European Network of
Transmission System Operators
for Electricity

Nordic and Baltic HVDC Utilisation and Unavailability Statistics 2017

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Regional Group Nordic

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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 2017, 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 TSO's 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 2017 is 10240 MW, which makes the annual transmission capacity 90.9 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.

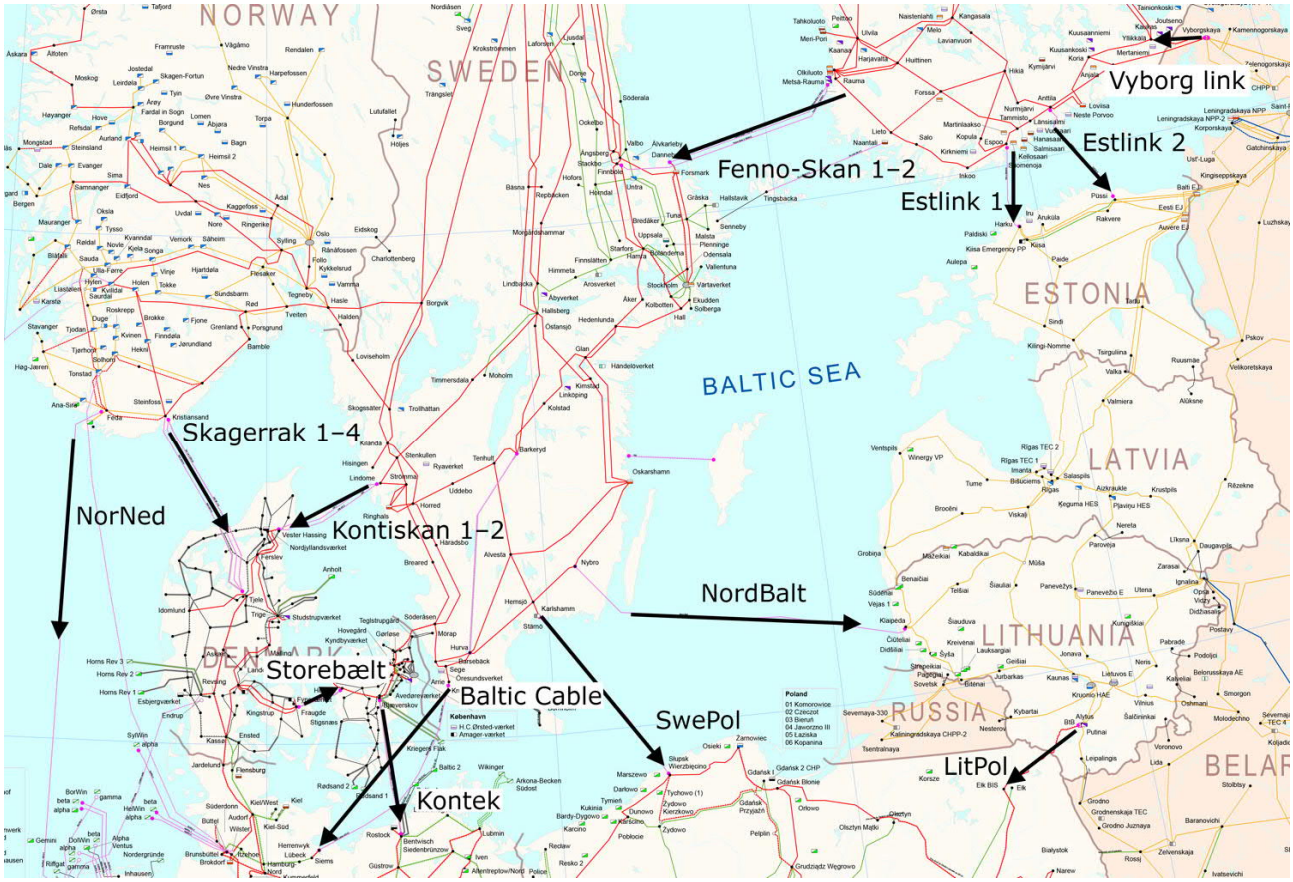

Figure 1.1 Part of Interconnected network of Northern Europe [1] map showing the HVDC links. To distinguish the direction of power flow, each link has a defined export direction in this report. This direction is indicated by the arrows.

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 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 is directly linked to 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 total outages, limitations and maintenance. This also means limitations based on maintenance in the AC grid that affects a HVDC connection. Disturbance outages are more thoroughly examined than other events.

The DISTAC HVDC statistics has a different scope than the CIGRÉ HVDC statistics, which focuses more on outages, faults and disturbances of the HVDC links. This means that CIGRÉ 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 CIGRÉ 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 A.

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 and ignoring outages and limitations, 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 partially or 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 (E_{MAX}) 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 (E_{MAX}) 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 (E_{MAX}) 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 (E_{MAX}) 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.

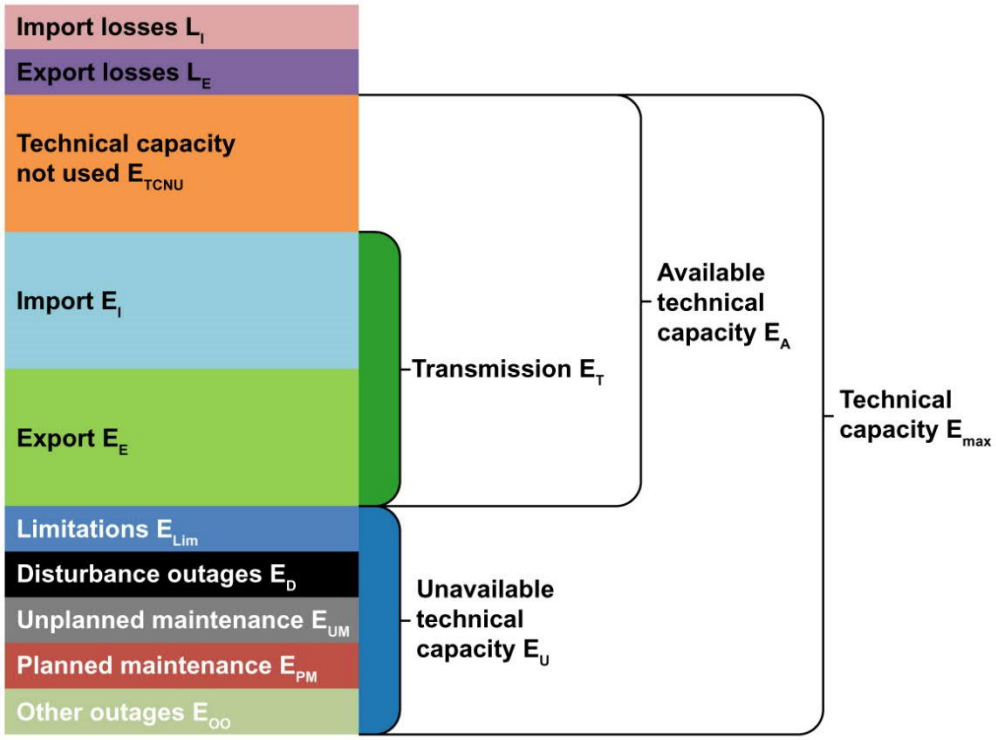

Figure 3.1 The availability and utilisation categories used in the HVDC statistics. Every value is an energy value and represents a part of the technical capacity. The technical capacity is divided into smaller categories. two categories*: available technical capacity (E_A)* and *unavailable technical 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 5.1 presents the main properties of the HVDC links while Table 5.2 presents the technical properties of the HVDC lines. The defined export directions are also presented in Figure 2.1.

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

Name of the link	Commis-sioning year	Market connec-tion	Type of HVDC converter	Rated power, mono-polar (MW)	Parallel mono-polar capacity (MW)	Bipolar capacity (MW)	Defined export direction (N–S, E–W)
Baltic Cable	1994	Yes	LCC	600			N–S
Estlink 1	2006	Yes	VSC	350	1000		N–S
Estlink 2	2014	Yes	LCC	650			N–S
Fenno-Skan 1	1989	Yes	LCC	400	1200	1200	E–W
Fenno-Skan 2	2011	Yes	LCC	800			E–W
Kontek	1995	Yes	LCC	600			N–S
Konti-Skan 1[2)]	2008	Yes	LCC	370	680/740		E–W
Konti-Skan 2[2)]	1988	Yes	LCC	370			E–W
LitPol Link	2015	Yes	LCC	500			E–W
NordBalt	2016	Yes	VSC	700			N–S
NorNed	2008	Yes	LCC	700			N–S
Skagerak 1	1976–1977	Yes	LCC	250	1000	1000	N–S
Skagerak 2		Yes	LCC	250			N–S
Skagerak 3	1993	Yes	LCC	500			N–S
Skagerak 4	2014	Yes	VSC	700			N–S
Storebaelt	2010	Yes	LCC	600			E–W
SwePol	2000	Yes	LCC	600			N–S
Vyborg Link[1)]	1981, 1982, 1984, 2000	Partly	LCC	1400			E–W
Total				**10340**	**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

Name of the 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 2017 and Section 5.2 provides an overview of the years 2012–2017. Section 5.3 presents the availability and utilisation of each HVDC link for the year 2017 as well as an annual overview of the utilisation and a trend of the utilisation and the number of outages for the years 2012–2017.

5.1 Overview of 2017

In 2017, 49.6 TWh of electric energy was transmitted through the Nordic and Baltic HVDC links. The total number of disturbance outages registered was 48, preventing 1.5 TWh of potential energy transmission, or 1.7 % of the total technical capacity (E_{max}).

Maintenance outages amounted to 3.6 TWh, or 4.1 % of the total technical capacity (E_{max}), and limitations reduced the transmission capacity by 2.7 TWh (3.1 %) 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. This enables a comparison between the connections. 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.

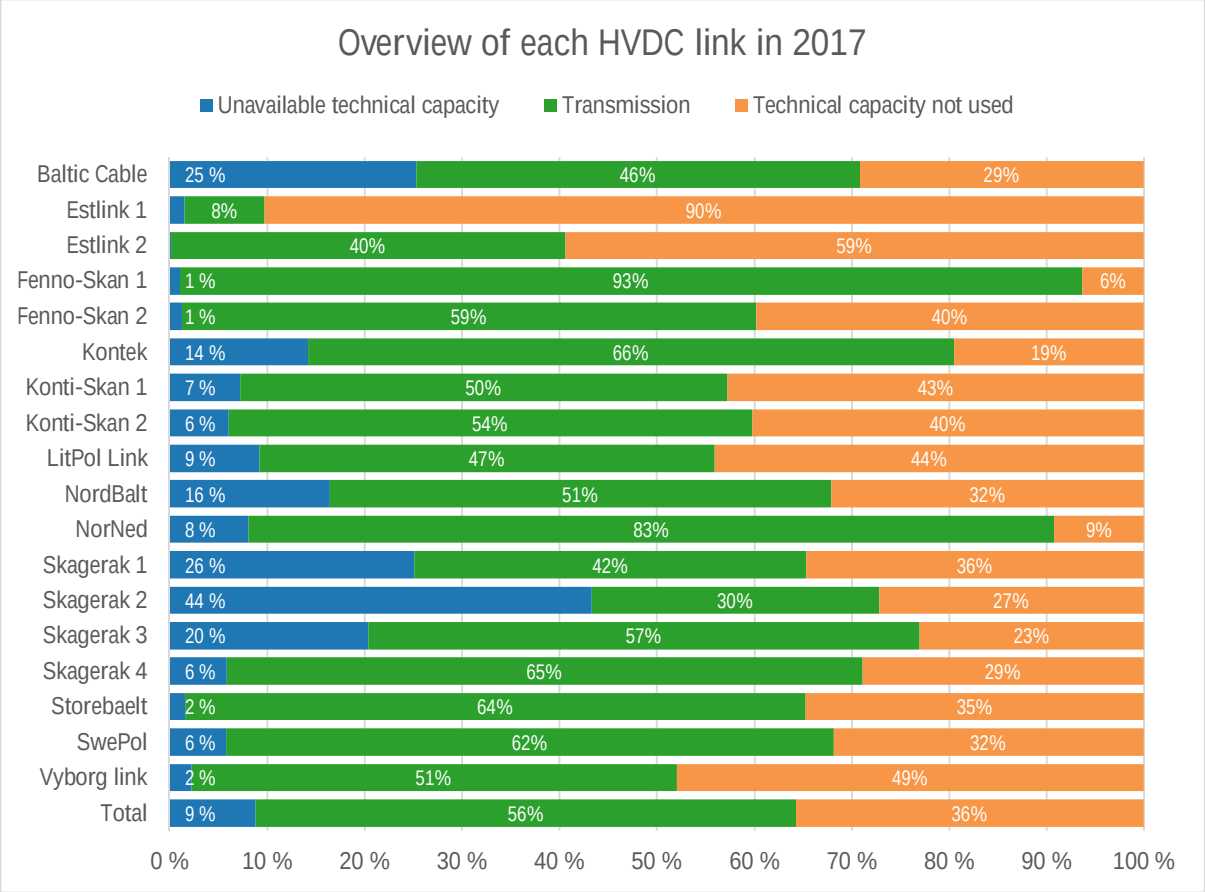

Figure 5.1 Annual overview of the availability and utilisation of each HVDC link in 2017. The unavailable technical capacity (E_U) is the amount of technical capacity (E_{MAX}) not available due to limitations or outages. Transmission (E_T) is the amount of technical capacity (E_{MAX}) imported and exported 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 2017 were the following:

- Baltic Cable limitations were mostly due to wind and solar energy feeds and minor maintenances.
- Kontek had a long-lasting unplanned maintenance because of a fault on the cable. The disturbance, fault tracing and repair took almost 2 months.
- NordBalt's disturbance outages was caused by 5 land cable joint faults that lasted about 43 days in total.
- Skagerak 2 had a cable fault, caused by a ship, that lasted more than 3 months.
- Skagerak 1,2 and 3 had their electrode masts regalvanized and electrode lines replaced, which caused the high amount of planned maintenance in 2017. This work will continue during most of year 2018 as well.
- The limitations on Skagerak 4 are related to the electrode current when Skagerak 3 was out due to maintenance.
- There were 3 other outages in 2017; 1 on NordBalt and 2 on Skagerak 4. They were black start tests.

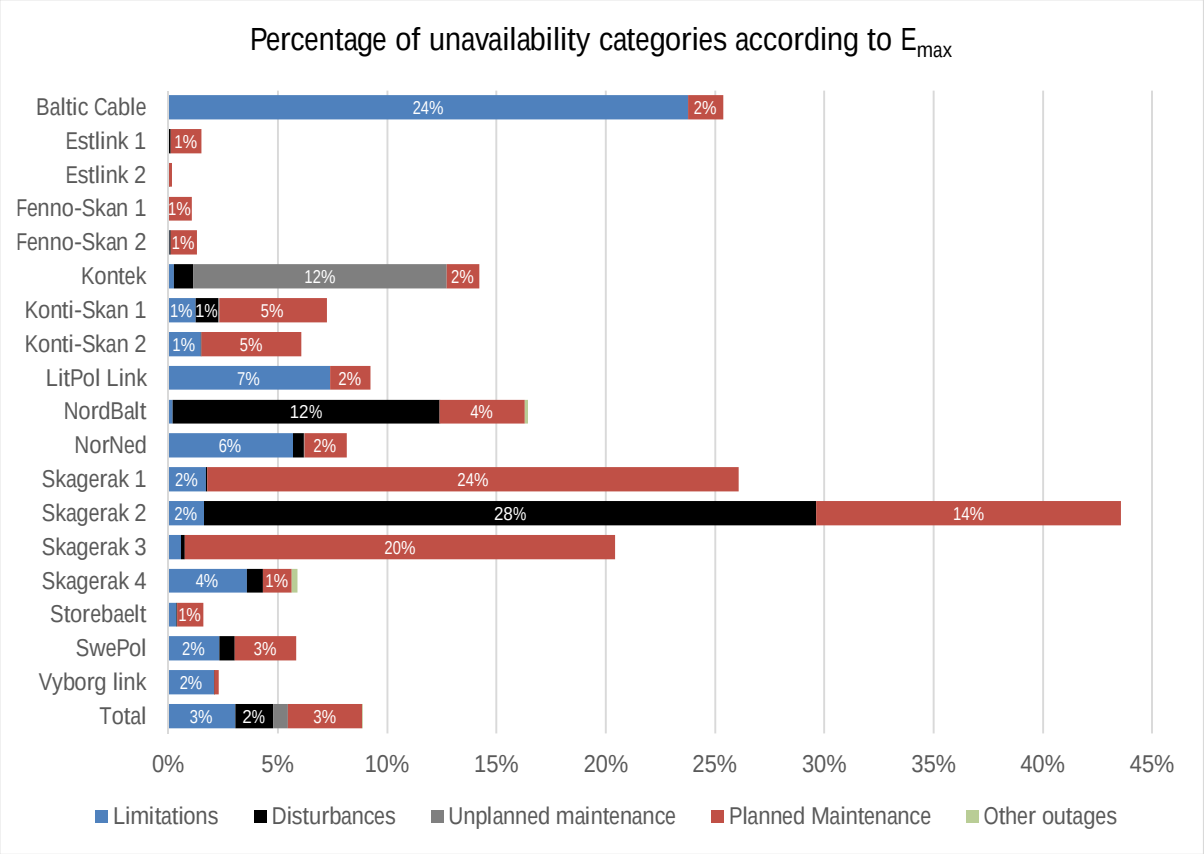

Figure 5.2 Percentage distribution of unavailable technical capacity (E_U) due to limitations, disturbance outages, unplanned and planned maintenance and other outages for each link in 2017.

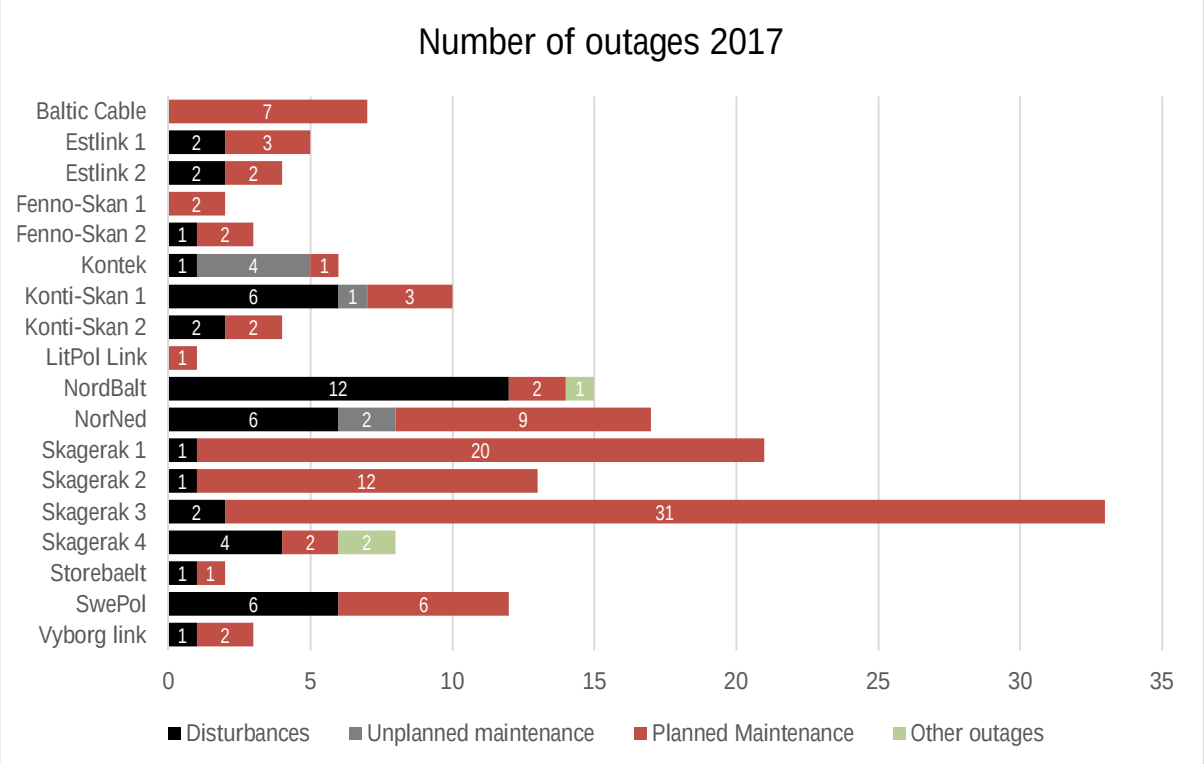

Figure 5.3 The number of disturbances, unplanned maintenance, planned maintenance and other outages for each link in 2017.

5.2 Overview of years 2012–2017

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 utilisation trend as a 2-year moving average for all HVDC links together and Figure 5.5 presents the annual utilisation with all utilisation categories.

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 5.6.

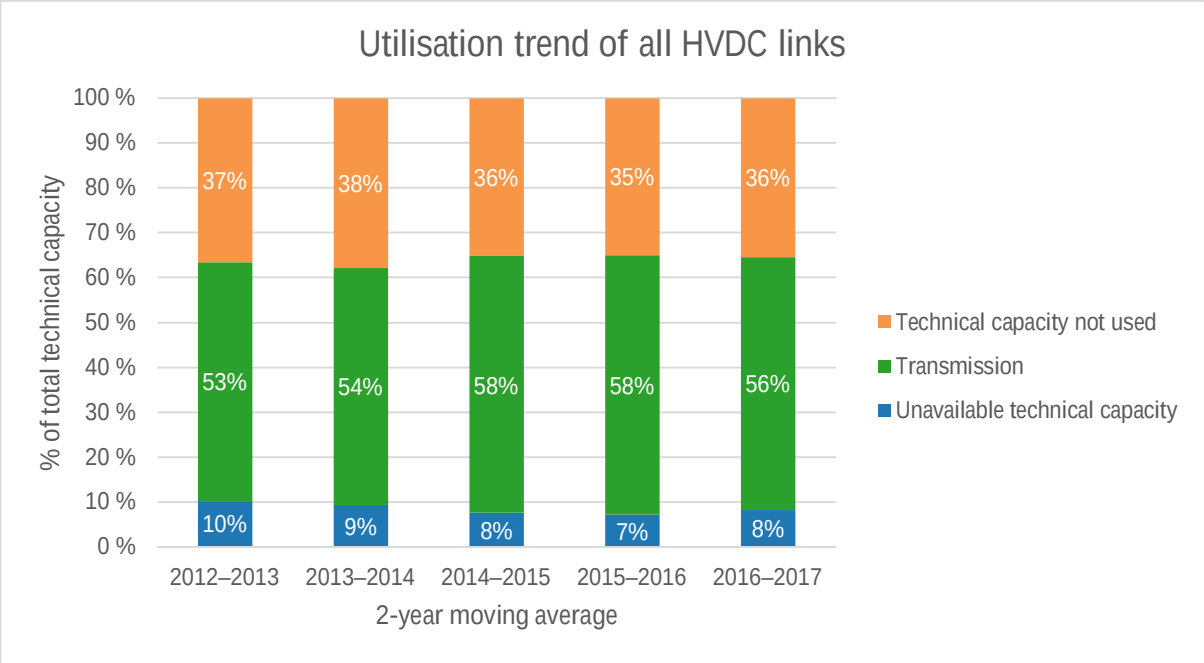

Figure 5.4 The utilisation trend of all HVDC links presented as a 2-year moving average beginning from 2012. The unavailable technical capacity (E_U) is the amount of technical capacity (E_{MAX}) not available due to limitations or outages. Transmission (E_T) is the amount of technical capacity (E_{MAX}) 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.

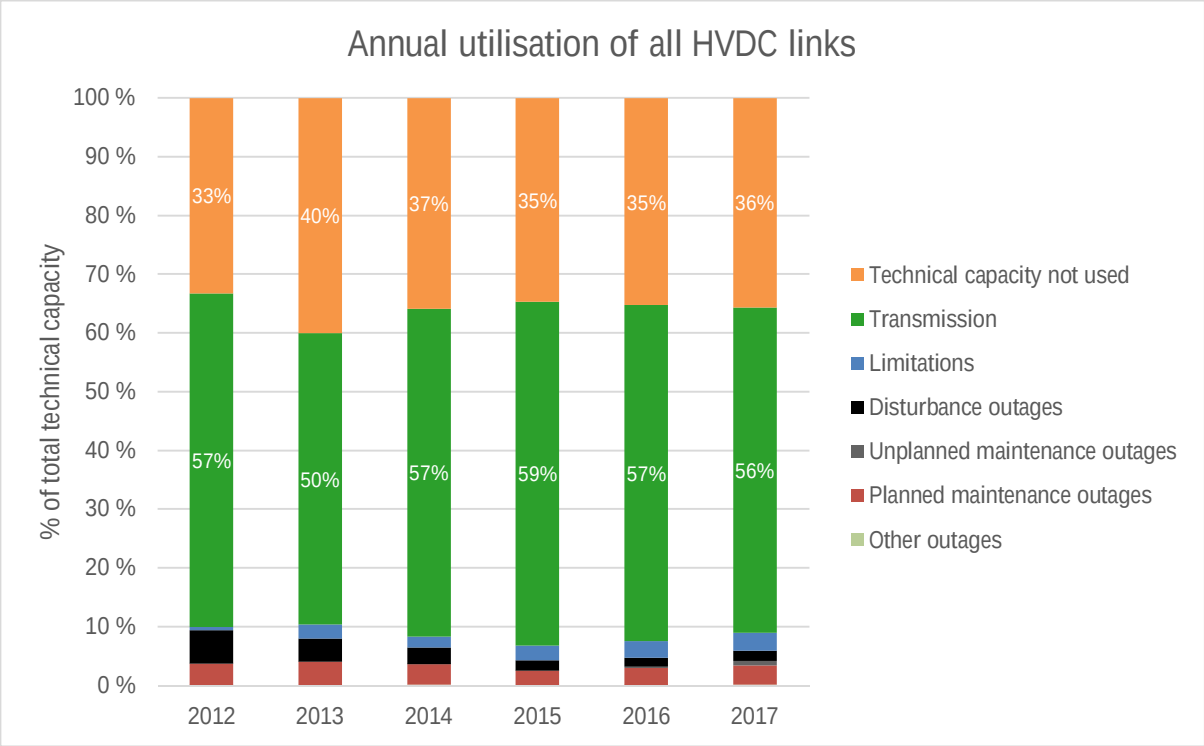

Figure 5.5 Annual utilisation of all HVDC links together. Technical capacity not used (E_{TCNU}) is the amount of energy that has not been imported or exported or been unavailable due to limitations or outages. Transmission (E_T) is the amount of technical capacity (E_{MAX}) imported and exported through 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.

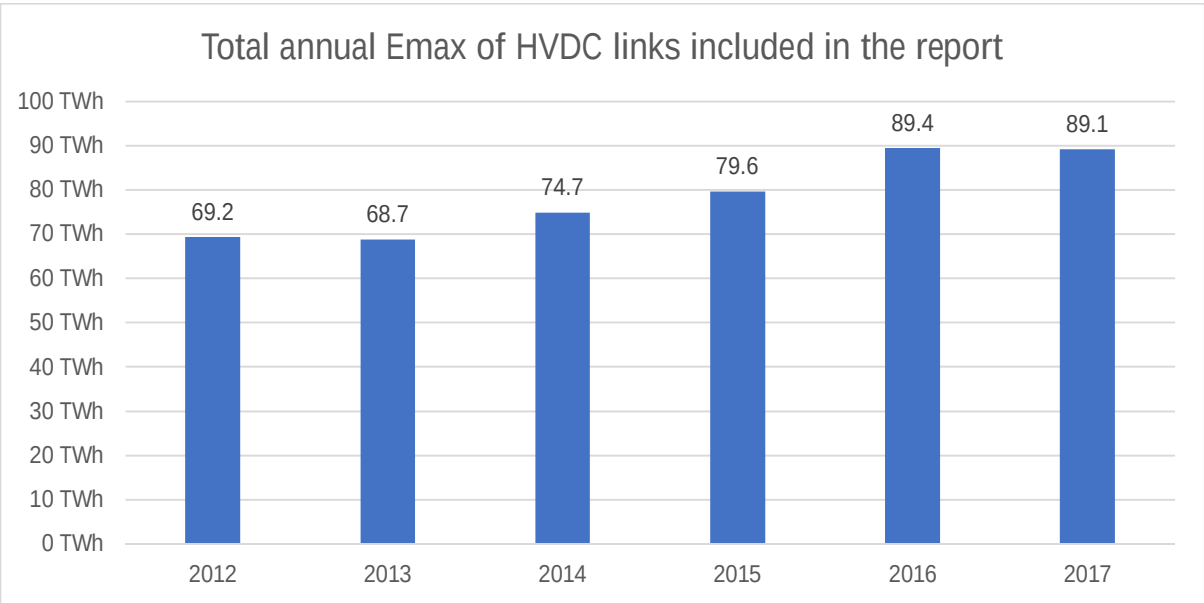

Figure 5.6 The total technical capacity (E_{max}) of all the HVDC links included in this report annually. From 2012, there are 14 HVDC links included. As of 2014, Estlink 2 and Skagerak 4 were added. In 2016, LitPol Link and NordBalt were added. The maximum technical capacity (E_{max}) is marginally higher in 2012 and 2016 because they are leap years.

