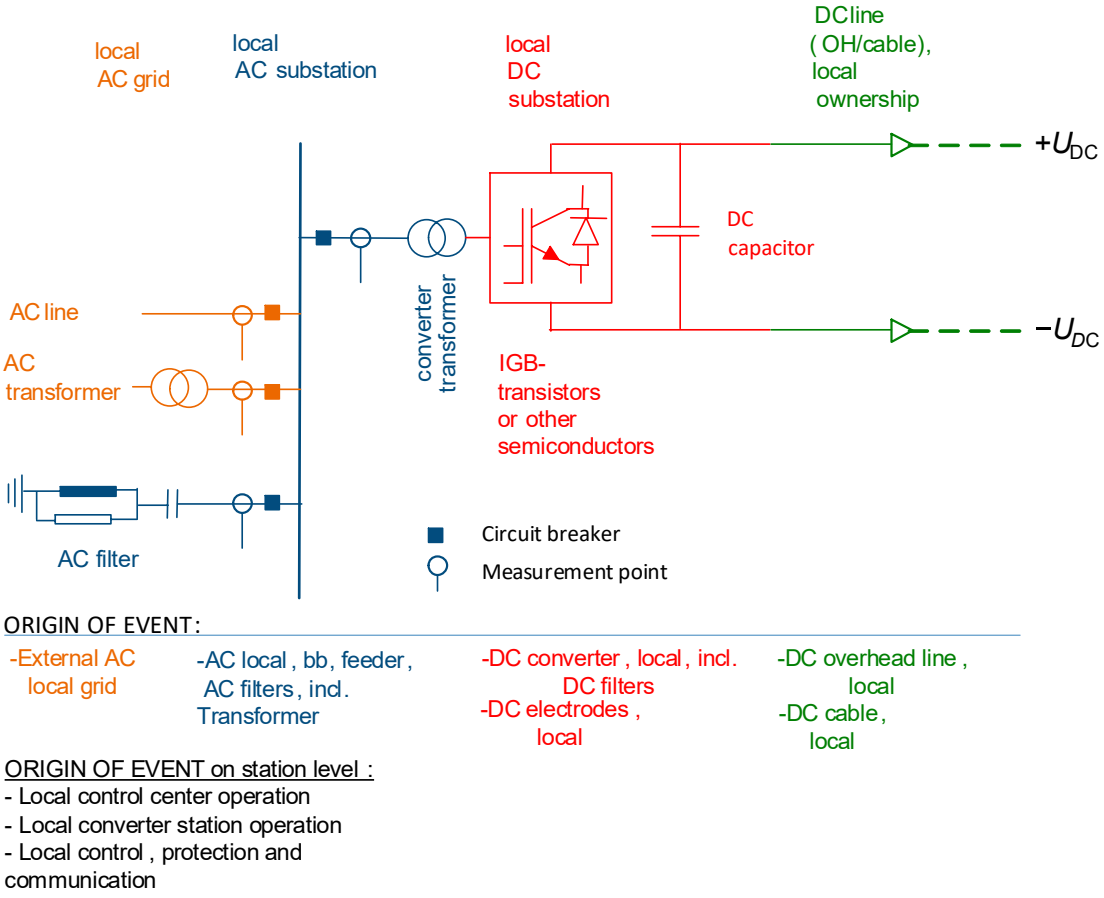

Figure A.4: A converter station of a voltage source converter HVDC link with the connection to the AC grid

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C Sorted overview of utilisation and unavailability for all HVDC links

This chapter contains sorted versions of Figure 5.1.

