



European Network of
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for Electricity

NORDIC AND BALTIC HVDC UTILI- SATION AND UNAVAILABILITY STATISTICS 2015

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REGIONAL GROUP NORDIC

Table of Contents

1	SUMMARY	3
2	INTRODUCTION AND BACKGROUND	4
3	SCOPE	5
3.1	CONTACT PERSONS	5
4	METHODS, DEFINITIONS AND CALCULATIONS	6
5	TECHNICAL DETAILS OF THE HVDC LINKS	10
6	PRESENTATION OF THE RESULTS FOR 2015	11
6.1	INTRODUCTION	11
6.2	OVERVIEW	11
6.3	INDIVIDUAL PRESENTATIONS OF ALL LINKS	14
6.3.1	BALTIC CABLE	15
6.3.2	ESTLINK 1	16
6.3.3	ESTLINK 2	17
6.3.4	FENNO-SKAN 1	18
6.3.5	FENNO-SKAN 2	19
6.3.6	KONTEK	20
6.3.7	KONTI-SKAN 1	21
6.3.8	KONTI-SKAN 2	22
6.3.9	NORNED	23
6.3.10	SKAGERRAK 1	24
6.3.11	SKAGERRAK 2	25
6.3.12	SKAGERRAK 3	26
6.3.13	SKAGERRAK 4	27
6.3.14	STOREBAELT	28
6.3.15	SWEPOL	29
6.3.16	VYBORG LINK	30
7	REFERENCES	31

1 SUMMARY

This report presents the availability and utilisation of HVDC links connected to the Nordic power system in 2015, with an emphasis on disturbance outages.

This report presents methods and definitions and statistics for 2015: 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 2015, 46.7 TWh of electric energy was transmitted through the Nordic HVDC links. 60 disturbance outages were registered, preventing 1.4 TWh of potential energy transmission. Approximately 70 % of the energy transmission lost due to disturbance outages was caused by one disturbance on Konti-Skan 1. This disturbance was caused by a transformer failure in Sweden which started in November 2014 and ended 24 April 2015.

Maintenance outages caused 2.0 TWh and limitations caused 1.6 TWh of reduced transmission capacity.

2 INTRODUCTION AND BACKGROUND

The total HVDC power transmission capacity connected to the Nordic power systems is 9040 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 1200 MW.

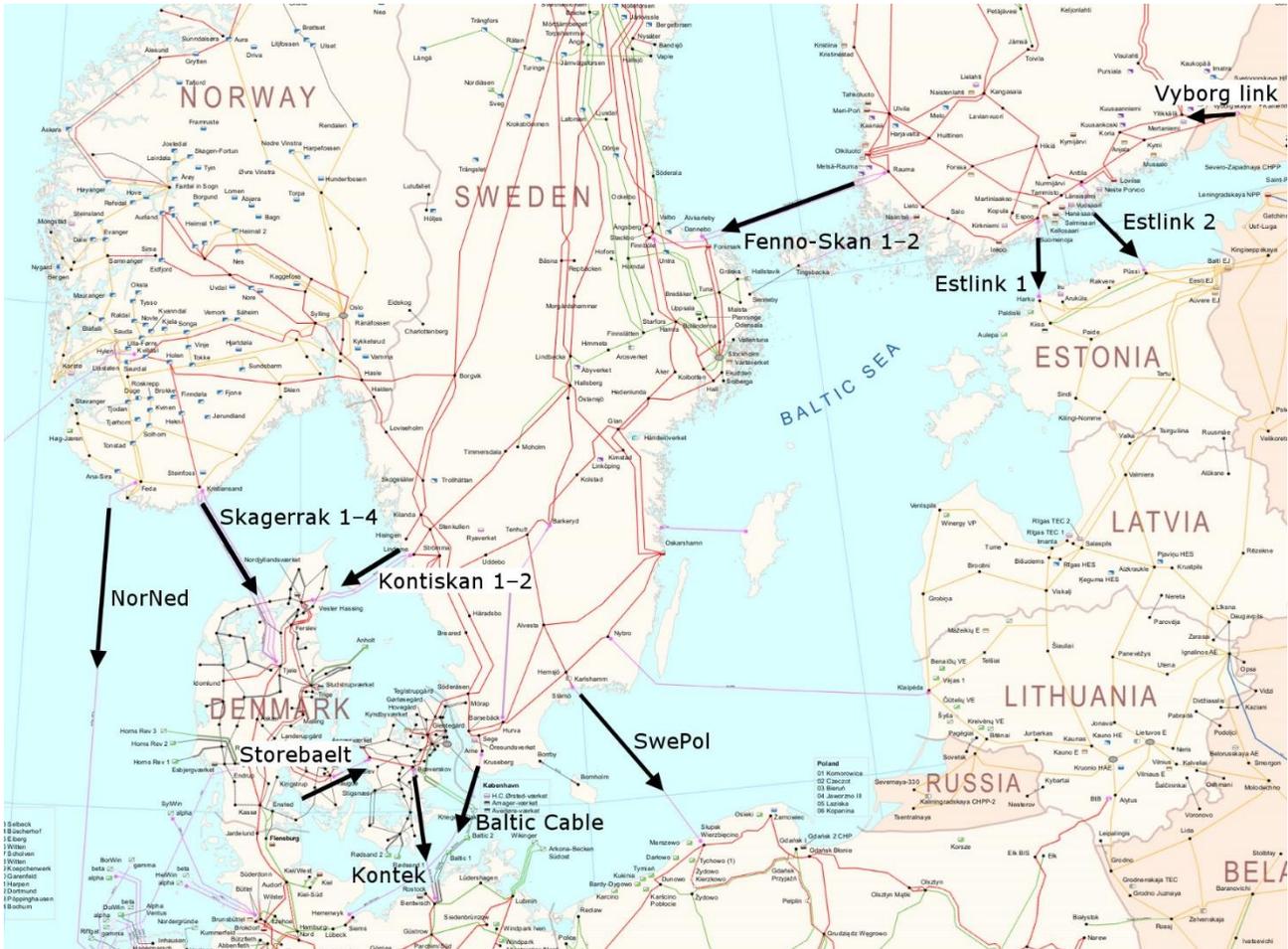


FIGURE 2.1 PART OF THE NORDIC GRID MAP SHOWING THE HVDC LINKS [1]. THE ARROWS INDICATES THE DIRECTION OF EXPORT USED IN THIS REPORT.