5.3 Individual presentations of all HVDC links

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 over the rated technical power capacity of the links. Other times, when power flow is under the rated technical capacity (and there is no limitation reported), the difference is registered in the category 'technical capacity not used'.

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5.3.1 Baltic Cable

Figure 5.7 presents the availability and utilisation of Baltic Cable for 2017 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 2017, Baltic Cable had an available technical capacity of 74.7 %. The technical capacity not used was 29.1 %. Totally, 2.1 TWh (40.8 % of the technical capacity) was exported from Sweden to Germany and 252 GWh (4.8 % of the technical capacity) was imported to Sweden.

The annual maintenance lasted 2 days in September and there were no disturbances on Baltic Cable but seven short outages due to maintenance on the link or in the AC grid connecting the link.

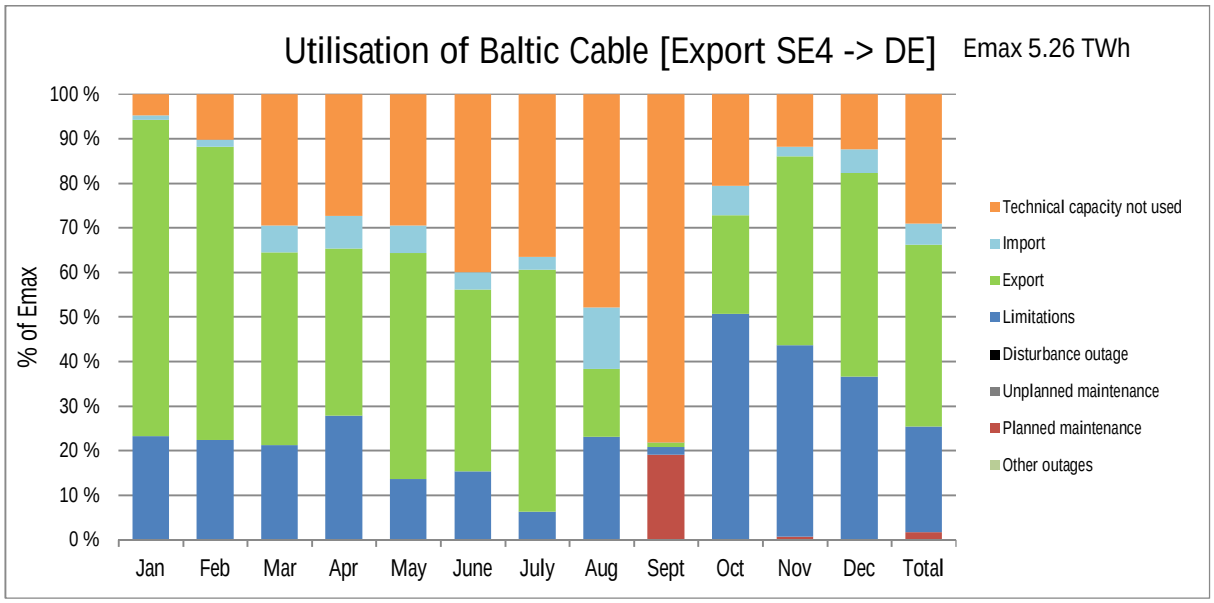

Figure 5.7 Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for The Baltic Cable in 2017

Table 5.1 Monthly distribution of the technical capacity (E_{MAX}) for The Baltic Cable in 2017

Baltic Cable [Export SE4 -> DE]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	83	132	518	668	604	369	289	1137	5	640	179	461	0.1
Export losses [MWh]	7948	6841	5389	4865	6809	5797	7750	1770	366	3861	4407	5140	1.2
Technical capacity not used [MWh]	21432	41350	131753	118168	132446	173067	163625	213734	338698	92128	51309	55441	29.1
Import [MWh]	4542.9	6650.5	27280	32003	27228	17157	12724	61944	285	29486	8899	23680	4.8
Export [MWh]	318080	266445	193246	162294	227352	176745	243547	67955	4020	98879	183571	204800	40.8
Limitations [MWh]	104098	90355	94246	120131	60513	65815	27995	102767	7811	226507	185832	163907	23.7
Disturbance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Unplanned maintenance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Planned maintenance outage [MWh]	0	0	0	0	0	0	0	0	82200	0	2400	0	1.6
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Rated capacity 600 MW	448153	404801	446525	432596	447539	432783	447891	446400	433014	447000	432011	447828	100.0

Figure 5.8 presents the annual utilization of Baltic Cable according to all the categories of technical capacity (E_{max}) annually for the years 2012–2017. Figure 5.9 presents the trend of the previous values, but with the categories technical capacity not used (E_{TCNU}), transmission (E_T) and unavailable technical capacity (E_U). Figure 5.10 presents the trend of number of disturbance outages, unplanned and planned maintenance and other outages with a 2-year rolling average.

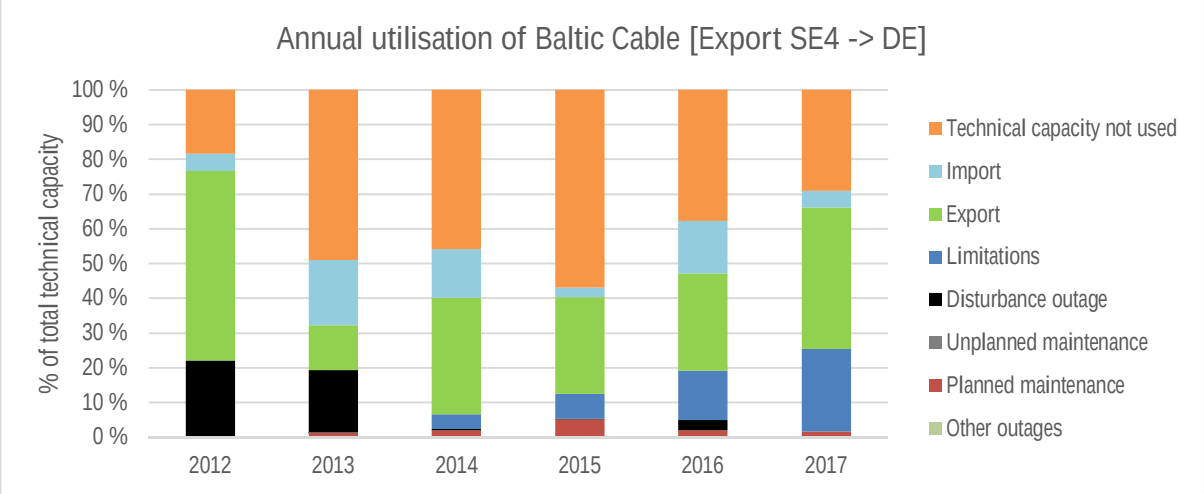

Figure 5.8 Annual utilisation of Baltic Cable according to the eight utilisation and unavailability categories for the years 2012–2017.

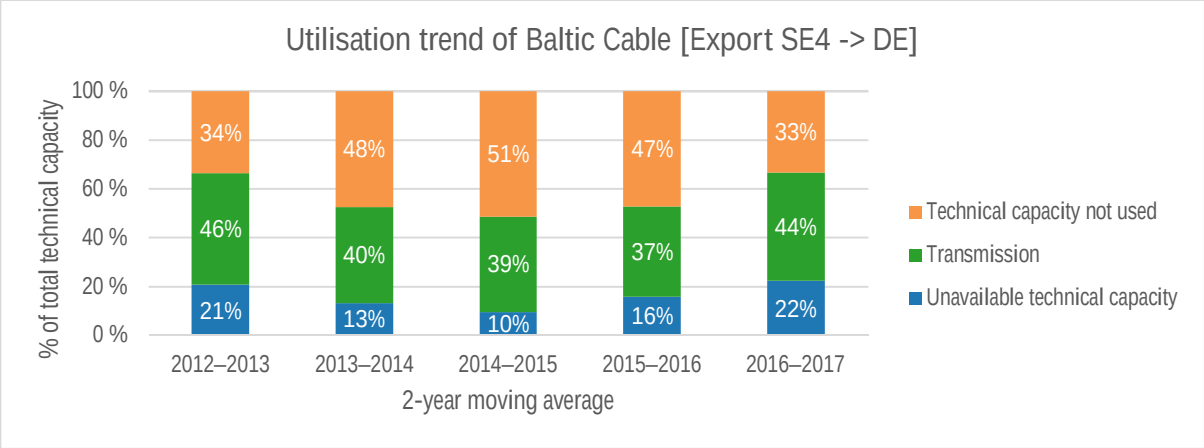

Figure 5.9 Utilisation trend of Baltic Cable according to unavailability, transmission and technical capacity not used for the years 2012–2017.

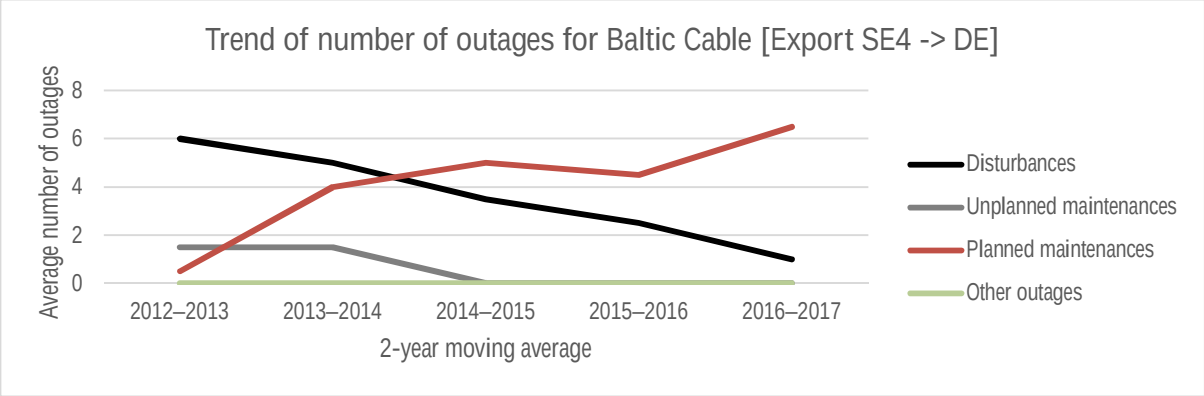

Figure 5.10 2-year moving average trend of number of outage events for Baltic Cable for the years 2012–2017.

5.3.2 Estlink 1

Figure 5.11 presents the availability and utilisation of Estlink 1 for 2017 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 (bidding zone FI), it is connected to Espoo substation and in Estonia (bidding zone EE) it is connected to Harku substation. The transmission capacity is 350 MW.

In 2017, Estlink 1 had an available technical capacity of 98.5 %. The technical capacity not used was 90.3 % due to that Estlink 2 is prioritised because of its lower transmission losses and that Estlink 1 is often used in Automatic Frequency Control Mode. Totally, 133 GWh (4.3 % of the technical capacity) was exported from Finland to Estonia and 119 GWh (3.9 % of the technical capacity) was imported to Finland.

The annual maintenance 2017 outage lasted five days in June and there were two minor disturbances in June on Estlink 1.

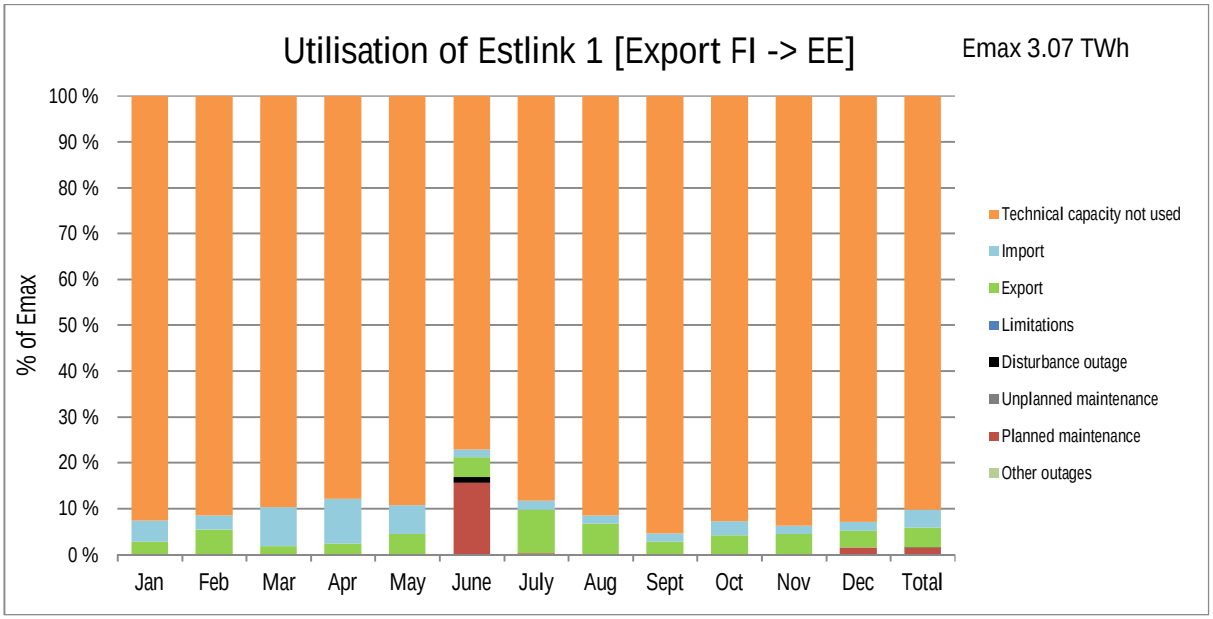

Figure 5.11 Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Estlink 1 in 2017

Table 5.2 Monthly distribution of the technical capacity (E_{MAX}) for Estlink 1 in 2017

Estlink 1 [Export FI -> EE]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	916	723	1107	1230	1037	654	700	786	776	861	732	773	0.3
Export losses [MWh]	742	781	580	547	862	773	1261	1069	778	832	845	786	0.3
Technical capacity not used [MWh]	241242	215404	233389	221567	232628	194595	229917	238559	240496	241831	236192	242107	90.3
Import [MWh]	12143	7198.7	22217	24652	16333	4384	5138	4509	4798	8195	4759	5015	3.9
Export [MWh]	7058.9	12597	4534.3	5907	11454	10955	24897	17333	6707	10724	11049	9547	4.3
Limitations [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Disturbance outage [MWh]	0	0	0	0	0	3180	0	0	0	0	0	0	0.1
Unplanned maintenance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Planned maintenance outage [MWh]	0	0	0	0	0	39165	449	0	0	0	0	3745	1.4
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Rated capacity 350 MW	260444	235200	260140	252125	260416	252278	260401	260400	252000	260750	252000	260414	100.0

Figure 5.12 presents the annual utilization of Estlink 1 according to all the categories of technical capacity (E_{max}) annually for the years 2012–2017. Figure 5.13 presents the trend of the previous values, but with the categories technical capacity not used (E_{TCNU}), transmission (E_T) and unavailable technical capacity (E_U). Figure 5.14 presents the trend of number of disturbance outages, unplanned and planned maintenance and other outages with a 2-year rolling average.

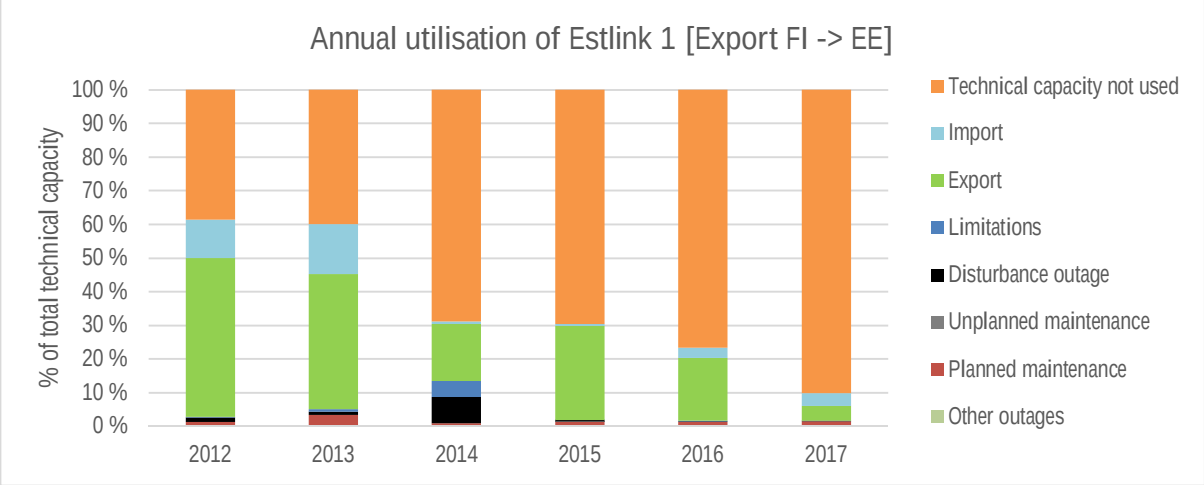

Figure 5.12 Annual utilisation of Estlink 1 according to the eight utilisation and unavailability categories for the years 2012–2017.

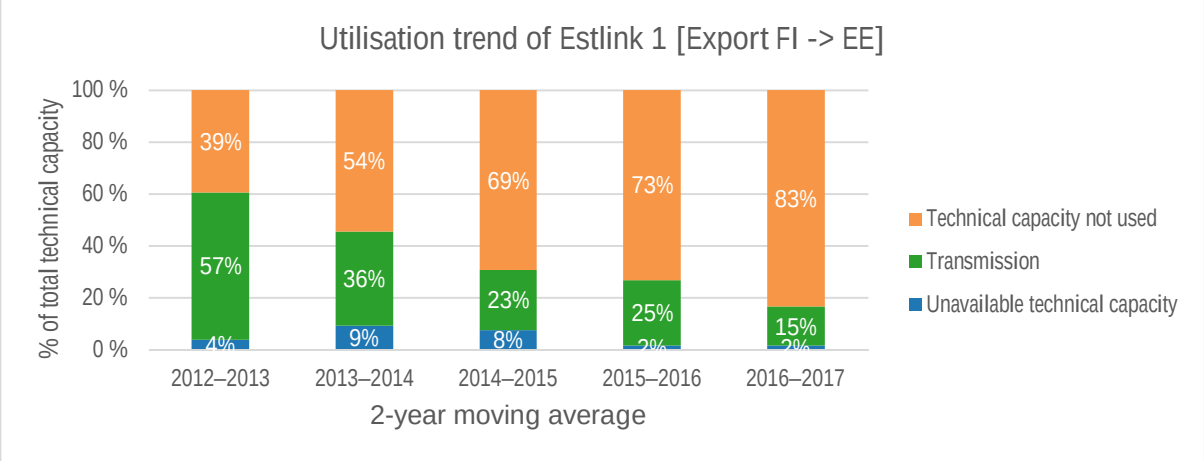

Figure 5.13 Utilisation trend of Estlink 1according to unavailability, transmission and technical capacity not used for the years 2012–2017.

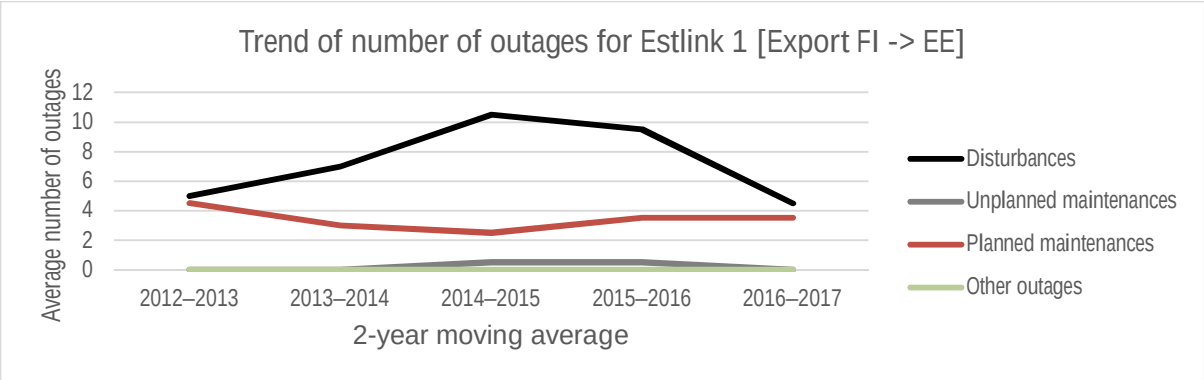

Figure 5.14 2-year moving average trend of number of outage events for Estlink 1 for the years 2012–2017.

5.3.3 Estlink 2

Figure 5.15 presents the availability and utilisation of Estlink 2 for 2017 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 (bidding zone FI), it is connected to Anttila substation and in Estonia (bidding zone EE) it is connected to Püssi substation. The transmission capacity is 650 MW.

In 2017, Estlink 2 had an available technical capacity of 99.8 %. The technical capacity not used was 59.4 %. Totally, 1.5 TWh (27.0 % of the technical capacity) was exported from Finland to Estonia and 768 GWh (13.5 % of the technical capacity) was imported to Finland.

No annual maintenance was held in 2017 for Estlink 2, as it is done every second year, and there were two minor disturbances on Estlink 2.

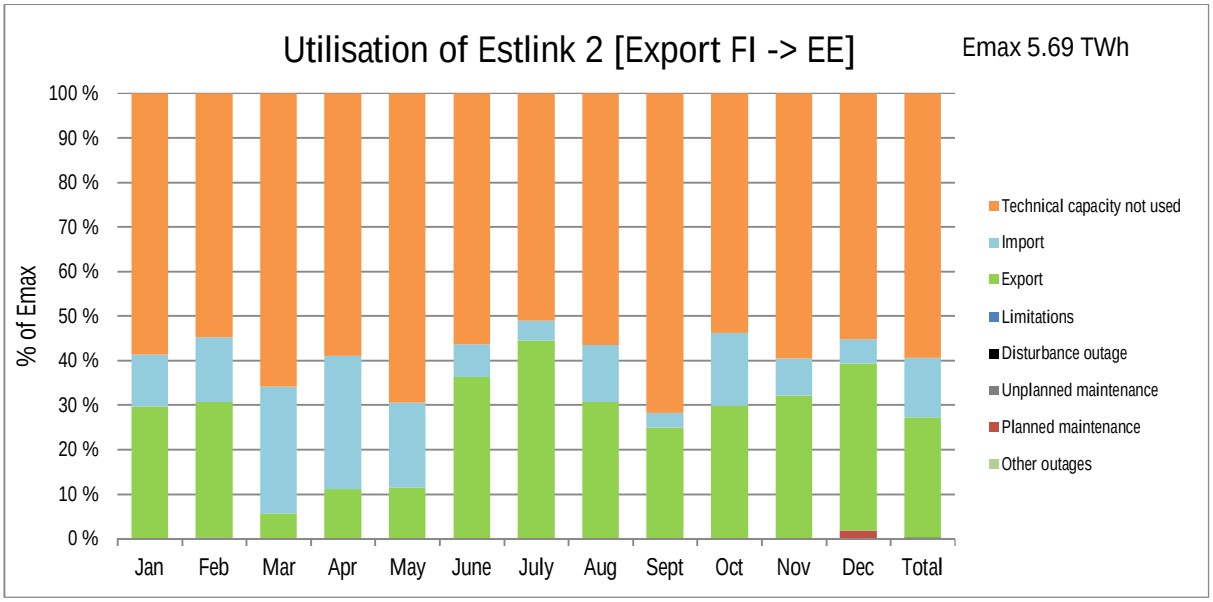

Figure 5.15 Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Estlink 2 in 2017

Table 5.3 Monthly distribution of the technical capacity (E_{MAX}) for Estlink 2 in 2017

Estlink 2 [Export FI -> EE]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	544	584	1302	1300	938	327	214	561	191	738	392	269	0.1
Export losses [MWh]	1320	1242	247	476	512	1639	2198	1471	1152	1431	1454	1763	0.3
Technical capacity not used [MWh]	283838	239368	318111	276189	336128	263952	247153	273773	336143	260832	279251	267577	59.4
Import [MWh]	56187	63847	137770	139688	92955	34178	21610	61378	15430	79291	38665	26527	13.5
Export [MWh]	143689	133195	27197	52235	54791	169919	214846	148464	116051	144252	150223	181463	27.0
Limitations [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Disturbance outage [MWh]	0	640	0	0	0	0	0	0	379	0	0	0	0.0
Unplanned maintenance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Planned maintenance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	8798	0.2
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Rated capacity 650 MW	483714	437050	483077	468113	483874	468050	483610	483615	468003	484375	468139	484364	100.0

Figure 5.16 presents the annual utilization of Estlink 2 according to all the categories of technical capacity (E_{max}) annually for the years 2012–2017. Figure 5.17 presents the trend of the previous values, but with the categories technical capacity not used (E_{TCNU}), transmission (E_T) and unavailable technical capacity (E_U). Figure 5.18 presents the trend of number of disturbance outages, unplanned and planned maintenance and other outages with a 2-year rolling average.

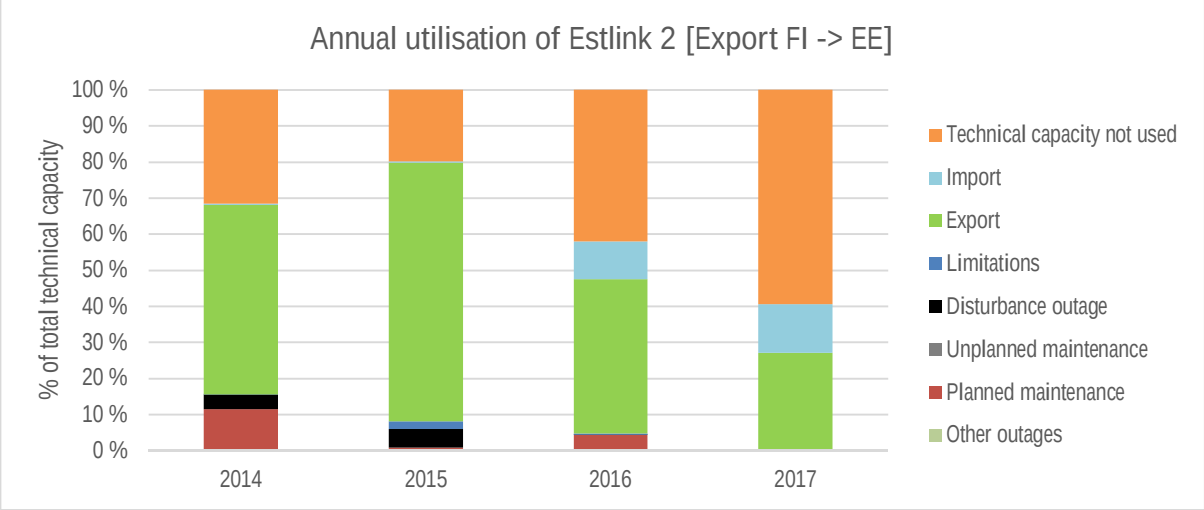

Figure 5.16 Annual utilisation of Estlink 2 according to the eight utilisation and unavailability categories for the years 2014–2017.

