European Network of
Transmission System Operators
for Electricity

NORDIC AND BALTIC HVDC UTILISATION AND UNAVAILABILITY STATISTICS 2014

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REGIONAL GROUP NORDIC

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1 SUMMARY

This report presents the availability and utilisation of HVDC links connected to the Nordic power system in 2014, with an emphasis on disturbance outages.

This report presents methods and definitions and statistics for 2014: An overview of availability and utilisation for all links, a closer look on the disturbances and separate presentations of the performance of each HVDC link.

In 2014, 42.6 TWh of electric energy was transmitted through the Nordic HVDC links. 63 disturbance outages were registered, preventing 1.2 TWh of potential energy transmission. Approximately half of the energy transmission lost due to disturbance outages was caused by three disturbances lasting longer than two weeks each with the longest lasting 50 days on Konti-Skan 1. Konti-Skan 1 had a cable fault in November, Konti-Skan 2 had a transformer fault and Estlink 1 had a cooling system leakage.

Maintenance outages caused 2.6 TWh and limitations caused 8.1 TWh of reduced transmission capacity.

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2 INTRODUCTION AND BACKGROUND

The total HVDC power transmission capacity connected to the Nordic power systems is 9220 MW. The majority of this capacity connects the Nordic synchronous system to other systems but Fenno-Skan 1 and Fenno-Skan 2 HVDC links connect Finland and Sweden as Figure 2.1 shows and provide the transmission capacity of 1350 MW.

FIGURE 2.1 PART OF THE NORDIC GRID MAP SHOWING THE HVDC LINKS [1]. THE ARROWS INDICATES THE DIRECTION OF EXPORT USED IN THIS REPORT.

The total annual HVDC transmission capacity is 81 TWh, which makes HVDC links important components for the stable operation of the Nordic power system, and the essential infrastructure for commercial power trade in the European energy markets. Hence, the advantages of keeping HVDC links in operation as much of the time as possible are obvious.

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.

Disturbances do happen, but high quality hardware components, thorough installation routines, and fault analysis combined with preventive maintenance are means to limit the number of such unfortunate events. Planned outages and limitations due to maintenance work are necessary, but

should be planned and conducted as efficient as possible. The result is more available capacity for energy transmission through HVDC links.

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 of interest in itself since this is the action that actually realizes the value through energy trade.

3 SCOPE

The scope of these statistics differs from the scope of the CIGRÉ HVDC statistics, which concentrate on the outages, faults and disturbances of the HVDC links, including the converter stations.

The main interest of this HVDC statistics is a macro view on the *availability* and *utilisation* of the HVDC links, including total outages and limitations. Disturbance outages are more thoroughly examined than other events.

The macro view of these statistics includes only links that were commissioned before the statistical year in question or were available for the electricity market the whole year.

3.1 CONTACT PERSONS

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

4 METHODS, DEFINITIONS AND CALCULATIONS

This chapter explains the availability and utilisation categories of the HVDC statistics. Interesting details in the collected data will be emphasized.

The utilisation of HVDC link capacities can be calculated by using the data received from SCADA, grid operation, market departments, Urgent Market Messages (UMMs) of the Nord Pool Spot and measurements on each side of a link.

The process of collecting and sorting data for these statistics will be described in the guidelines of this report. This chapter describes how the collected data is defined and used in the calculations.

The technical capacity (E_{max}) of the HVDC link is the maximum energy that can be transmitted from the AC grid to the converter station on the exporting side, including all HVDC link losses, if there are no outages or limitations, the technical capacity is calculated:

$$E_{\max} = P_{\mathrm{R}} \cdot 24 \cdot d, \tag{4.1}$$

where P_R is the rated power capacity and d is the number of days in the reported time period (month or year). The column in Figure 4.1 describes the nine main categories of these statistics, as well as aggregated categories used for simplified presentations.

In Figure 4.1, technical capacity (E_{max}) is represented as the total height of the column. This section explains the mutual exclusivity and mathematical consistence of all categories used in the HVDC statistics.

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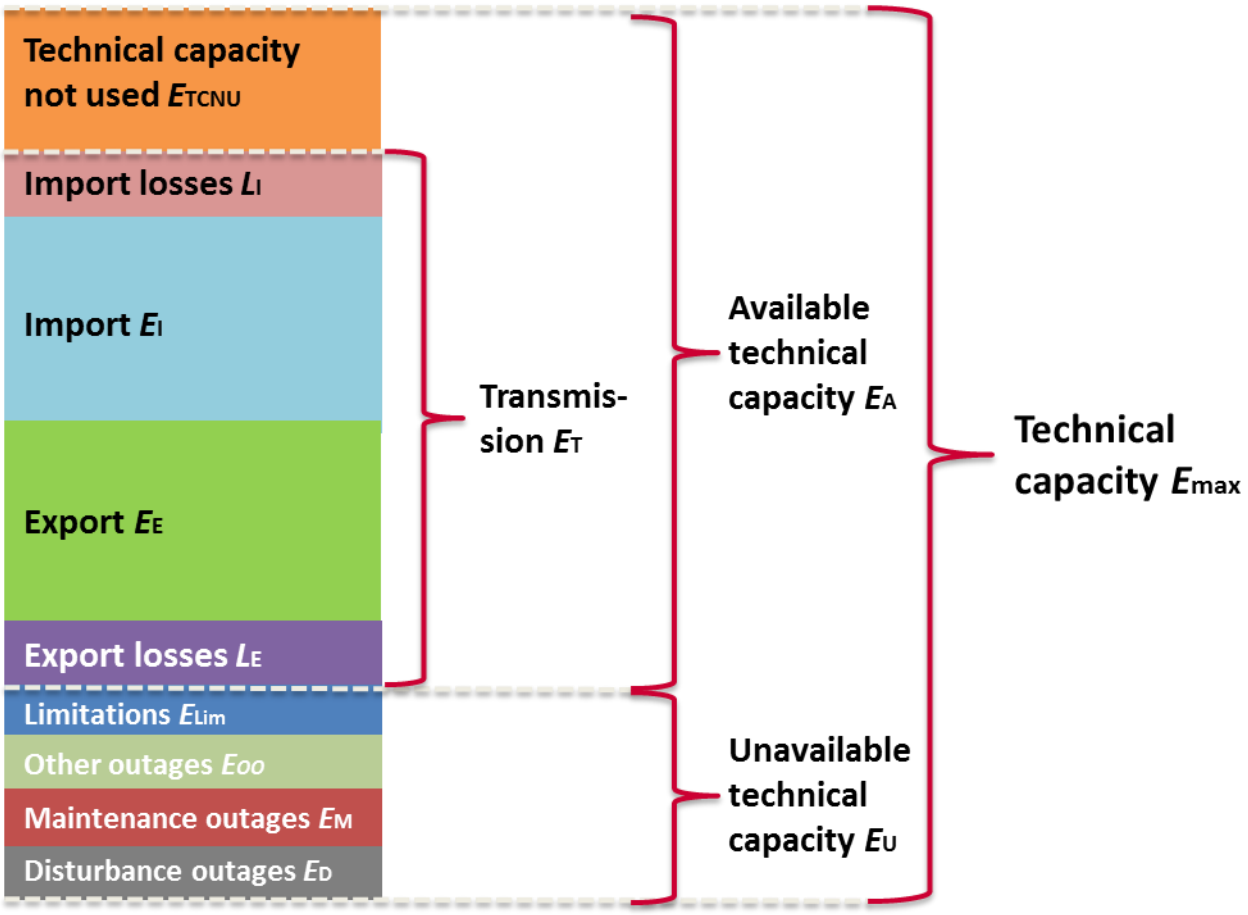

FIGURE 4.1 THE AVAILABILITY AND UTILISATION CATEGORIES USED IN THE HVDC STATISTICS. THE DEFINITIONS AND CALCULATIONS ARE EXPLAINED IN CHAPTER 4. EVERY VALUE IS AN ENERGY VALUE AND REPRESENTS A PART OF THE AVAILABLE OR UNAVAILABLE TECHNICAL CAPACITY. THE NINE CATEGORIES OF THE COLUMN TO THE LEFT ARE INTERNALLY EXCLUSIVE AND THEIR SUM AMOUNTS TO THE TOTAL TECHNICAL CAPACITY.

The technical capacity of the link is a theoretical value and can be divided into **available technical capacity (E_A) and unavailable technical capacity (E_U)**. The unavailable technical capacity E_U is due to outages or limitations.

An **outage** is *any* state when a component is disconnected from the system and the transfer capacity is reduced to zero. There are different types of outages:

- **Disturbance outages (E_D)** are *total outages* 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.
- **Maintenance outages (E_M)** are *total outages* due to all technically motivated actions on the HVDC link or in the AC grid intended to retain an entity in, or restore it to, a state where it can perform its required function.
- **Other outages (E_{OO})** are *total outages* 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.

The energy transfer made unavailable due to disturbance, maintenance and other outages are calculated by multiplying the **rated power (P_R)** by the **disturbance outage duration (h_D)**, **maintenance outage duration (h_M)**, and **other outage duration (h_{OO})** in the following way:

$$E_{\mathrm{D}} = P_{\mathrm{R}} \cdot h_{\mathrm{D}}, \tag{4.2}$$

$$E_{\mathrm{M}} = P_{\mathrm{R}} \cdot h_{\mathrm{M}}, \tag{4.3}$$

$$E_{\mathrm{OO}} = P_{\mathrm{R}} \cdot h_{\mathrm{OO}}. \tag{4.4}$$

A limitation (E_{Lim}) is a condition when the transmission capacity of an HVDC link is limited, i.e. 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 as long as they 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;[1]
- link capacity reserved as power reserves.

Limitations lasting less than ten minutes should not be reported. In the scope of this statistics report, these limitations are too small to have an actual significance on the presented data. Hence, short ramping limitations and commutation failures are not cases included in this category.

Limitations are calculated by multiplying the **limited power capacity (P_{Lim})** by the **duration of the limitation in hours (h_{Lim})**:

$$E_{\mathrm{Lim}} = P_{\mathrm{Lim}} \cdot h_{\mathrm{Lim}}. \tag{4.5}$$

Now it is possible to define the mathematical description of the unavailable technical capacity (E_{U}) as the part of technical capacity that is *not* available for transmission due to outages (disturbance, maintenance, other) and limitations:

$$E_{\mathrm{U}} = E_{\mathrm{D}} + E_{\mathrm{M}} + E_{\mathrm{OO}} + E_{\mathrm{Lim}} = P_{\mathrm{R}}(h_{\mathrm{D}} + h_{\mathrm{M}} + h_{\mathrm{OO}}) + P_{\mathrm{Lim}} \cdot h_{\mathrm{Lim}}. \tag{4.6}$$

The counterpart to unavailable technical capacity (E_{U}) is the available technical capacity (E_{A}), which consists of the remaining of the technical capacity (E_{max}). The available technical capacity equals **the capacity used for transmission (E_{T})** and **technical capacity not used E_{TCNU}**.

$$E_{\mathrm{A}} = E_{\mathrm{max}} - E_{\mathrm{U}} = E_{\mathrm{T}} + E_{\mathrm{TCNU}}. \tag{4.7}$$

The capacity used for transmission (E_{T}) is the sum of exported and imported energy including losses:

[1] The transmission capacity of some links is limited during the summer season due to a decreased convection of heat from transmission losses. The full capacity is as rated by the manufacturer, and is given for all links in Table 5.1.

$$E_{\mathrm{T}} = E_{\mathrm{E}} + L_{\mathrm{E}} + E_{\mathrm{I}} + L_{\mathrm{I}}, \tag{4.8}$$

where **Imported energy (E_{I})** is the energy transferred from the HVDC link to the importing AC side. It does not include **import losses (L_{I})**, i.e. the energy losses in any of the HVDC link components during import. **The exported energy (E_{E})** and **export losses (L_{E})** are explained likewise, with an opposite point of view. Exported energy E_{E} from one side of the link equals imported energy E_{I} considered from the opposite side of the link.

Technical capacity not used (E_{TCNU}) can now be calculated:

$$\begin{aligned} E_{\mathrm{TCNU}} &= E_{\max} - E_{\mathrm{U}} - E_{\mathrm{T}} \\ &= E_{\max} - [P_{\mathrm{R}}(h_{\mathrm{D}} + h_{\mathrm{M}} + h_{\mathrm{OO}}) + P_{\mathrm{Lim}} \cdot h_{\mathrm{Lim}}] - [E_{\mathrm{E}} + L_{\mathrm{E}} + E_{\mathrm{I}} + L_{\mathrm{I}}]. \end{aligned} \tag{4.9}$$

Technical capacity not used (E_{TCNU}) is what remains when all other categories are mapped and calculated. The content of this category is complex and consists of both technical and market related details. The most important of these are:

- When bidding differences between the markets on each side of the HVDC link are too small to promote transmission, in spite of technical availability. The link is still available and can be used for balancing or transmitting emergency power, and hence not disconnected.
- Any limitations lasting less than ten minutes (does not include total outages):
  - Ramping time: When the power flow is changed the capacity is fully released to the market. Note that, depending on the type of converter technology, the nominal voltage, and hence the full transmission capacity, may not be obtained immediately.
  - Commutation failures may interrupt the power transmission. In the CIGRÉ statistics, commutation failures are categorized as 'transient disturbances'.
  - Emergency power is not usually used for more than ten minutes for a given event. Longer lasting disturbances will be registered as outages or limitations.

5 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.

TABLE 5.1 MAIN PROPERTIES OF THE HVDC LINKS

Name of the link	Commissioning year	Market connection (Y/N)	Type of HVDC converter	Rated power, monopolar (MW)	Parallel monopolar capacity (MW)	Bipolar capacity (MW)	Defined export direction (N–S, E–W)
Baltic Cable	1994	Y	LCC	600			N–S
Estlink 1	2006	Y	VSC	350	1000		N–S
Estlink 2	2014	Y	LCC	650			N–S
Fenno-Skan 1	1989	Y	LCC	550	1350	1350	E–W
Fenno-Skan 2	2011	Y	LCC	800			E–W
Kontek	1986	Y	LCC	600			N–S
Konti-Skan 1	2008	Y	LCC	370	740		E–W
Konti-Skan 2	1988	Y	LCC	370			E–W
NorNed	2008	Y	LCC	730			N–S
Skagerrak 1	1976–1977	Y	LCC	250	1000	1000	N–S
Skagerrak 2		Y	LCC	250			N–S
Skagerrak 3	1993	Y	LCC	500			N–S
Skagerrak 4	2014	Y	VSC	700			N–S
Storebaelt	2010	Y	LCC	600			E–W
SwePol	2000	Y	LCC	600			N–S
Vyborg Link	1981, 1982, 1984, 2000		LCC	1400			E–W

TABLE 5.2 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	
NorNed	580	580			
Skagerrak 1	212.5	133.6		78.5	
Skagerrak 2	211.4	132.9		78.5	
Skagerrak 3	212.9	134.4		78.5	
Skagerrak 4	226	226			
Storebaelt	57		57		
SwePol	254	254			
Vyborg Link	< 1				< 1

6 PRESENTATION OF THE RESULTS FOR 2014

6.1 INTRODUCTION

During 2014 there were 63 disturbance outages affecting the HVDC links connected to the Nordic power system. The disturbances caused a capacity reduction that corresponds to 1.2 TWh (1.5 %) of the total technical HVDC transmission capacity.