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, excluding all HVDC link losses, if there are no outages or limitations, the technical capacity is calculated:

$$E_{\max} = P_R \cdot 24 \cdot d, \quad (4.1)$$

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.

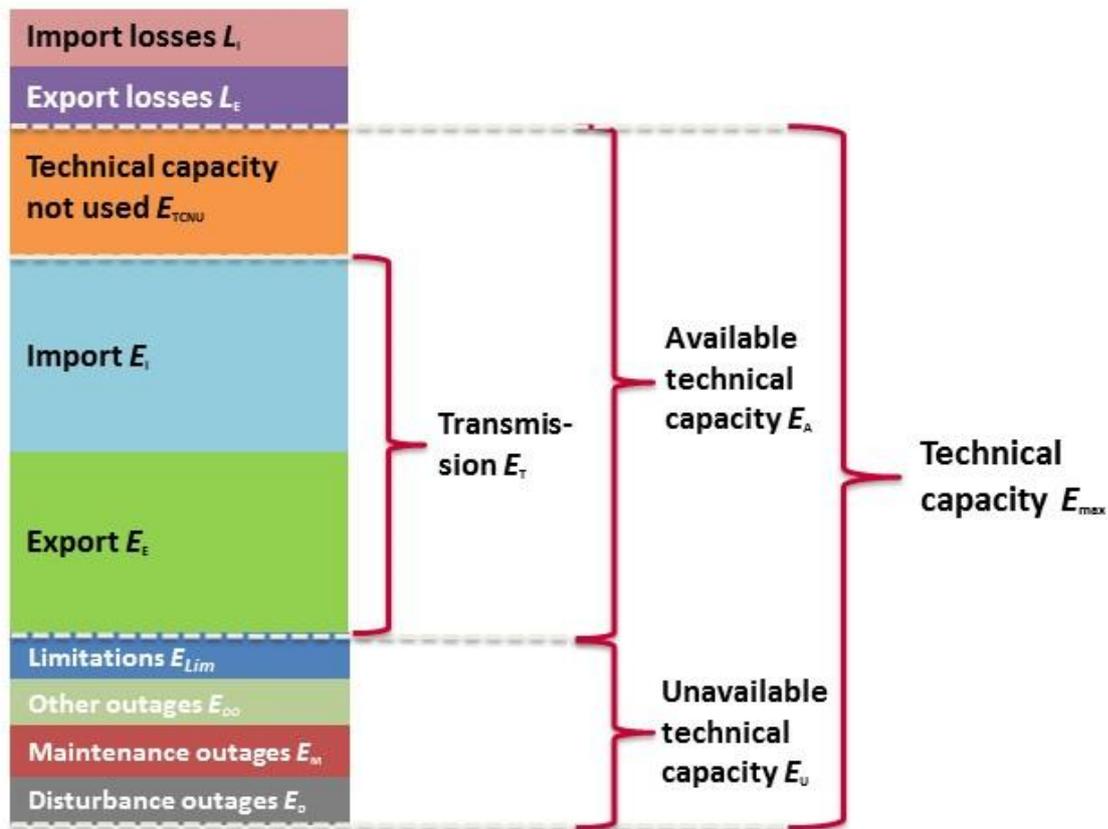


FIGURE 4.1 THE AVAILABILITY AND UTILISATION CATEGORIES USED IN THE HVDC STATISTICS. THE DEFINITIONS AND CALCULATIONS ARE EXPLAINED IN CHAPTER 4. EVERY VALUE IS AN ENERGY VALUE AND REPRESENTS A PART OF THE AVAILABLE OR UNAVAILABLE TECHNICAL CAPACITY. THE NINE CATEGORIES OF THE COLUMN TO THE LEFT ARE INTERNALLY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

The capacity used for transmission (E_T) is the sum of exported and imported energy:

$$E_T = E_E + E_I, \tag{4.2}$$

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, which are calculated by subtracting the received energy from the transferred energy. **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. It should be noted that these values are measurements and therefore considered factual.

An **outage** is when a component is partially or fully 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:

$$E_D = P_R \cdot h_D, \quad (4.3)$$

$$E_M = P_R \cdot h_M, \quad (4.4)$$

$$E_{OO} = P_R \cdot h_{OO}. \quad (4.5)$$

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})**:

$$E_{Lim} = P_{Lim} \cdot h_{Lim}. \quad (4.6)$$

The limited power capacity (P_{Lim}) describes the amount of power reduced from the rated power.

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.

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:

$$E_U = E_D + E_M + E_{OO} + E_{Lim} = P_R(h_D + h_M + h_{OO}) + P_{Lim} \cdot h_{Lim}. \quad (4.7)$$

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}** .

$$E_A = E_{max} - E_U = E_T + E_{TCNU}. \quad (4.8)$$

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

$$\begin{aligned} E_{TCNU} &= E_{max} - E_U - E_T \\ &= E_{max} - [P_R(h_D + h_M + h_{OO}) + P_{Lim} \cdot h_{Lim}] - [E_E + E_I]. \end{aligned} \quad (4.9)$$

However, there is an exception when calculating the technical capacity not used. If the **transmission (E_T)** and **unavailable technical capacity (E_U)** equals more than 90 % of the total **technical capacity (E_{max})**, then all of the remaining capacity is categorised as **limitations (E_{Lim})**. If this is not the case, no limitations are recorded and the remaining capacity is categorised as **technical capacity not used (E_{TCNU})**. That is:

$$E_{Lim} = E_{max} - E_D - E_M - E_{OO} - E_T, \quad \text{if } E_{max} \cdot 0.9 \leq E_T + E_U \quad (4.10)$$

$$E_{TCNU} = E_{max} - E_D - E_M - E_{OO} - E_T, \quad \text{otherwise.}$$

Technical capacity not used (E_{TCNU}) and limitations (E_{Lim}) are 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	Com-mis-sioning year	Market connec-tion (Y/N)	Type of HVDC con-verter	Rated power, mono-polar (MW)	Parallel monopolar capacity (MW)	Bipolar capac-ity (MW)	Defined ex-port direc-tion (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	400	1200	1200	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	700			N-S
Skagerrak 1	1976–	Y	LCC	250	1000	1000	N-S
Skagerrak 2	1977	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	1300			E-W

TABLE 5.2 TECHNICAL DETAILS OF THE HVDC LINES

Name of the link	Total length of the link (km)	Length of mass ca-ble (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 2015

6.1 INTRODUCTION

During 2015 there were 60 disturbance outages affecting the HVDC links connected to the Nordic power system. The disturbances caused a capacity reduction that corresponds to 1.4 TWh (1.7 %) of the total technical HVDC transmission capacity.