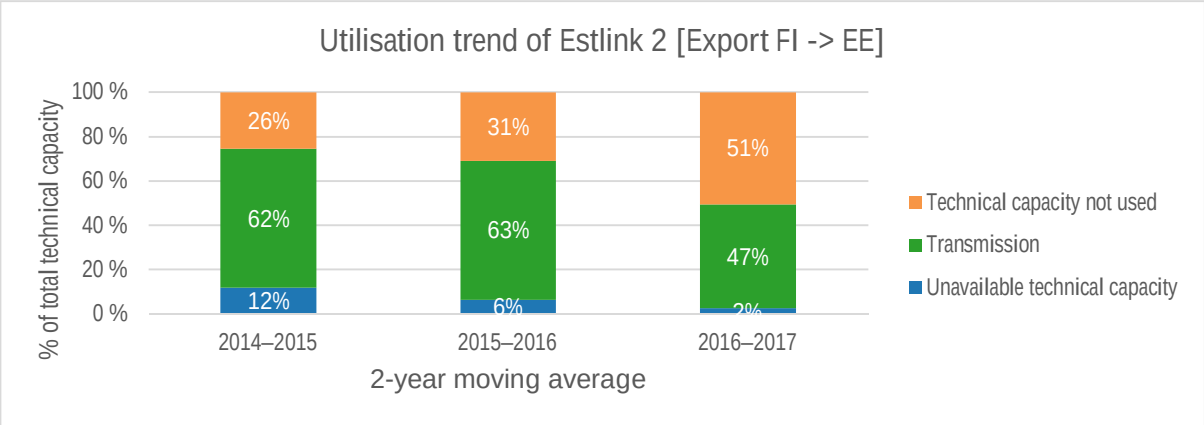

Figure 5.17 Utilisation trend of Estlink 2 according to unavailability, transmission and technical capacity not used for the years 2014–2017.

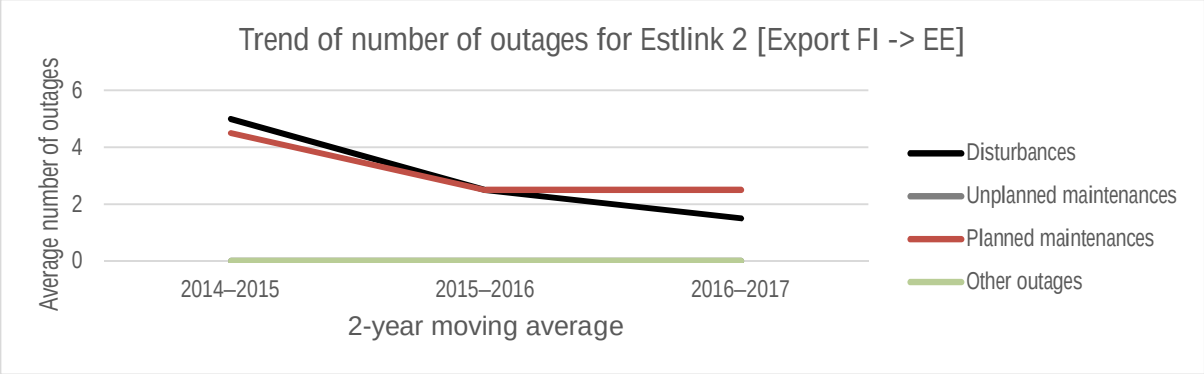

Figure 5.18 2-year moving average trend of number of outage events for Estlink 2 for the years 2014–2017.

5.3.4 Fenno-Skan 1

Figure 5.19 presents the availability and utilisation of Fenno-Skan 1 for 2017 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 investigations were completed. The investigations were started after a cable issue in 12.2.2013.

In 2017, Fenno-Skan 1 had an available technical capacity of 98.9 %. The technical capacity not used was 6.3 %. Totally, 22 MWh (0.6 % of the technical capacity) was exported from Finland to Sweden and 3.2 TWh (92.0 % of the technical capacity) was imported to Finland.

The annual maintenance was between 28.9–1.10 and there were no disturbances on Fenno-Skan 1.

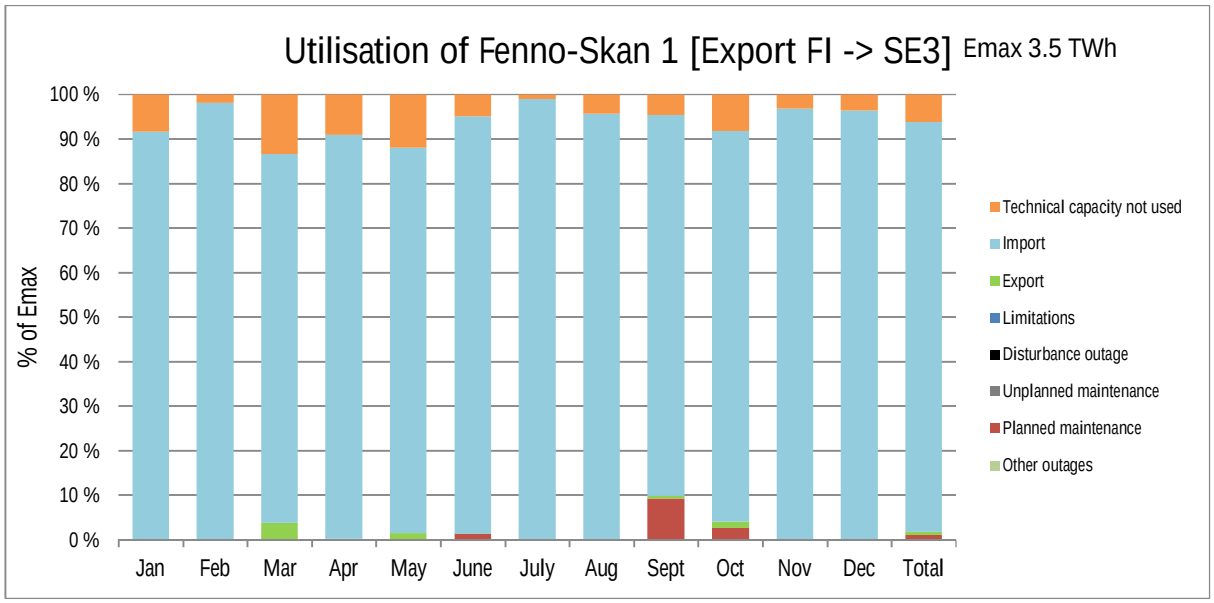

Figure 5.19 Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Fenno-Skan 1 in 2017

Table 5.4 Monthly distribution of the technical capacity (E_{MAX}) for Fenno-Skan 1 in 2017

Fenno-Skan 1 [Export FI -> SE3]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	7299	7210	6991	6852	6879	7118	7666	7554	6813	6991	7555	7736	2.5
Export losses [MWh]	0	0	372	8	164	0	0	0	129	130	0	0	0.0
Technical capacity not used [MWh]	25336	5126.4	39968	26384	35988	14208	3096	13033	13386	24773	9376	11051	6.3
Import [MWh]	272924	264447	246707	261916	257980	271117	295513	285396	247074	261917	279260	287219	92.0
Export [MWh]	0	0	11040	395	4271	0	0	0	1765	4167	0	0	0.6
Limitations [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Disturbance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Unplanned maintenance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Planned maintenance outage [MWh]	0	0	0	0	0	3720	0	0	26367	7687	0	0	1.1
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Rated capacity 400 MW	298260	269574	297715	288695	298238	289045	298609	298429	288592	298544	288636	298269	100.0

Figure 5.20 presents the annual utilization of Fenno-Skan 1 according to all the categories of technical capacity (E_{max}) annually for the years 2012–2017. Figure 5.21 presents the trend of the previous values, but with the categories technical capacity not used (E_{TCNU}), transmission (E_T) and unavailable technical capacity (E_U). Figure 5.22 presents the trend of number of disturbance outages, unplanned and planned maintenance and other outages with a 2-year rolling average.

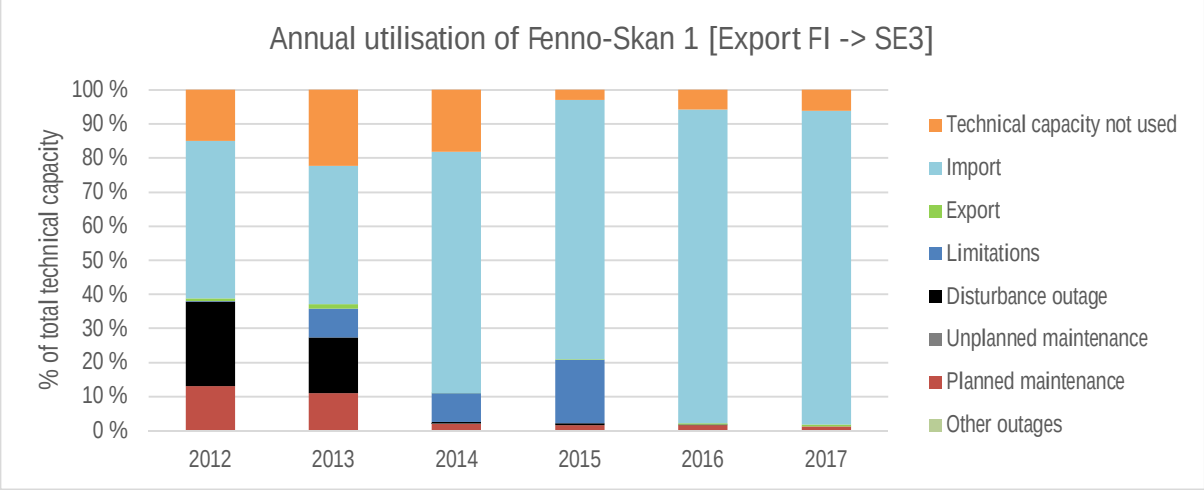

Figure 5.20 Annual utilisation of Fenno-Skan 1 according to the eight utilisation and unavailability categories for the years 2012–2017.

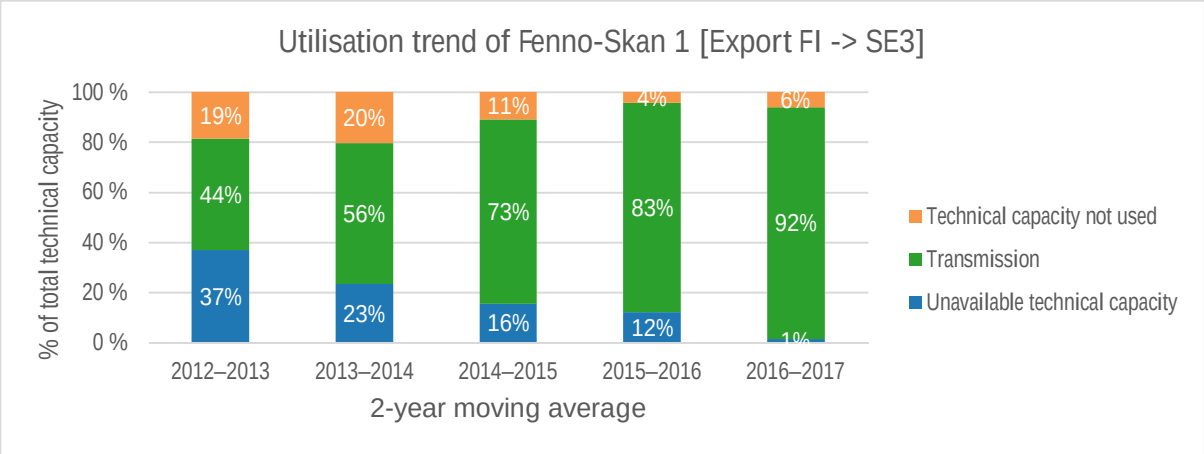

Figure 5.21 Utilisation trend of Fenno-Skan 1 according to unavailability, transmission and technical capacity not used for the years 2012–2017.

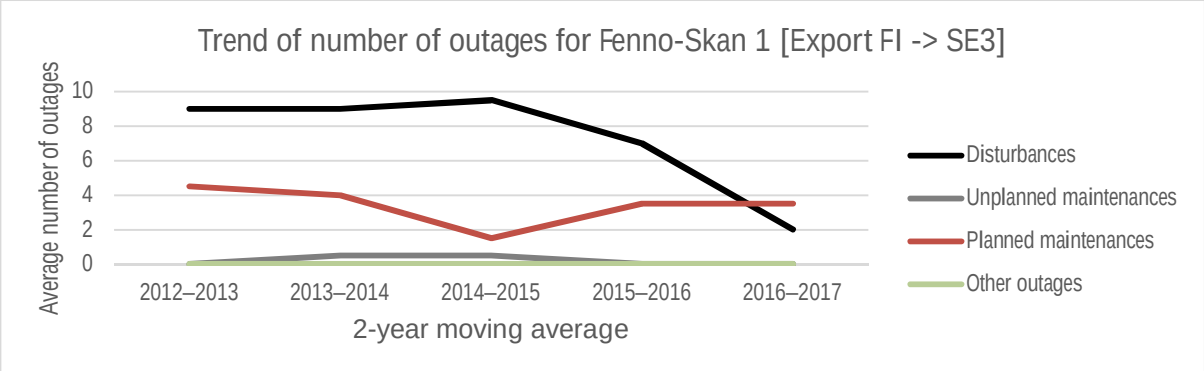

Figure 5.22 2-year moving average trend of number of outage events for Fenno-Skan 1 for the years 2012–2017.

5.3.5 Fenno-Skan 2

Figure 5.23 presents the availability and utilisation of Fenno-Skan 2 for 2017 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 is 800 MW.

In 2017, Fenno-Skan 2 had an available technical capacity of 98.7 %. The technical capacity not used was 39.8 %. Totally, 223 GWh (3.2 % of the technical capacity) was exported from Finland to Sweden and 3.9 TWh (55.8 % of the technical capacity) was imported to Finland.

The annual maintenance was in the beginning of October and there was one minor disturbance on Fenno-Skan 2.

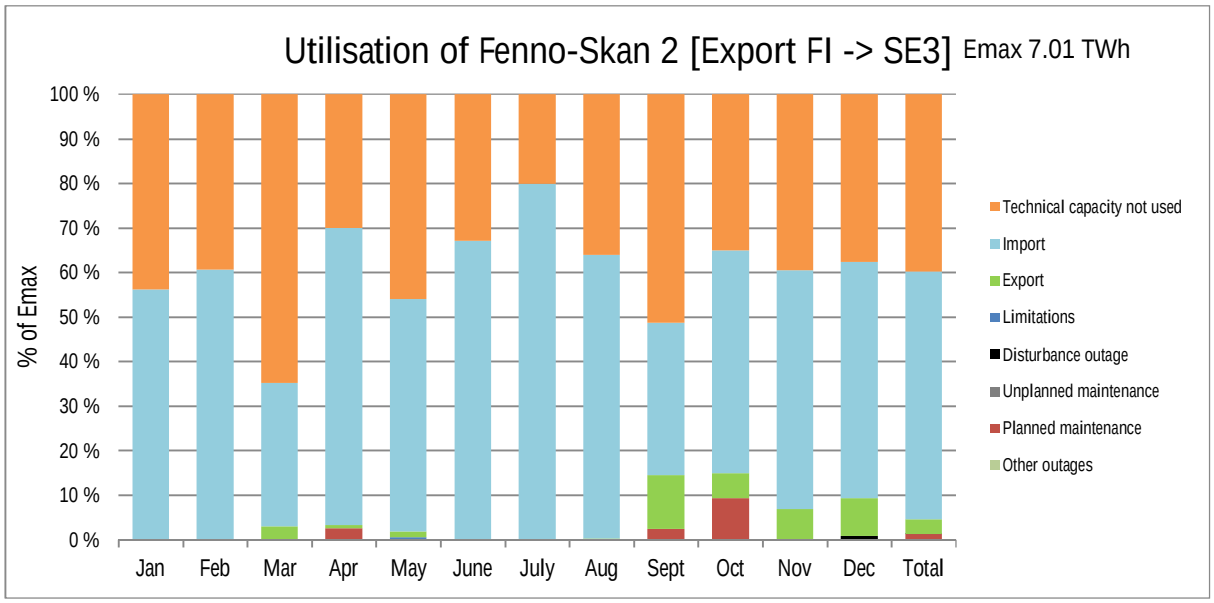

Figure 5.23 Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Fenno-Skan 2 in 2017

Table 5.5 Monthly distribution of the technical capacity (E_{MAX}) for Fenno-Skan 2 in 2017

Fenno-Skan 2 [Export FI -> SE3]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	6898	6927	3559	8575	6609	8379	10745	8428	4019	6363	6450	6675	1.2
Export losses [MWh]	7	0	317	74	184	0	0	27	1243	565	613	838	0.1
Technical capacity not used [MWh]	260332	211378	384915	172393	273102	188755	118704	213962	295204	207953	226467	222855	39.6
Import [MWh]	333698	325711	191511	384564	310339	386615	475816	378966	196978	298438	309220	316454	55.8
Export [MWh]	247	0	17431	3993	7897	0	0	1552	69450	33192	39136	50538	3.2
Limitations [MWh]	1086	702	598	769	4003	831	989	1031	869	994	1300	1046	0.2
Disturbance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	4454	0.1
Unplanned maintenance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Planned maintenance outage [MWh]	0	0	0	14547	0	0	0	0	13573	55600	0	0	1.2
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Rated capacity 800 MW	595364	537791	594456	576267	595341	576202	595508	595510	576074	596177	576124	595347	100.0

Figure 5.24 presents the annual utilization of Fenno-Skan 2 according to all the categories of technical capacity (E_{max}) annually for the years 2012–2017. Figure 5.25 presents the trend of the previous values, but with the categories technical capacity not used (E_{TCNU}), transmission (E_T) and unavailable technical capacity (E_U). Figure 5.26 presents the trend of number of disturbance outages, unplanned and planned maintenance and other outages with a 2-year rolling average.

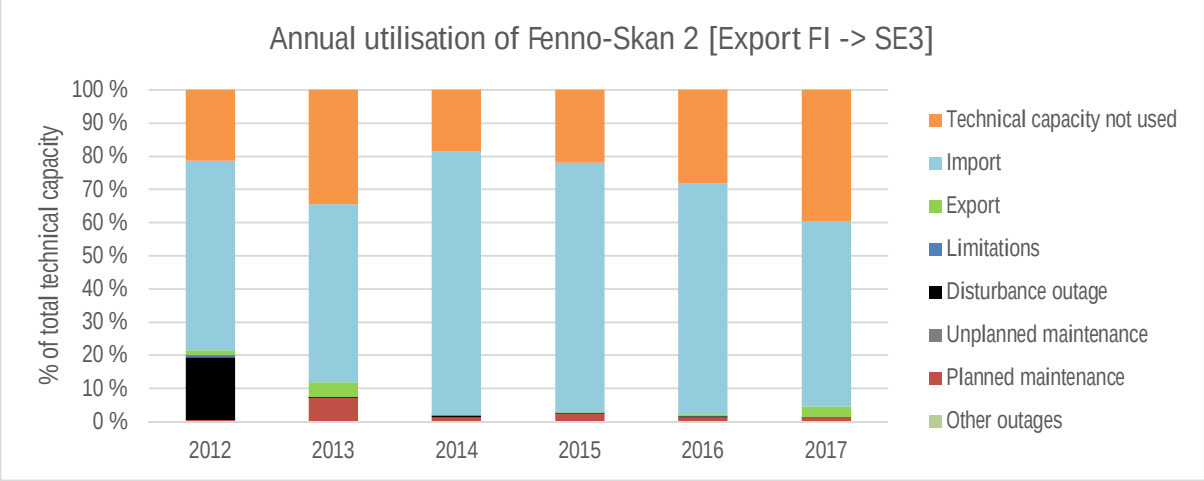

Figure 5.24 Annual utilisation of Fenno-Skan 2 according to the eight utilisation and unavailability categories for the years 2012–2017.

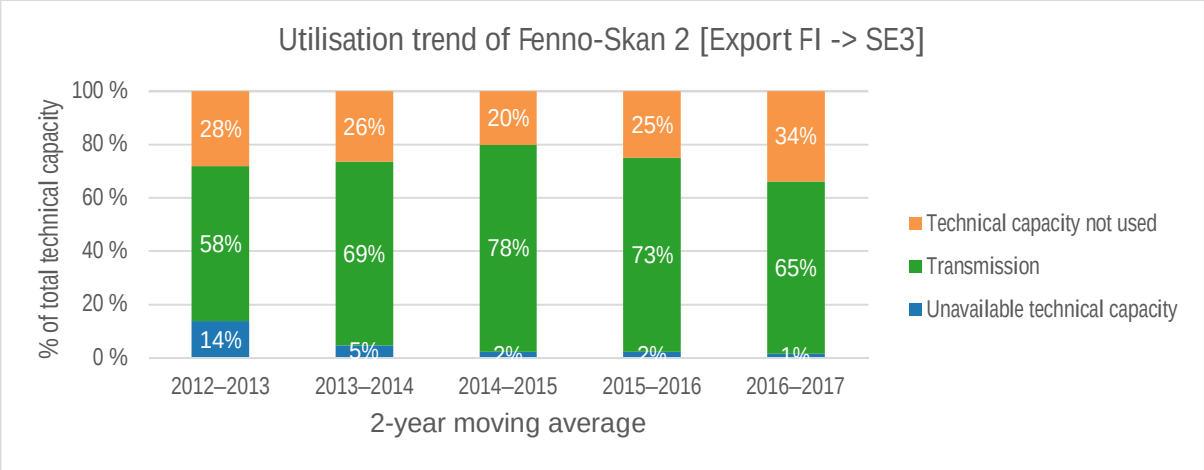

Figure 5.25 Utilisation trend of Fenno-Skan 2 according to unavailability, transmission and technical capacity not used for the years 2012–2017.

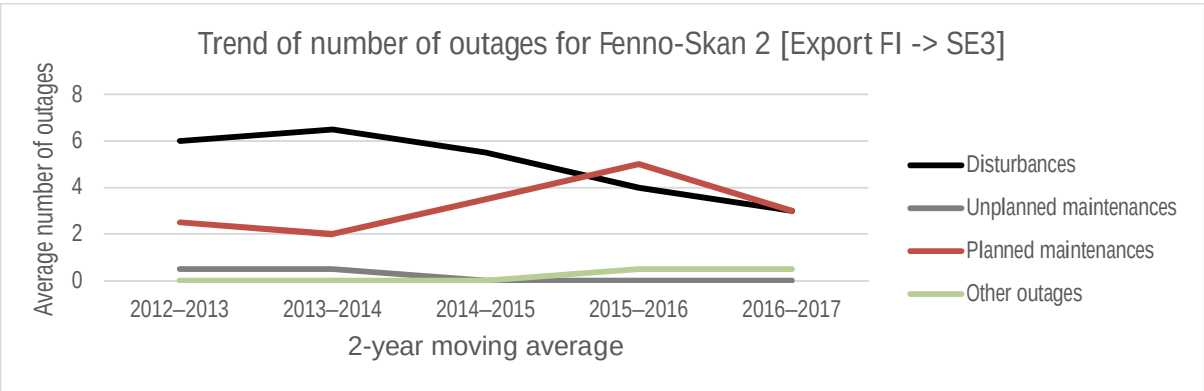

Figure 5.26 2-year moving average trend of number of outage events for Fenno-Skan 2 for the years 2012–2017.

5.3.6 Kontek

Figure 5.27 presents the availability and utilisation of Kontek for 2017 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-TenneT). The transmission capacity is 600 MW.

In 2017, Kontek had an available technical capacity of 85.8 %. The technical capacity not used was 19.4 %. Totally, 2.6 TWh (48.5 % of the technical capacity) was exported from Denmark to Germany and 0.9 TWh (17.8 % of the technical capacity) was imported to Denmark.

The annual maintenance in 2017 lasted 6 days in May. Furthermore, Kontek had a long-lasting unplanned maintenance in August and September because of a fault on the cable. The disturbance, fault tracing and repair took almost 2 months.

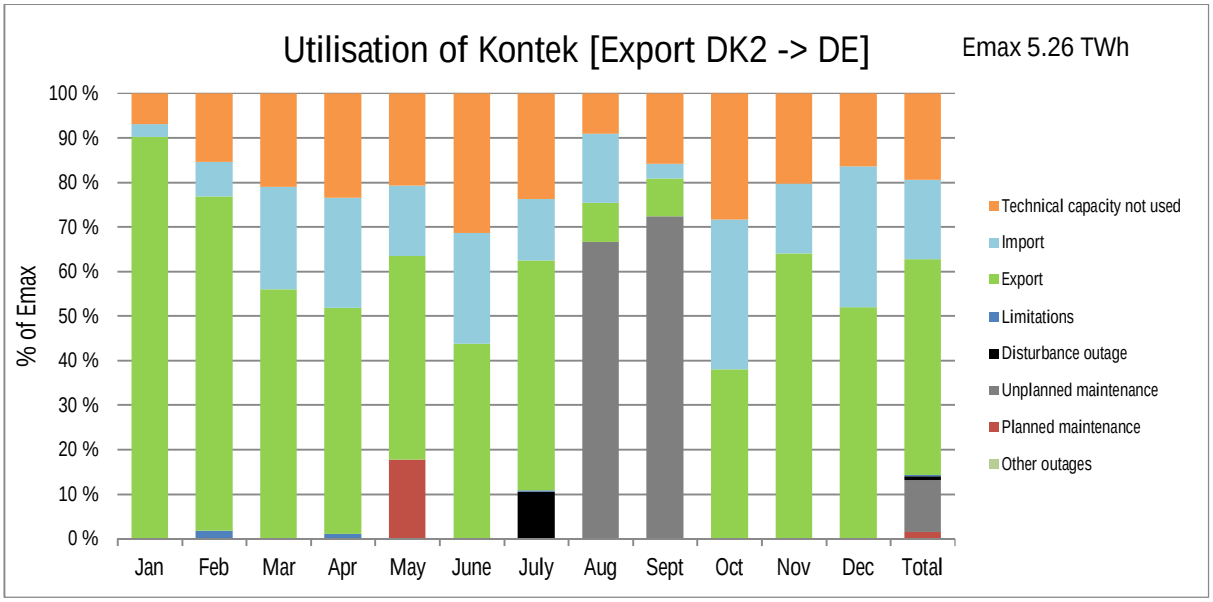

Figure 5.27 Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Kontek in 2017

Table 5.6 Monthly distribution of the technical capacity (E_{MAX}) for Kontek in 2017

Kontek [Export DK2 -> DE]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	272	633	2114	2218	1425	2167	1253	1497	259	3089	1344	2905	0.4
Export losses [MWh]	8110	6006	4982	4317	4080	3753	4606	762	647	3428	5793	4850	1.0
Technical capacity not used [MWh]	31279	62393	94135	101638	92809	135902	106123	40900	68388	127063	87885	73756	19.4
Import [MWh]	12871	31001	102257	106433	70781	107388	61557	69467	14266	150391	67956	140825	17.8
Export [MWh]	402251	302722	249408	219759	203905	188711	230335	39282	37048	169547	276159	231819	48.5
Limitations [MWh]	0	7084.7	0	4170	0	0	1575	0	0	0	0	0	0.2
Disturbance outage [MWh]	0	0	0	0	0	0	46810	0	0	0	0	0	0.9
Unplanned maintenance outage [MWh]	0	0	0	0	0	0	0	297340	312300	0	0	0	11.6
Planned maintenance outage [MWh]	0	0	0	0	79200	0	0	0	0	0	0	0	1.5
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Rated capacity 600 MW	446400	403200	445800	432000	446695	432000	446401	446989	432002	447000	432000	446400	100.0

Figure 5.28 presents the annual utilization of Kontek according to all the categories of technical capacity (E_{max}) annually for the years 2012–2017. Figure 5.29 presents the trend of the previous values, but with the categories technical capacity not used (E_{TCNU}), transmission (E_T) and unavailable technical capacity (E_U). Figure 5.30 presents the trend of number of disturbance outages, unplanned and planned maintenance and other outages with a 2-year rolling average.

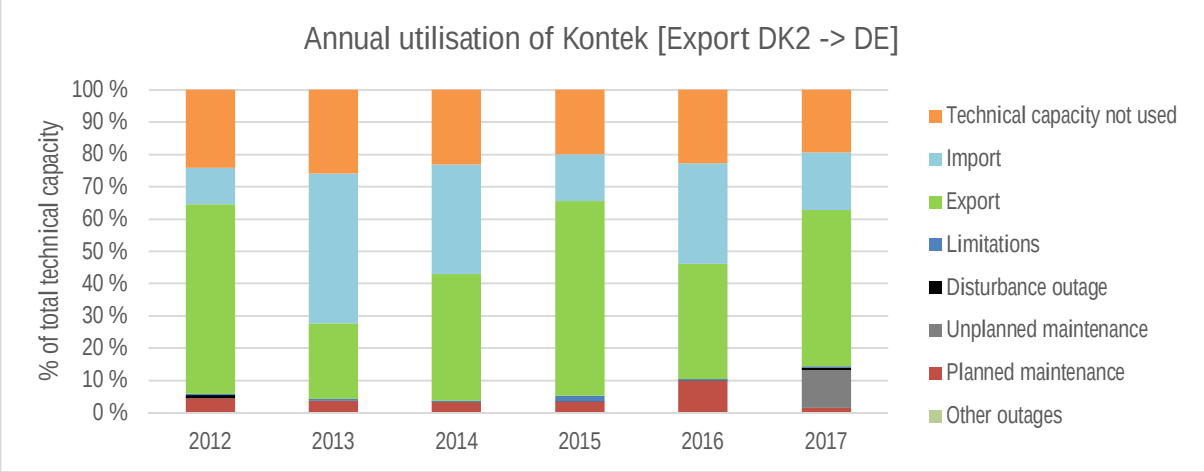

Figure 5.28 Annual utilisation of Kontek according to the eight utilisation and unavailability categories for the years 2012–2017.