Maintenance outages amounted to 2.6 TWh (3.2 %), and limitations reduced the transmission capacity by 8.1 TWh (9.8 %) of the total technical HVDC transmission capacity.

Section 6.2 provides an overview of the HVDC links and Section 6.3 presents the availability and utilisation of each HVDC link. The unavailable technical capacity (E_U) due to disturbance outages, the origins that triggered the events, and the performance of all the HVDC links connected to the Nordic power system in 2014 are presented and explained.

6.2 OVERVIEW

Figure 6.2.1 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 6.2.1 but ranked according to the highest unavailable technical capacity, according to the highest transmission, and according to the highest technical capacity not used.

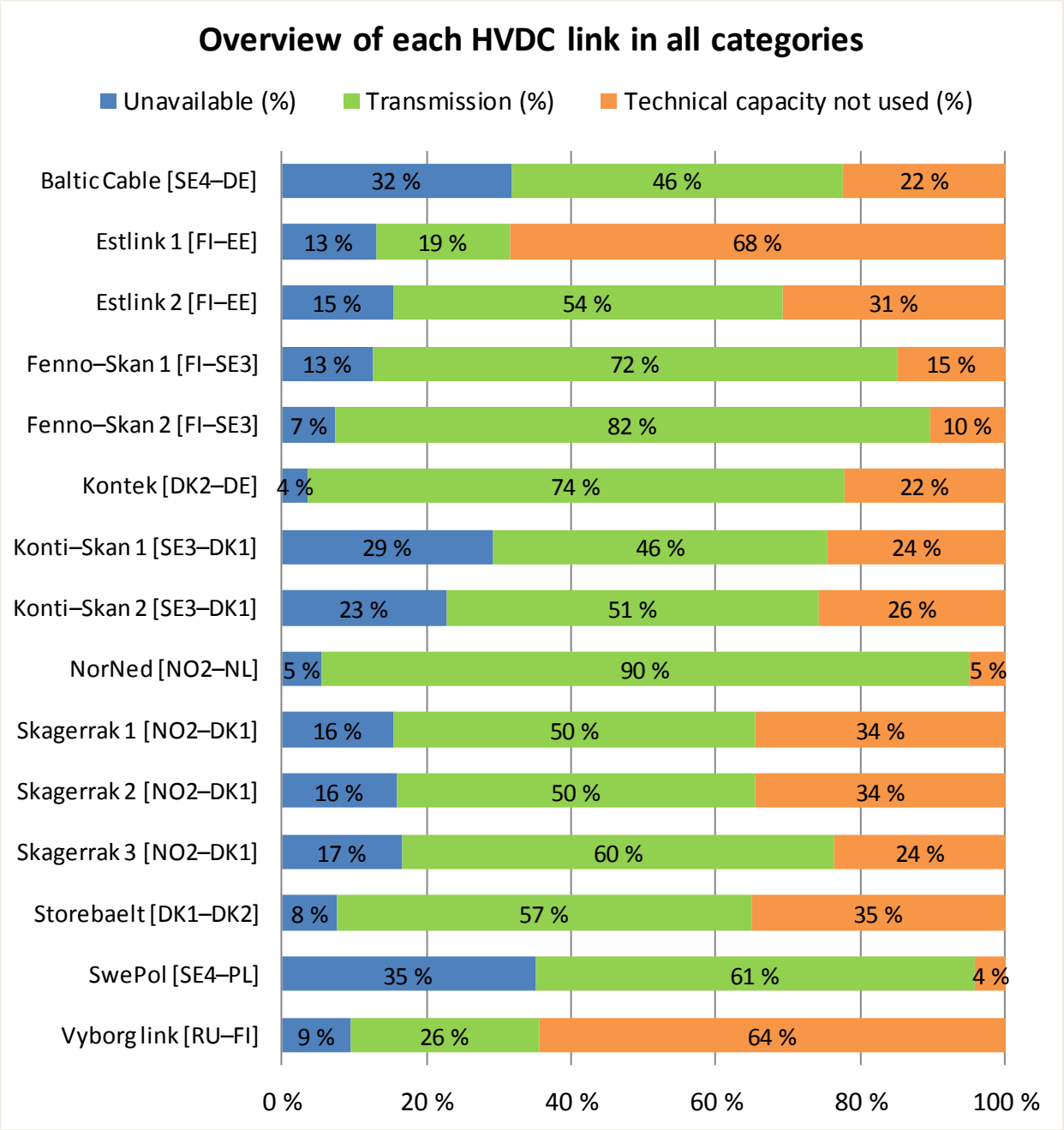

FIGURE 6.2.1 ANNUAL OVERVIEW OF THE AVAILABILITY AND UTILISATION OF EACH HVDC LINK IN 2014. THE CATEGORIES USED REFER TO THE METHODS, DEFINITIONS AND CALCULATIONS DEFINED IN CHAPTER.

Figure 6.2.2 presents the percentage unavailable technical capacity (E_U) of the annual technical capacity E_{max} due to the disturbance outages. The comments are added below the figure.

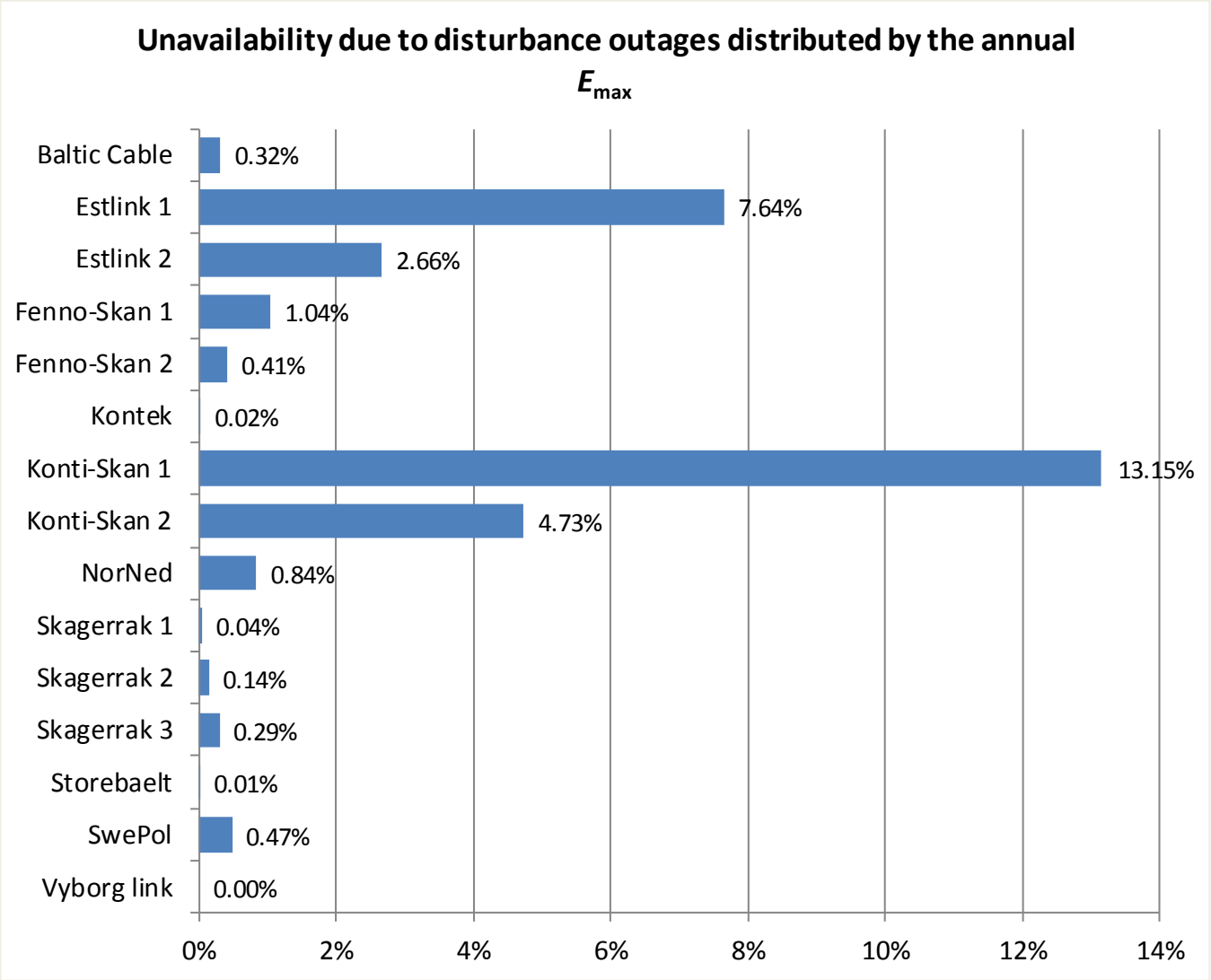

FIGURE 6.2.2 PERCENTAGE DISTRIBUTION OF UNAVAILABLE TECHNICAL CAPACITY E_U DUE TO DISTURBANCE OUTAGES FOR EACH LINK IN 2014

1) On 11 November 2014, Konti-Skan 1 had a transformer fault. The outage caused by the fault lasted to the end of the year. This transformer fault was the main cause for unavailability.
2) Estlink 1 had a cooling system leakage on 9 October, which caused an outage that lasted 15 days.

Figure 6.2.3 presents the number of all outages and limitations for each link.

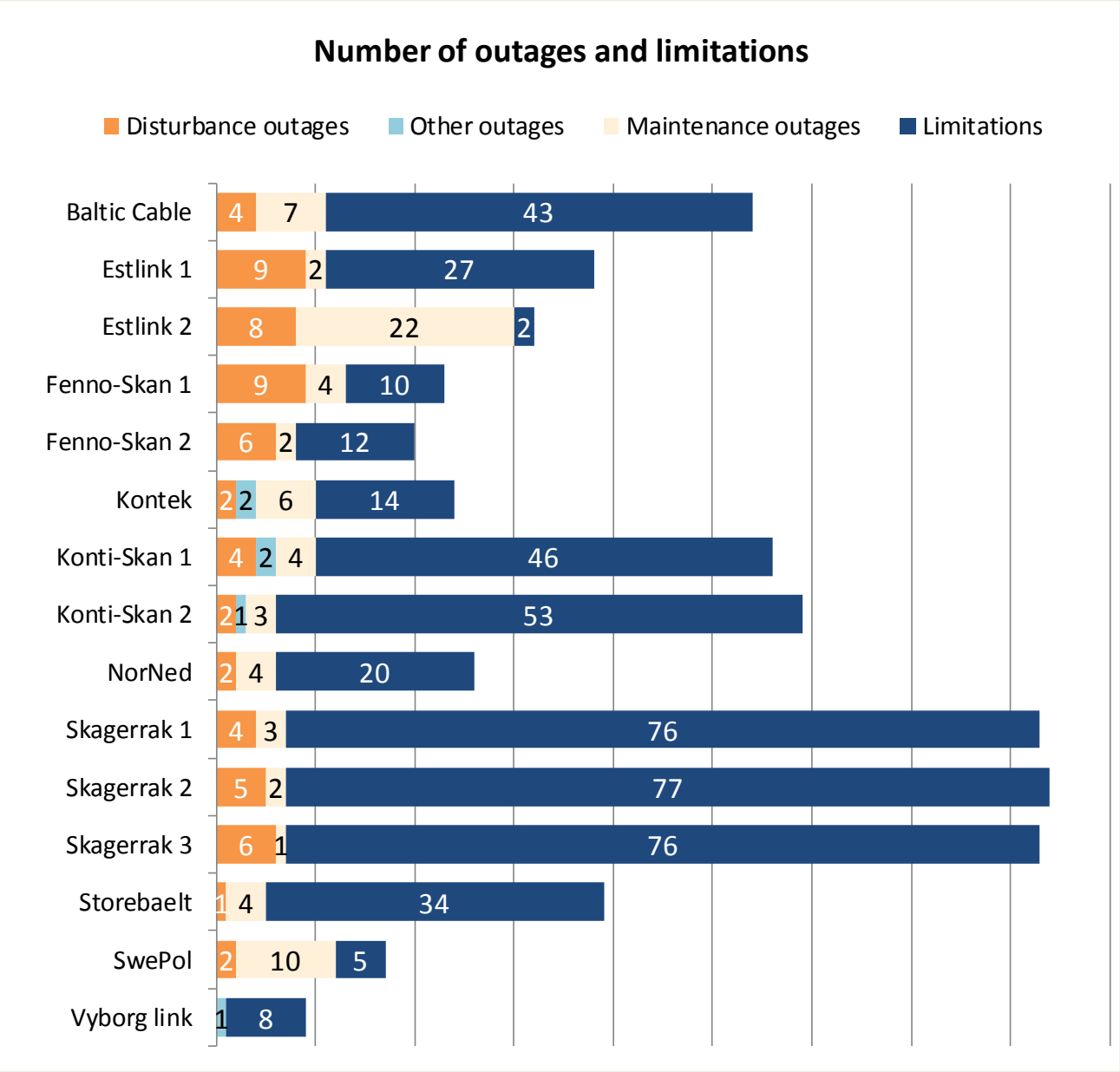

FIGURE 6.2.3 THE NUMBER OF OUTAGES AND LIMITATIONS FOR EACH LINK IN 2014

For SwePol link caution should be taken when looking at the number of limitations and comparing that with the actual limitation on the link in section 6.3.15. There are actually a lot of limitations, but they are varying each hour. Because of that Sweden cannot calculate an exact number of limitations. Sweden can only show accurate values for limitations in section 6.3.15.

6.3 INDIVIDUAL PRESENTATIONS OF ALL 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 4.

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'.

6.3.1 BALTIC CABLE

Figure 6.3.1 presents the availability and utilisation of Baltic Cable for 2014. 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.