Maintenance outages amounted to 2.0 TWh (2.5 %), and limitations reduced the transmission capacity by 1.6 TWh (2.0 %) 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 2015 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.

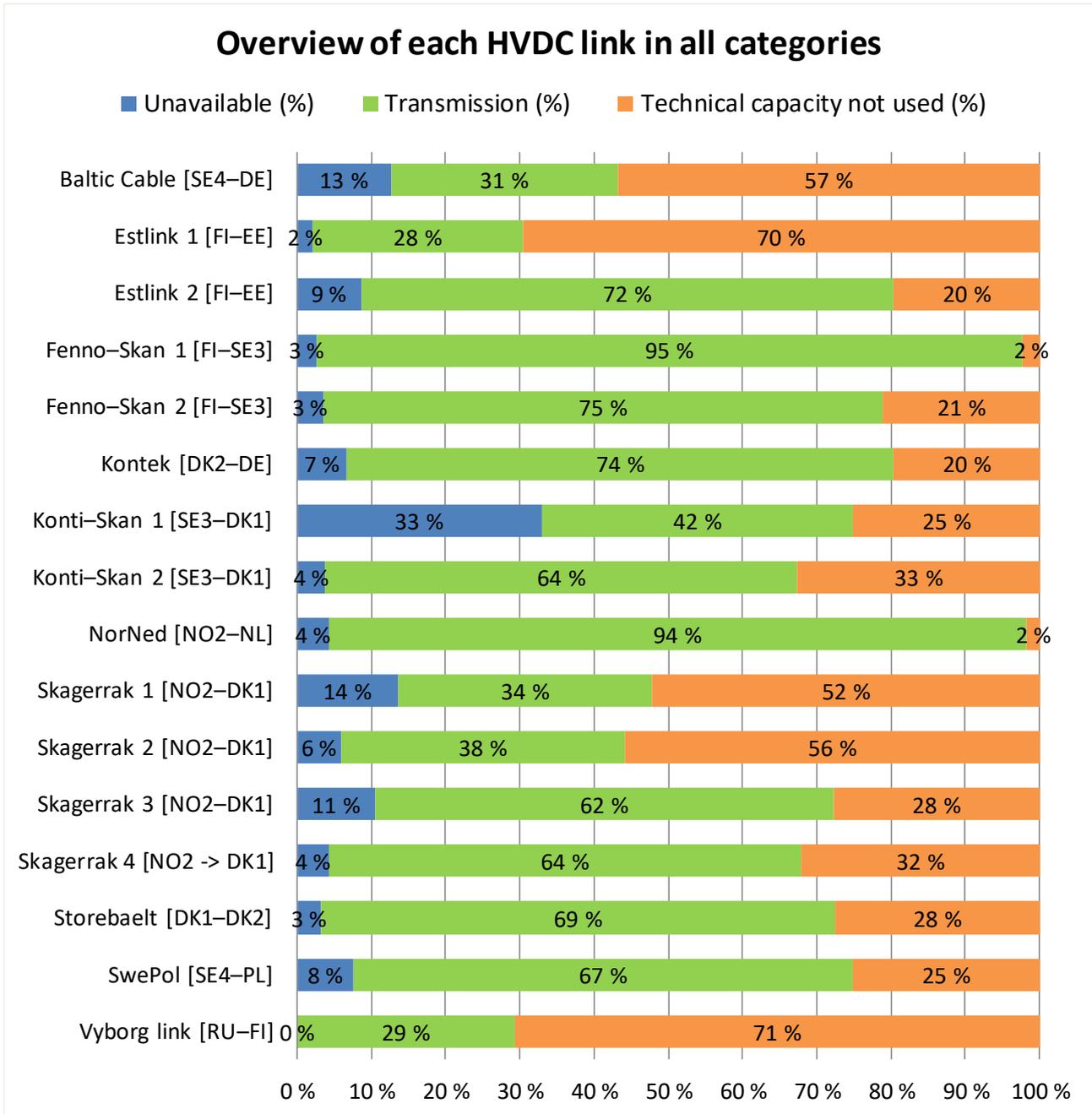


FIGURE 6.2.1 ANNUAL OVERVIEW OF THE AVAILABILITY AND UTILISATION OF EACH HVDC LINK IN 2015. THE CATEGORIES USED REFER TO THE METHODS, DEFINITIONS AND CALCULATIONS DEFINED IN CHAPTER 4.

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.