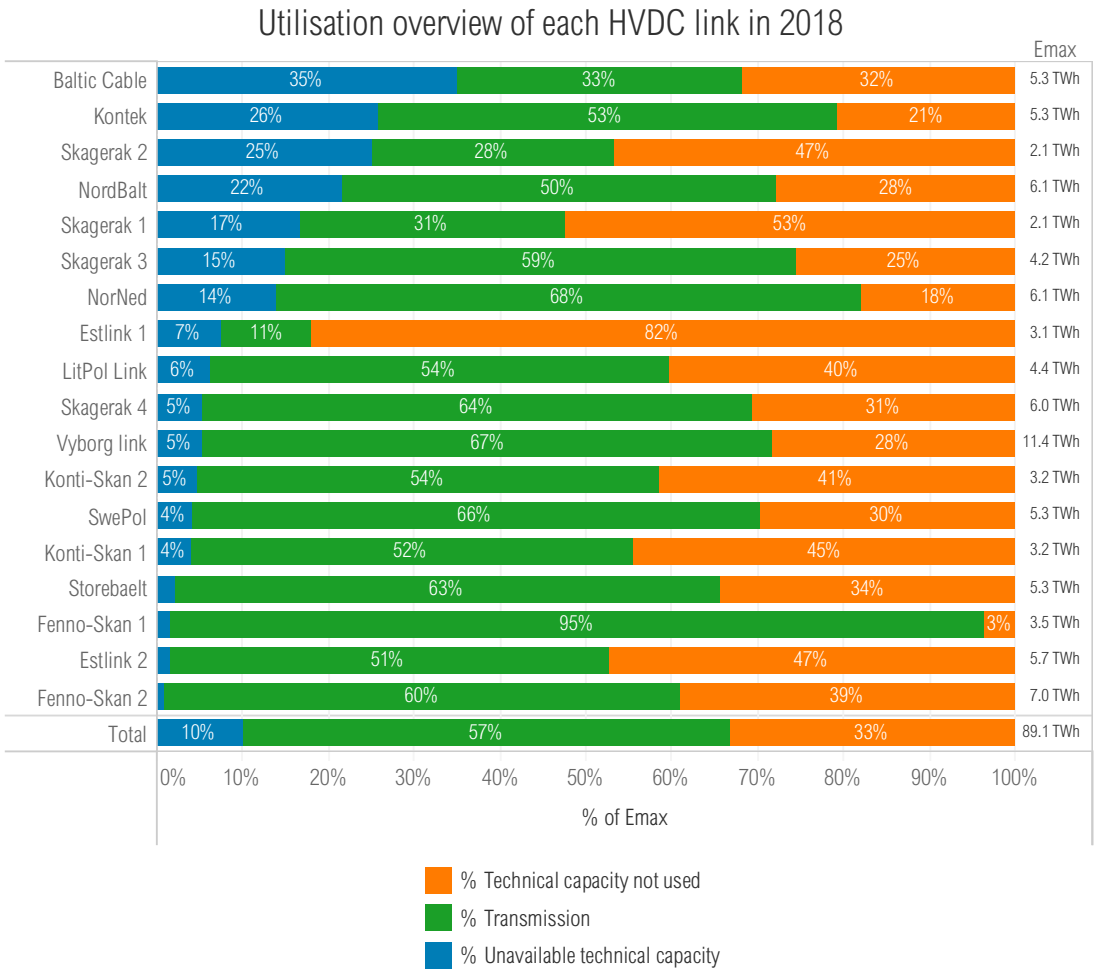

Figure C.1: Overview of each HVDC link sorted by descending unavailable technical capacity (E_U) in 2018.