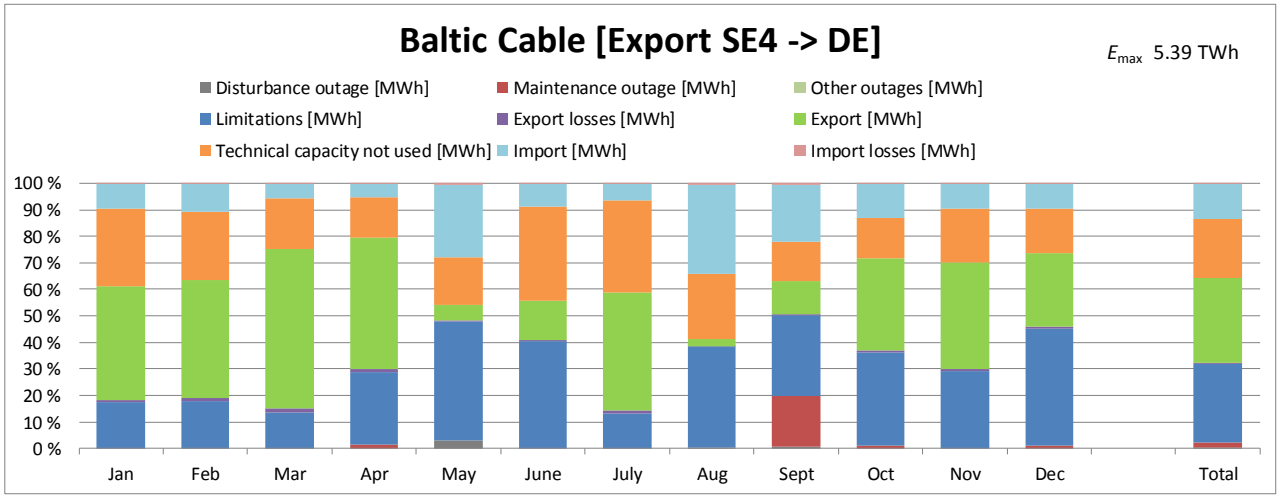

FIGURE 6.3.1 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR THE BALTIC CABLE IN 2014

Baltic Cable had an available technical capacity of 68 %. The technical capacity not used was 22 %. Totally, 1.8 TWh (32 % of the technical capacity) was exported from Sweden to Denmark and 0.7 TWh (13 % of the technical capacity) was imported to Sweden. Table 6.3.1 presents the numerical values behind Figure 6.3.1.

The annual maintenance outages lasted for five days in September. The large amount of limitation affecting the link was caused mostly by maintenance in the German AC grid. The limitations were caused mostly by maintenance.

TABLE 6.3.1 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR THE BALTIC CABLE IN 2014

Baltic Cable [SE4 -> DE]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Disturbance outage [MWh]	0	0	0	0	13970	0	0	1200	2410	0	0	0	0.3
Maintenance outage [MWh]	0	0	0	6000	0	0	0	0	86700	5790	0	5100	1.9
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Limitations [MWh]	80077	74315	63999	121869	214318	179914	60479	175470	135644	177241	138452	223093	29.6
Export losses [MWh]	4625	4406	6865	4877	571	1515	4795	310	1359	4590	4338	3035	0.7
Export [MWh]	196108	185425	285670	221014	27550	65109	205405	11702	56021	175496	191062	140217	31.6
Technical capacity not used [MWh]	134171	108601	91497	68017	86653	158195	159905	113096	64978	75853	96526	85443	22.3
Import [MWh]	44125	43505	25570	23528	129140	38578	28506	153306	96439	65042	43924	47160	13.3
Import losses [MWh]	909	852	556	498	2968	782	637	2991	2230	1354	909	955	0.3
P_r (600 MW)	460016	417103	474157	445803	475169	444092	459728	458075	445780	505366	475211	505003	100.0

6.3.2 ESTLINK 1

Figure 6.3.2 presents the availability and utilisation of Estlink 1 for 2014. 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.

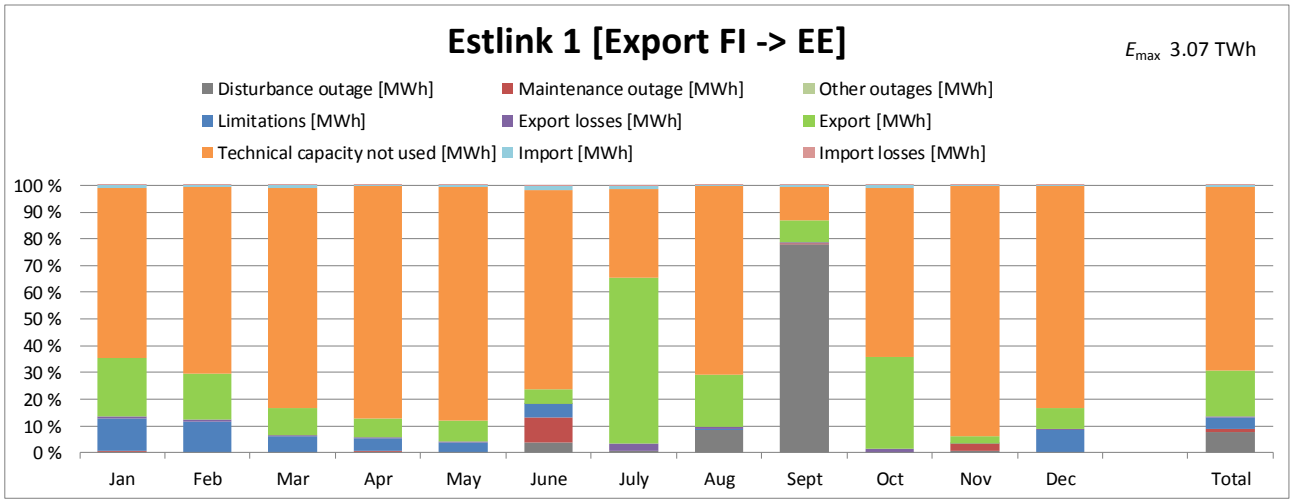

FIGURE 6.3.2 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR ESTLINK 1 IN 2014

In 2014, Estlink 1 had an available technical capacity of 87 %. The technical capacity not used was 69 %. Totally, 524 GWh (17 % of the technical capacity) was exported from Finland to Estonia and 21 GWh (0.7 % of the technical capacity) was imported to Finland. Table 6.3.2 presents the numerical values behind Figure 6.3.2.

There were 9 disturbance outages on Estlink 1, of which the longest lasted two weeks in September and was primarily caused by a cooling system leakage in Harku, Estonia. This led in turn to IGB transistor faults and finally the link tripped. The Finland–Estonia connection (Estlink 1 and Estlink 2 together) was limited towards Estonia to 860 MW from January to July. Most of this limitation caused limited flow on Estlink 1. There were also some limitations to Finland due to maintenance works in Estonia on the 330 kV network in spring.

A maintenance outage lasted one day in November on the Estonian side and the annual maintenance took place in 10–12 June.

TABLE 6.3.2 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR ESTLINK 1 IN 2014

Estlink 1 [FI -> EE]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Disturbance outage [MWh]	1307	0	0	846	0	9444	1644	22546	196362	0	2193	0	7.6
Maintenance outage [MWh]	443	0	0	586	0	24208	0	0	1254	0	6399	0	1.1
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Limitations [MWh]	31330	26950	15866	12434	10406	12024	0	126	0	156	0	22078	4.3
Export losses [MWh]	2493	1813	1171	770	876	606	7135	2253	889	3940	288	908	0.8
Export [MWh]	56407	41020	26493	17418	19814	13718	161431	50964	20120	89145	6511	20540	17.1
Technical capacity not used [MWh]	166227	164170	214735	219127	227313	187750	86610	184132	31561	164922	235782	216354	68.5
Import [MWh]	2100	1194	2045	784	1907	4070	3428	363	1737	2142	792	498	0.7
Import losses [MWh]	93	53	90	35	84	180	152	16	77	95	35	22	0.0
P_r (350 MW)	260400	235200	260400	252000	260400	252000	260400	260400	252000	260400	252000	260400	100.0

6.3.3 ESTLINK 2

Figure 6.3.2 presents the availability and utilisation of Estlink 2 for 2014. Estlink 2 was commissioned in Feb 2014 but was available for the market during the test period 6 dec 2013 – 6 Feb 2014. During this period the link was already available for the electricity markets. Estlink 2 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.

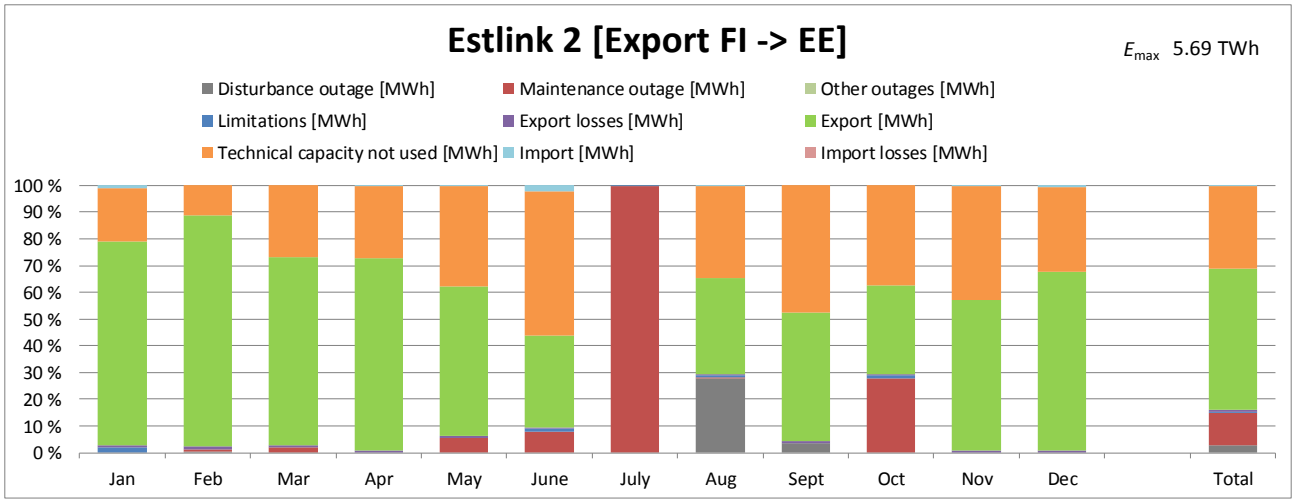

FIGURE 6.3.3 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR ESTLINK 2 IN 2014

In 2014, Estlink 2 had an available technical capacity of 86 %. The technical capacity not used was 31 %. Totally, 3.0 TWh (53 % of the technical capacity) was exported from Finland to Estonia and 25 GWh (0.4 % of the technical capacity) was imported to Finland. Table 6.3.3 presents the numerical values behind Figure 6.3.3.

There were 4 disturbance outages on Estlink 2. Two of them, one in August and one in September, were more severe. Both faults were in a joint on a metallic return cable close to Püssi substation, but different earth cables and caused 212 GWh of lost transmission.

Estlink 2 had several short maintenance outages in Anttila substation and one long maintenance outage, lasting whole July, to complete the marine cable jetting operations close to the Estonian shore.

TABLE 6.3.3 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR ESTLINK 2 IN 2014

Estlink 2 [FI -> EE]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Disturbance outage [MWh]	0	1126	0	0	0	0	0	134009	16450	0	0	0	2.7
Maintenance outage [MWh]	0	4796	9870	0	26978	36848	481785	2855	0	134890	0	0	12.3
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Limitations [MWh]	9400	0	0	0	0	4620	1580	2528	0	4572	0	0	0.4
Export losses [MWh]	4456	4558	4110	4060	3271	1955	3	2112	2653	1957	3201	3917	0.6
Export [MWh]	368275	376707	339651	335567	270360	161561	232	174554	219296	161765	264508	323760	52.6
Technical capacity not used [MWh]	96442	49427	129778	127248	182163	252460	0	165862	215997	180327	198842	152240	30.7
Import [MWh]	4967	184	189	1111	818	10430	0	1660	53	88	1432	3638	0.4
Import losses [MWh]	60	2	2	13	10	126	0	20	1	1	17	44	0.0
P_r (650 MW)	483600	436800	483600	468000	483600	468000	483600	483600	468000	483600	468000	483600	99.8

6.3.4 FENNO-SKAN 1

Figure 6.3.4 presents the availability and utilisation of Fenno-Skan 1 for 2014. 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) to Dannebo. The transmission capacity is 500 MW during summer and 550 MW during winter.

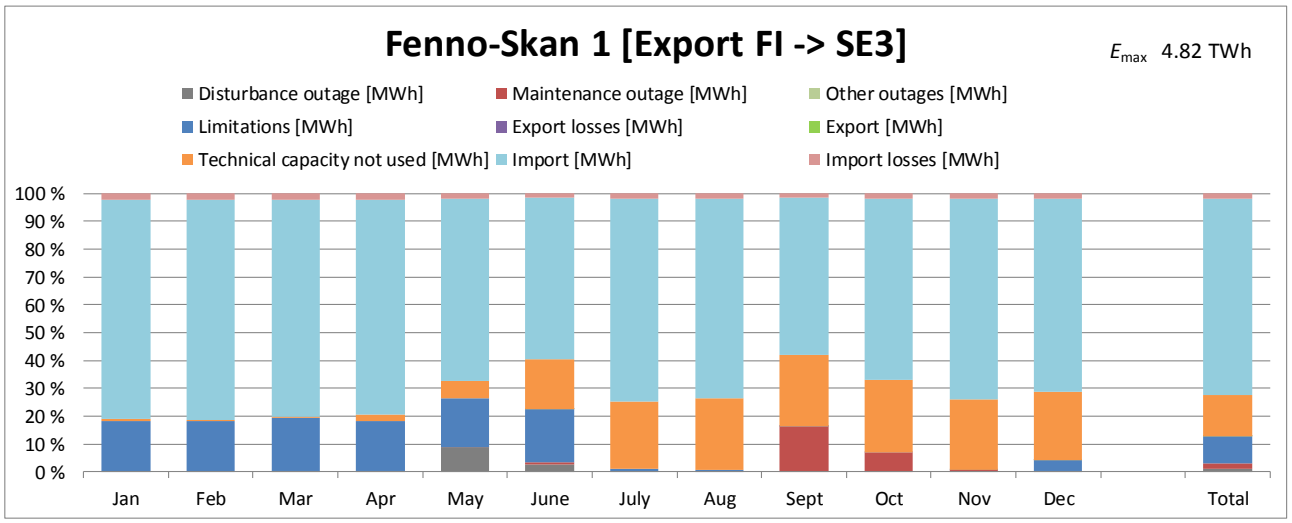

FIGURE 6.3.4 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR FENNO-SKAN 1 IN 2014

In 2014, Fenno-Skan 1 had an available technical capacity of 87 %. The technical capacity not used was 15 %. Totally, 602 MWh (0.01 % of the technical capacity) was exported from Finland to Sweden and 3.4 TWh (70 % of the technical capacity) was imported to Finland. The direction of the transmission was almost all of the time from Sweden to Finland (97% of the transmitted energy). Table 6.3.4 presents the numerical values behind Figure 6.3.4.