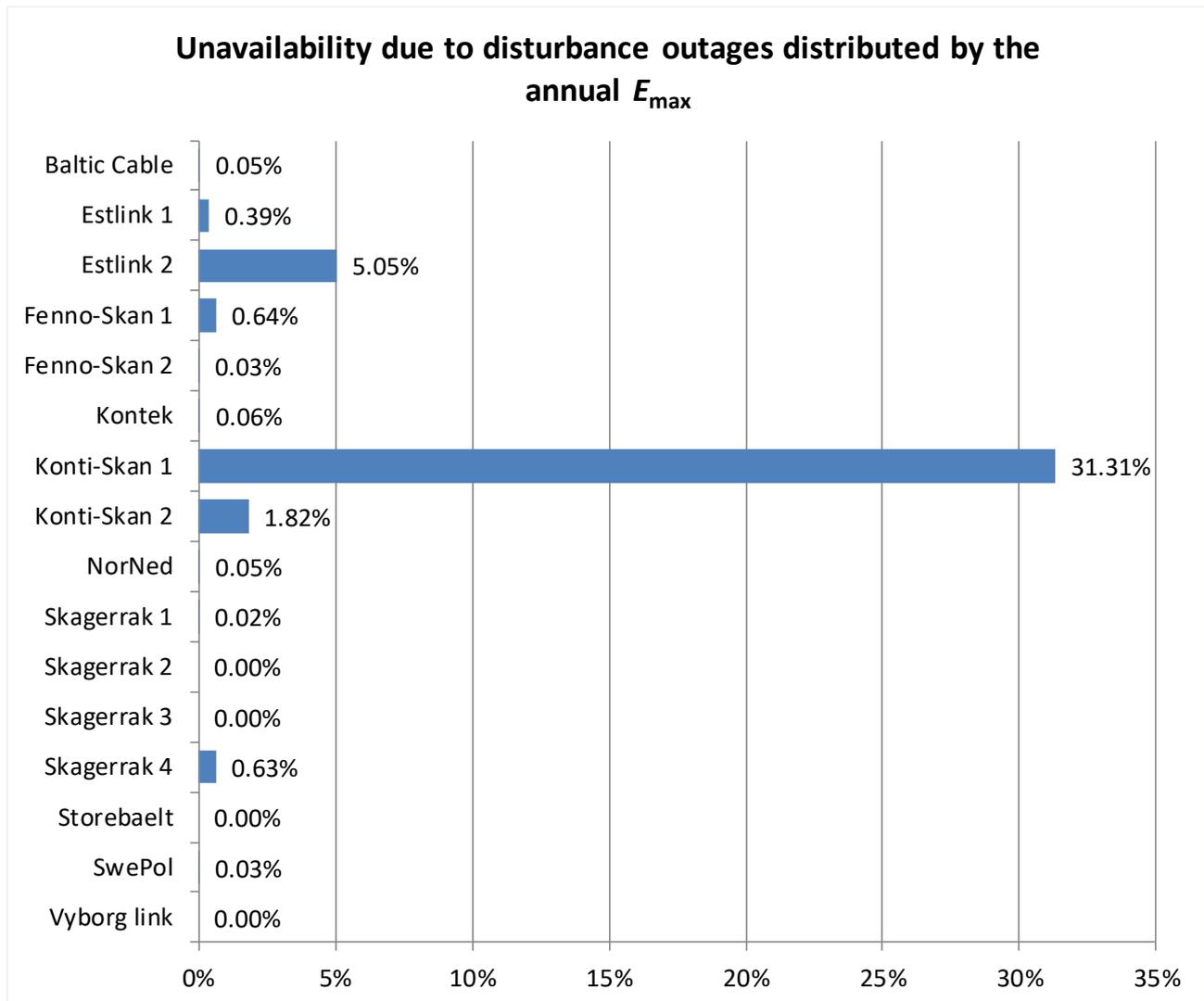


FIGURE 6.2.2 PERCENTAGE DISTRIBUTION OF UNAVAILABLE TECHNICAL CAPACITY E_U DUE TO DISTURBANCE OUTAGES FOR EACH LINK IN 2015

- 1) On 11 November 2014, Konti-Skan 1 had a transformer fault. The outage caused by the fault lasted to 24 April 2015. This transformer fault was the main cause for unavailability.
- 2) Estlink 2 had a cooling system leakage on 30 April, which caused an outage that lasted 18 days.

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

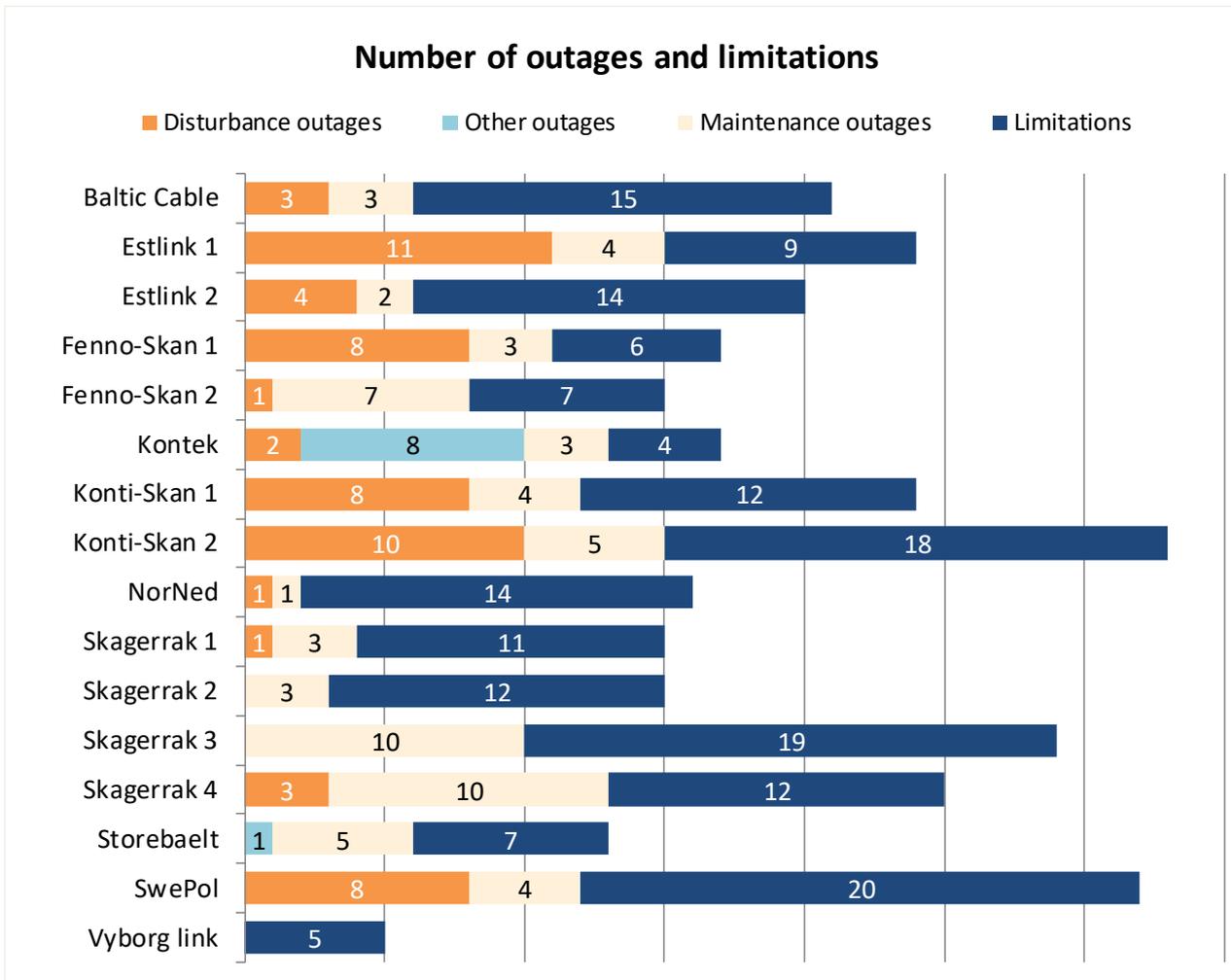


FIGURE 6.2.3 THE NUMBER OF OUTAGES AND LIMITATIONS FOR EACH LINK IN 2015

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 2015. 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.