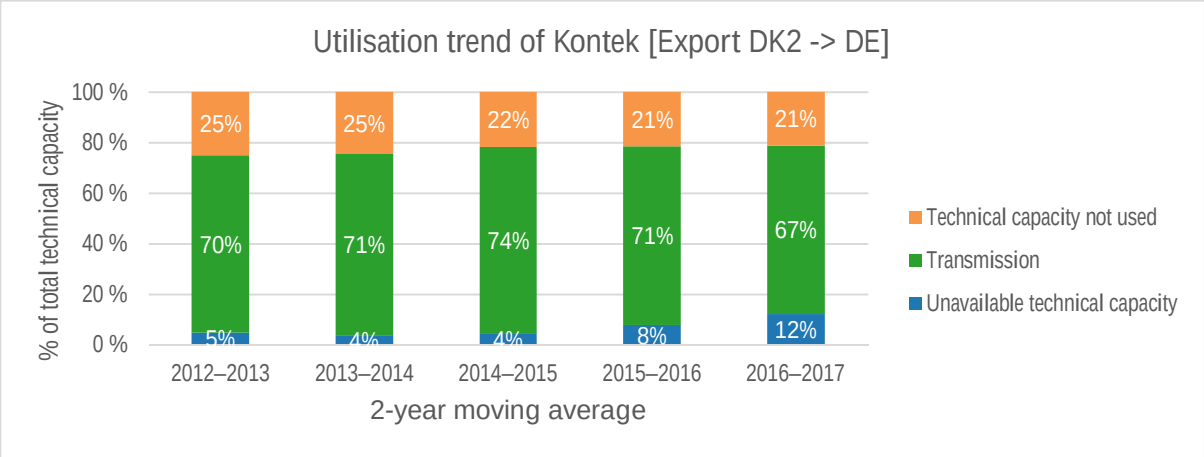

Figure 5.29 Utilisation trend of Kontek according to unavailability, transmission and technical capacity not used for the years 2012–2017.

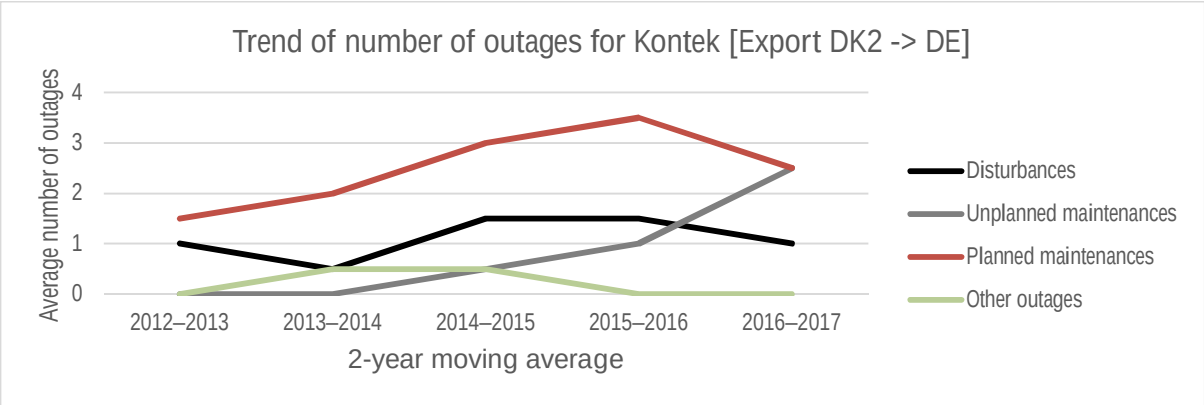

Figure 5.30 2-year moving average trend of number of outage events for Kontek for the years 2012–2017.

5.3.7 Konti-Skan 1

Figure 5.31 presents the availability and utilisation of Konti-Skan 1 for 2017 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 2017, Konti-Skan 1 had an available technical capacity of 92.8 % and the technical capacity not used was 42.7 %. Totally, 0.8 TWh (25.1 % of the technical capacity) was exported from Sweden to Denmark and 0.8 TWh (24.9 % of the technical capacity) was imported to Sweden.

The annual maintenance of Konti-Skan 1 lasted 17 days in September. Furhermore, Konti-Skan 1 had 6 minor disturbances during 2017.

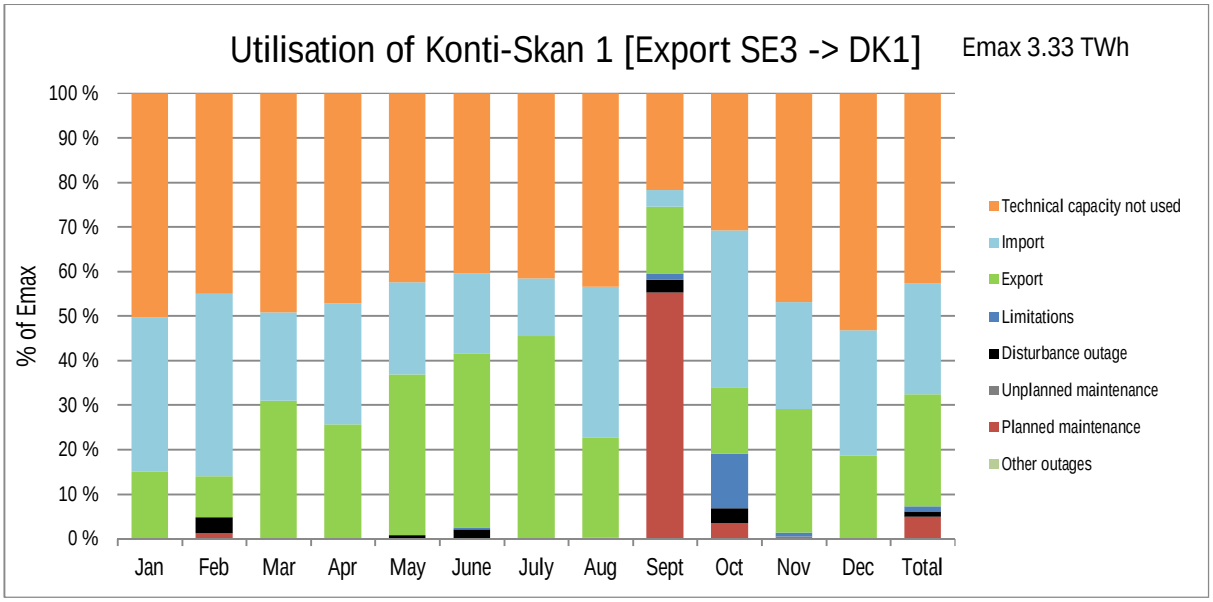

Figure 5.31 Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Konti-Skan 1 in 2017

Table 5.7 Monthly distribution of the technical capacity (E_{MAX}) for Konti-Skan 1 in 2017

Konti-Skan 1 [Export SE3 -> DK1]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	2644	2855	1485	1996	1639	1372	1067	2788	294	2633	1730	2060	0.7
Export losses [MWh]	780	507	1757	1264	2075	2264	2666	1408	866	804	1433	1110	0.5
Technical capacity not used [MWh]	127380	103826	119133	111871	99970	90929	95222	106407	49938	70023	102873	134903	38.7
Import [MWh]	98039	104878	56079	74389	58613	49331	36569	95782	10227	99731	65574	79842	26.5
Export [MWh]	42361	23291	87457	70040	101933	107124	128309	63364	41524	42312	76410	52434	26.7
Limitations [MWh]	0	0	0	380	0	916	0	547	3180	38484	9729	0	1.7
Disturbance outage [MWh]	0	9158	0	0	2166	5738	0	0	7942	9533	0	0	1.1
Unplanned maintenance outage [MWh]	0	0	0	0	0	0	0	0	0	0	1077	0	0.0
Planned maintenance outage [MWh]	0	3091	0	0	0	0	0	0	151189	9753	0	0	5.2
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Rated capacity 370 MW	267780	244245	262670	256680	262681	254037	260100	266100	264000	269836	255664	267180	100.0

Figure 5.32 presents the annual utilization of Konti-Skan 1 according to all the categories of technical capacity (E_{max}) annually for the years 2012–2017. Figure 5.33 presents the trend of the previous values, but with the categories technical capacity not used (E_{TCNU}), transmission (E_T) and unavailable technical capacity (E_U). Figure 5.34 presents the trend of number of disturbance outages, unplanned and planned maintenance and other outages with a 2-year rolling average.

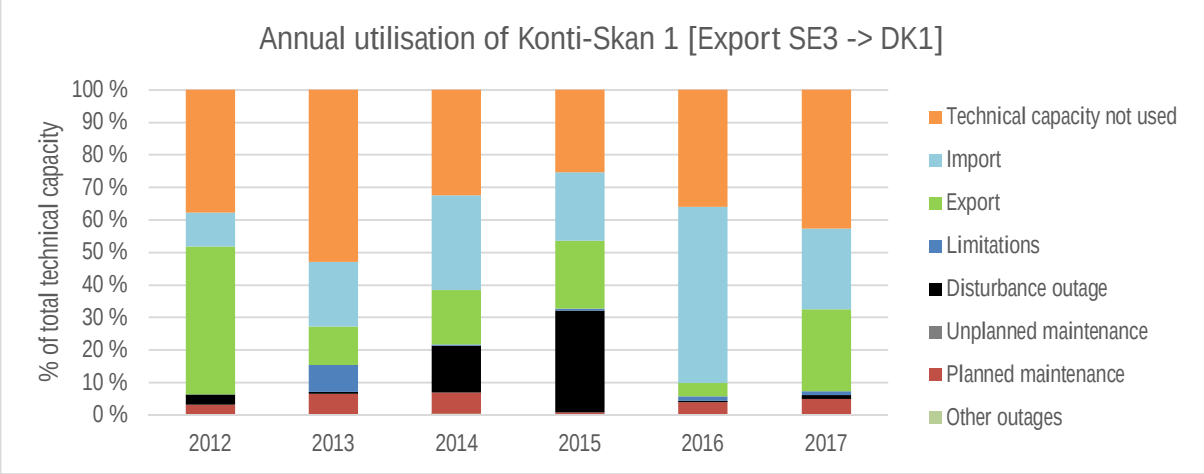

Figure 5.32 Annual utilisation of Konti-Skan 1 according to the eight utilisation and unavailability categories for the years 2012–2017.

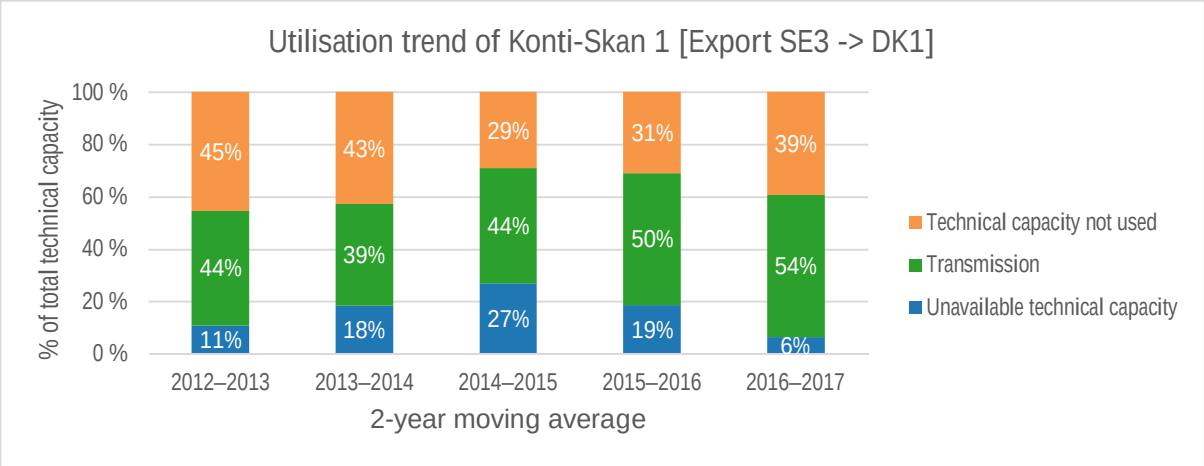

Figure 5.33 Utilisation trend of Konti-Skan 1 according to unavailability, transmission and technical capacity not used for the years 2012–2017.

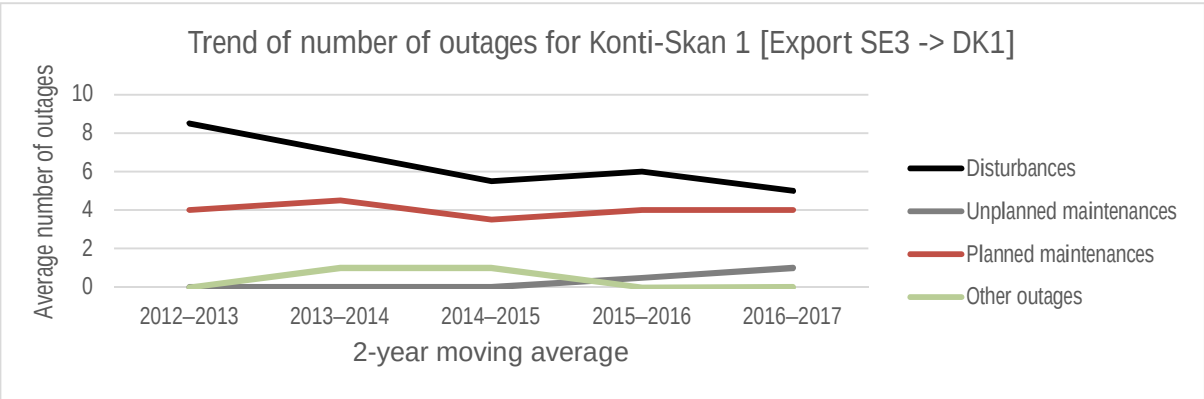

Figure 5.34 2-year moving average trend of number of outage events for Konti-Skan 1 for the years 2012–2017.

5.3.8 Konti-Skan 2

Figure 5.35 presents the availability and utilisation of Konti-Skan 2 for 2017 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 2017, Konti-Skan 2 had an available technical capacity of 93.9 % and the technical capacity not used was 40.2 %. Totally, 0.8 TWh (26.5 % of the technical capacity) was exported from Sweden to Denmark and 0.9 TWh (27.2 % of the technical capacity) was imported to Sweden.

The annual maintenance lasted 16 days in September. Konti-Skan 2 had no disturbances during 2017.

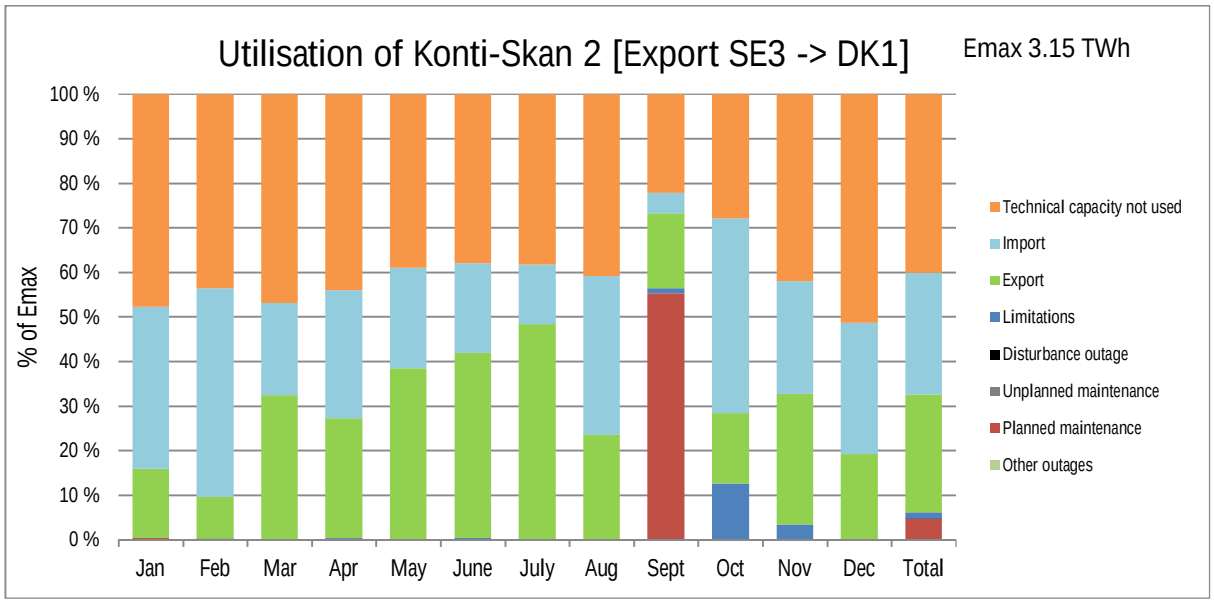

Figure 5.35 Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Konti-Skan 2 in 2017

Table 5.8 Monthly distribution of the technical capacity (E_{MAX}) for Konti-Skan 2 in 2017

Konti-Skan 2 [Export SE3 -> DK1]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	2389	2942	1286	1733	1522	1414	939	2798	317	3165	1615	1918	0.7
Export losses [MWh]	989	562	2222	1793	2792	2941	3404	1640	1063	1023	1778	1247	0.7
Technical capacity not used [MWh]	128442	108158	121637	111868	99798	93618	95448	108219	59135	75152	104803	137588	39.7
Import [MWh]	97560	113483	55403	74550	60565	52203	36019	95731	11893	116984	65354	78978	27.4
Export [MWh]	41391	22456	86438	69547	102749	107832	129449	62867	43681	42513	76032	51426	26.7
Limitations [MWh]	0	0	0	380	0	420	0	0	2520	34955	9576	0	1.5
Disturbance outage [MWh]	0	510	0	618	0	0	0	0	0	0	0	0	0.0
Unplanned maintenance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Planned maintenance outage [MWh]	990	0	0	0	0	0	0	0	143232	0	0	0	4.6
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Rated capacity 370 MW	268382	244607	263479	256963	263112	254073	260917	266817	260462	269604	255765	267992	100.0

Figure 5.36 presents the annual utilization of Konti-Skan 2 according to all the categories of technical capacity (E_{max}) annually for the years 2012–2017. Figure 5.37 presents the trend of the previous values, but with the categories technical capacity not used (E_{TCNU}), transmission (E_T) and unavailable technical capacity (E_U). Figure 5.38 presents the trend of number of disturbance outages, unplanned and planned maintenance and other outages with a 2-year rolling average.

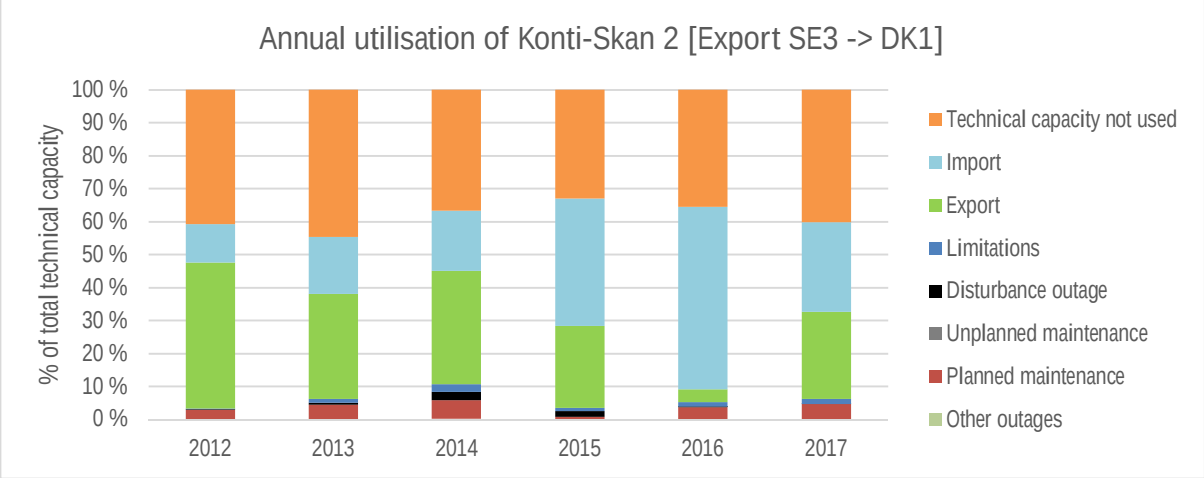

Figure 5.36 Annual utilisation of Konti-Skan 2 according to the eight utilisation and unavailability categories for the years 2012–2017.

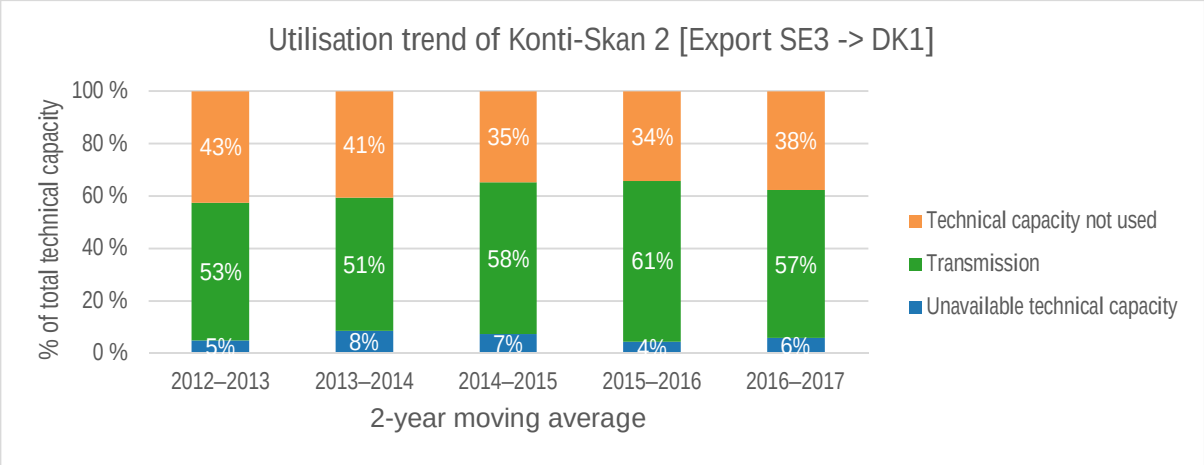

Figure 5.37 Utilisation trend of Konti-Skan 2 according to unavailability, transmission and technical capacity not used for the years 2012–2017.

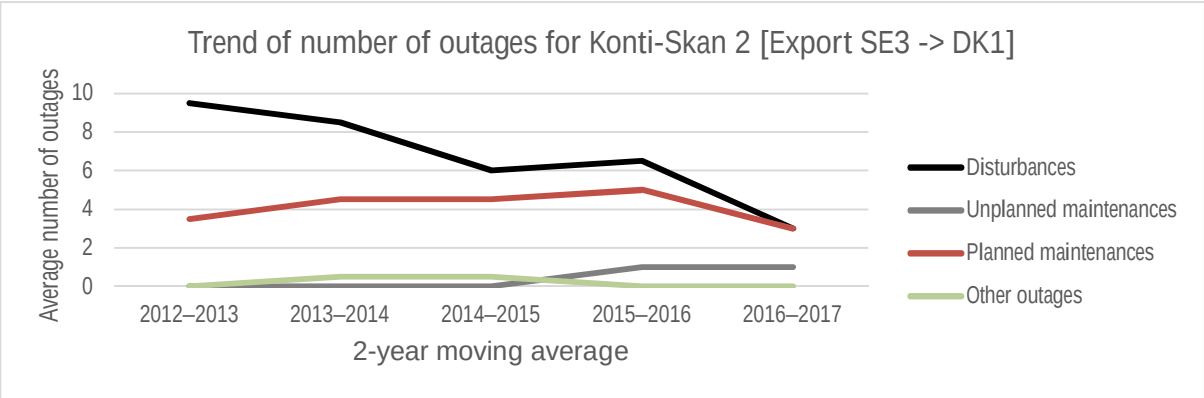

Figure 5.38 2-year moving average trend of number of outage events for Konti-Skan 2 for the years 2012–2017.

5.3.9 LitPol Link

Figure 5.39 presents the availability and utilisation of LitPol Link for 2017 and Table 5.9 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 is 500 MW.

In 2017, LitPol Link had had an available technical capacity of 90.7 %. The technical capacity not used was 44.1 %. Totally, 1.6 TWh (35.4 % of the technical capacity) was exported from Lithuania to Poland and 0.5 TWh (11.3 % of the technical capacity) was imported to Lithuania.

The annual maintenance lasted six days in September and there were no disturbances on LitPol Link in 2017.

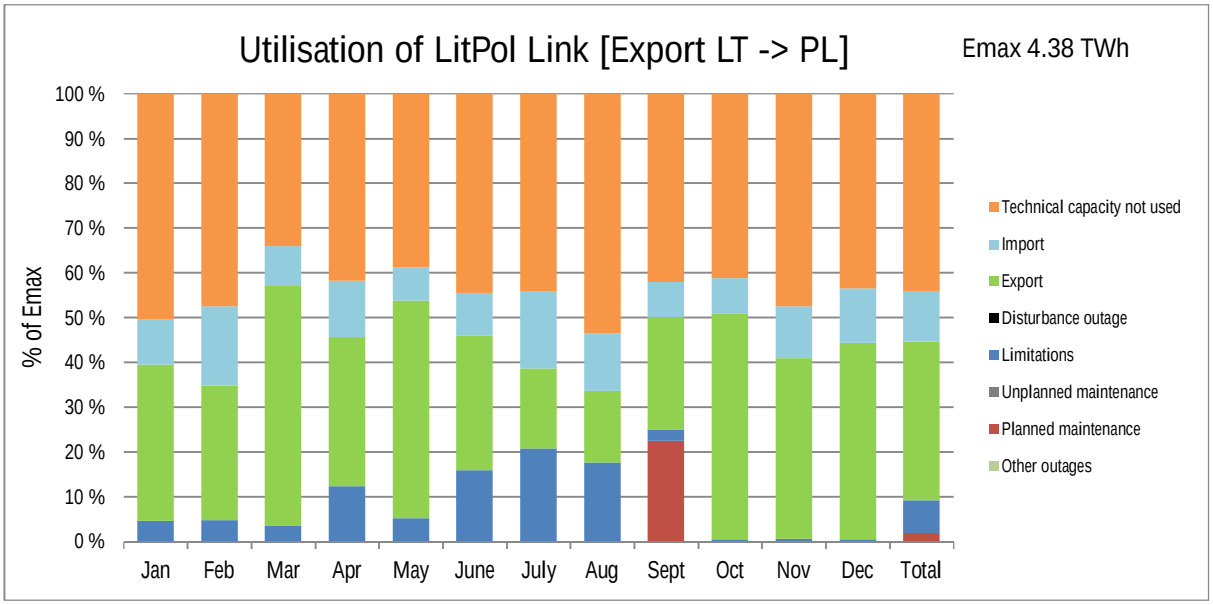

Figure 5.39 Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for LitPol Link in 2017

Table 5.9 Monthly distribution of the technical capacity (E_{MAX}) for LitPol Link in 2017

LitPol Link [Export LT -> PL]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	1256	1503	832	1162	865	1456	1458	1460	698	842	1053	1086	0.3
Export losses [MWh]	1624	1239	2692	1706	2399	1399	1132	854	1428	2601	1983	2114	0.5
Technical capacity not used [MWh]	187204	159688	126616	150550	144478	160259	164565	198906	151555	153531	171059	161667	44.1
Import [MWh]	38168	59732	32188	45215	27587	34627	63989	48208	28148	29088	41890	45510	11.3
Export [MWh]	129286	100423	199733	119720	180700	107933	66360	59288	90782	188174	144841	162908	35.4
Limitations [MWh]	17342	16156	12963	44515	19236	57181	77085	65598	8521	1708	2210	1915	7.4
Disturbance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Unplanned maintenance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Planned maintenance outage [MWh]	0	0	0	0	0	0	0	0	81000	0	0	0	1.8
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Rated capacity 500 MW	372000	336000	371500	360000	372000	360000	372000	372000	360005	372500	360000	372000	100.0

Figure 5.40 presents the annual utilization of LitPol Link according to all the categories of technical capacity (E_{max}) annually for the years 2016–2017. The year span is different because LitPol Link has data available since 2016. Figure 5.41 presents the number of disturbance outages, unplanned and planned maintenance and other outages with a 2-year rolling average.