Fenno-Skan 1 had 9 disturbances in 2014. They all caused minor outages, of which the longest lasted three days in May and was probably caused by a problem in the communications with the valve interface. The limitation from January to June was caused by an investigation of the technical condition of Fenno-Skan 1, during which the cable was operating with a reduced voltage (80 % of the rated voltage) to avoid cable damage.

The annual maintenance outage was between 24 September and 3 October.

TABLE 6.3.4 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR FENNO-SKAN 1 IN 2014

Fenno-Skan 1 [FI -> SE3]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Disturbance outage [MWh]	0	0	1137	1622	35969	10697	0	0	0	0	631	454	1.0
Maintenance outage [MWh]	0	0	0	0	500	2200	0	0	64400	27600	1600	0	2.0
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Limitations [MWh]	76142	67200	80400	71500	73108	75944	4400	2900	550	0	917	16867	9.7
Export losses [MWh]	0	0	0	0	0	6	0	0	2	0	0	8	0.0
Export [MWh]	0	0	0	0	0	311	0	0	0	0	0	291	0.0
Technical capacity not used [MWh]	1959	1751	1474	8967	24855	72405	99423	105624	101122	107862	99817	101142	15.0
Import [MWh]	326355	295001	325745	307276	270922	229960	298624	293024	224102	267528	287140	288966	70.4
Import losses [MWh]	9728	8748	9793	8869	7670	6423	7847	7652	6171	6766	7292	7442	1.9
P_t (550 MW)	414184	372701	418549	398234	413024	397946	410295	409200	396347	409756	397397	415170	100.0

6.3.5 FENNO-SKAN 2

Figure 6.3.5 presents the availability and utilisation of Fenno-Skan 2 for 2014. 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 (bidding zone SE3) to Finnböle (bidding zone SE3). The transmission capacity is 800 MW.

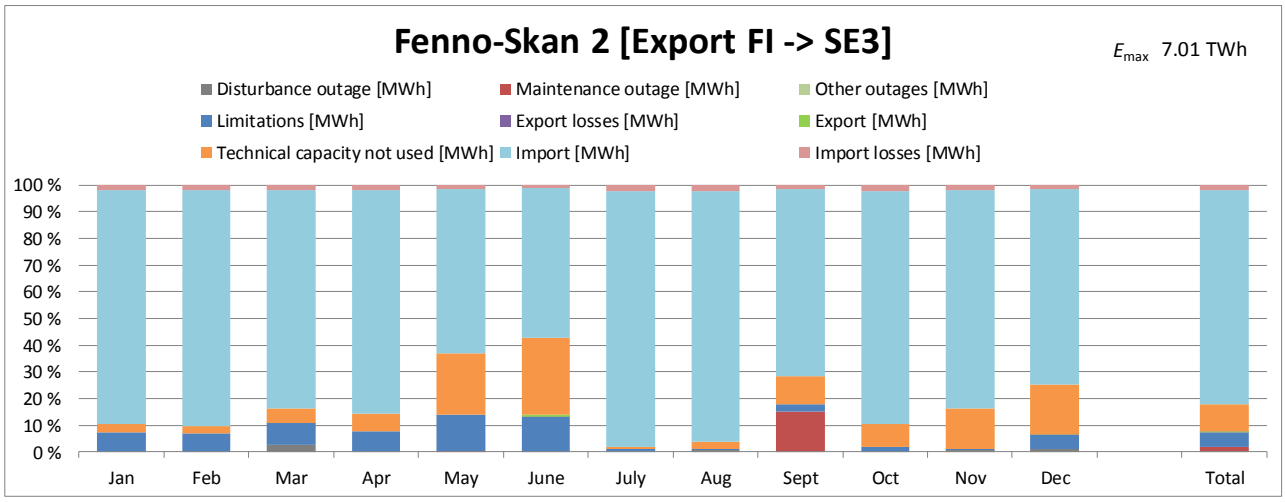

FIGURE 6.3.5 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR FENNO-SKAN 2 IN 2014

In 2014, Fenno-Skan 2 had an available technical capacity of 93 %. The technical capacity not used was 13 %. Totally, 6.6 GWh (0.1 % of the capacity) was exported from Finland to Sweden and 6.0 TWh (77.8 % of the capacity) was imported to Finland. The direction of the transmission was almost all of the time from Sweden to Finland (92% of the transmitted energy). Table 6.3.5 presents the numerical values behind Figure 6.3.5.

The number of disturbances of Fenno-Skan 2 was 6 and all of them caused minor consequences. The annual maintenance outage was 24–28 September.

TABLE 6.3.5 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR FENNO-SKAN 2 IN 2014

Fenno-Skan 2 [FI -> SE3]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Disturbance outage [MWh]	0	0	16387	0	0	0	0	3627	0	0	4427	6000	0.4
Maintenance outage [MWh]	0	0	0	0	500	0	0	0	91800	0	0	0	1.2
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Limitations [MWh]	47644	39822	54044	48296	86122	77941	6400	3300	14933	11733	1333	34200	5.8
Export losses [MWh]	0	0	0	0	0	128	0	0	0	0	0	0	0.0
Export [MWh]	0	0	7	0	0	6566	0	0	0	0	0	2	0.1
Technical capacity not used [MWh]	19335	15831	35439	42114	146953	171212	4800	16334	63840	51480	89409	115655	10.5
Import [MWh]	565409	517090	538547	522861	389270	337779	586209	572150	421251	540709	480229	455684	80.2
Import losses [MWh]	12695	11807	12324	11899	7876	6980	14281	13629	9638	12731	10778	9851	1.8
P_r (800MW)	645084	584550	656748	625170	630721	600606	611690	609041	601463	616653	586176	621392	100.0

6.3.6 KONTEK

Figure 6.3.6 presents the availability and utilisation of Kontek for 2014. Kontek has been in operation since 1986. 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.

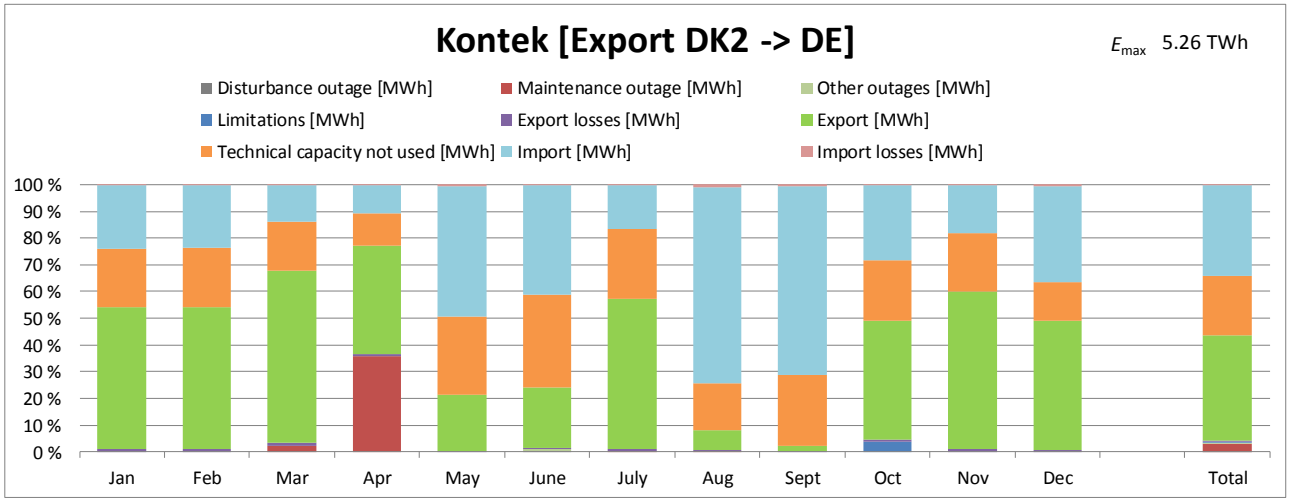

FIGURE 6.3.6 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR KONTEK IN 2014

In 2014, Kontek had an available technical capacity of 96 %. The technical capacity not used was 22 %. Totally, 2.1 TWh (39 % of the technical capacity) was exported from Denmark to Germany and 1.8 TWh (34 % of the technical capacity) was imported to Denmark. Table 6.3.6 presents the numerical values behind Figure 6.3.6.

There were 2 minor disturbance outage in May. The annual maintenance outage was from 31 March to 11 April.

TABLE 6.3.6 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR KONTEK IN 2014

Kontek [DK2 -> DE]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Disturbance outage [MWh]	0	0	0	0	0	1200	0	0	0	0	0	0	0.0
Maintenance outage [MWh]	0	0	10200	155150	0	0	1200	1790	0	0	0	0	3.2
Other outages [MWh]	0	0	0	0	0	3550	0	0	0	0	0	0	0.1
Limitations [MWh]	0	0	0	0	0	0	0	0	0	17775	0	0	0.3
Export losses [MWh]	4165	3757	4351	2685	1919	1983	4043	1272	495	3712	4104	3403	0.7
Export [MWh]	237986	214523	288533	176123	93061	98145	251029	33581	9600	199125	255121	215549	39.3
Technical capacity not used [MWh]	98197	90510	82269	51837	130837	149926	117616	77533	114314	100868	94272	65412	22.3
Import [MWh]	105697	93917	60639	46387	218709	177004	73602	329600	304442	126300	78381	160755	33.7
Import losses [MWh]	1199	1061	684	471	2178	1684	713	3760	3244	1394	860	1933	0.4
P_r (600MW)	447245	403768	446676	432654	446704	433491	448204	447536	432094	449174	432738	447053	100.0

6.3.7 KONTI-SKAN 1

Figure 6.3.7 presents the availability and utilisation of Konti-Skan 1 for 2014. In south-western Sweden it is connected to Lindome (bidding zone SE3) and in Denmark to Vester Hassing (bidding zone DK1). It has been in operation since 1965. Today the transmission capacity is 370 MW and the upgraded converter stations were commissioned in 2008.

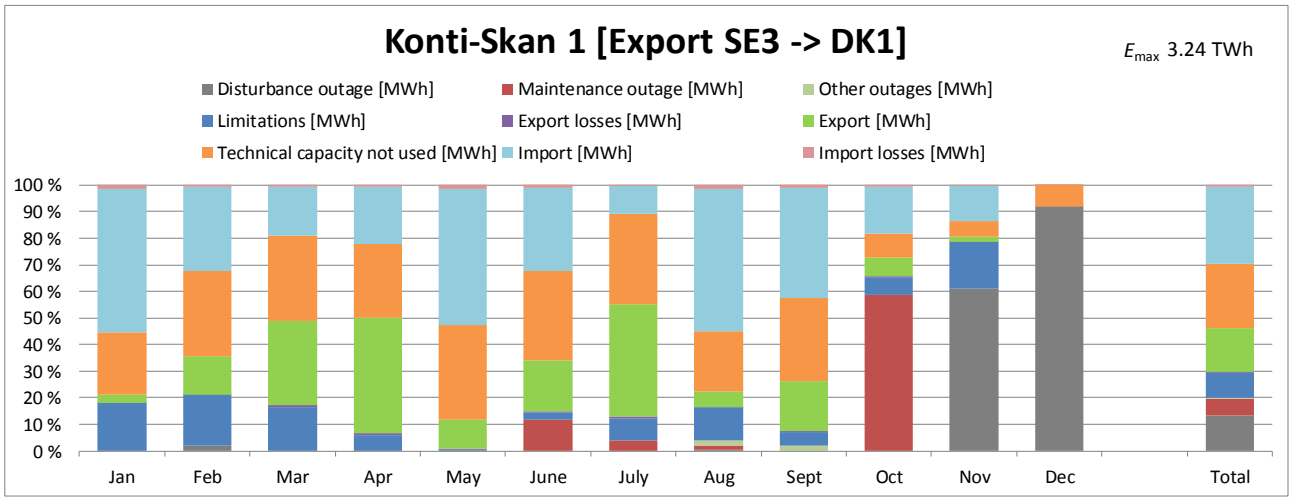

FIGURE 6.3.7 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR KONTI-SKAN 1 IN 2014

In 2014, Konti-Skan 1 had an available technical capacity of 71 % and the technical capacity not used was 25 %. Totally, 0.5 TWh (17 % of the technical capacity) was exported from Sweden to Denmark and 0.9 TWh (29 % of the technical capacity) was imported to Sweden. The available technical capacity of the link was 2 percentage points lower in comparison with 2013. Table 6.3.7 presents the numerical values behind Figure 6.3.7.

There were 4 disturbances on Konti-Skan 1, of which 2 were more significant than the others. The longest lasted 50 days starting from November and was initiated by an alarm in the gas relay for the transformer in Lindome. The second largest disturbance was caused by a transformer failure in Sweden and lasted nine days. The annual maintenance was in October.

TABLE 6.3.7 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR KONTI-SKAN 1 IN 2014

Konti-Skan 1 [SE3 -> DK1]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of Emax)
Disturbance outage [MWh]	0	5270	0	0	0	0	0	1553	0	0	173971	252960	13.2
Maintenance outage [MWh]	0	0	0	0	0	31080	10360	4386	0	165020	0	0	6.4
Other outages [MWh]	0	0	0	0	0	0	0	4810	5180	0	0	0	0.3
Limitations [MWh]	51215	48479	46259	15787	1250	7863	22845	34473	13354	19244	50040	0	9.4
Export losses [MWh]	163	764	1774	2406	630	1059	2437	320	1126	470	163	1	0.3
Export [MWh]	8306	37078	89058	116526	30966	51482	117007	16429	50296	20009	6021	0	16.5
Technical capacity not used [MWh]	67218	82026	90975	74744	97674	89217	94645	63304	83785	25506	15896	22320	24.5
Import [MWh]	153388	80266	51727	57876	140917	84165	28578	147899	110427	50253	37786	0	28.6
Import losses [MWh]	4158	2110	1381	1686	4108	2379	916	4458	3224	1436	1175	13	0.8
P_r (370 MW)	284448	255992	281173	269024	275544	267245	276788	277633	267392	281939	285052	275294	100.0

6.3.8 KONTI-SKAN 2

Figure 6.3.8 presents the availability and utilisation of Konti-Skan 2 for 2014. Konti-Skan 2 is connected between Sweden and Denmark in parallel to Konti-Skan 1. It has a transmission capacity of 370 MW and has been in operation since 1988.