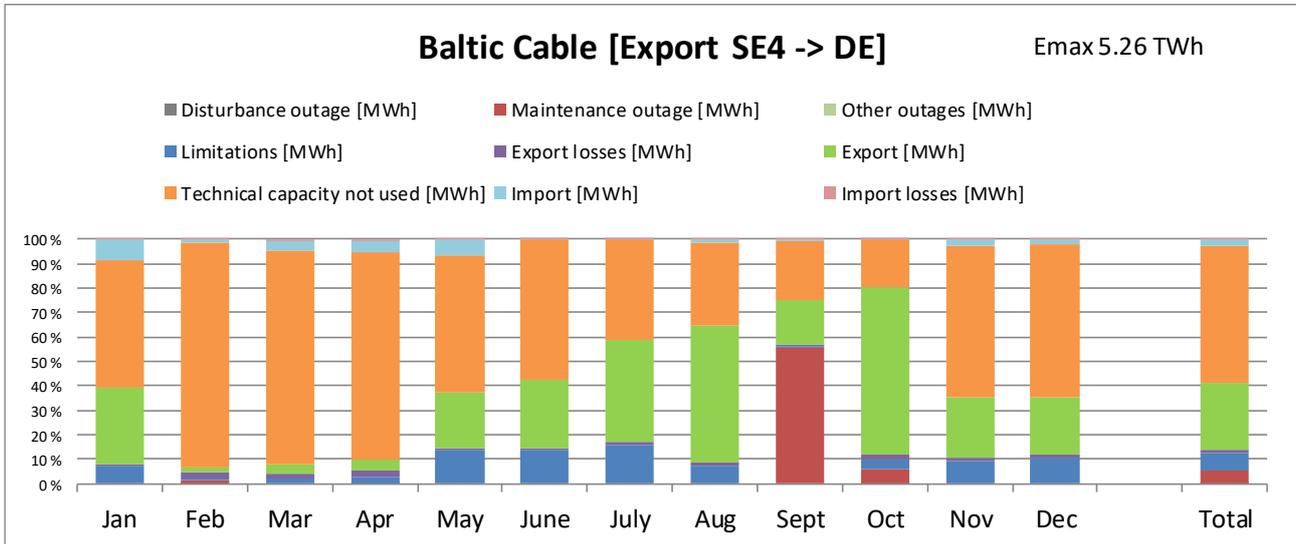


FIGURE 6.3.1 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR THE BALTIC CABLE IN 2015

Baltic Cable had an available technical capacity of 87 %. The technical capacity not used was 56 %. Totally, 1.5 TWh (28 % of the technical capacity) was exported from Sweden to Denmark and 144 GWh (2.7 % of the technical capacity) was imported to Sweden. Table 6.1 presents the numerical values behind Figure 6.3.1.

The annual maintenance outages lasted 18 days in September. Baltic Cable had three minor disturbances during year 2015.

TABLE 6.1 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR THE BALTIC CABLE IN 2015

Baltic Cable [SE4 -> DE]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	766	1194	3125	3322	582	8	23	136	55	39	266	178	0.2
Export losses [MWh]	4157	9538	6766	10936	3940	4523	5302	6218	2598	7585	5180	4818	1.4
Technical capacity not used [MWh]	237019	380340	398864	378831	252073	252364	184631	155155	106589	87589	272137	284573	56.8
Import [MWh]	36897	6131	18108	21299	29673	377	846	6325	2684	1994	11175	8154	2.7
Export [MWh]	140257	7478	19486	22589	102955	120734	188983	252174	78751	313226	108966	106941	27.8
Limitations [MWh]	32694	3014	9940	10353	61903	58685	72368	33630	4209	19971	40034	47020	7.5
Disturbance outage [MWh]	0	360	0	910	0	0	0	0	0	1555	0	0	0.1
Maintenance outage [MWh]	0	5877	0	0	0	0	0	0	240000	23972	0	0	5.1
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
P_r (600 MW)	446867	403200	446399	433981	446604	432160	446828	447284	432233	448305	432312	446688	101.5

6.3.2 ESTLINK 1

Figure 6.3.2 presents the availability and utilisation of Estlink 1 for 2015. 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.

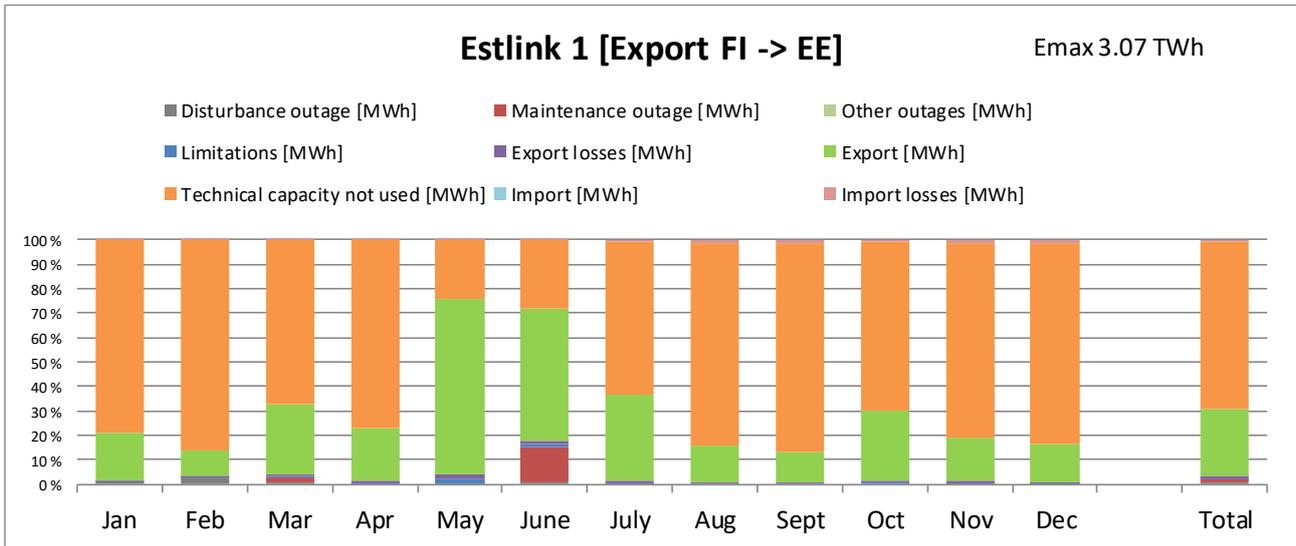


FIGURE 6.3.2 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR ESTLINK 1 IN 2015

In 2015, Estlink 1 had an available technical capacity of 98 %. The technical capacity not used was 70 %. Totally, 864 GWh (28 % of the technical capacity) was exported from Finland to Estonia and none was imported to Finland. Table 6.2 presents the numerical values behind Figure 6.3.2.