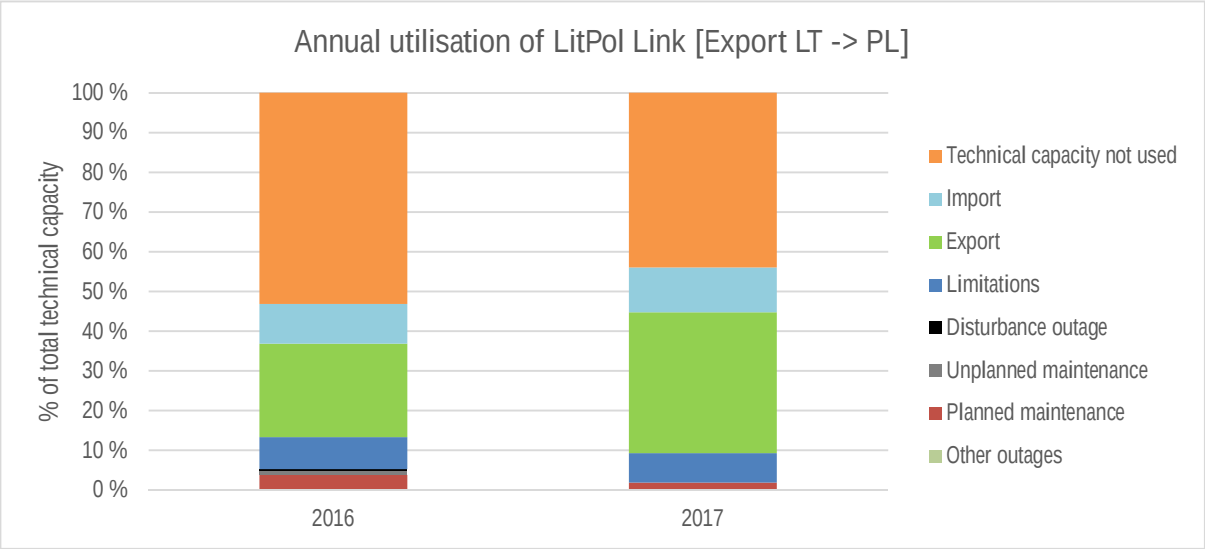

Figure 5.40 Annual utilisation of LitPol Link according to the eight utilisation and unavailability categories for the years 2016–2017.

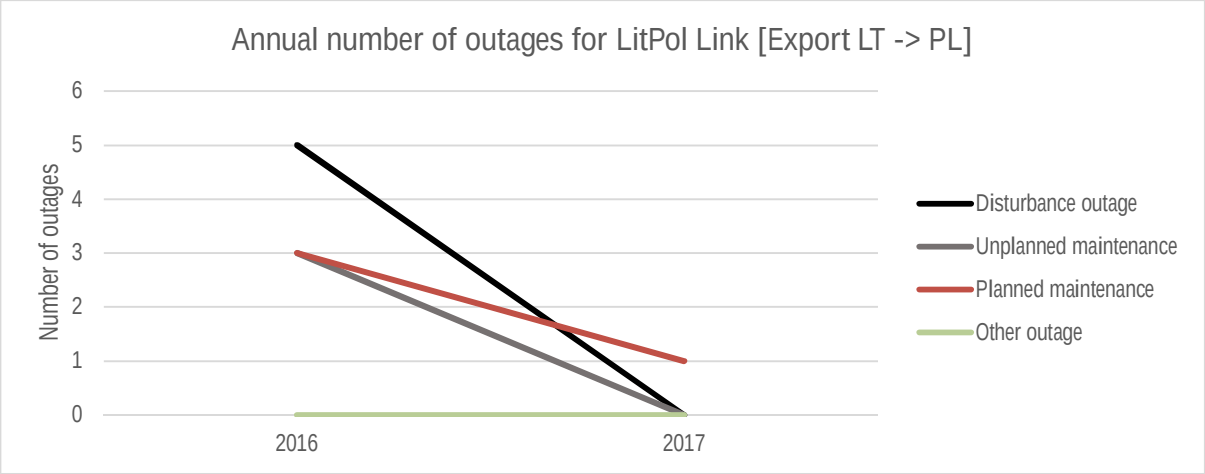

Figure 5.41 Annual number of disturbance outages, unplanned and planned maintenance and other outages for LitPol Link for the years 2016–2017.

5.3.10 NordBalt

Figure 5.42 presents the availability and utilisation of NordBalt for 2017 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 is 700 MW at the receiving end.

In 2017, NordBalt had had an available technical capacity of 83.6 %. The technical capacity not used was 32.1 %. Totally, 3.0 TWh (49.6 % of the technical capacity) was exported from Sweden to Lithuania and 0.1 TWh (1.9 % of the technical capacity) was imported to Sweden.

The annual maintenance lasted fourteen days in June and there were 12 disturbances on NordBalt, of which five were caused by fault in a cable joints on the onshore in January, February, 2 in July and November 2017.

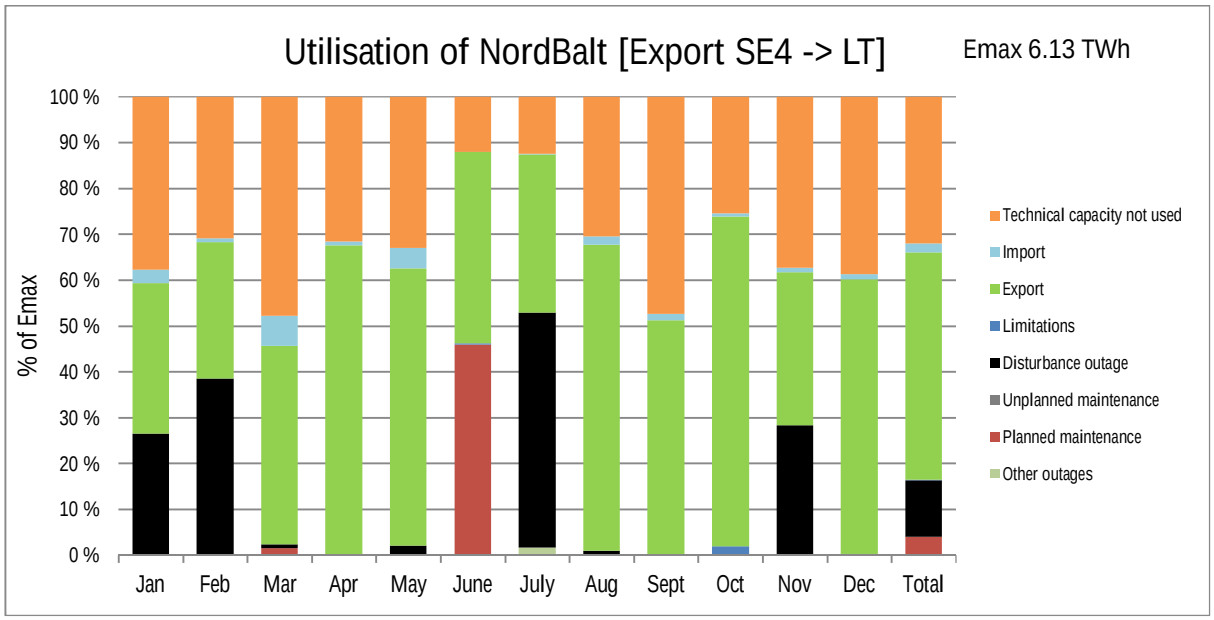

Figure 5.42 Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for NordBalt in 2017

Table 5.10 Monthly distribution of the technical capacity (E_{MAX}) for NordBalt in 2017

NordBalt [Export SE4 -> LT]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	583	208	1090	254	783	64	68	405	301	164	270	278	0.1
Export losses [MWh]	7051	5835	9188	15092	13755	9332	7860	15614	10781	16444	6893	13284	2.1
Technical capacity not used [MWh]	196857	145556	248568	159268	171985	60991	64775	158622	238514	132571	188129	201367	32.1
Import [MWh]	15029	4009.9	33925	4510	23312	52	764	9926	7483	3721	5340	6370	1.9
Export [MWh]	170828	140000	225187	340222	314948	209920	180084	347703	258003	375124	168172	312118	49.6
Limitations [MWh]	0	0	0	0	0	1399	0	0	0	9904	0	0	0.2
Disturbance outage [MWh]	138086	180834	4375	0	10617	0	266828	4550	0	100	142823	945	12.2
Unplanned maintenance outage [MWh]	0	0	0	0	0	0	0	0	0	30	0	0	0.0
Planned maintenance outage [MWh]	0	0	8050	0	0	231688	0	0	0	30	0	0	3.9
Other outages [MWh]	0	0	0	0	0	0	8400	0	0	20	0	0	0.1
Rated capacity 700 MW	520800	470400	520106	504000	520861	504050	520850	520800	504000	521500	504464	520800	100.0

Figure 5.43 presents the annual utilization of NordBalt according to all the categories of technical capacity (E_{max}) annually for the years 2016–2017. The year span is different because NordBalt has data available since 2016. Figure 5.44 presents the number of disturbance outages, unplanned and planned maintenance and other outages with a 2-year rolling average.

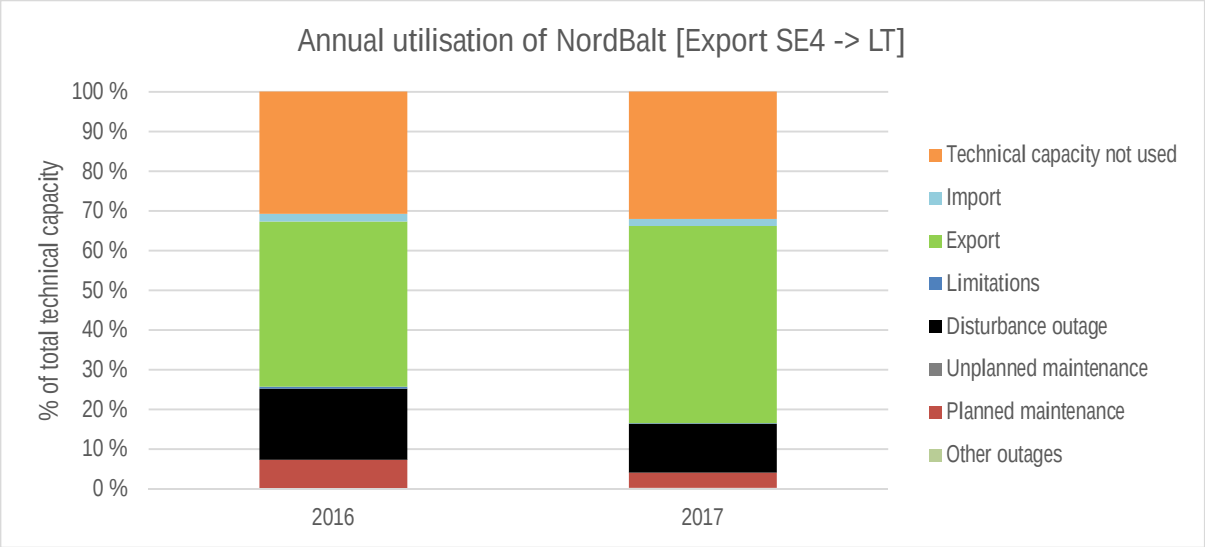

Figure 5.43 Annual utilisation of NordBalt according to the eight utilisation and unavailability categories for the years 2016–2017.

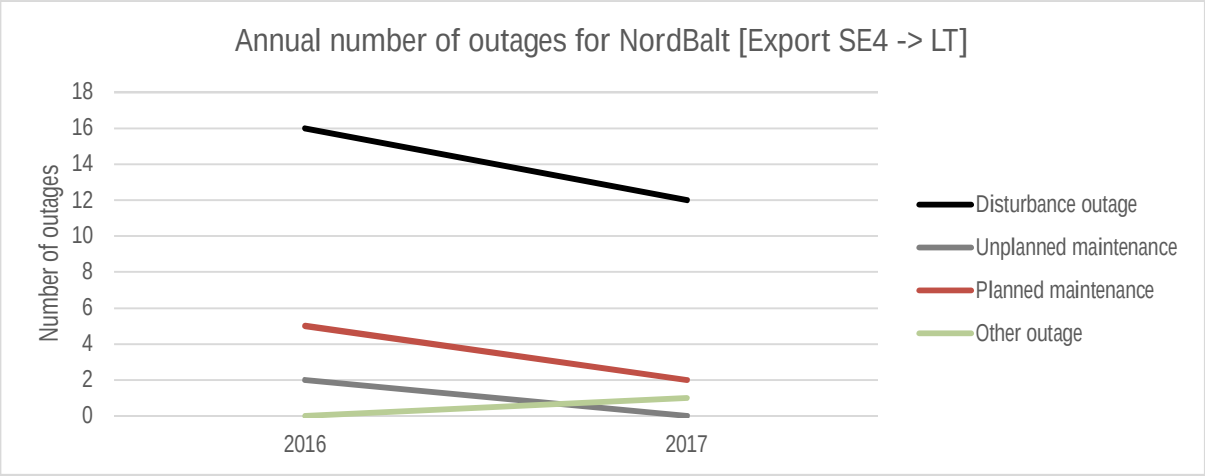

Figure 5.44 Annual number of disturbance outages, unplanned and planned maintenance and other outages for NordBalt for the years 2016–2017.

5.3.11 NorNed

Figure 5.45 presents the availability and utilisation of NorNed for 2017 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 is 700 MW.

In 2017, NorNed had had an available technical capacity of 91.9 %. The technical capacity not used was 9.2 %. Totally, 5.0 TWh (80.9 % of the technical capacity) was exported from Norway to the Netherlands and 0.1 TWh (1.8 % of the technical capacity) was imported to Norway.

There were 5 minor disturbances on NorNed in 2017. The annual maintenances were carried out in February, April and September.

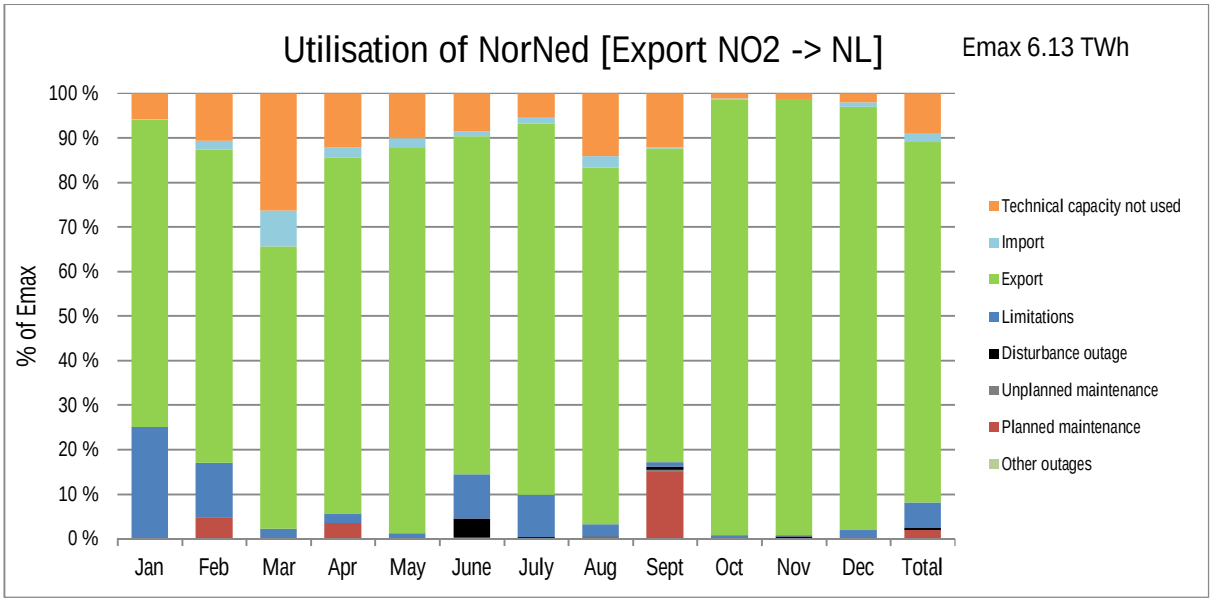

Figure 5.45 Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Norned in 2017

Table 5.11 Monthly distribution of the technical capacity (E_{MAX}) for NorNed in 2017

NorNed [Export NO2 -> NL]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	27	353	1530	415	422	183	238	488	43	33	3	223	0.1
Export losses [MWh]	10768	11591	12478	15635	17713	13989	16150	16326	14100	20399	19784	19628	3.1
Technical capacity not used [MWh]	30286	50713	137311	61164	52652	43529	29215	74138	61609	6658	7803	10605	9.2
Import [MWh]	866	9454.6	41859	11810	11029	5887	6171	13574	1260	879	94	5707	1.8
Export [MWh]	359501	331276	330533	405835	452903	384174	435418	419624	357621	512189	494491	496607	80.9
Limitations [MWh]	130147	58281	11163	9726	5768	50168	49119	14021	5161	4229	2082	9739	5.7
Disturbance outage [MWh]	0	0	0	0	0	22041	1692	1109	4200	0	1984	0	0.5
Unplanned maintenance outage [MWh]	0	0	0	0	0	0	0	0	900	0	0	0	0.0
Planned maintenance outage [MWh]	0	22150	0	17850	0	500	0	1400	77000	0	0	0	1.9
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Rated capacity 700 MW	520800	471875	520867	506385	522352	506298	521614	523867	507751	523955	506455	522659	100.0

Figure 5.46 presents the annual utilization of NorNed according to all the categories of technical capacity (E_{max}) annually for the years 2012–2017. Figure 5.47 presents the trend of the previous values, but with the categories technical capacity not used (E_{TCNU}), transmission (E_T) and unavailable technical capacity (E_U). Figure 5.48 presents the trend of number of disturbance outages, unplanned and planned maintenance and other outages with a 2-year rolling average.

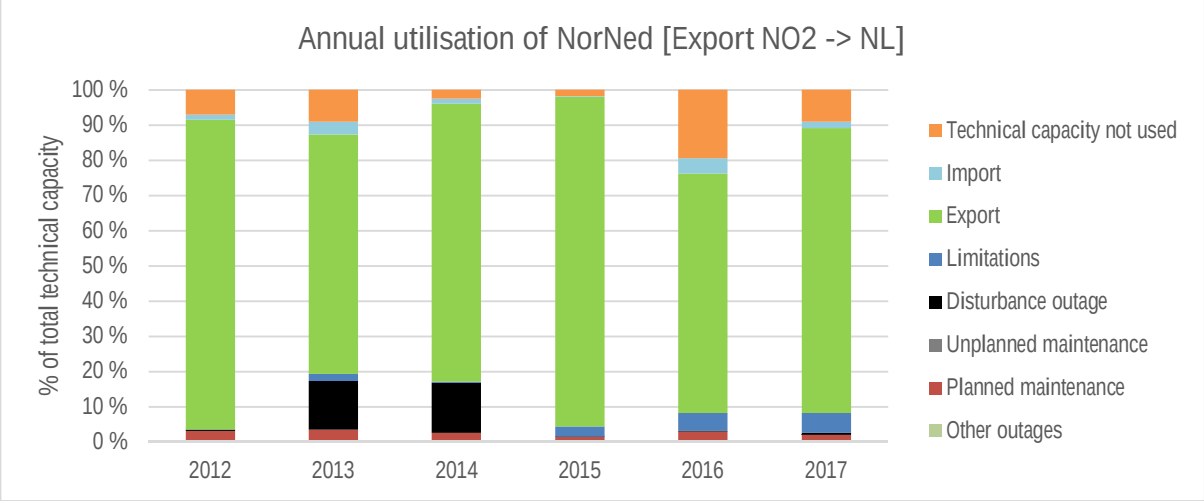

Figure 5.46 Annual utilisation of NorNed according to the eight utilisation and unavailability categories for the years 2012–2017.

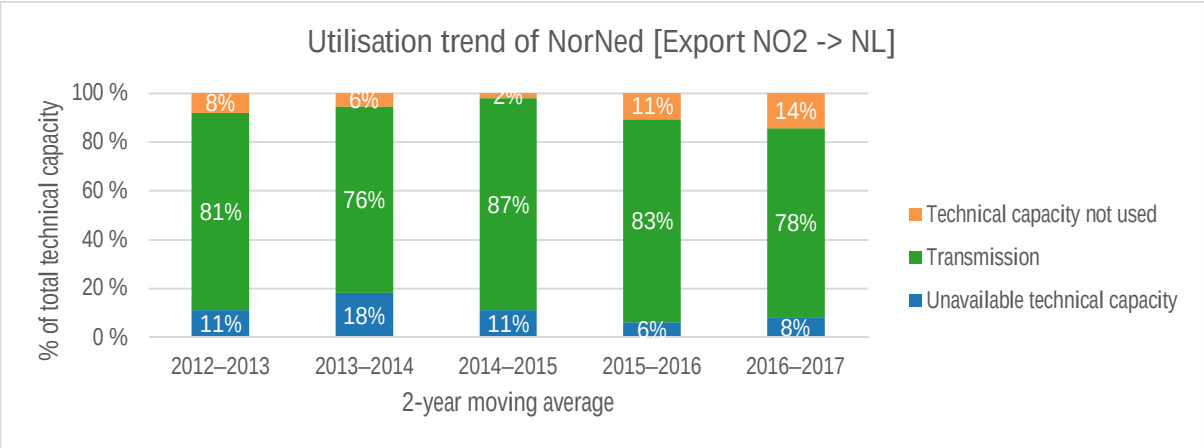

Figure 5.47 Utilisation trend of NorNed according to unavailability, transmission and technical capacity not used for the years 2012–2017.

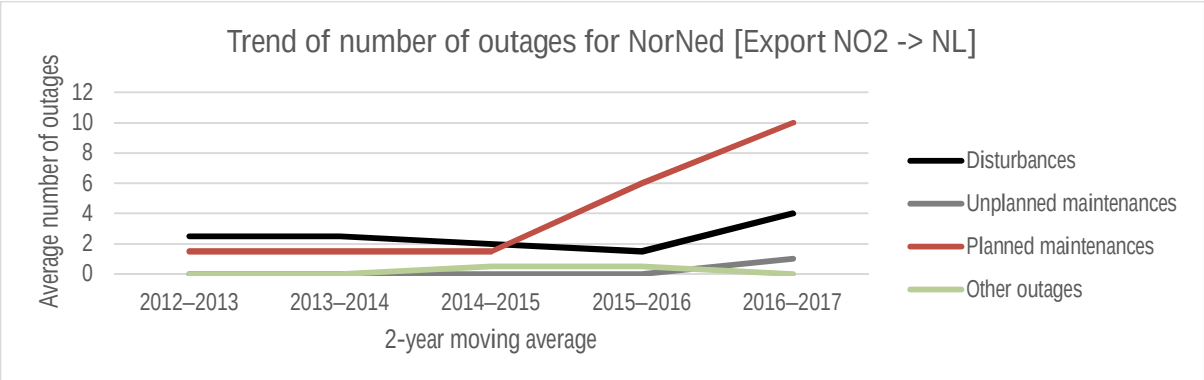

Figure 5.48 2-year moving average trend of number of outage events for NorNed for the years 2012–2017.

5.3.12 Skagerak 1

Figure 5.49 presents the availability and utilisation of Skagerak 1 for 2017 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 2017, Skagerak 1 had an available technical capacity of 74.8 %. The technical capacity not used was 34.7 %. Totally, 0.6 TWh (29.5 % of the technical capacity) was exported from Norway to the Denmark and 0.2 TWh (10.7 % of the technical capacity) was imported to Norway.

Skagerak 1,2 and 3 had their electrode masts regalvanized and electrode lines replaced, which caused the high amount of planned maintenance in 2017. This work will continue during most of year 2018 as well. There was 1 minor disturbance in February on Skagerak 1.

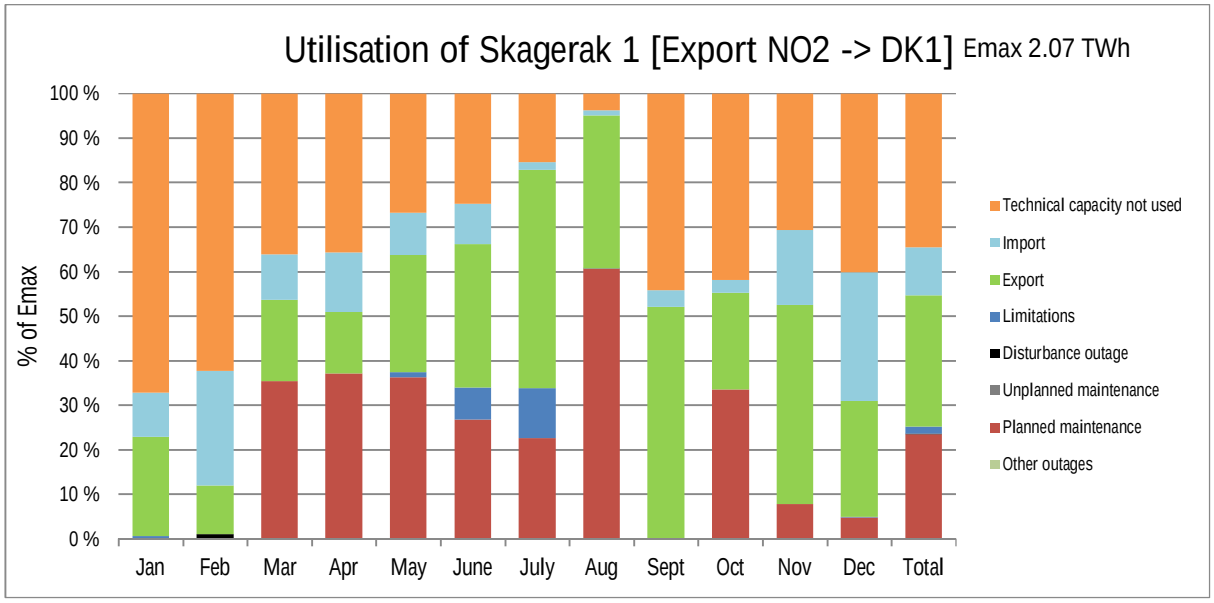

Figure 5.49 Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Skagerak 1 in 2017

Table 5.12 Monthly distribution of the technical capacity (E_{MAX}) for Skagerak 1 in 2017

Skagerak 1 [Export NO2 -> DK1]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	876	2032	857	1173	906	767	161	156	362	297	1417	2574	0.5
Export losses [MWh]	1917	859	1724	1292	2241	2707	4364	4266	4835	2026	3881	2155	1.5
Technical capacity not used [MWh]	118550	99908	63691	61381	47493	42517	27346	9376	75228	73736	52431	71334	34.7
Import [MWh]	17366	41181	17933	22850	16747	15340	2902	2745	6415	5145	28793	51265	10.7
Export [MWh]	39179	17419	32047	23684	46313	55230	86477	83242	88358	38177	76497	46282	29.5
Limitations [MWh]	1105.9	0	0	0	2027	12195	19637	3	0	0	0	237	1.6
Disturbance outage [MWh]	0	1683	0	0	0	0	0	0	0	0	0	0	0.1
Unplanned maintenance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Planned maintenance outage [MWh]	0	0	62068	63484	63956	45784	39695	146977	0	59000	13216	8323	23.4
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Rated capacity 236 MW	176201	160191	175739	171399	176536	171065	176057	242344	170001	176058	170937	177441	100.0

Figure 5.50 presents the annual utilization of Skagerak 1 according to all the categories of technical capacity (E_{max}) annually for the years 2012–2017. Figure 5.51 presents the trend of the previous values, but with the categories technical capacity not used (E_{TCNU}), transmission (E_T) and unavailable technical capacity (E_U). Figure 5.52 presents the trend of number of disturbance outages, unplanned and planned maintenance and other outages with a 2-year rolling average.