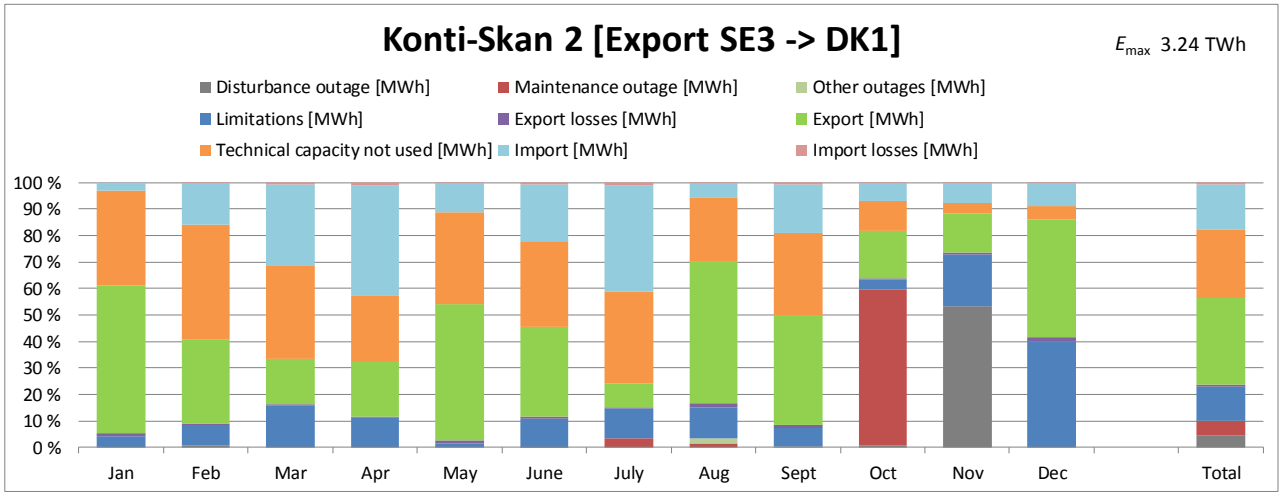

FIGURE 6.3.8 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR KONTI-SKAN 2 IN 2014

In 2014, Konti-Skan 2 had an available technical capacity of 77 %. The technical capacity not used was 26 %. Totally, 1.1 TWh (33 % of the technical capacity) was exported from Sweden to Denmark and 0.6 TWh (17 %) was imported to Sweden. The availability of the link is 17 percentage points lower in comparison with 2013. Table 6.3.8 presents the numerical values behind Figure 6.3.8.

There were 5 disturbance outages on Konti-Skan 2. A significant amount of lost capacity was caused by a transformer inspection at the beginning of November and a transformer fault in November at the same time Konti-Skan 1 suffered from a similar fault too. This fault also caused limitations in November and December. The annual maintenance was in October.

TABLE 6.3.8 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR KONTI-SKAN 2 IN 2014

Konti-Skan 2 [SE3 -> DK1]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of Emax)
Disturbance outage [MWh]	0	2040	0	0	0	112	0	0	952	1360	157064	0	4.7
Maintenance outage [MWh]	0	0	0	0	0	0	10360	4386	0	165020	0	0	5.3
Other outages [MWh]	0	0	0	0	0	0	0	4810	0	0	0	0	0.1
Limitations [MWh]	11528	18552	45430	30995	3920	29452	32695	33929	18870	11175	58305	138465	12.7
Export losses [MWh]	3772	1820	1175	1443	3835	2485	625	4263	2922	1320	1264	5258	0.9
Export [MWh]	153931	79983	50221	56955	142008	94583	26396	150894	111510	50333	44784	153422	32.7
Technical capacity not used [MWh]	99369	108886	101915	69454	96482	90338	99658	68869	83789	31364	10618	17321	25.7
Import [MWh]	7904	39063	88609	115780	29768	59663	116748	15471	50201	18832	22356	30098	17.4
Import losses [MWh]	165	999	2344	3200	744	1625	3194	376	1372	514	678	868	0.5
P_r (370 MW)	276668	251342	289694	277827	276756	278258	289674	282997	269616	279919	295069	345432	100.0

6.3.9 NorNed

Figure 6.3.9 presents the availability and utilisation of NorNed for 2014. 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 730 MW.

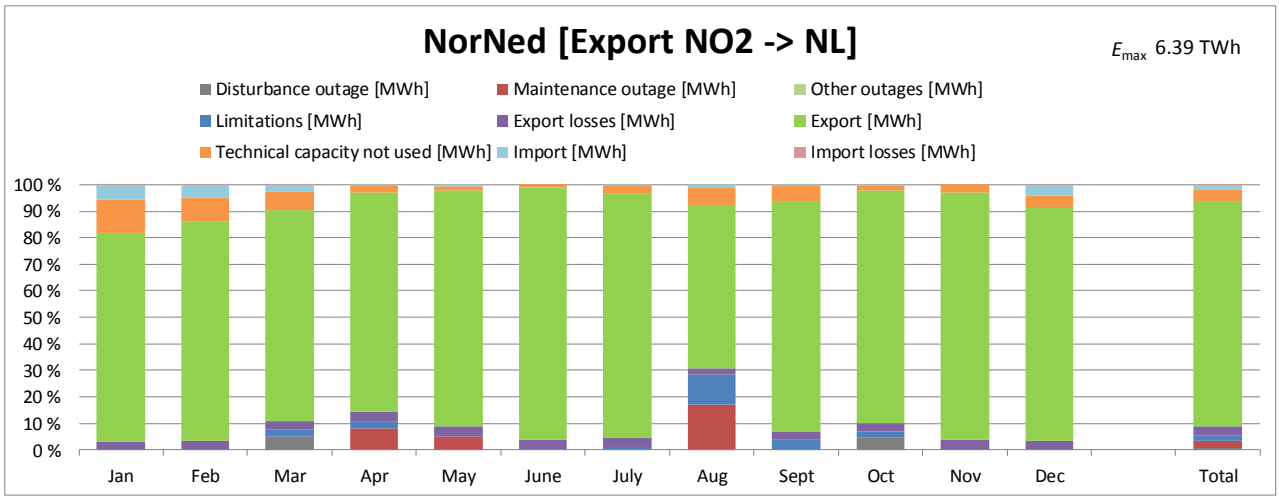

Figure 6.3.9 Percentage distribution of the availability and utilisation categories defined in Chapter 4 according to month for NorNed in 2014

In 2014, NorNed had had an available technical capacity of 95 %. The technical capacity not used was 4.9 %. Totally, 5.5 TWh (86 % of the technical capacity) was exported from Norway to the Netherlands and 0.1 TWh (1.6 % of the technical capacity) was imported to Norway.

Table 6.3.9 presents the numerical values behind Figure 6.3.9.

There were 2 disturbance outages on NorNed with minor significance. There were also some limitations due to maintenance work and faults in AC system units in the in Netherlands and Norway.

The annual maintenance outage lasted for six days in the end of August and the roof in Eemshaven converter station was repaired in the end of April and beginning of May.

Table 6.3.9 Monthly distribution of the technical capacity E_{MAX} for NorNed in 2014

NorNed [NO2 -> NL]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Disturbance outage [MWh]	0	0	26623	0	0	700	0	0	0	26717	0	0	0.8
Maintenance outage [MWh]	0	0	0	43657	28035	0	0	95632	0	0	0	0	2.6
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Limitations [MWh]	0	0	15200	14400	0	0	5900	62797	19302	12000	0	0	2.0
Export losses [MWh]	16842	16009	16650	17049	19249	20060	20081	12370	17622	19477	19524	18915	3.3
Export [MWh]	428999	406944	433957	435155	485085	501064	503108	342401	460952	497360	491021	475853	84.7
Technical capacity not used [MWh]	66356	43710	37673	15613	7525	4866	17168	38435	32462	11113	15753	25746	4.9
Import [MWh]	30526	23625	13628	524	3766	0	1250	4959	1339	1311	0	22018	1.6
Import losses [MWh]	1100	848	479	18	134	1	44	210	45	41	1	837	0.1
P_r (730 MW)	543823	491136	544210	526416	543793	526691	547550	556804	531722	568020	526298	543370	100.0

6.3.10 SKAGERRAK 1

Figure 6.3.10 presents the availability and utilisation of Skagerrak 1 for 2014. Skagerrak 1 and Skagerrak 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 250 MW.

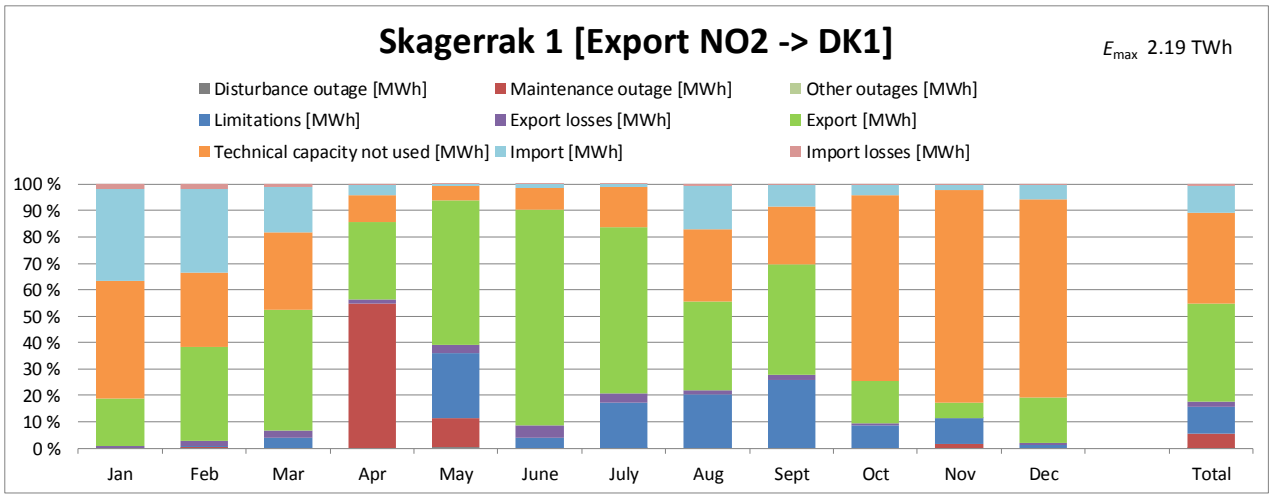

FIGURE 6.3.10 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR SKAGERRAK 1 IN 2014

In 2014, Skagerrak 1 had an available technical capacity of 84 %. The technical capacity not used was 34 %. Totally, 0.8 TWh (37 % of the technical capacity) was exported from Norway to the Denmark and 0.2 TWh (10 % of the technical capacity) was imported to Norway. Table 6.3.10 presents the numerical values behind Figure 6.3.10.

There were 4 disturbance outages with minor significance on Skagerrak 1. There were 3 maintenance outages with the longest lasting from 14 April to 3 May.

TABLE 6.3.10 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR SKAGERRAK 1 IN 2014

Skagerrak 1 [NO2 -> DK1]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Disturbance outage [MWh]	0	107	0	0	430	0	413	0	0	0	0	0	0.0
Maintenance outage [MWh]	0	750	0	98750	21667	0	0	0	0	0	3000	0	5.5
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Limitations [MWh]	0	825	7708	0	47940	7225	35694	39592	50882	16224	17597	2260	10.0
Export losses [MWh]	1533	3255	4470	2954	5478	8653	7286	3017	3666	1499	532	1664	1.9
Export [MWh]	33242	60107	85495	52240	106427	150058	132789	65958	82319	30359	10611	32324	37.2
Technical capacity not used [MWh]	83088	48012	54613	18433	10540	15287	32255	53876	43489	131896	147024	140517	34.4
Import [MWh]	65119	53667	32632	7313	1399	2441	2174	31558	15864	7501	4074	10039	10.3
Import losses [MWh]	3561	3031	1779	390	54	109	97	1565	689	325	195	495	0.5
P_r (250 MW)	186544	169755	186698	180081	193935	183773	210709	195566	196909	187803	183034	187299	100.0

6.3.11 SKAGERRAK 2

Figure 6.3.11 presents the availability and utilisation of Skagerrak 1 for 2014. Skagerrak 1 and Skagerrak 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 250 MW.

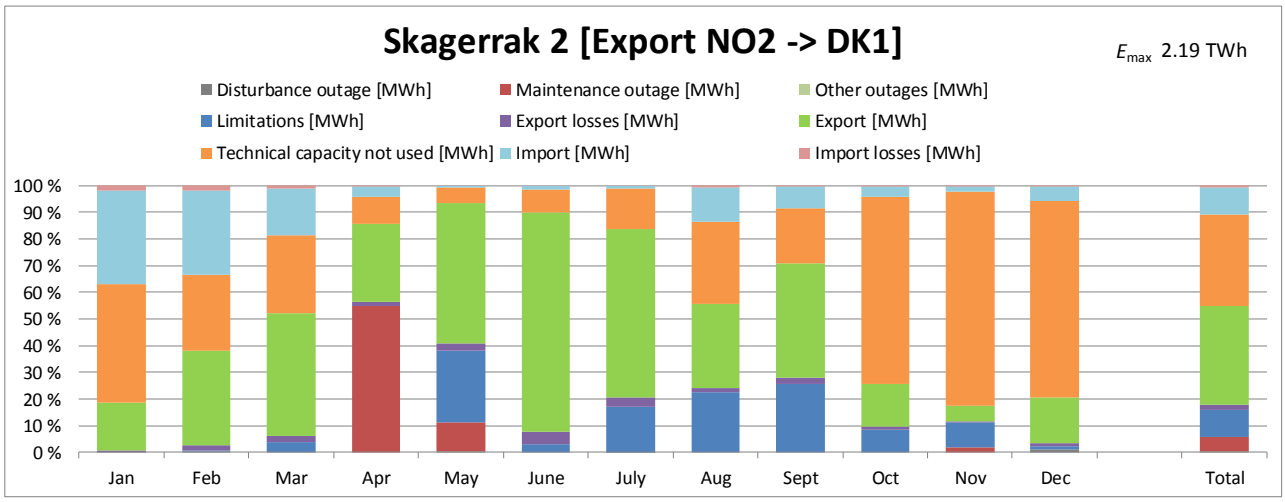

FIGURE 6.3.11 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR SKAGERRAK 2 IN 2014

In 2014, Skagerrak 2 had an available technical capacity of 84 %. The technical capacity not used was 35 %. Totally, 0.8 TWh (31% of the technical capacity) was exported from Norway to the Denmark and 0.2 TWh (26% of the technical capacity) was imported to Norway. Table 6.3.11 presents the numerical values behind Figure 6.3.11.