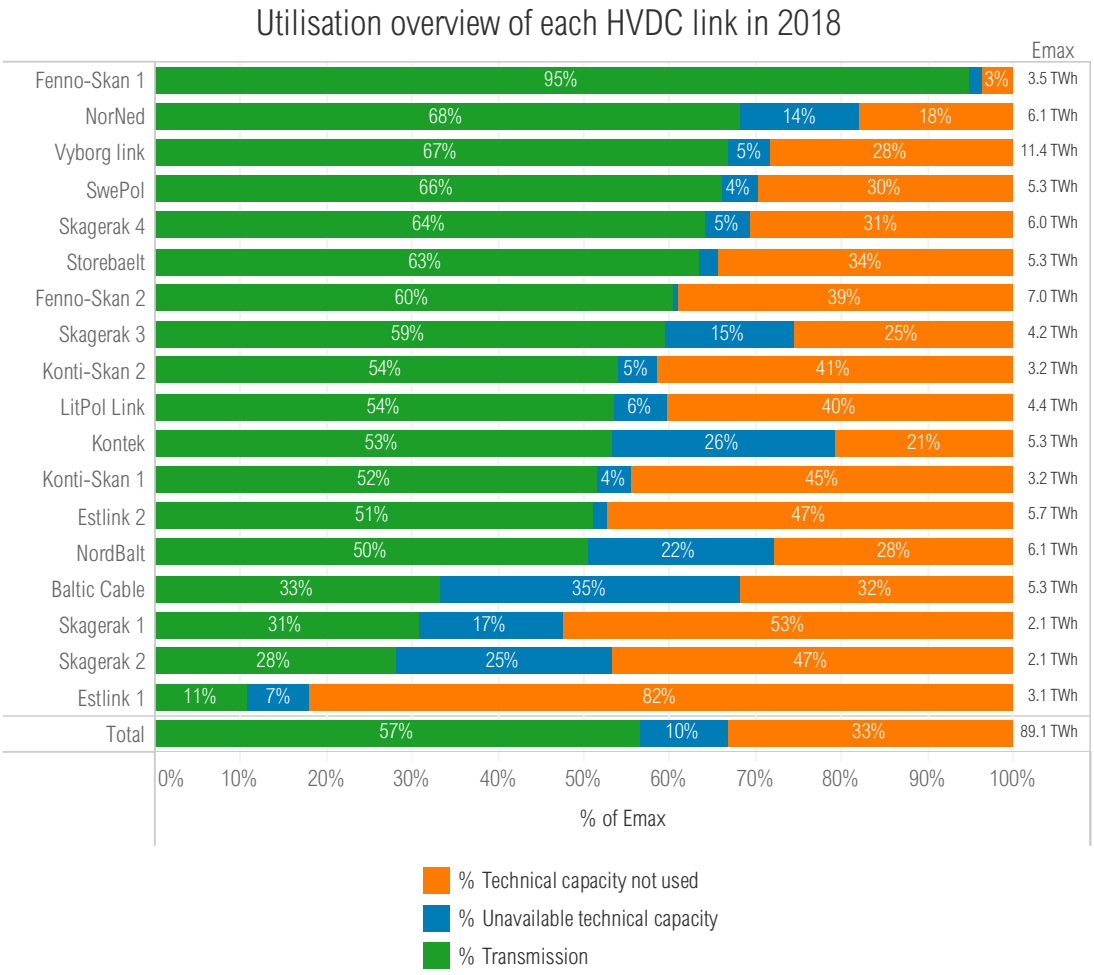

Figure C.2: Overview of each HVDC link sorted by descending transmission (E_T) in 2018.

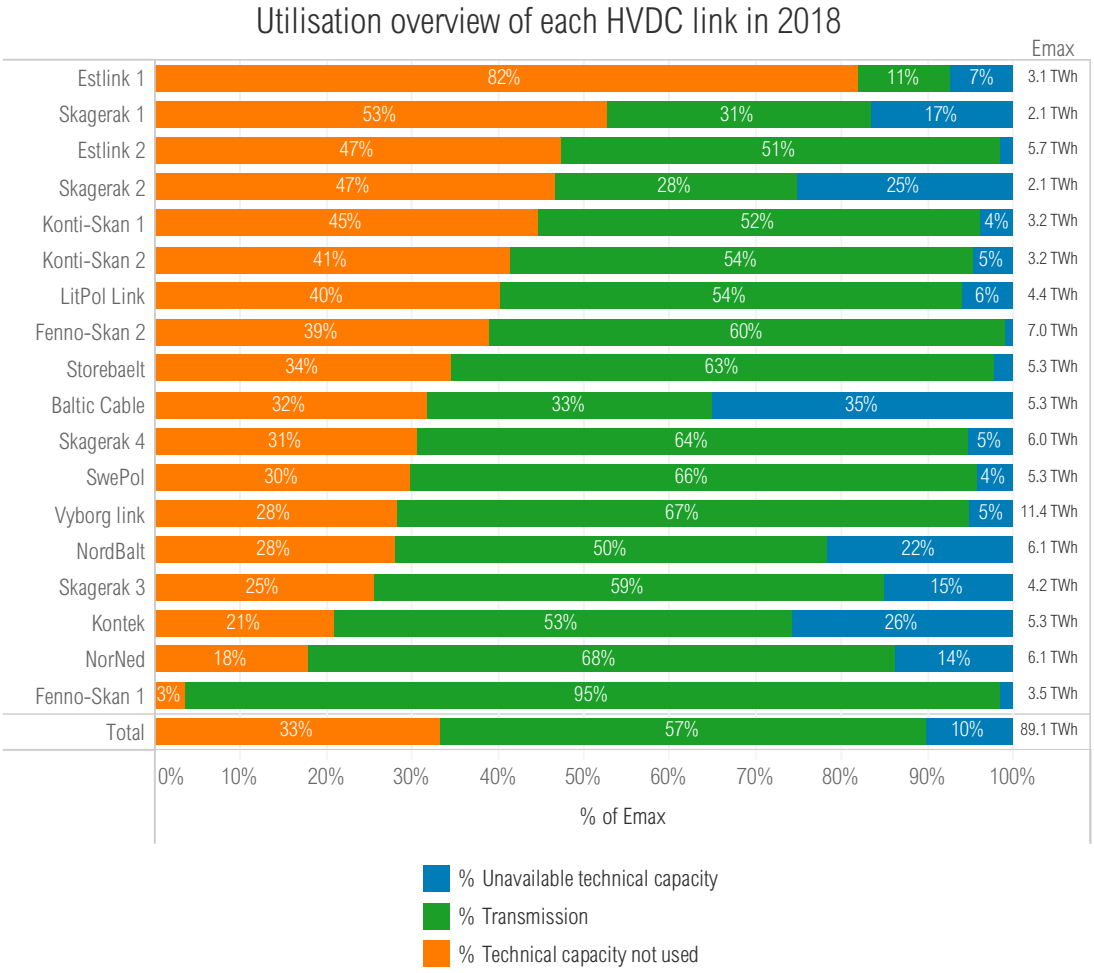

Figure C.3: Overview of each HVDC link sorted by descending technical capacity not used (E_{TCNU}) in 2018.