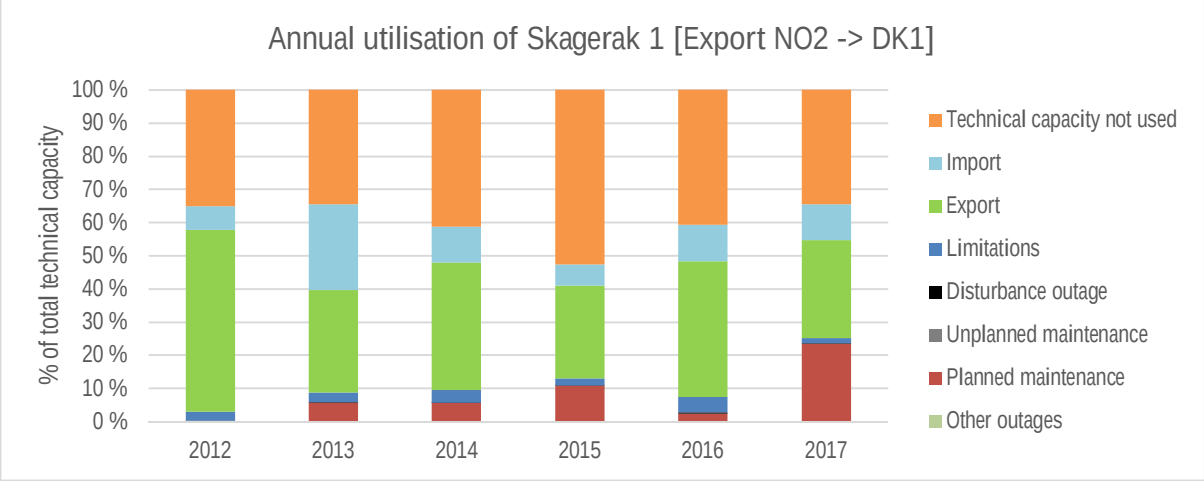

Figure 5.50 Annual utilisation of Skagerak 1 according to the eight utilisation and unavailability categories for the years 2012–2017.

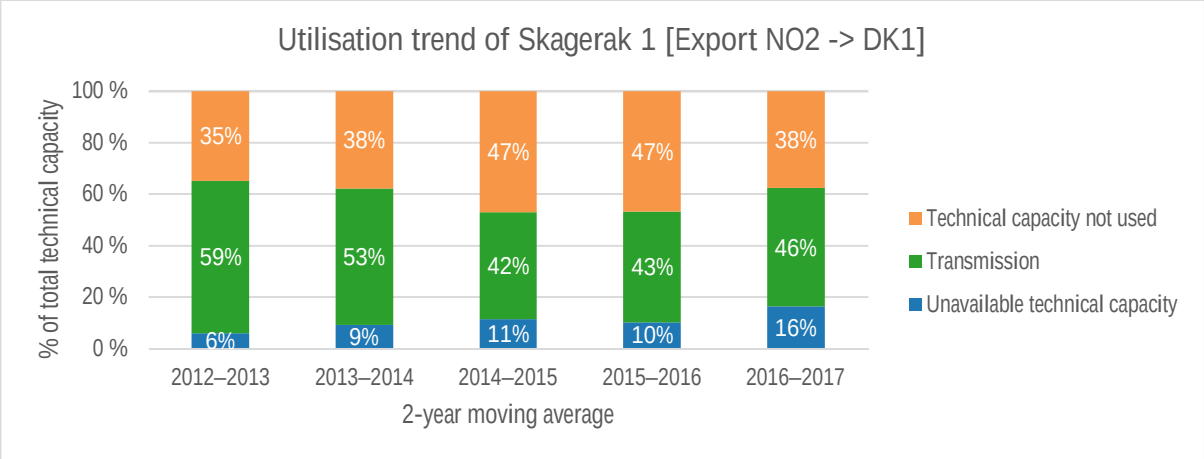

Figure 5.51 Utilisation trend of Skagerak 1 according to unavailability, transmission and technical capacity not used for the years 2012–2017.

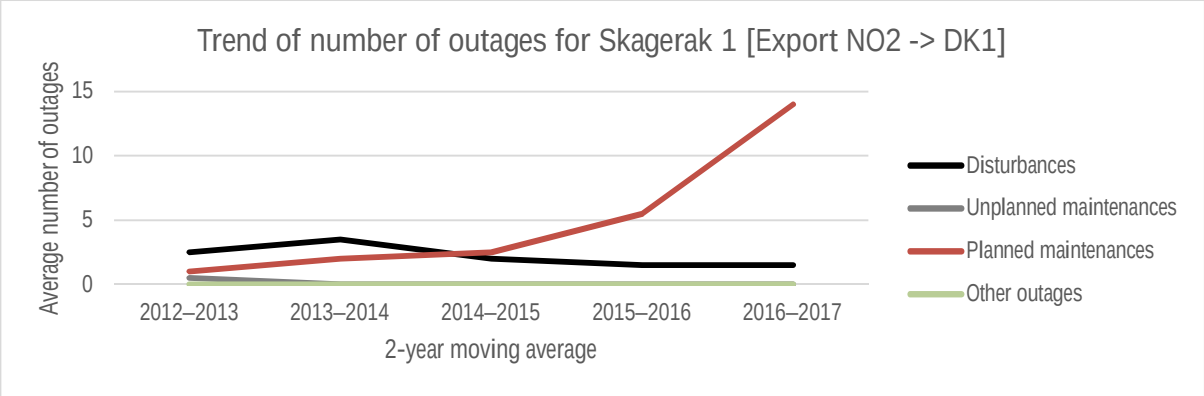

Figure 5.52 2-year moving average trend of number of outage events for Skagerak 1 for the years 2012–2017.

5.3.13 Skagerak 2

Figure 5.53 presents the availability and utilisation of Skagerak 2 for 2017 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 is 236 MW at the receiving end.

In 2017, Skagerak 2 had an available technical capacity of 56.6 %. The technical capacity not used was 27.2 %. Totally, 0.4 TWh (19.3 % of the technical capacity) was exported from Norway to the Denmark and 0.2 TWh (10.2 % of the technical capacity) was imported to Norway.

Skagerak 2 had 1 disturbance outage in 2017. It was a cable fault, caused by a ship and lasted more than 3 months. The high amount of planned maintenance was done to regalvanize the electrode masts and to replace the electrode lines, which was also done to Skagerak 1 and 3. The maintenance will continue during most of year 2018 as well.

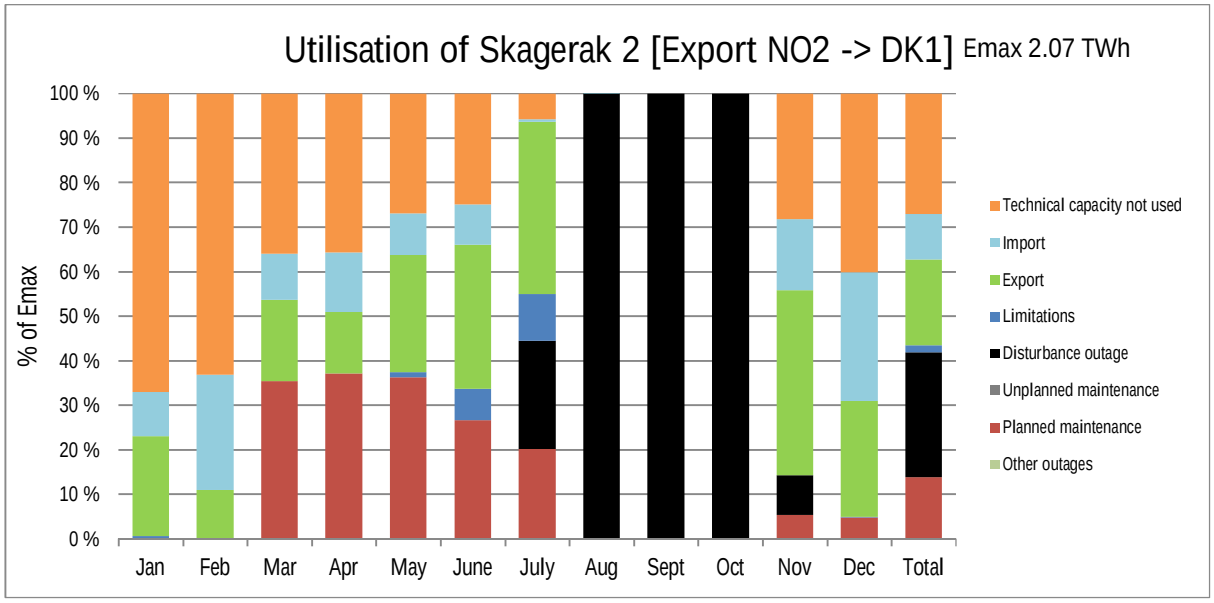

Figure 5.53 Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Skagerak 2 in 2017

Table 5.13 Monthly distribution of the technical capacity (E_{MAX}) for Skagerak 2 in 2017

Skagerak 2 [Export NO2 -> DK1]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	885	2110	874	1172	797	827	47	0	0	0	1421	2561	0.5
Export losses [MWh]	1924	860	1578	1155	2441	2497	2981	0	0	0	3377	2197	0.9
Technical capacity not used [MWh]	118285	101146	63474	61273	47541	42704	10378	0	0	0	48334	71341	27.2
Import [MWh]	17461	41542	18052	22934	16665	15417	913	0	0	0	27486	51362	10.2
Export [MWh]	39423	17410	32198	23825	46381	55269	68029	0	0	0	71030	46273	19.3
Limitations [MWh]	1103.8	0	0	0	1953	11994	18343	0	0	0	0	238	1.6
Disturbance outage [MWh]	0	0	0	0	0	0	42687	175584	169920	175820	15340	0	27.9
Unplanned maintenance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Planned maintenance outage [MWh]	0	0	62068	63484	63956	45548	35447	0	0	0	8968	8323	13.9
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Rated capacity 236 MW	176272	160098	175792	171516	176497	170933	175797	175584	169920	175820	171159	177537	100.0

Figure 5.54 presents the annual utilization of Skagerak 2 according to all the categories of technical capacity (E_{max}) annually for the years 2012–2017. Figure 5.55 presents the trend of the previous values, but with the categories technical capacity not used (E_{TCNU}), transmission (E_T) and unavailable technical capacity (E_U). Figure 5.56 presents the trend of number of disturbance outages, unplanned and planned maintenance and other outages with a 2-year rolling average.

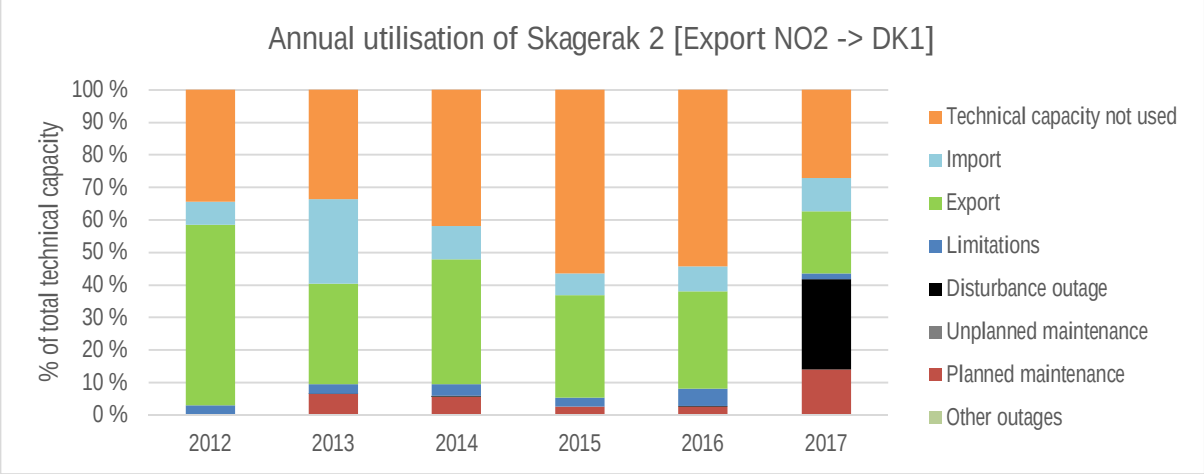

Figure 5.54 Annual utilisation of Skagerak 2 according to the eight utilisation and unavailability categories for the years 2012–2017.

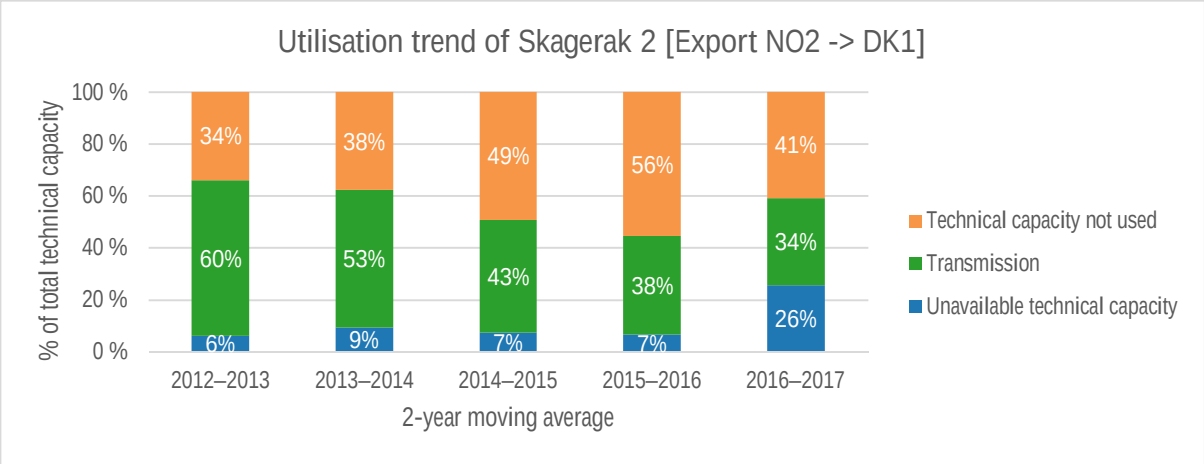

Figure 5.55 Utilisation trend of Skagerak 2 according to unavailability, transmission and technical capacity not used for the years 2012–2017.

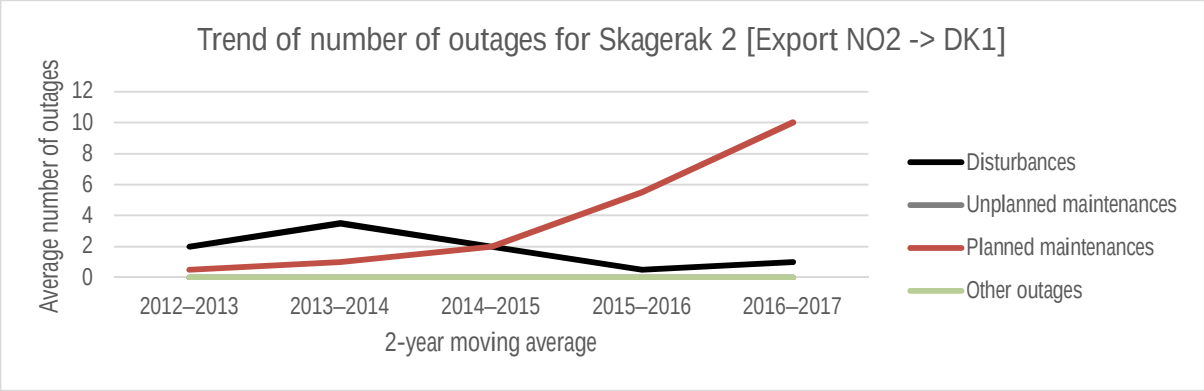

Figure 5.56 2-year moving average trend of number of outage events for Skagerak 2 for the years 2012–2017.

5.3.14 Skagerak 3

Figure 5.57 presents the availability and utilisation of Skagerak 3 for 2017 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 is 478 MW at the receiving end.

In 2017, 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 had their electrode masts regalvanized and electrode lines replaced, which caused the high amount of planned maintenance in 2017. This work will continue during most of year 2018 as well. There were 2 minor disturbances on Skagerak 3 in 2017.

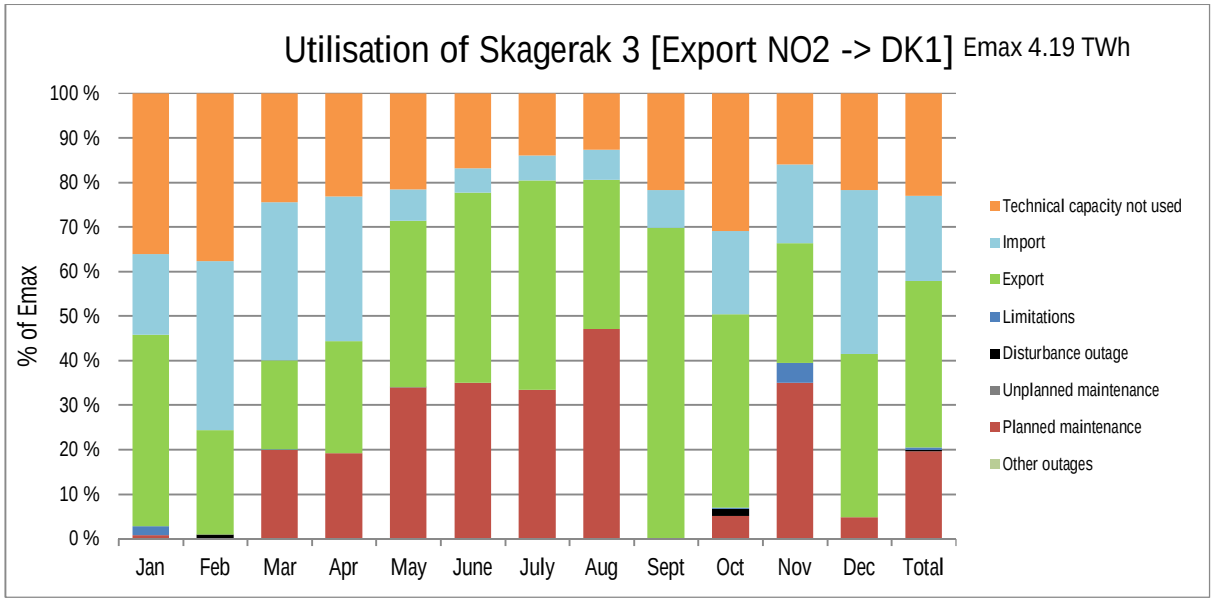

Figure 5.57 Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Skagerak 3 in 2017

Table 5.14 Monthly distribution of the technical capacity (E_{MAX}) for Skagerak 3 in 2017

Skagerak 3 [Export NO2 -> DK1]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	3754	1835	1664	2119	3398	3744	4125	2892	5334	3433	2122	3088	0.9
Export losses [MWh]	1730	3282	3427	3020	631	485	497	622	712	1702	1574	3499	0.5
Technical capacity not used [MWh]	128463	121466	86951	80384	77106	58061	50127	45334	74982	110496	55247	77278	23.0
Import [MWh]	64522	121990	126659	112437	25243	18809	19915	24245	29325	66863	60600	131401	19.1
Export [MWh]	152942	75572	70848	86904	133795	147401	167279	119392	239921	154973	92741	130424	37.5
Limitations [MWh]	6971.4	0	396	0	22	0	0	0	0	927	15313	0	0.6
Disturbance outage [MWh]	0	2640	0	0	0	0	0	0	0	5696	0	0	0.2
Unplanned maintenance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Planned maintenance outage [MWh]	2868	0	70744	66442	121412	120456	119022	167300	0	18164	120456	16857	19.6
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Rated capacity 478 MW	355766	321668	355597	346167	357579	344727	356343	356270	344228	357118	344356	355960	100.0

Figure 5.58 presents the annual utilization of Skagerak 3 according to all the categories of technical capacity (E_{max}) annually for the years 2012–2017. Figure 5.59 presents the trend of the previous values, but with the categories technical capacity not used (E_{TCNU}), transmission (E_T) and unavailable technical capacity (E_U). Figure 5.60 presents the trend of number of disturbance outages, unplanned and planned maintenance and other outages with a 2-year rolling average.

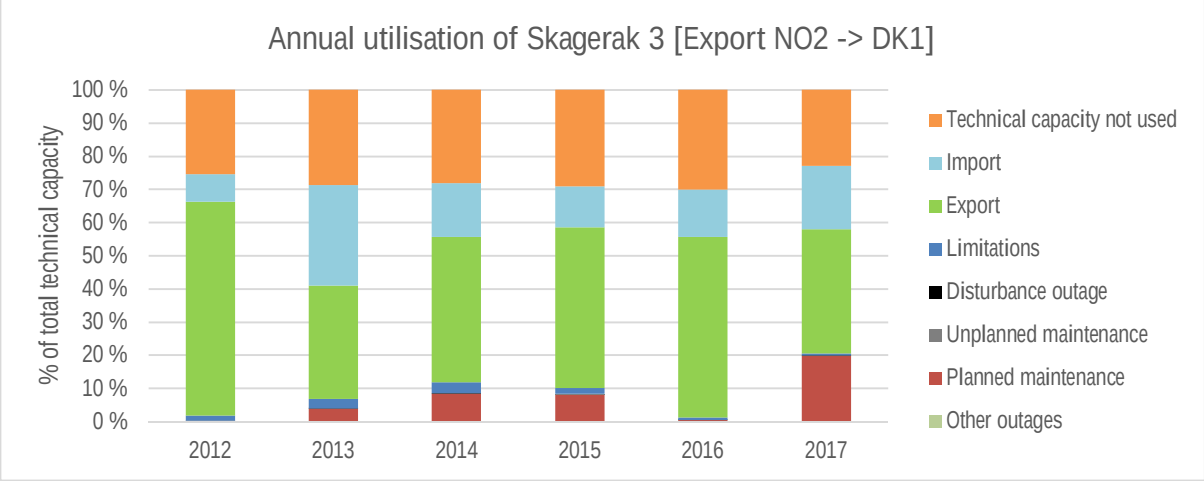

Figure 5.58 Annual utilisation of Skagerak 3 according to the eight utilisation and unavailability categories for the years 2012–2017.

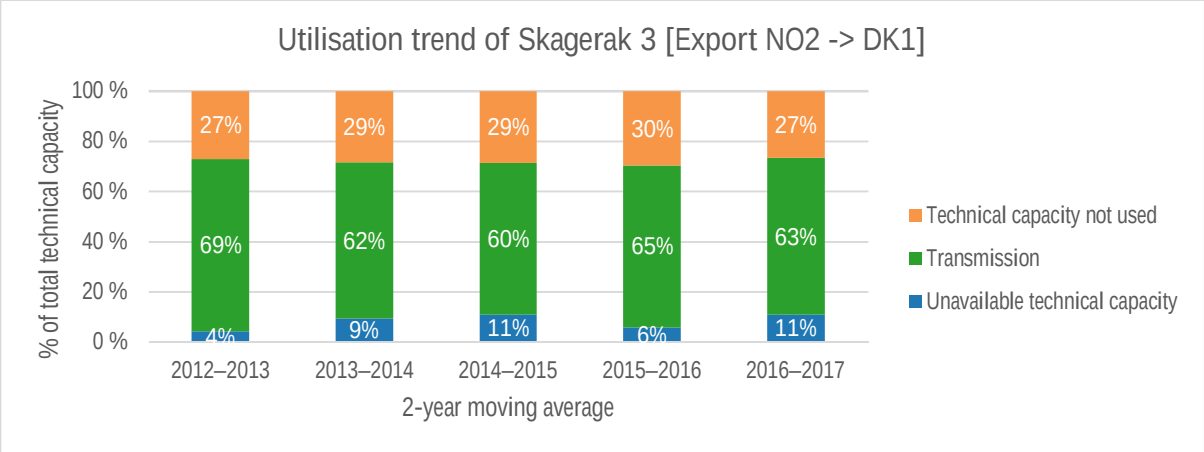

Figure 5.59 Utilisation trend of Skagerak 3 according to unavailability, transmission and technical capacity not used for the years 2012–2017.

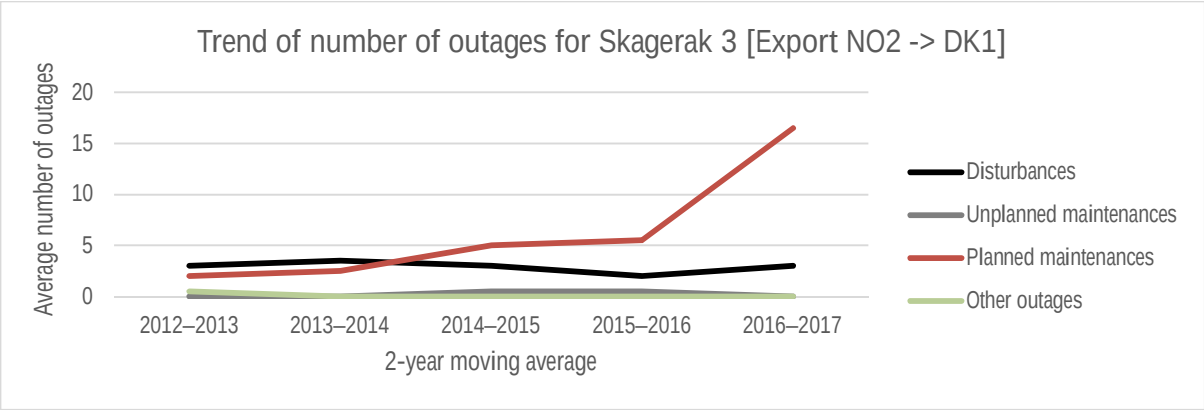

Figure 5.60 2-year moving average trend of number of outage events for Skagerak 3 for the years 2012–2017.

5.3.15 Skagerak 4

Figure 5.61 presents the availability and utilisation of Skagerak 4 for 2017 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 2017, Skagerak 4 had an available technical capacity of 94.1 %. The technical capacity not used was 28.8 %. Totally, 2.7 TWh (44.9 % of the technical capacity) was exported from Norway to the Denmark and 1,2 TWh (20.4 % of the technical capacity) was imported to Norway.

Skagerak 4 had one longer planned maintenance outage in November to repair its cable terminal. There were also 4 minor disturbance outages in 2017. The limitations on Skagerak 4 are related to the electrode current when Skagerak 3 was out due to maintenance.

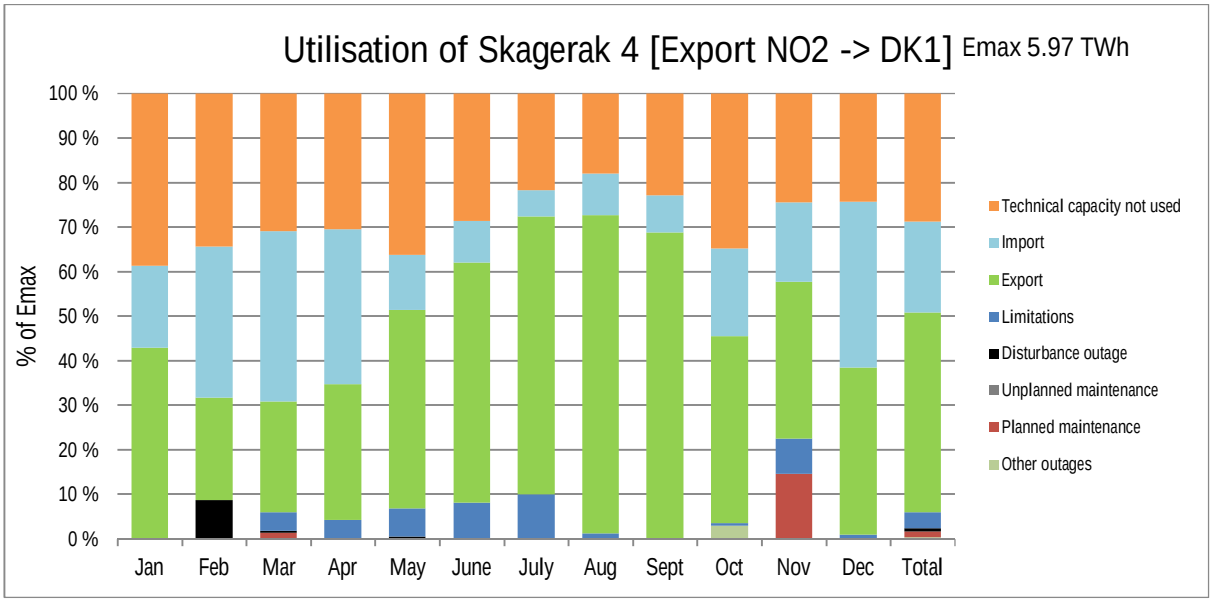

Figure 5.61 Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Skagerak 4 in 2017

Table 5.15 Monthly distribution of the technical capacity (E_{MAX}) for Skagerak 4 in 2017

Skagerak 4 [Export NO2 -> DK1]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	2246	3751	4615	4140	1506	1104	720	1162	1014	2447	2132	4529	0.5
Export losses [MWh]	4083	2000	2314	2930	4343	5076	6155	7662	7064	4315	3320	3654	0.9
Technical capacity not used [MWh]	196803	158203	157384	150007	184705	140602	110870	91582	112521	177584	120443	123442	28.8
Import [MWh]	93404	155493	193470	170750	62581	45936	29738	47126	41109	100842	87848	189235	20.4
Export [MWh]	217226	105540	125948	150000	226580	264951	316506	362983	337450	214066	172652	190383	44.9
Limitations [MWh]	0	0	21575	20430	31913	39574	50310	5717	0	2375	38663	4392	3.6
Disturbance outage [MWh]	0	39556	1847	0	2319	0	0	0	0	0	0	0	0.7
Unplanned maintenance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Planned maintenance outage [MWh]	0	0	6820	0	0	0	0	0	0	0	71485	0	1.3
Other outages [MWh]	0	0	0	0	0	0	0	0	0	15004	0	0	0.3
Rated capacity 682 MW	507434	458792	507044	491187	508098	491063	507424	507408	491079	509870	491091	507451	100.0

Figure 5.62 presents the annual utilization of Skagerak 4 according to all the categories of technical capacity (E_{max}) annually for the years 2012–2017. Figure 5.63 presents the trend of the previous values, but with the categories technical capacity not used (E_{TCNU}), transmission (E_T) and unavailable technical capacity (E_U). Figure 5.64 presents the trend of number of disturbance outages, unplanned and planned maintenance and other outages with a 2-year rolling average.