There were 5 disturbance outages with minor significance on Skagerrak 2. There were 3 maintenance outages with the longest lasting from 14 April to 3 May.

TABLE 6.3.11 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR SKAGERRAK 2 IN 2014

Skagerrak 2 [NO2 -> DK1]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Disturbance outage [MWh]	0	357	0	0	430	0	109	0	0	0	0	2254	0.1
Maintenance outage [MWh]	0	0	0	98750	21667	0	0	0	0	0	3000	0	5.5
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Limitations [MWh]	0	825	7258	0	53565	5550	35994	43692	50957	16224	17597	2260	10.3
Export losses [MWh]	1519	3214	4416	2924	5281	8541	7207	3106	4469	1747	558	1795	2.0
Export [MWh]	33329	60115	85622	52358	104112	150010	133004	61322	84399	30376	10630	32455	37.0
Technical capacity not used [MWh]	82839	48284	54925	18325	11279	15427	32396	59715	40919	131539	147010	137948	34.5
Import [MWh]	65429	53462	32762	7339	1387	2450	2189	25122	15933	7548	4103	10082	10.1
Import losses [MWh]	3569	3012	1778	390	55	109	99	1270	855	412	230	573	0.5
P_r (250 MW)	186685	169269	186760	180087	197776	182087	210998	194227	197533	187846	183129	187366	100.0

6.3.12 SKAGERRAK 3

Figure 6.3.12 presents the availability and utilisation of Skagerrak 3 for 2014. Skagerrak 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 500 MW.

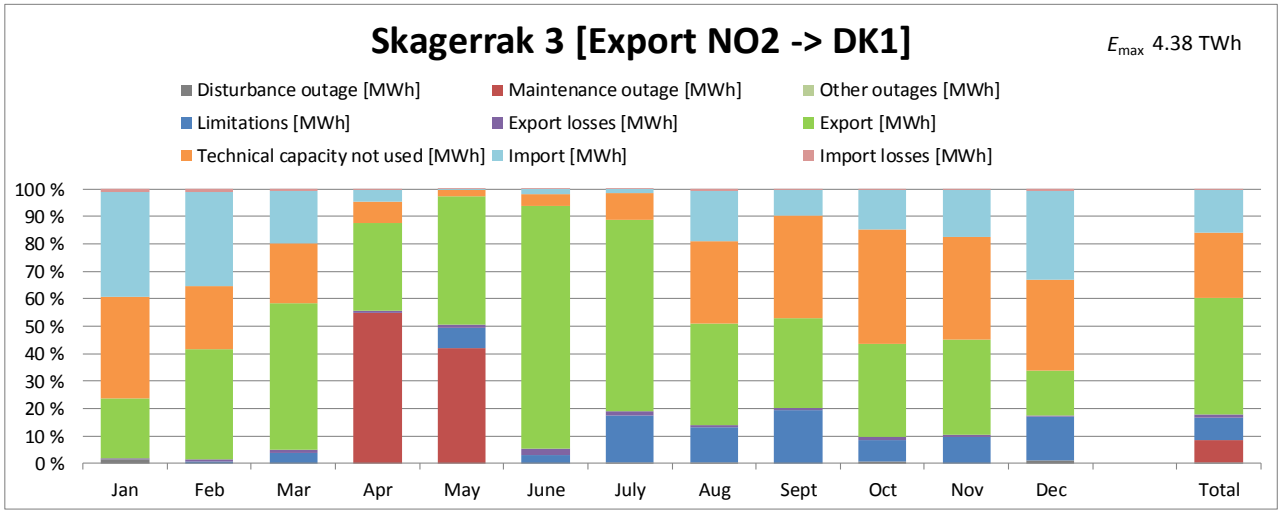

FIGURE 6.3.12 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR SKAGERRAK 3 IN 2014

In 2014, Skagerrak 3 had an available technical capacity of 83 %. The technical capacity not used was 24 %. Totally, 1.9 TWh (43 % of the technical capacity) was exported from Norway to Denmark and 0.7 TWh (16 % of the technical capacity) was imported to Norway. Table 6.3.12 presents the numerical values behind Figure 6.3.12.

There were 6 disturbance outages with minor significance on Skagerrak 3. There was one maintenance outage from 14 April to 13 May when a new control system was installed.

TABLE 6.3.12 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR SKAGERRAK 3 IN 2014

Skagerrak 3 [NO2 -> DK1]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Disturbance outage [MWh]	4959	0	0	0	0	0	992	1000	0	2716	0	3625	0.3
Maintenance outage [MWh]	0	0	0	197500	166458	0	0	0	0	0	0	0	8.1
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Limitations [MWh]	0	1650	14517	0	28200	11100	74043	48750	73974	29690	35179	60370	8.4
Export losses [MWh]	1851	3203	4832	2758	4682	8596	7868	3415	3157	2965	2774	1411	1.1
Export [MWh]	82832	136222	201384	115098	185634	326412	301377	141524	124008	127763	125437	61237	42.7
Technical capacity not used [MWh]	138369	77291	82946	27725	8198	15423	42230	114060	141780	155715	134636	123962	23.5
Import [MWh]	143916	116016	72928	16559	1666	6370	5474	70485	35380	54165	61961	120339	15.6
Import losses [MWh]	3866	3154	1967	444	44	178	144	1984	998	1449	1585	3143	0.4
P_r (500 MW)	375793	337535	378574	360084	394882	368079	432128	381218	379297	374463	361571	374087	100.0

6.3.13 SKAGERRAK 4

Figure 6.3.13 presents the availability and utilisation of Skagerrak 4 for 2014. Skagerrak 4 has been in commercial operation since 29 December 2014 and in test operation since late August 2014. In Norway it is connected to Kristiansand (bidding zone NO2) and in Denmark to Tjele (bidding zone DK1). The transmission capacity is 700 MW.

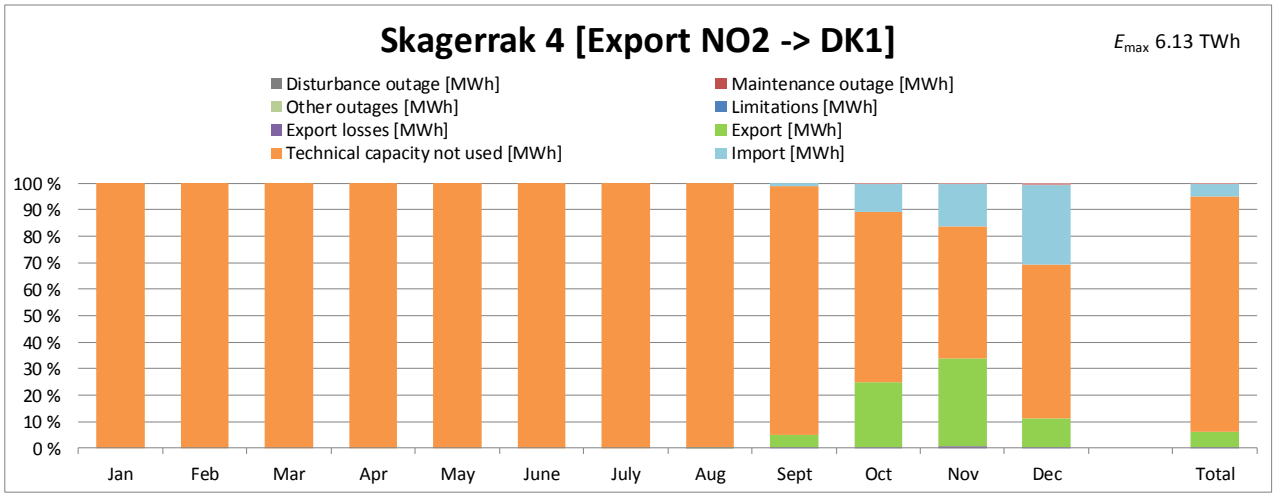

FIGURE 6.3.13 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR SKAGERRAK 4 IN 2014

In 2014, Skagerrak 4 had an available technical capacity of 100 %. The technical capacity not used was 89 %. Totally, 0.4 TWh (6.1 % of the technical capacity) was exported from Norway to the Denmark and 0.3 TWh (4.8 % of the technical capacity) was imported to Norway. Table 6.3.13 presents the numerical values behind Figure 6.3.13.

There were no disturbance outages on Skagerrak 4.

TABLE 6.3.13 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR SKAGERRAK 4 IN 2014

Skagerrak 4 [NO2 -> DK1]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Disturbance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Maintenance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Limitations [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Export losses [MWh]	0	0	0	0	0	0	0	23	571	2304	3018	1030	0.1
Export [MWh]	0	0	0	0	0	0	0	572	24582	126944	168190	56822	6.1
Technical capacity not used [MWh]	520800	470400	520100	504000	520800	504000	520800	520211	474570	336157	252076	304304	88.8
Import [MWh]	0	0	0	0	0	0	0	122	5059	55555	79295	155394	4.8
Import losses [MWh]	0	0	0	0	0	0	0	8	137	1322	1876	3700	0.1
P_r (700 MW)	520800	470400	520100	504000	520800	504000	520800	520936	504920	522283	504455	521250	100.0

6.3.14 STOREBAELT

Figure 6.3.14 presents the availability and utilisation of Storebaelt for 2014. Storebaelt has been in operation since 2010. It connects together the western part of the Danish system that belongs to the Continental European synchronous system (Jutland and the island of Fynen) and 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.

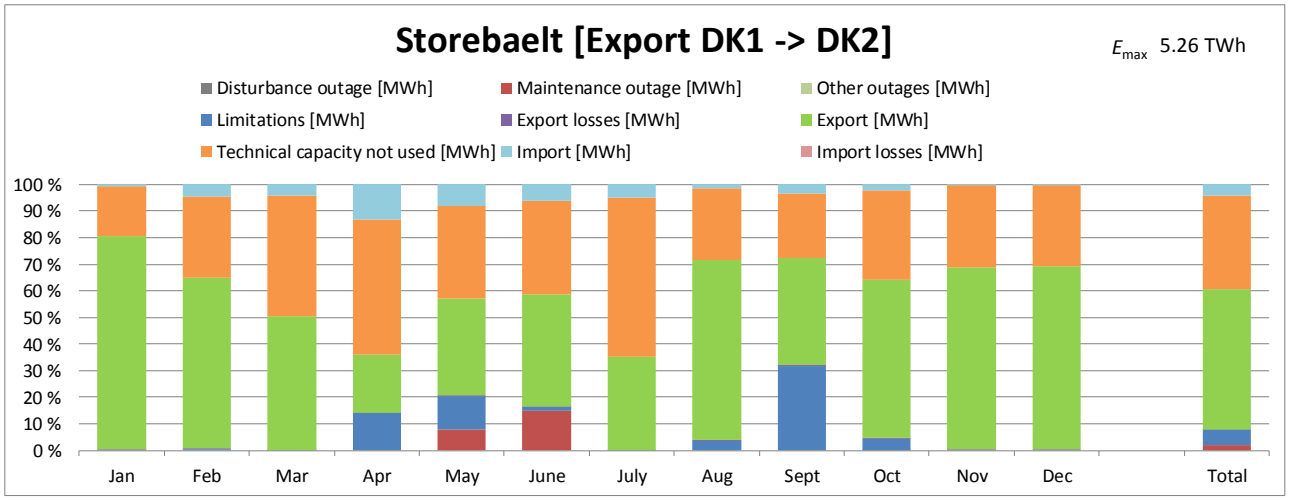

FIGURE 6.3.14 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR STOREBELT IN 2014

In 2014, Storebaelt had an available technical capacity of 92 %. The technical capacity not used was 35 %. Totally, 2.8 TWh (53 % of the technical capacity) was exported from Jutland to Zealand and 0.2 TWh (4.1 % of the technical capacity) was imported to Jutland. Table 6.3.14 presents the numerical values behind Figure 6.3.14.

There was one disturbance outage with minor significance on Storebaelt. The annual maintenance was 23–27 June and the control system was updated 12–14 May.

TABLE 6.3.14 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR IN 2014

Storebaelt [DK1 -> DK2]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Disturbance outage [MWh]	0	0	0	0	0	0	0	0	0	590	0	0	0.0
Maintenance outage [MWh]	0	0	0	0	35400	65000	0	0	0	0	0	0	1.9
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Limitations [MWh]	0	2250	0	60600	57300	6000	0	15817	147870	18225	0	0	5.8
Export losses [MWh]	1786	1137	958	418	518	908	544	1462	772	1611	2642	2626	0.3
Export [MWh]	358549	259405	224246	95504	164802	181719	156906	302158	187971	267558	295089	307931	52.8
Technical capacity not used [MWh]	82862	122531	202557	220788	157870	152326	267609	121870	112437	151336	134663	135484	35.1
Import [MWh]	3314	18899	18770	56594	36950	26872	22267	5700	15973	9794	532	1494	4.1
Import losses [MWh]	9	54	57	233	120	122	58	10	48	25	3	6	0.0
P_r (600 MW)	446519	404277	446588	434138	452960	432946	447385	447018	465070	449139	432929	447541	100.0

6.3.15 SWEPOL

Figure 6.3.15 presents the availability and utilisation of SwePol for 2014. 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.