The annual maintenance outage lasted three days in June. There were 11 minor disturbance outages on Estlink 1.

TABLE 6.2 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR ESTLINK 1 IN 2015

Estlink 1 [FI -> EE]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	249	659	334	189	1080	44	1853	3182	3385	2732	3164	3421	0.7
Export losses [MWh]	2084	1355	2811	2345	4148	3629	3362	2186	1765	2911	2156	2077	1.0
Technical capacity not used [MWh]	207629	204097	176999	195538	63212	72706	167477	220260	219868	182740	205441	219046	69.6
Import [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Export [MWh]	50661	24958	74897	55859	191606	138113	92486	40140	32132	76844	45826	40861	28.2
Limitations [MWh]	343	271	1522	603	4660	3241	437	0	0	1166	733	493	0.4
Disturbance outage [MWh]	1767	5874	1289	0	922	1983	0	0	0	0	0	0	0.4
Maintenance outage [MWh]	0	0	5343	0	0	35957	0	0	0	0	0	0	1.3
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
P_r (350 MW)	260400	235200	260050	252000	260400	252000	260400	260400	252000	260750	252000	260400	101.7

6.3.3 ESTLINK 2

Figure 6.3.3 presents the availability and utilisation of Estlink 2 for 2015. Estlink 2 was commissioned in Feb 2014 but was available for the electricity markets during the test period 6 dec 2013 – 6 Feb 2014. 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.

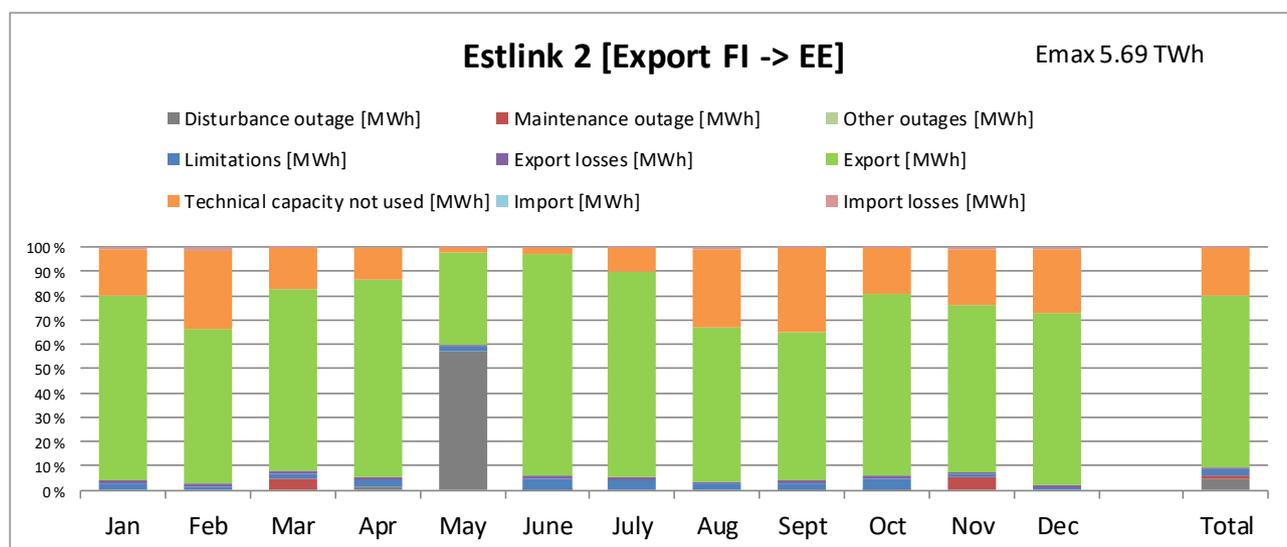


FIGURE 6.3.3 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR ESTLINK 2 IN 2015

In 2015, Estlink 2 had an available technical capacity of 91 %. The technical capacity not used was 20 %. Totally, 4.1 TWh (72 % of the technical capacity) was exported from Finland to Estonia and none was imported to Finland. Table 6.3 presents the numerical values behind Figure 6.3.3.

There were 4 disturbance outages on Estlink 2. All of them were minor except one in May which lasted 18 days. It was caused by a leakage in the valve cooling system which subsequently caused a flashover on the cable conduits.

Estlink 2 had two maintenance outages: one in March and one in November.

TABLE 6.3 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR ESTLINK 2 IN 2015

Estlink 2 [FI->EE]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	(% of E_{max})
Import losses [MWh]	2751	5458	489	0	0	0	238	4739	475	1296	4103	5950	0.4
Export losses [MWh]	6020	6055	7085	5554	2303	5557	5133	4631	5292	5153	5222	6040	1.1
Technical capacity not used [MWh]	94709	146320	85090	61978	9481	14887	48264	158210	165849	94224	108626	129072	19.6
Import [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Export [MWh]	376065	282764	364800	386382	185514	429603	414801	312181	289135	366801	328215	351647	71.8
Limitations [MWh]	12828	7716	9200	13328	11133	22921	20535	13209	11944	21431	7028	2881	2.7
Disturbance outage [MWh]	0	0	0	6381	277474	590	0	0	1072	1794	0	0	5.0
Maintenance outage [MWh]	0	0	23877	0	0	0	0	0	0	0	24131	0	0.8
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
P_r (650 MW)	483602	436801	482967	468069	483603	468001	483600	483600	468000	484250	468002	483600	101.6

6.3.4 FENNO-SKAN 1

Figure 6.3.4 presents the availability and utilisation of Fenno-Skan 1 for 2015. 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 decreased to 400 MW due to a cable issue for the year 2015.