D Additional figures

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

Figure D.1 presents the annual utilisation of all HVDC links using line-commutated converters (LCC) and Figure D.2 all HVDC links using voltage-source converters (VSC).

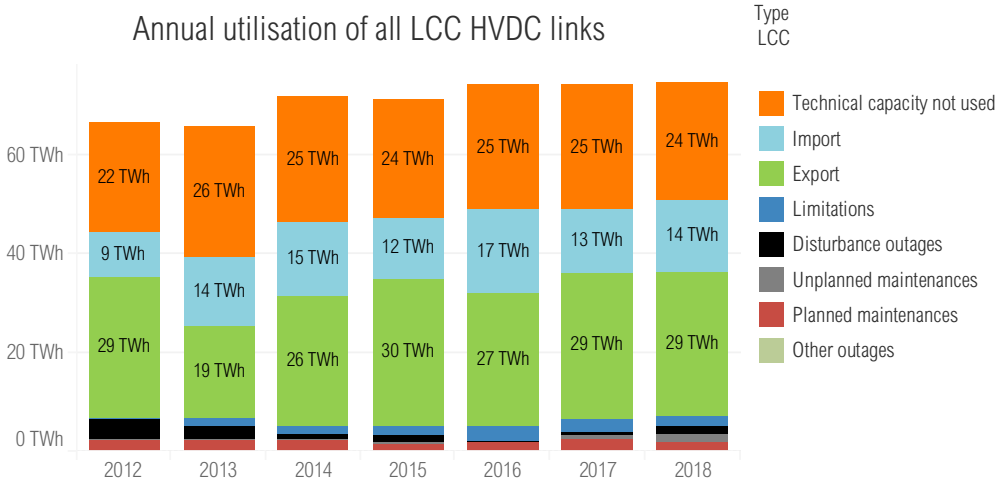

Figure D.1: Annual utilisation of all HVDC links using line-commutated converters (LCC) together presented in megawatt hours (MWh).

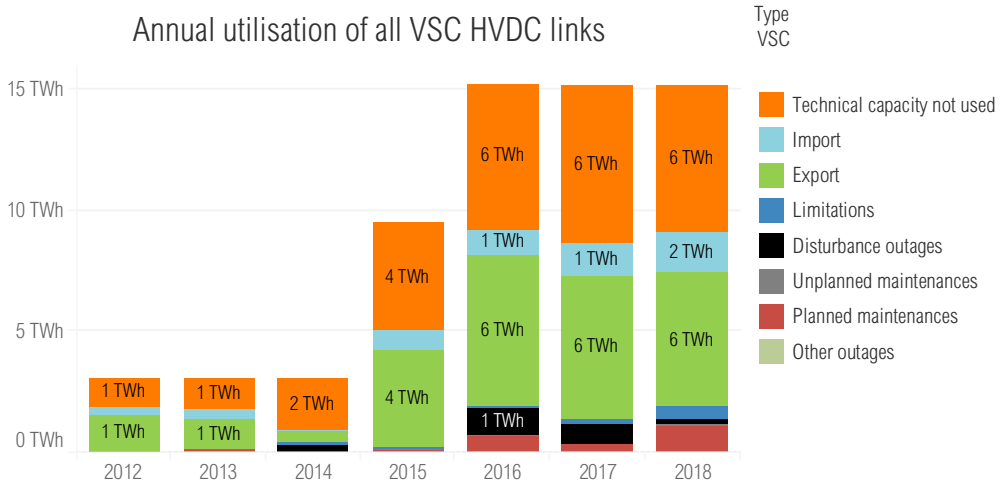

Figure D.2: Annual utilisation of all HVDC links using voltage-source converters (VSC) together presented in megawatt hours (MWh).

Figure D.3 and Figure D.4 presents the percentage of hours all the Nordic and Baltic HVDC links have been limited due to seasonal causes and AC limiting conditions, respectively.