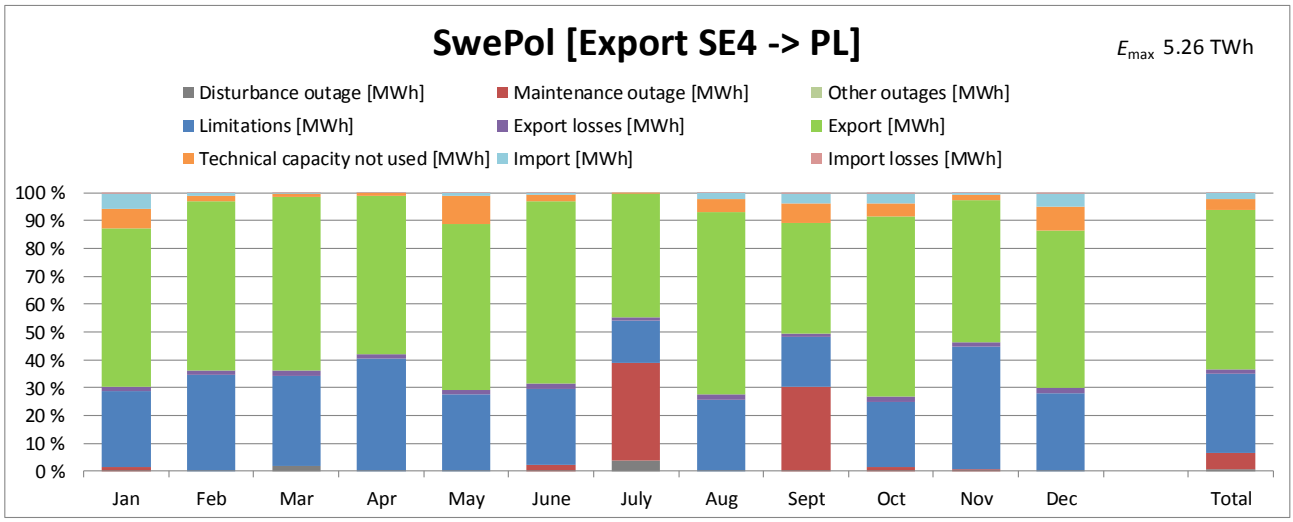

FIGURE 6.3.15 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR SWEPOL IN 2014

In 2014, SwePol had an available technical capacity of 65 %. The technical capacity not used was 42 %. Totally, 3.1 TWh (57 % of the technical capacity) was exported from Sweden to Poland and 0.1 TWh (2.0 % of the technical capacity) was imported to Sweden. Table 6.3.15 presents the numerical values behind Figure 6.3.15.

There were 2 disturbance outages with minor significance on SwePol. The disturbance in July lasted one day and was caused by an unknown reason. The limitations were mostly market limitations. There was one maintenance outage from 30 June to 12 July, which had to be rescheduled, and several smaller ones during September.

TABLE 6.3.15 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR SWEPOL IN 2014

SwePol [SE4 -> PL]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Disturbance outage [MWh]	0	0	7650	0	0	0	18060	0	0	0	0	0	0.5
Maintenance outage [MWh]	6000	0	0	0	0	10200	163200	0	132900	5790	2550	0	5.9
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Limitations [MWh]	126796	141684	150279	180100	124200	123734	70800	117300	78600	108115	197700	130900	28.6
Export losses [MWh]	7480	7089	8177	7148	7486	8429	5931	8348	4865	8575	6605	7583	1.6
Export [MWh]	266193	249449	287381	253340	270119	298921	207117	297002	175579	294829	227516	264462	57.1
Technical capacity not used [MWh]	31644	8414	4869	4022	47357	10869	961	21667	29777	19997	9402	38694	4.2
Import [MWh]	26204	4211	967	246	4021	2585	0	10136	16485	17272	2718	22789	2.0
Import losses [MWh]	610	98	21	6	101	67	0	240	381	407	64	521	0.0
P_r (600 MW)	464928	410945	459344	444862	453284	454805	466069	454694	438587	454986	446555	464949	100.0

6.3.16 VYBORG LINK

Figure 6.3.16 presents the availability and utilisation of the Vyborg Link for 2014. 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 commercial trade from Finland to Russia started on 1 December 2014.

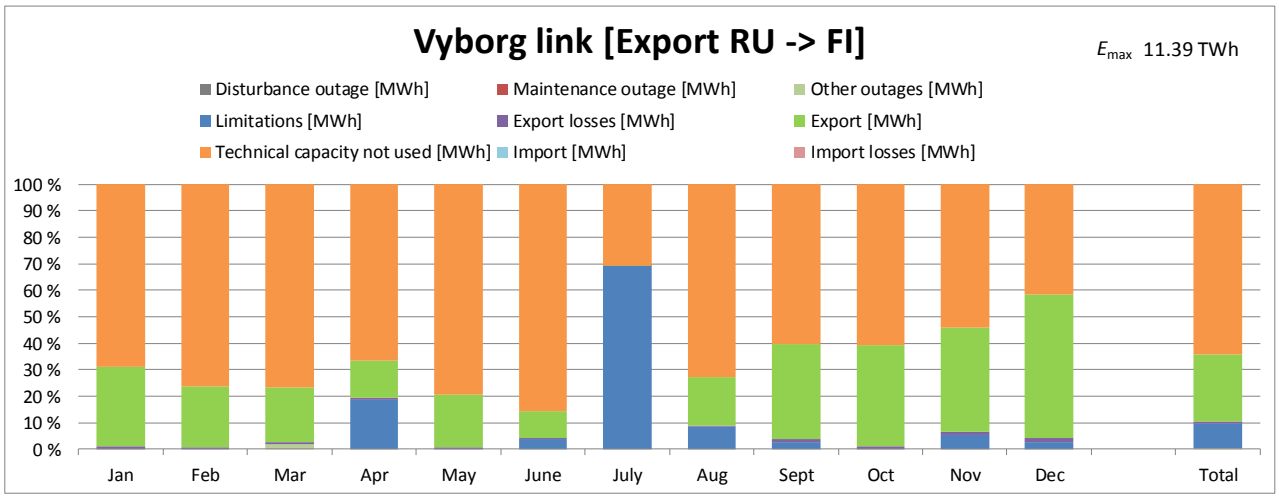

FIGURE 6.3.16 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR VYBORG LINK IN 2014

In 2014, the Vyborg Link had an available technical capacity of 92 %. The technical capacity not used was 66 %. Totally, 2.9 TWh (25 % of the technical capacity) was exported from Russia to Finland and nothing was imported to Russia. Table 6.3.16 presents the numerical values behind Figure 6.3.16.

There were no disturbance outages on the Vyborg link. There was a longer limitation due to the annual maintenance of the link in July and 8 shorter limitations during the year.

TABLE 6.3.16 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR VYBORG LINK IN 2014

Vyborg link [RU -> FI]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Disturbance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Maintenance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Other outages [MWh]	0	0	18200	0	0	0	0	0	0	0	0	0	0.2
Limitations [MWh]	0	0	0	175890	0	36000	669600	80800	24180	0	49600	26400	9.3
Export losses [MWh]	8808	6034	6024	4020	5784	2813	27	5301	10110	11084	11091	15723	0.8
Export [MWh]	293590	201120	200803	134000	192792	93770	900	176700	337010	369469	369700	524092	25.4
Technical capacity not used [MWh]	664802	666446	741154	622090	768624	803417	296673	704399	564700	587947	505609	406598	64.4
Import [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Import losses [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
P_r (1300 MW)	967200	873600	966181	936000	967200	936000	967200	967200	936000	968500	936000	972813	100.0

7 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 19 October 2015].

Appendix A SCHEMATIC PRESENTATION OF HVDC LINKS

Figure 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-3, 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.

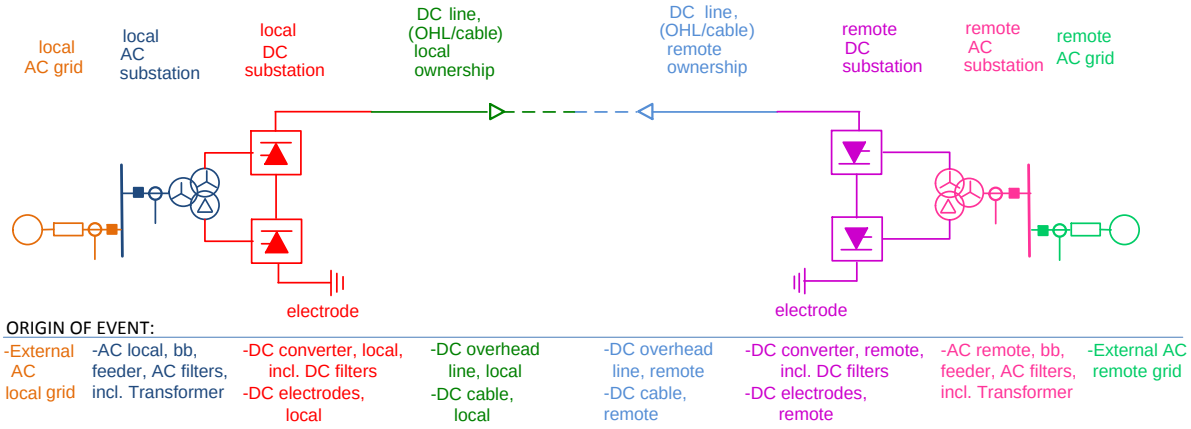

FIGURE A-1 A SCHEMATIC PRESENTATION OF A HVDC LINK WITH LINE COMMUTATED CONVERTERS (LCC)

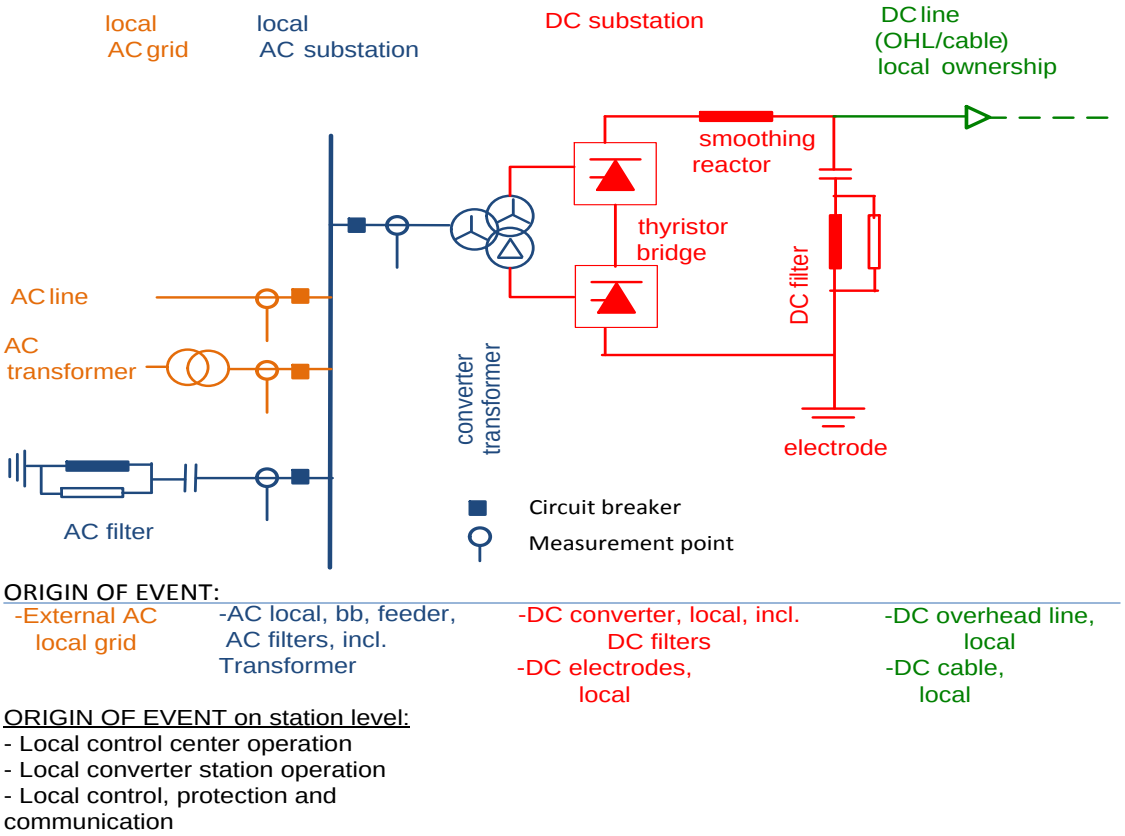

FIGURE A-2 A CONVERTER STATION OF A LINE COMMUTATED CONVERTER HVDC LINK WITH THE CONNECTION TO THE AC GRID

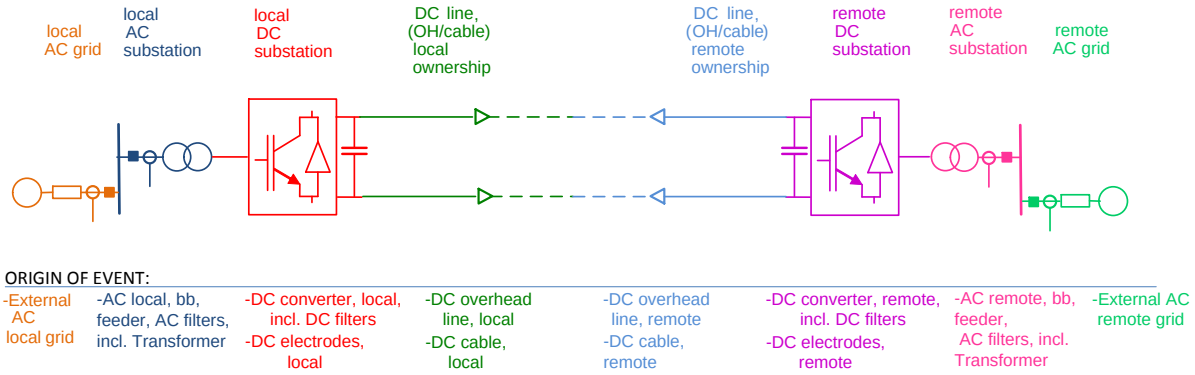

FIGURE A-3 A SCHEMATIC PRESENTATION OF A HVDC LINK WITH VOLTAGE SOURCE CONVERTERS (VSC)