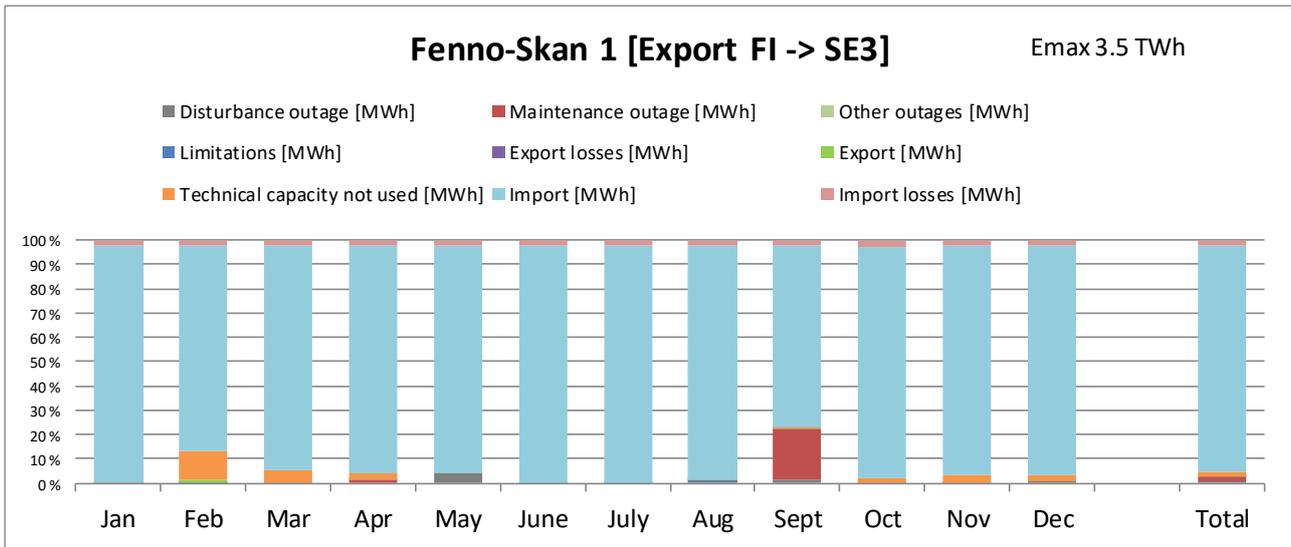


FIGURE 6.3.4 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR FENNO-SKAN 1 IN 2015

In 2015, Fenno-Skan 1 had an available technical capacity of 97 %. The technical capacity not used was 2.3 %. Totally, 3.8 GWh (0.1 % of the technical capacity) was exported from Finland to Sweden and 3.3 TWh (95 % of the technical capacity) was imported to Finland. Table 6.4 presents the numerical values behind Figure 6.3.4.

Fenno-Skan 1 had 8 disturbances in 2015 which caused only minor outages. The annual maintenance outage was between 21–27 September.

TABLE 6.4 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR FENNO-SKAN 1 IN 2015

Fenno-Skan 1 [FI -> SE3]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	7709	6001	7663	7291	7552	7232	7397	7203	5669	7758	7449	7458	2.5
Export losses [MWh]	0	111	0	0	0	0	0	0	2	0	0	0	0.0
Technical capacity not used [MWh]	766	31815	15477	8596	974	0	0	1029	909	6016	9795	6783	2.3
Import [MWh]	297712	232981	281758	276656	285552	288661	298316	293833	221160	292653	278453	288362	95.0
Export [MWh]	0	3830	0	0	0	0	0	0	2	0	0	0	0.1
Limitations [MWh]	26	174	766	36	173	1	3	12	5	263	468	132	0.1
Disturbance outage [MWh]	0	612	0	0	11834	0	0	3412	3685	0	0	3029	0.6
Maintenance outage [MWh]	0	0	0	3597	0	0	0	0	62767	0	0	0	1.9
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
P_r (400 MW)	298504	269411	298001	288885	298533	288661	298319	298286	288528	298931	288717	298306	100.0

6.3.5 FENNO-SKAN 2

Figure 6.3.5 presents the availability and utilisation of Fenno-Skan 2 for 2015. 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.

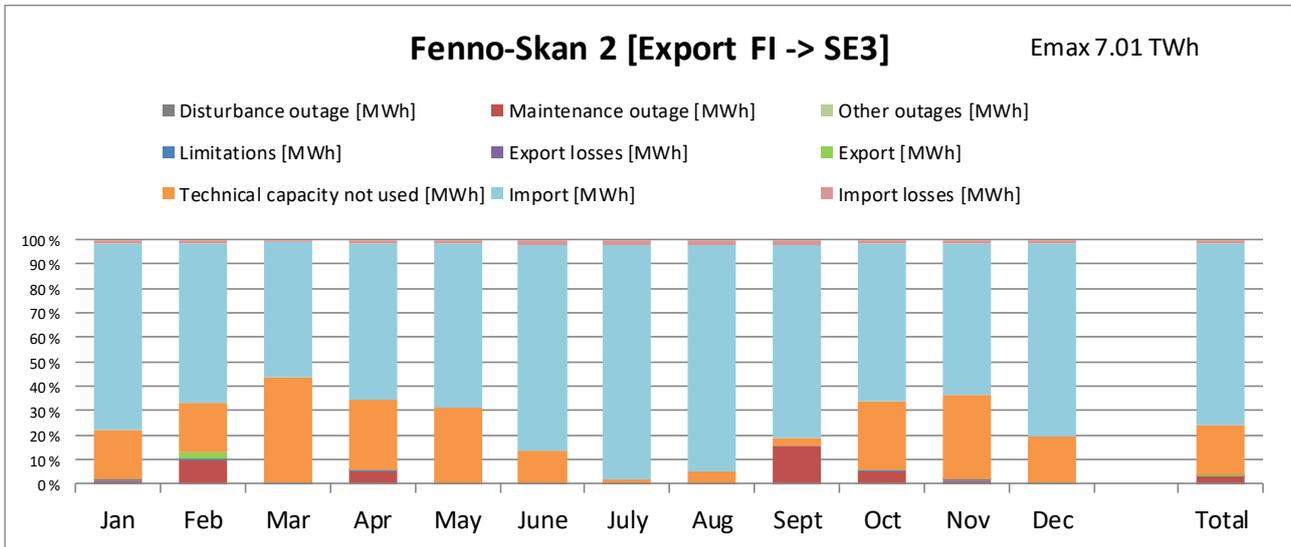


FIGURE 6.3.5 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR FENNO-SKAN 2 IN 2015

In 2015, Fenno-Skan 2 had an available technical capacity of 97 %. The technical capacity not used was 21 %. Totally, 19 GWh (0.3 % of the technical capacity) was exported from Finland to Sweden and 5.3 TWh (75 % of the technical capacity) was imported to Finland. Table 6.5 presents the numerical values behind Figure 6.3.5.