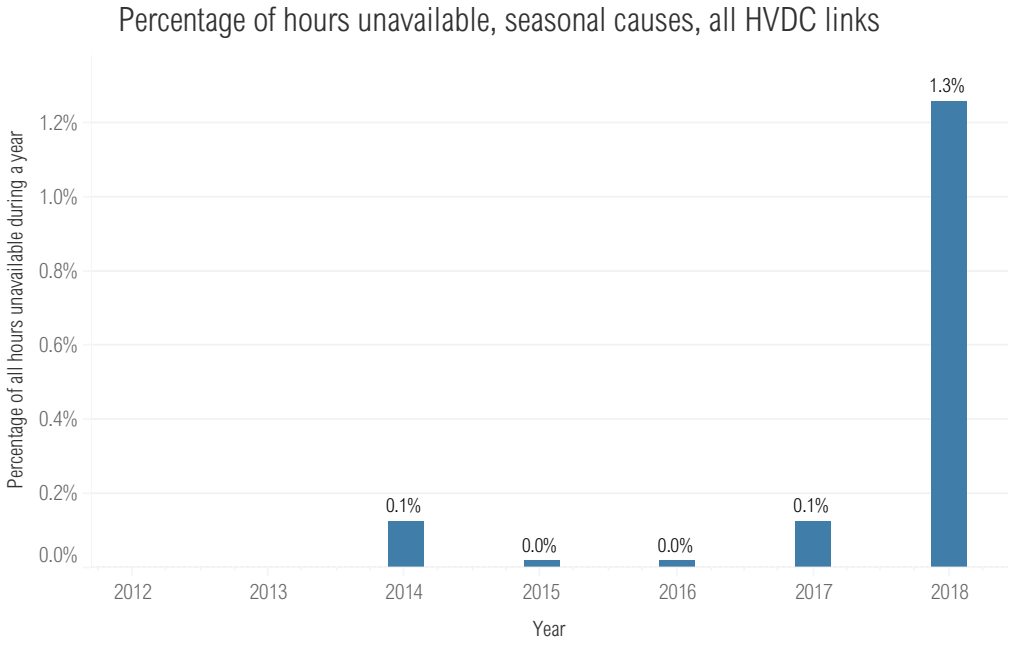

Figure D.3: Percentage of hours all HVDC links have been affected by a limitation due to seasonal causes.

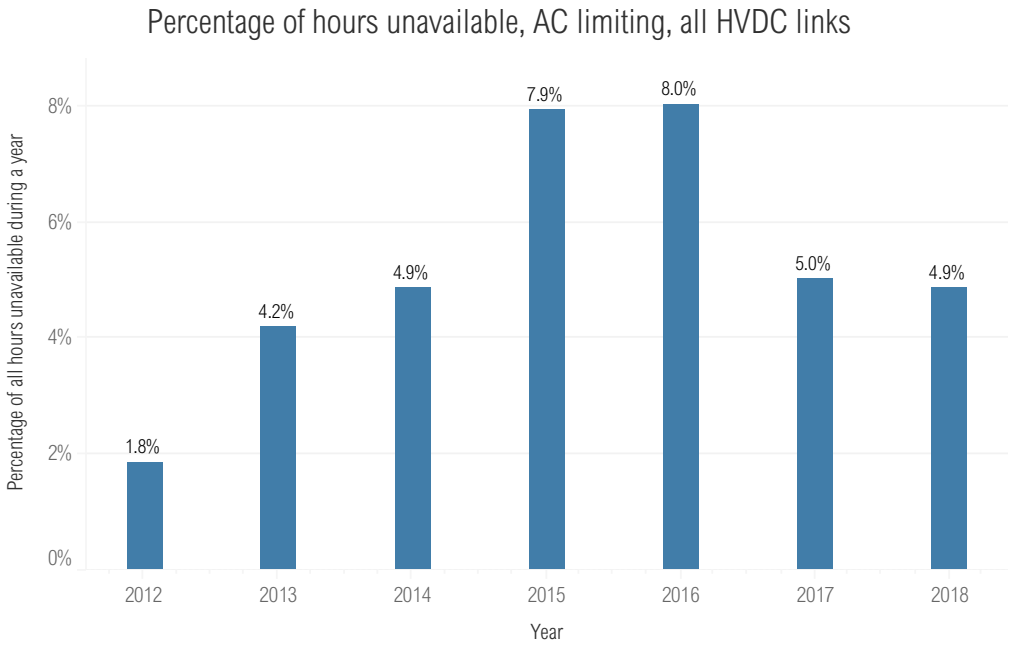

Figure D.4: Percentage of hours all HVDC links have been affected by a limitation due to AC limiting conditions.