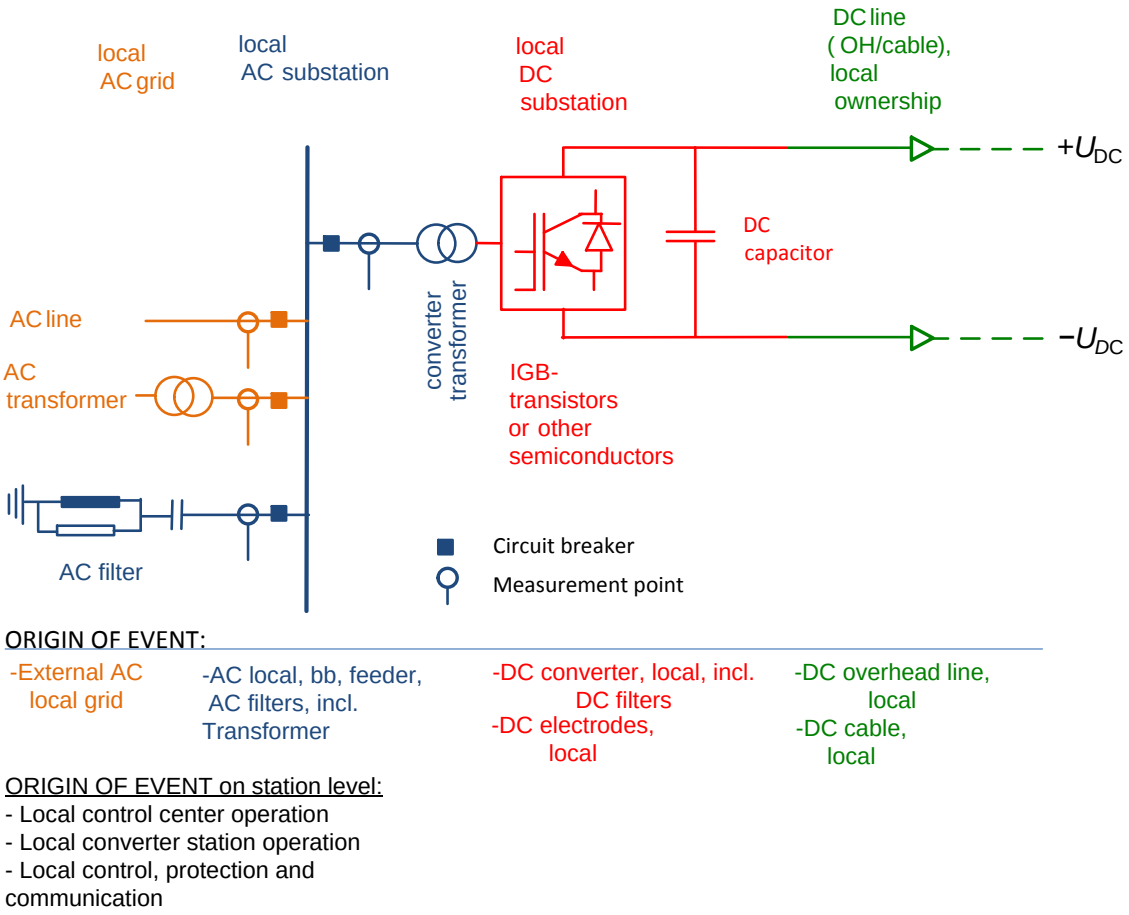

FIGURE A-4 A CONVERTER STATION OF A VOLTAGE SOURCE CONVERTER HVDC LINK WITH THE CONNECTION TO THE AC GRID

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Appendix C ANNUAL OVERVIEW OF ALL HVDC DATA WITH SORTED CATEGORIES

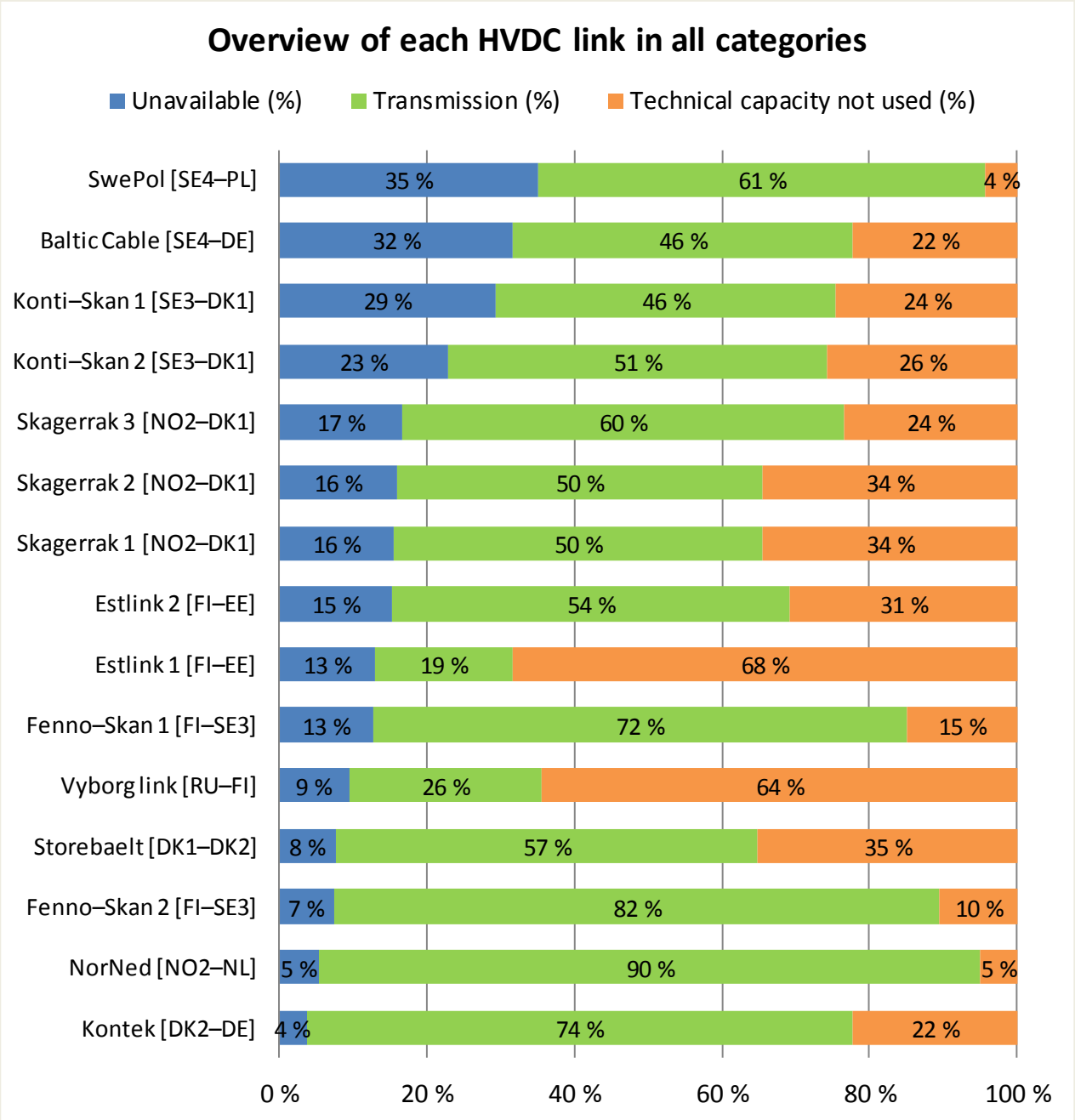

FIGURE C-1 ANNUAL OVERVIEW OF EACH HVDC LINK SORTED BY HIGHEST UNAVAILABLE TECHNICAL CAPACITY E_U IN 2014

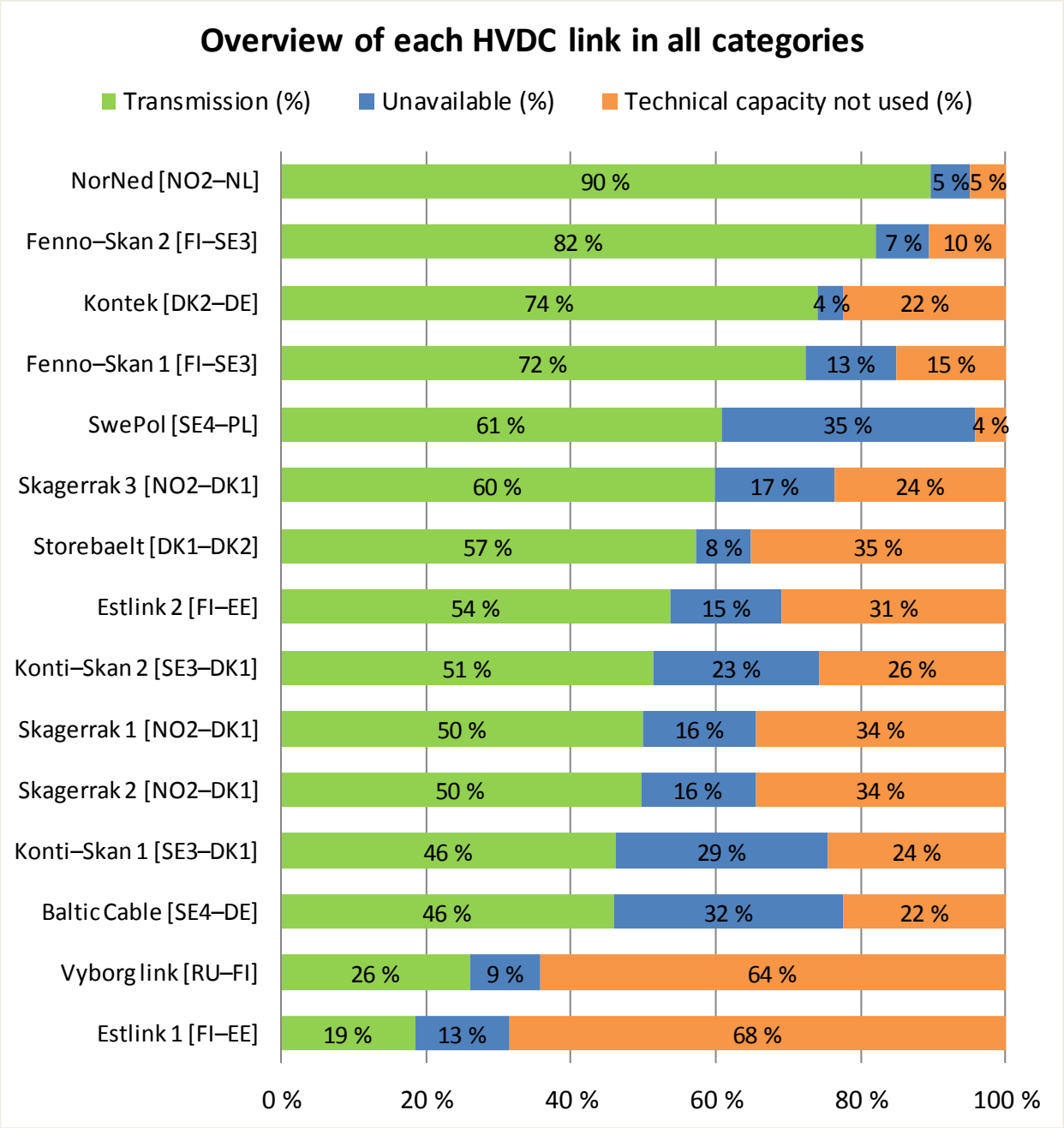

FIGURE C-2 ANNUAL OVERVIEW OF EACH HVDC LINK SORTED BY HIGHEST TRANSMISSION IN 2014

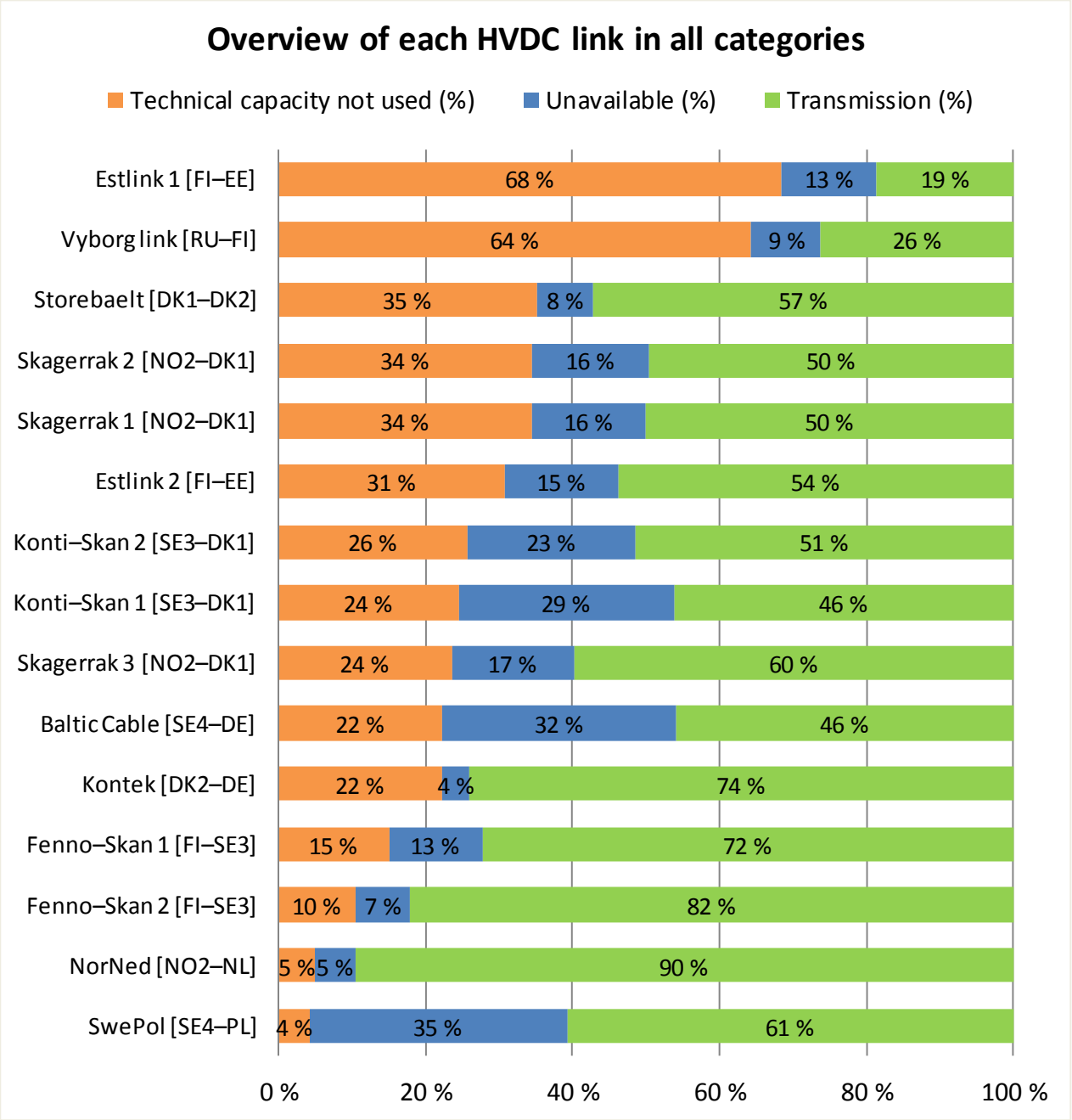

FIGURE C-3 ANNUAL OVERVIEW OF EACH HVDC LINK SORTED BY HIGHEST TECHNICAL CAPACITY NOT USED IN 2014