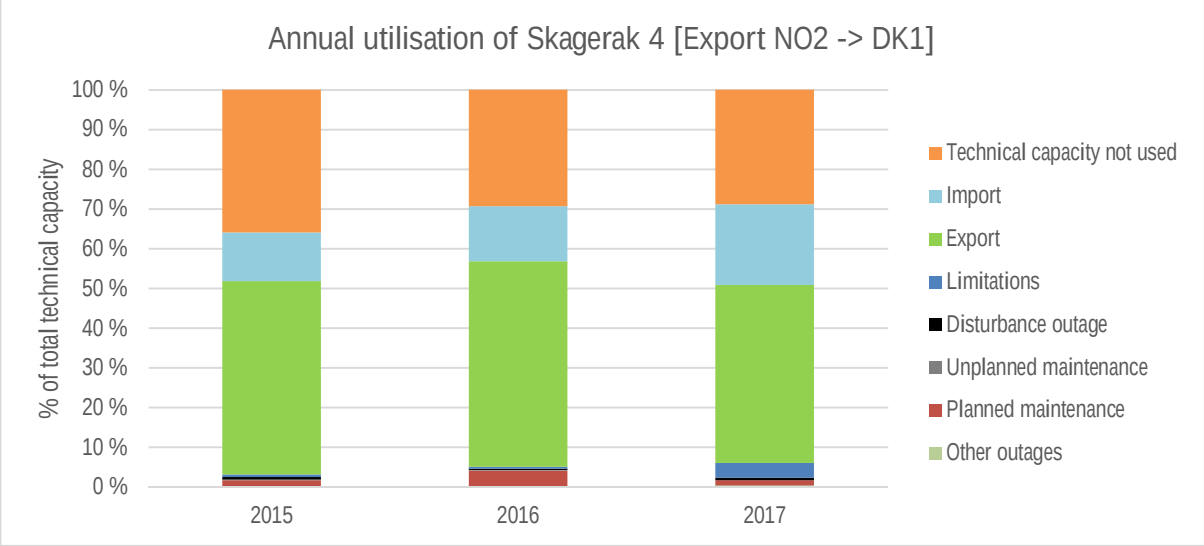

Figure 5.62 Annual utilisation of Skagerak 4 according to the eight utilisation and unavailability categories for the years 2015–2017.

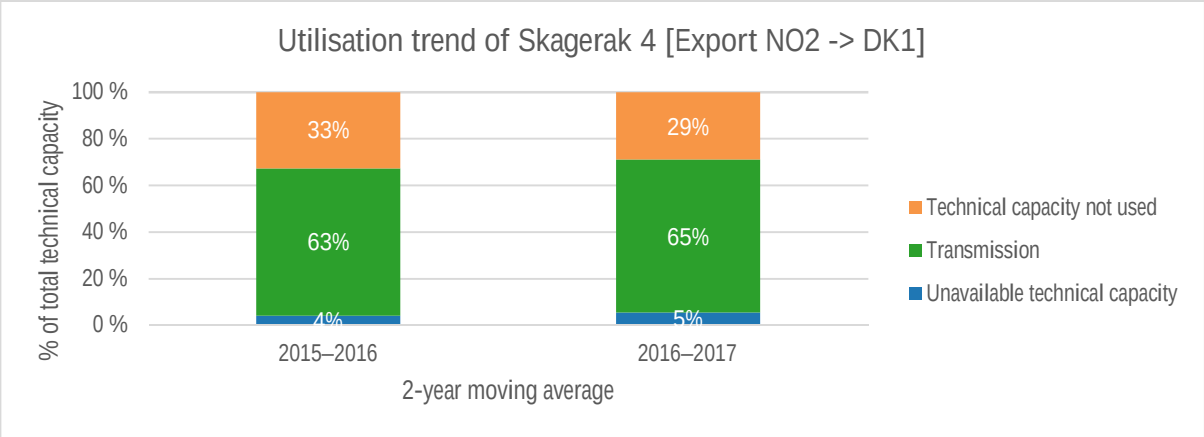

Figure 5.63 Utilisation trend of Skagerak 4 according to unavailability, transmission and technical capacity not used for the years 2015–2017.

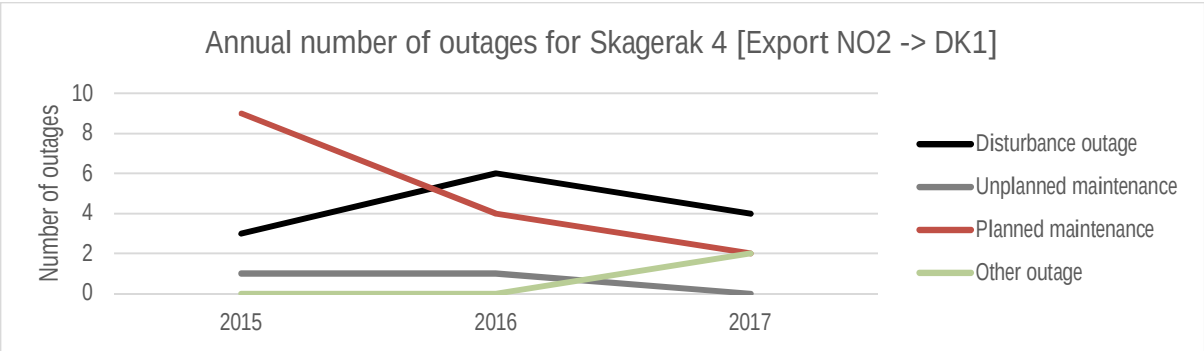

Figure 5.64 Annual number of outage events for Skagerak 4 for the years 2015–2017.

5.3.16 Storebaelt

Figure 5.65 presents the availability and utilisation of Storebaelt for 2017 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 2017, Storebaelt had an available technical capacity of 98.4 %. The technical capacity not used was 34.7 %. Totally, 3.1 TWh (59.7 % of the technical capacity) was exported from Jutland to Zealand and 0.2 TWh (3.9 % of the technical capacity) was imported to Jutland.

The annual maintenance lasted 5 days in April and there were 1 minor disturbance in April on Storebaelt.

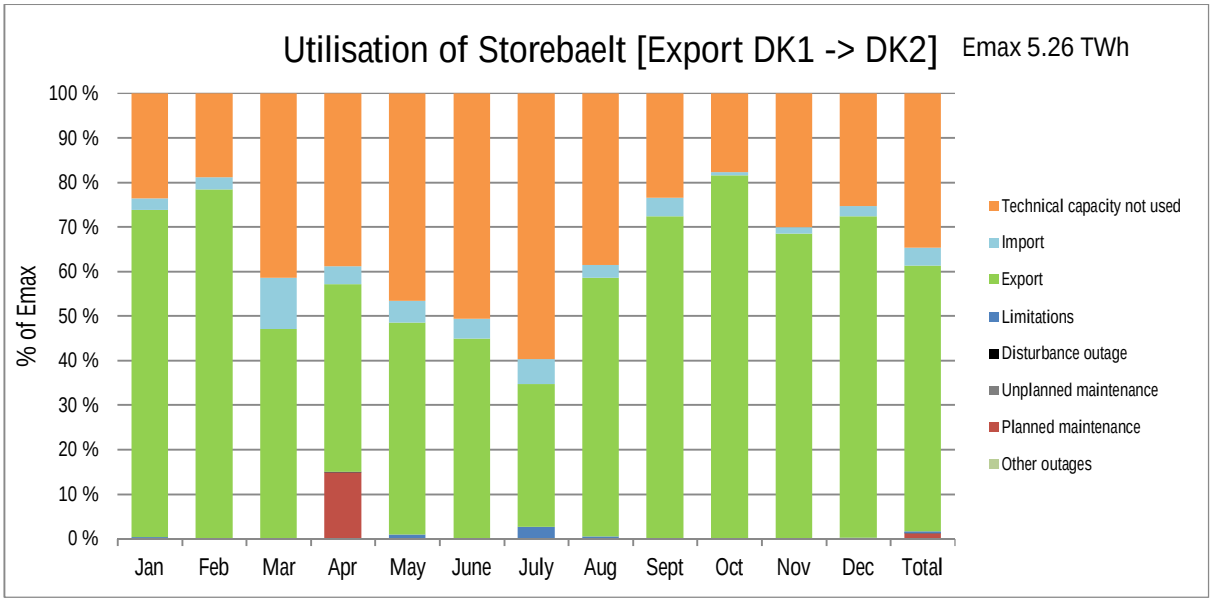

Figure 5.65 Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Storebelt in 2017

Table 5.16 Monthly distribution of the technical capacity (E_{MAX}) for Storebaelt in 2017

Storebaelt [Export DK1 -> DK2]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	194	176	846	295	376	342	437	239	295	62	140	172	0.1
Export losses [MWh]	5654	5403	3507	3007	3519	3222	2392	4359	5406	6357	5010	5469	1.0
Technical capacity not used [MWh]	105964	76506	185119	168009	208144	219038	266877	172580	101538	79693	129970	113215	34.7
Import [MWh]	11086	10864	51212	17387	22154	19020	24852	12788	17992	3160	6606	10471	3.9
Export [MWh]	328719	316254	209633	182292	212255	194054	142757	258937	313016	364849	295723	322428	59.7
Limitations [MWh]	1076.3	0	0	0	3960	0	11967	2350	0	0	0	680	0.4
Disturbance outage [MWh]	0	0	0	364	0	0	0	0	0	0	0	0	0.0
Unplanned maintenance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Planned maintenance outage [MWh]	0	0	0	64050	0	0	0	0	0	0	0	0	1.2
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Rated capacity 600 MW	446846	403624	445964	432102	446512	432112	446452	446655	432546	447701	432299	446794	100.0

Figure 5.66 presents the annual utilization of Storebaelt according to all the categories of technical capacity (E_{max}) annually for the years 2012–2017. Figure 5.67 presents the trend of the previous values, but with the categories technical capacity not used (E_{TCNU}), transmission (E_T) and unavailable technical capacity (E_U). Figure 5.68 presents the trend of number of disturbance outages, unplanned and planned maintenance and other outages with a 2-year rolling average.

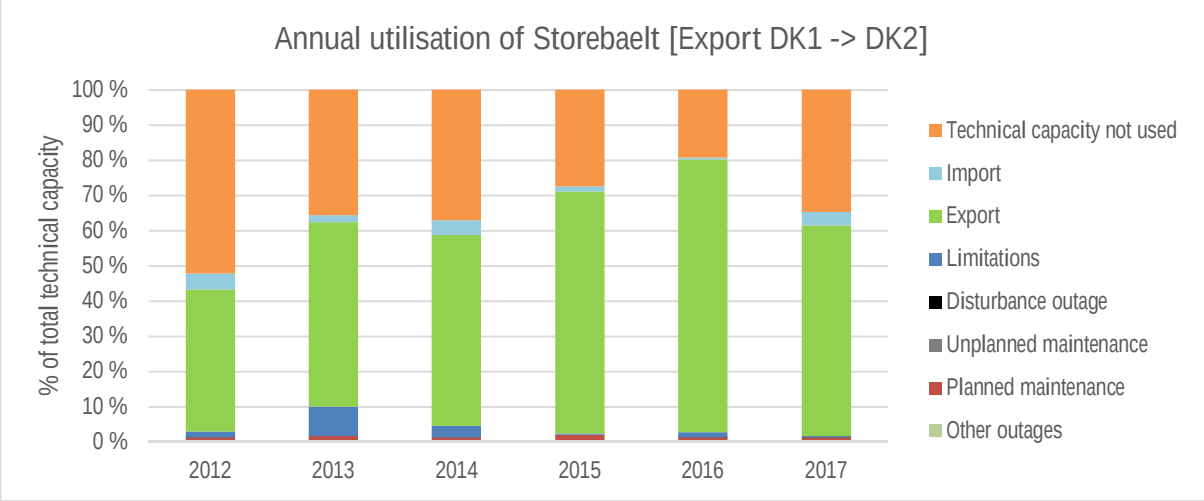

Figure 5.66 Annual utilisation of Storebaelt according to the eight utilisation and unavailability categories for the years 2012–2017.

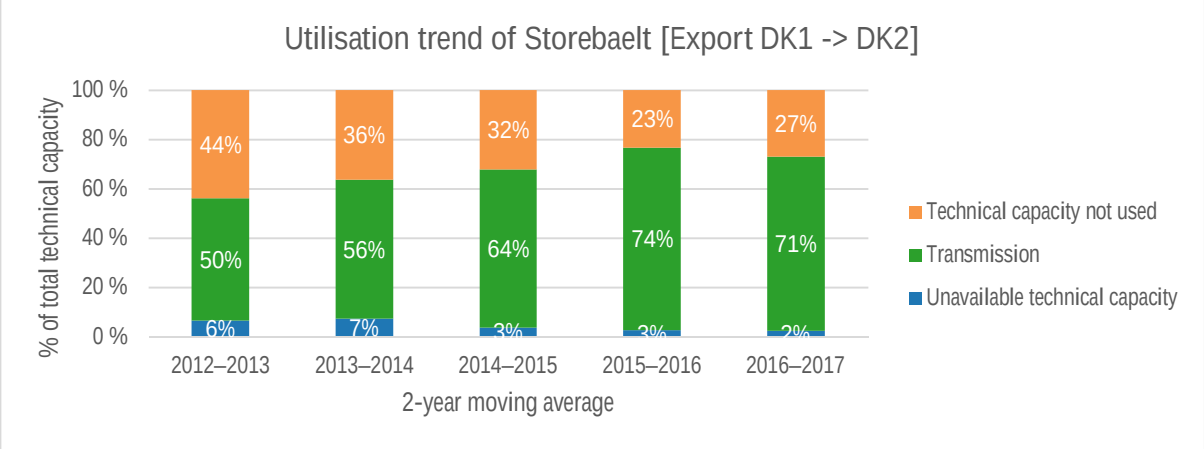

Figure 5.67 Utilisation trend of Storebaelt according to unavailability, transmission and technical capacity not used for the years 2012–2017.

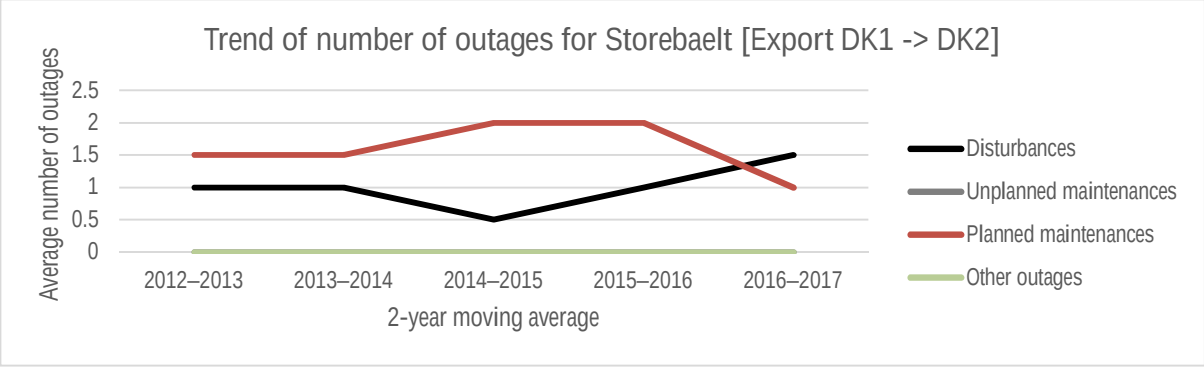

Figure 5.68 2-year moving average trend of number of outage events for Storebaelt for the years 2012–2017.

5.3.17 SwePol

Figure 5.69 presents the availability and utilisation of SwePol for 2017 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 2017, SwePol had an available technical capacity of 94.2 %. The technical capacity not used was 31.9 %. Totally, 3.1 TWh (59.4 % of the technical capacity) was exported from Sweden to Poland and 0.2 TWh (2.9 % of the technical capacity) was imported to Sweden.

The annual maintenance lasted 7 days in September. SwePol had 6 minor disturbances in 2017.

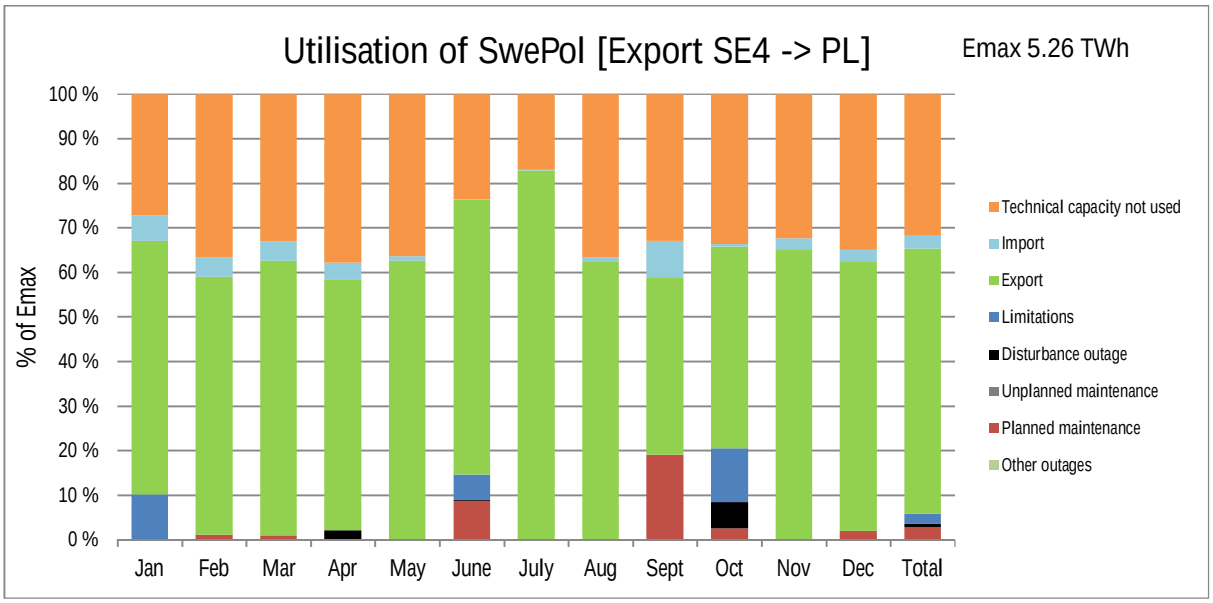

Figure 5.69 Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Swepol in 2017

Table 5.17 Monthly distribution of the technical capacity (E_{MAX}) for SwePol in 2017

SwePol [Export SE4 -> PL]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	586	386	426	356	85	11	21	101	915	48	261	282	0.1
Export losses [MWh]	7303	6634	7926	6885	7978	7353	10653	7783	4708	5291	7912	7733	1.7
Technical capacity not used [MWh]	121494	147781	147857	163766	162895	102157	75941	163887	142417	150683	139979	155973	31.9
Import [MWh]	25694	17507	19199	16458	4079	473	925	4425	36129	2509	10559	12518	2.9
Export [MWh]	254434	233722	274551	243385	279426	267055	369533	278088	171254	202697	281153	269585	59.4
Limitations [MWh]	44779	0	0	0	0	24653	0	0	0	53874	0	0	2.3
Disturbance outage [MWh]	0	0	0	8880	0	810	0	0	0	26600	310	0	0.7
Unplanned maintenance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Planned maintenance outage [MWh]	0	4200	4200	0	0	37800	0	0	82200	10800	0	8400	2.8
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Rated capacity 600 MW	446400	403209	445807	432489	446400	432949	446400	446400	432000	447162	432001	446476	100.0

Figure 5.70 presents the annual utilization of SwePol according to all the categories of technical capacity (E_{max}) annually for the years 2012–2017. Figure 5.71 presents the trend of the previous values, but with the categories technical capacity not used (E_{TCNU}), transmission (E_T) and unavailable technical capacity (E_U). Figure 5.72 presents the trend of number of disturbance outages, unplanned and planned maintenance and other outages with a 2-year rolling average.

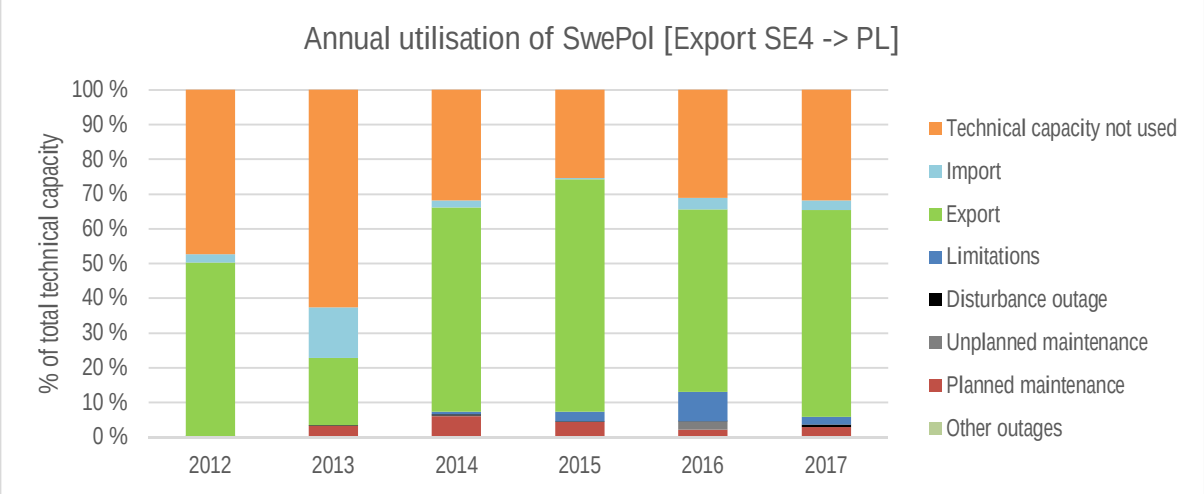

Figure 5.70 Annual utilisation of SwePol according to the eight utilisation and unavailability categories for the years 2012–2017.

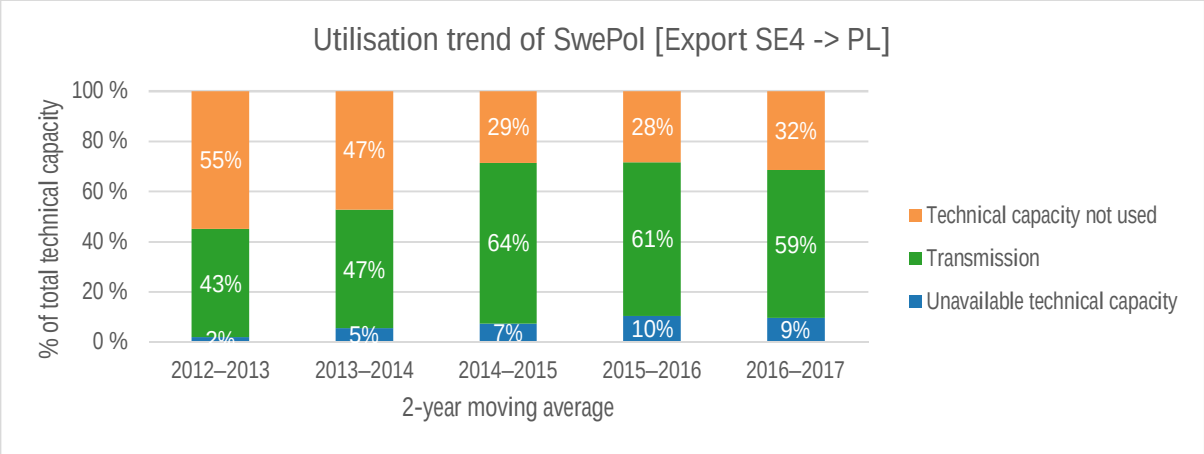

Figure 5.71 Utilisation trend of SwePol according to unavailability, transmission and technical capacity not used for the years 2012–2017.

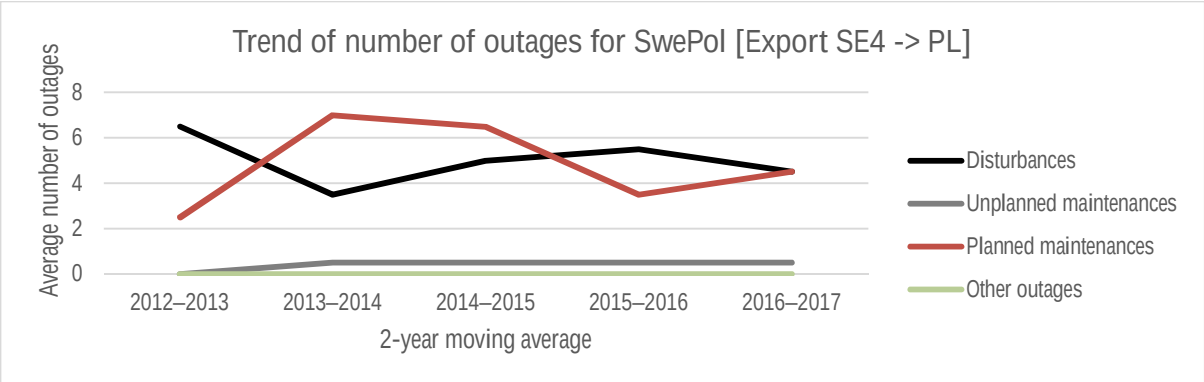

Figure 5.72 2-year moving average trend of number of outage events for SwePol for the years 2012–2017.

5.3.18 Vyborg Link

Figure 5.73 presents the availability and utilisation of the Vyborg Link for 2017 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 2017, the Vyborg Link had an available technical capacity of 97.7 %. The technical capacity not used was 47.9 %. Totally, 5.8 TWh (49.8 % of the technical capacity) was exported from Russia to Finland and none was imported to Russia.

There were 2 minor planned maintenance outages and 1 minor disturbance outage on Vyborg link in 2017. The limitation in July was due to maintenance. Normally, maintenance work causes only limitations because the 350 MW units are not worked on simultaneously.

Measurements from the other side of the Vyborg link is unknown and therefore losses are based on assumptions. Therefore, the table with exact numbers of the monthly distribution of the technical capacity is not shown.

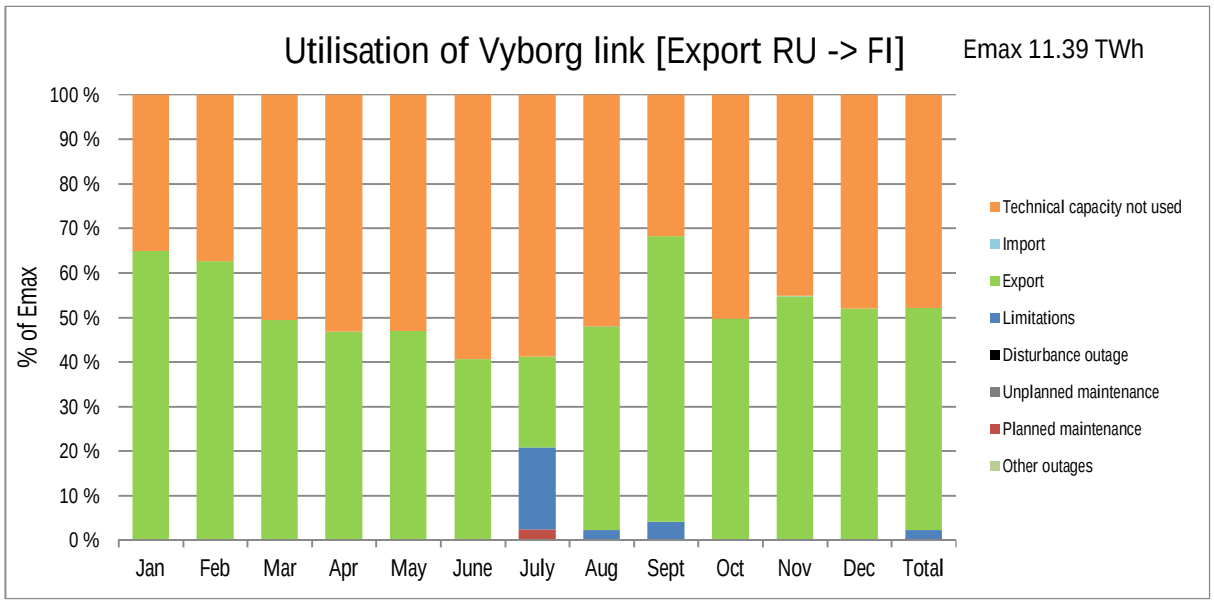

Figure 5.73 Percentage distribution of the availability and utilisation categories defined in Chapter 3 according to month for Vyborg Link in 2017

Figure 5.8 presents the annual utilization of Vyborg Link according to all the categories of technical capacity (E_{max}) annually for the years 2012–2017. Figure 5.9 presents the trend of the previous values, but with the categories technical capacity not used (E_{TCNU}), transmission (E_T) and unavailable technical capacity (E_U). Figure 5.10 presents the trend of number of disturbance outages, unplanned and planned maintenance and other outages with a 2-year rolling average.

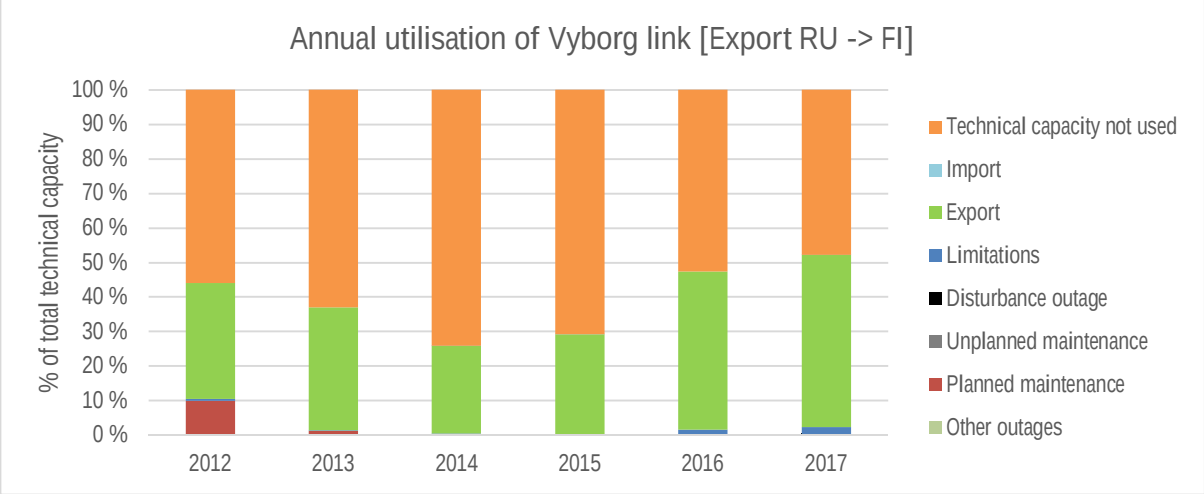

Figure 5.74 Annual utilisation of Vyborg Link according to the eight utilisation and unavailability categories for the years 2012–2017.

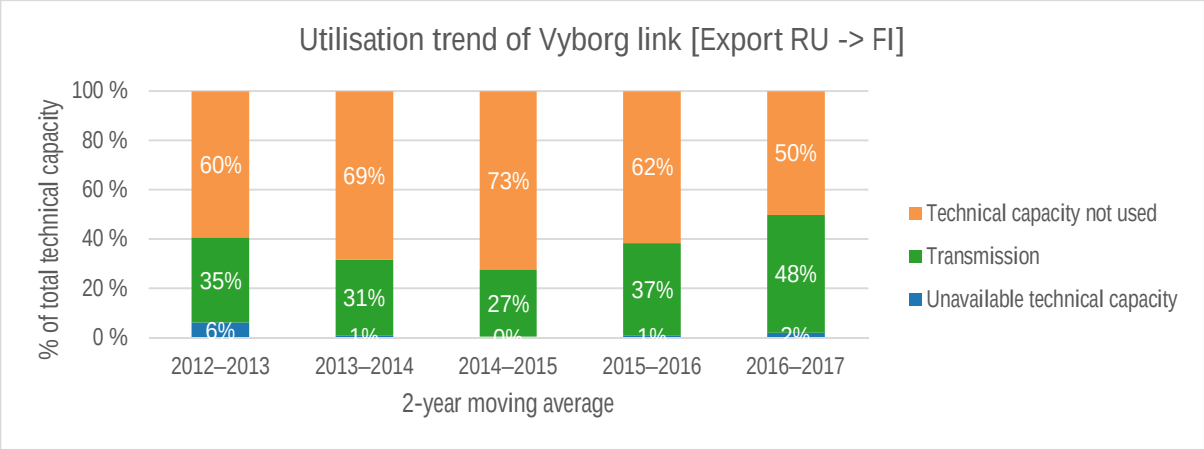

Figure 5.75 Utilisation trend of Vyborg Link according to unavailability, transmission and technical capacity not used for the years 2012–2017.

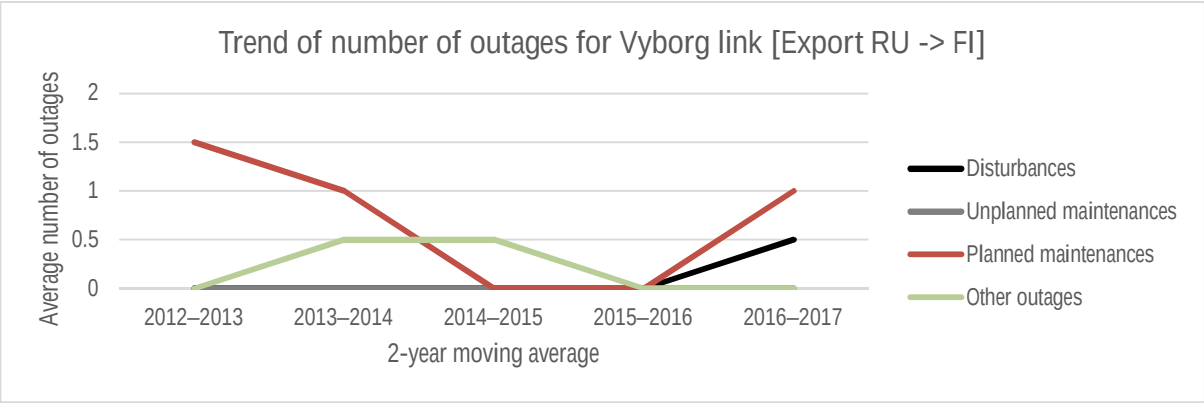

Figure 5.76 2-year moving average trend of number of outage events for Vyborg Link for the years 2012–2017.

6 References

[1] ENTSO-E, "The ENTSO-E Interconnected System Grid Map," [Online]. Available: https://www.entsoe.eu/publications/order-maps-and-publications/electronic-grid-maps/Pages/default.aspx. [Accessed 4 May 2018].

[2] DISTAC, *Guideline for HVDC Utilisation and Unavailability Statistics*, ENTSO-E.

Appendix 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.

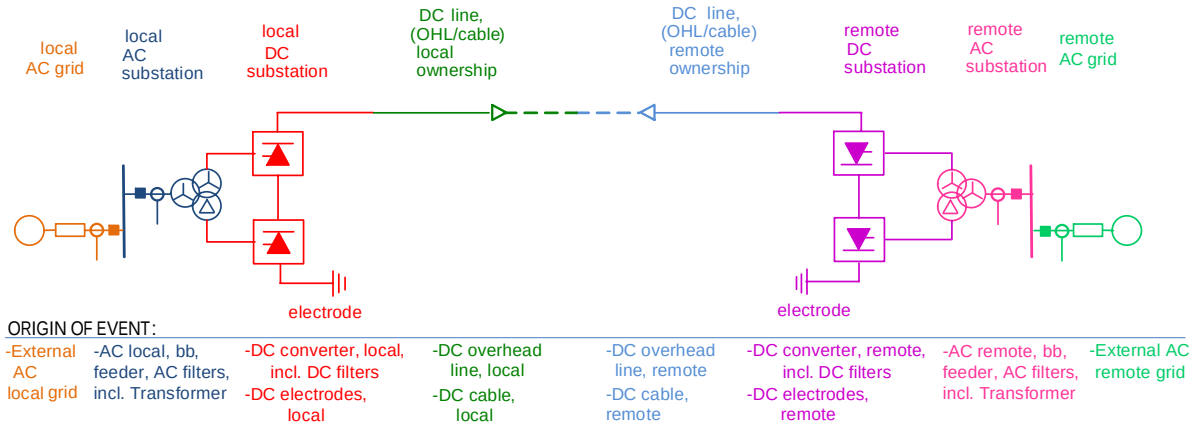

Figure A-1 A schematic presentation of a HVDC link with line commutated converters (LCC)

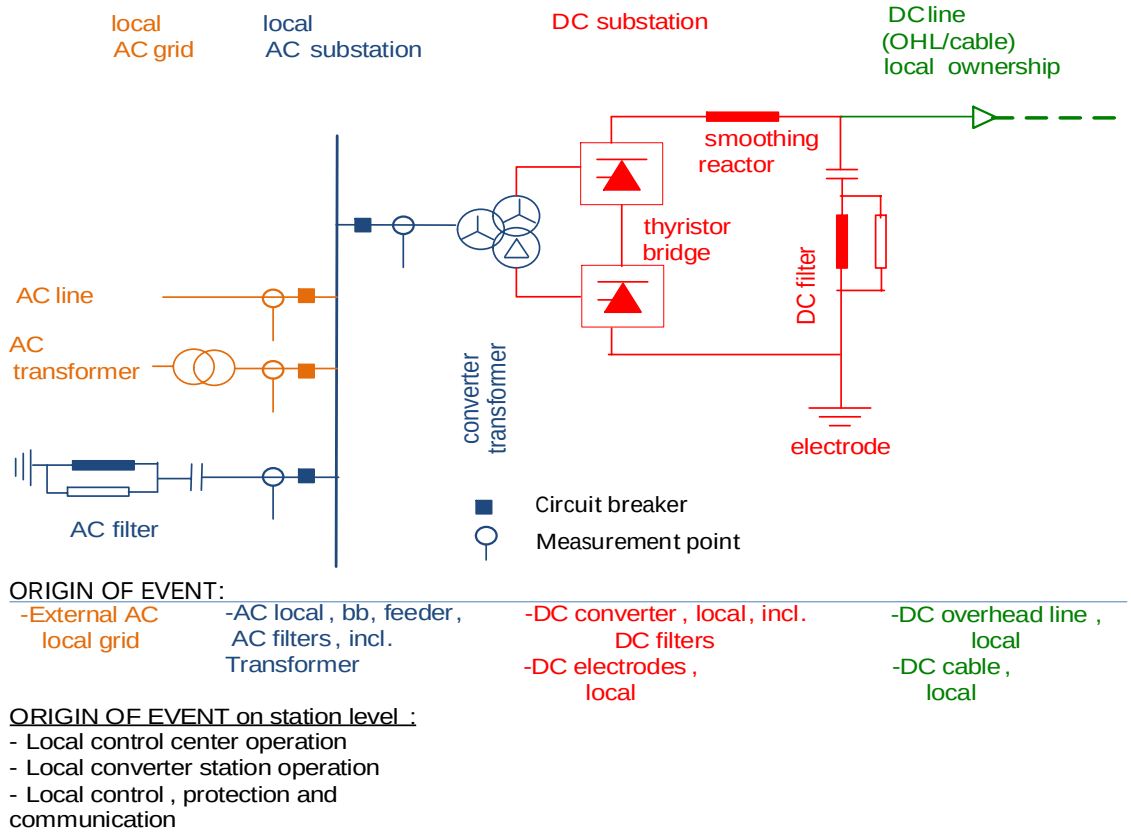

Figure A-2 A converter station of a line commutated converter HVDC link with the connection to the AC grid

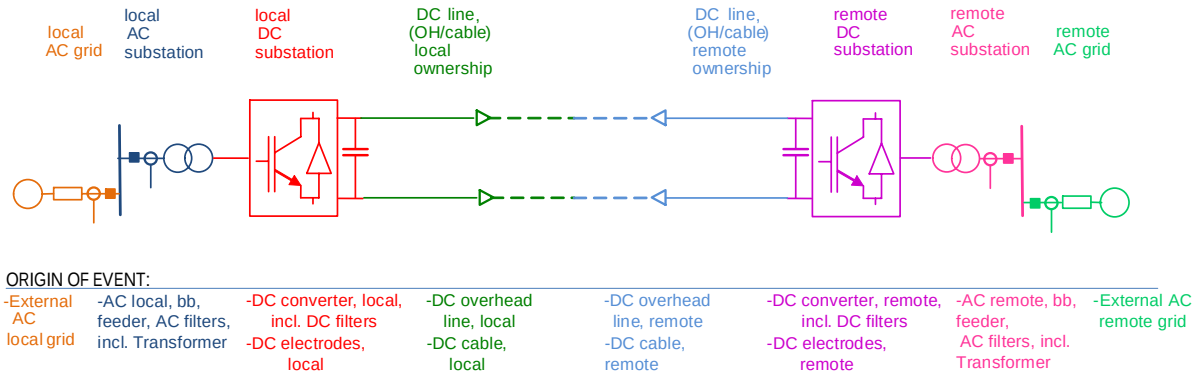

Figure A-3 A schematic presentation of a HVDC link with voltage source converters (VSC)

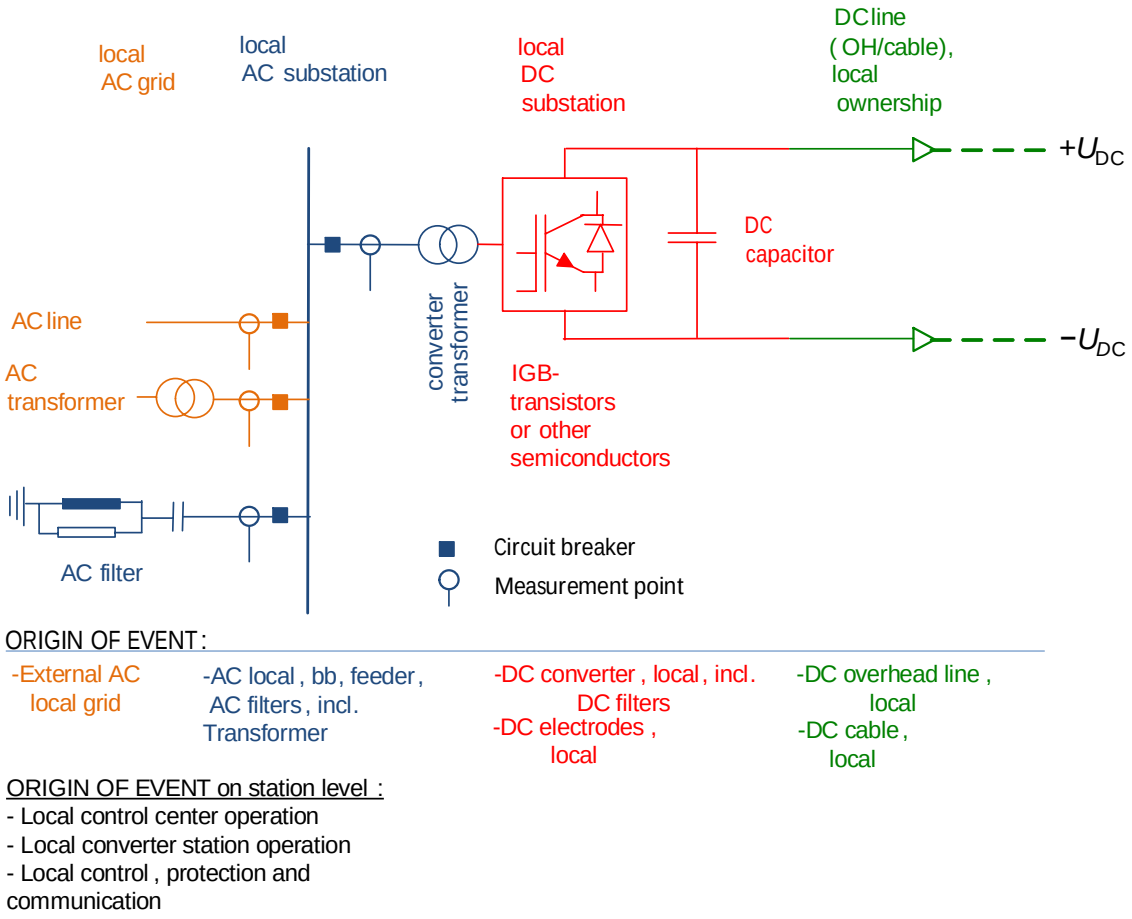

Figure A-4 A converter station of a voltage source converter HVDC link with the connection to the AC grid

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Appendix C Annual overview of all HVDC data with sorted categories

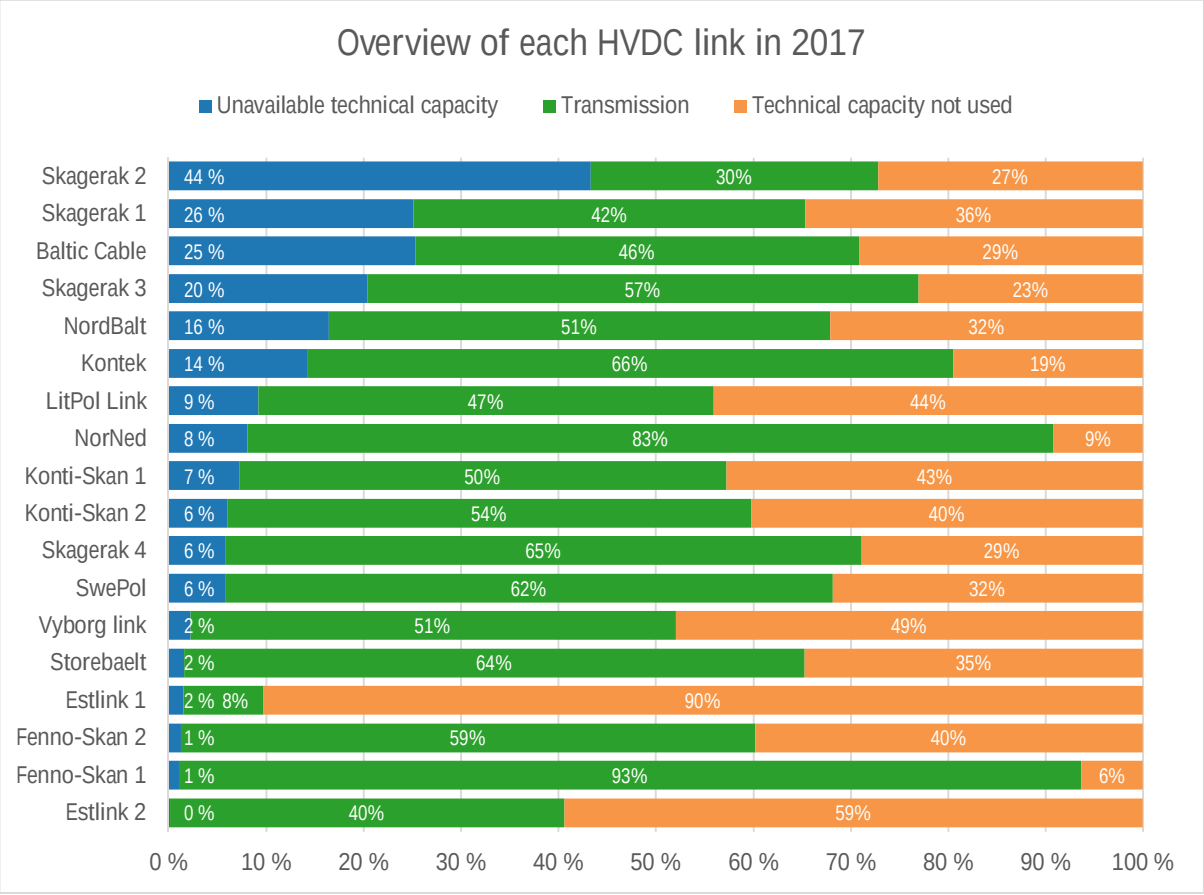

Figure C-1 Annual overview of each HVDC link sorted by descending unavailable technical capacity (E_U) in 2017

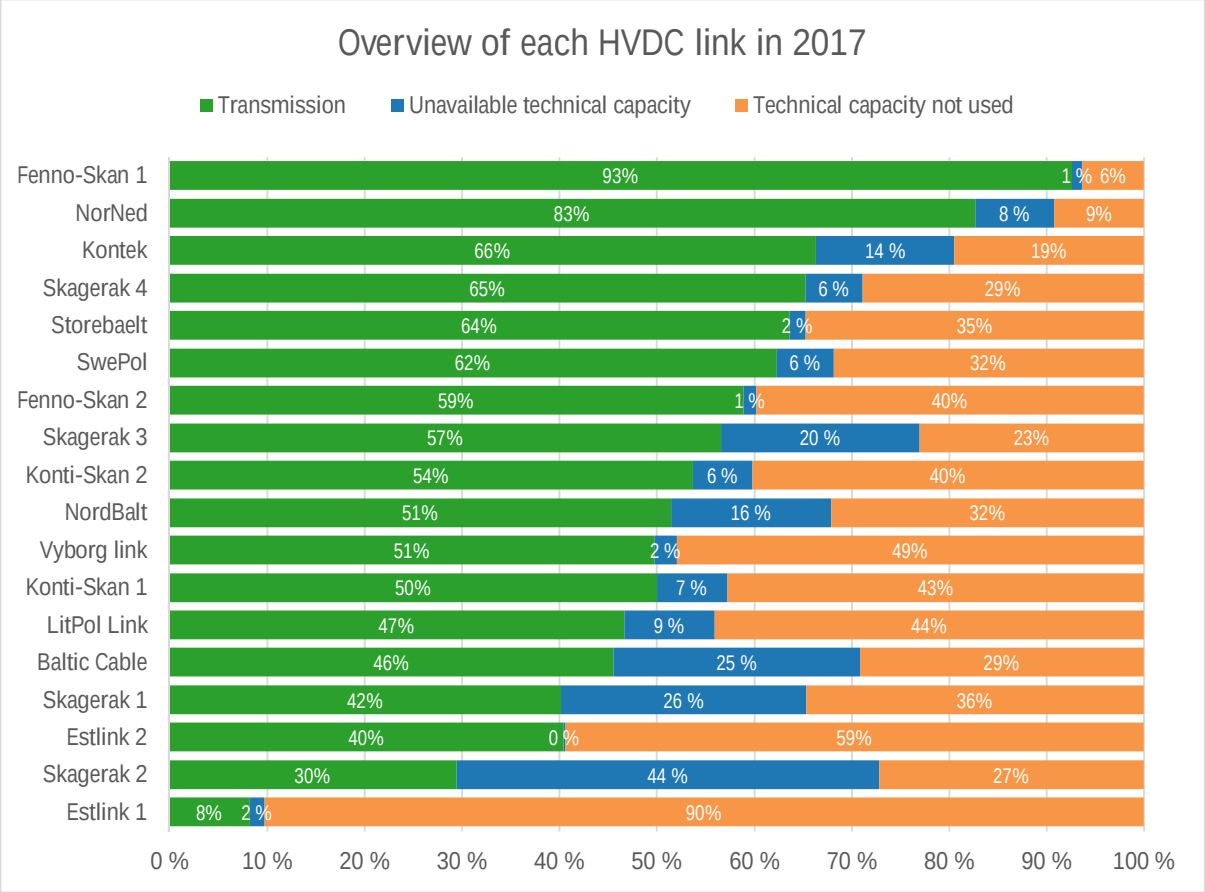

Figure C-2 Annual overview of each HVDC link sorted by descending transmission (E_T) in 2017

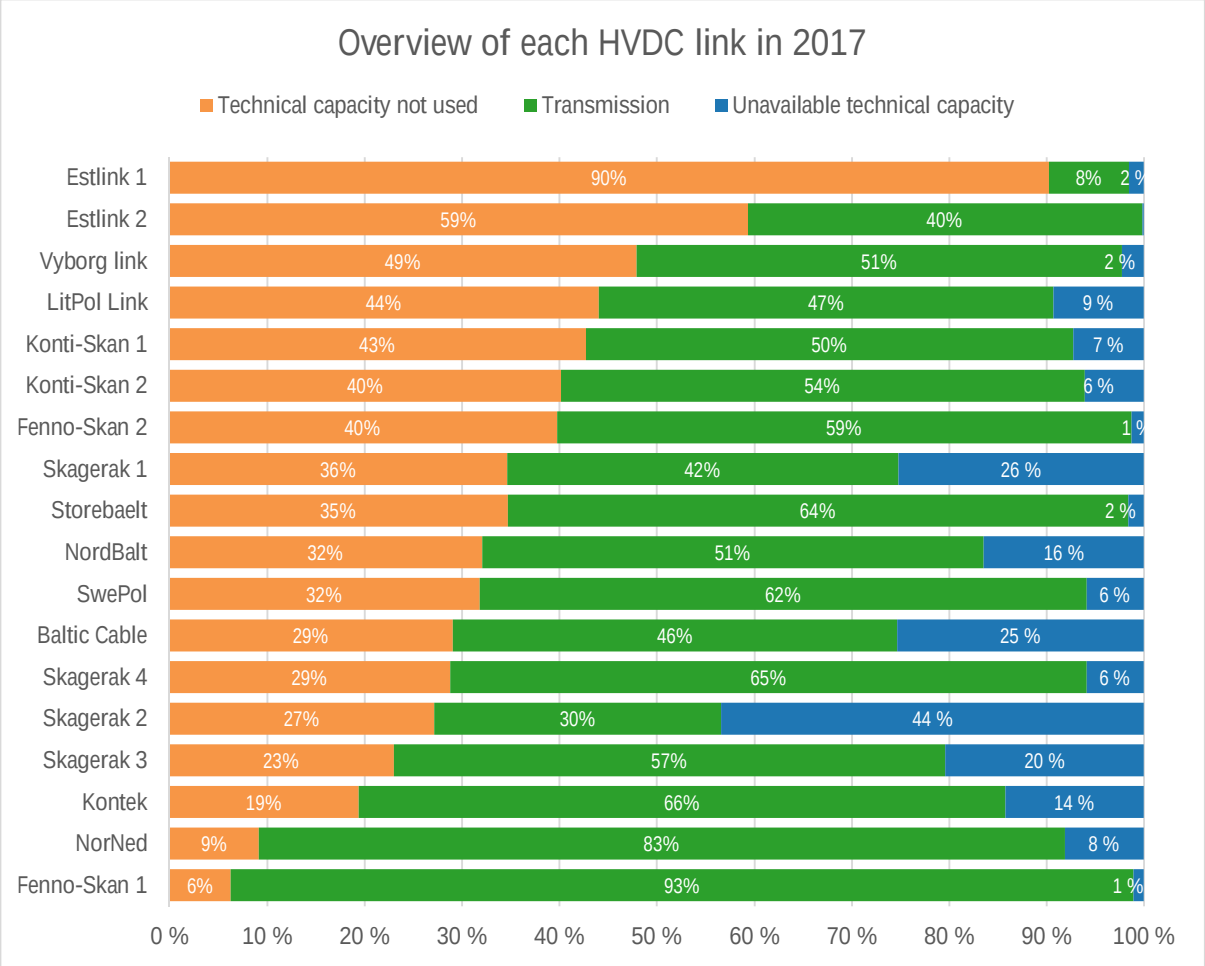

Figure C-3 Annual overview of each HVDC link sorted by descending technical capacity not used (E_{TCNU}) in 2017