Fenno-Skan 1 had only 1 disturbance outage. The annual maintenance outage was between 26 September and 2 October.

TABLE 6.5 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR FENNO-SKAN 2 IN 2015

Fenno-Skan 2 [FI -> SE3]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	9931	7646	5978	7835	8823	11114	13990	13355	11339	8448	7906	10377	1.7
Export losses [MWh]	0	300	1	0	0	0	0	0	0	0	46	43	0.0
Technical capacity not used [MWh]	124778	110757	259974	168560	186792	77630	11809	31092	20782	168026	200203	116187	21.1
Import [MWh]	460133	357717	330539	374669	407504	497014	583072	563941	464277	392878	363290	475276	75.2
Export [MWh]	3	14204	67	13	0	0	0	0	0	1	2568	2262	0.3
Limitations [MWh]	2048	1343	1632	1469	1027	1522	524	553	869	2307	906	1558	0.2
Disturbance outage [MWh]	0	0	2240	0	0	0	0	0	0	0	0	0	0.0
Maintenance outage [MWh]	8398	53712	0	31401	0	0	0	0	90400	33004	9121	0	3.2
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
P_r (800MW)	595360	537734	594452	576112	595323	576166	595405	595586	576329	596216	576088	595283	101.7

6.3.6 KONTEK

Figure 6.3.6 presents the availability and utilisation of Kontek for 2015. 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.

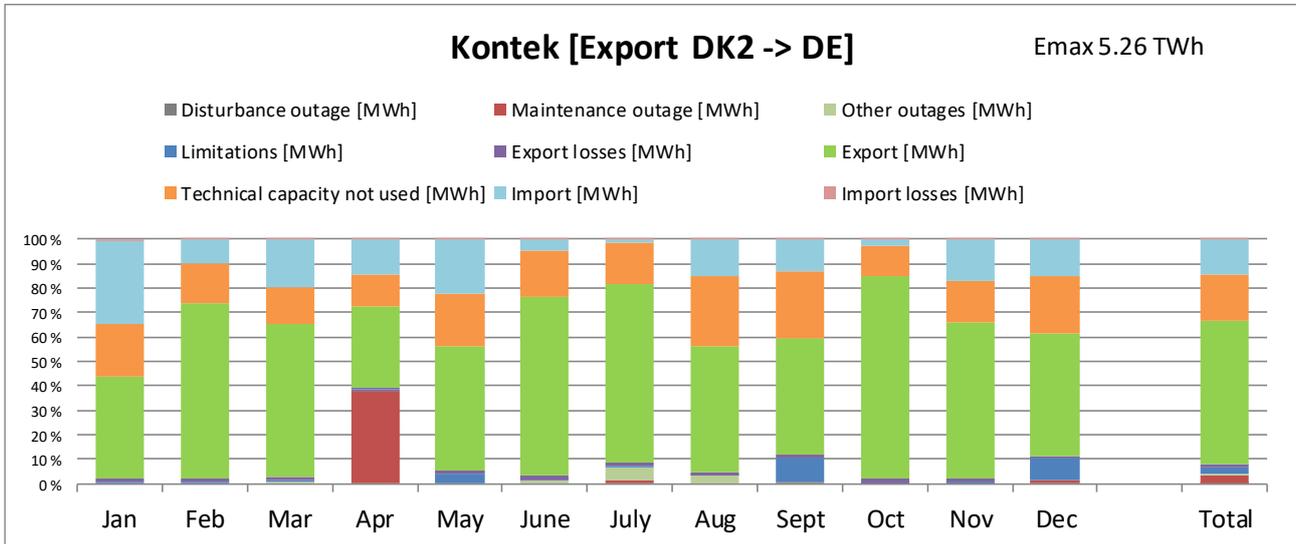


FIGURE 6.3.6 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR KONTEK IN 2015

In 2015, Kontek had an available technical capacity of 93 %. The technical capacity not used was 20 %. Totally, 3.1 TWh (59 % of the technical capacity) was exported from Denmark to Germany and 0.7 TWh (14 % of the technical capacity) was imported to Denmark. Table 6.6 presents the numerical values behind Figure 6.3.6.

There were 2 minor disturbance outages in on Kontek. The annual maintenance outage was from 13 April to 24 April.

TABLE 6.6 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR KONTEK IN 2015

Kontek [DK2 -> DE]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	3373	960	2091	1448	1997	426	156	1357	1215	250	1600	1433	0.3
Export losses [MWh]	4285	6559	6553	3144	4811	6754	7042	4828	4202	7669	5649	4245	1.3
Technical capacity not used [MWh]	97015	67543	67988	56063	98283	83454	75718	128690	119762	56432	74359	106563	19.6
Import [MWh]	154864	40387	86973	62148	98566	21395	7824	67187	55784	11843	73423	68125	14.2
Export [MWh]	189930	292708	285151	146583	231249	320612	331147	234733	210365	377201	279922	224928	59.4
Limitations [MWh]	4591	2562	3891	2100	18596	1647	1813	1923	43628	1525	3706	40216	2.4
Disturbance outage [MWh]	0	0	0	0	0	0	0	0	2507	0	590	0	0.1
Maintenance outage [MWh]	0	0	0	165304	0	0	4817	0	0	0	0	6569	3.4
Other outages [MWh]	0	0	1797	0	0	5400	25723	14162	0	0	0	0	0.9
P_r (600MW)	446400	403200	445800	432198	446693	432507	447042	446694	432047	447001	432000	446400	101.6

6.3.7 KONTI-SKAN 1

Figure 6.3.7 presents the availability and utilisation of Konti-Skan 1 for 2015. 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.

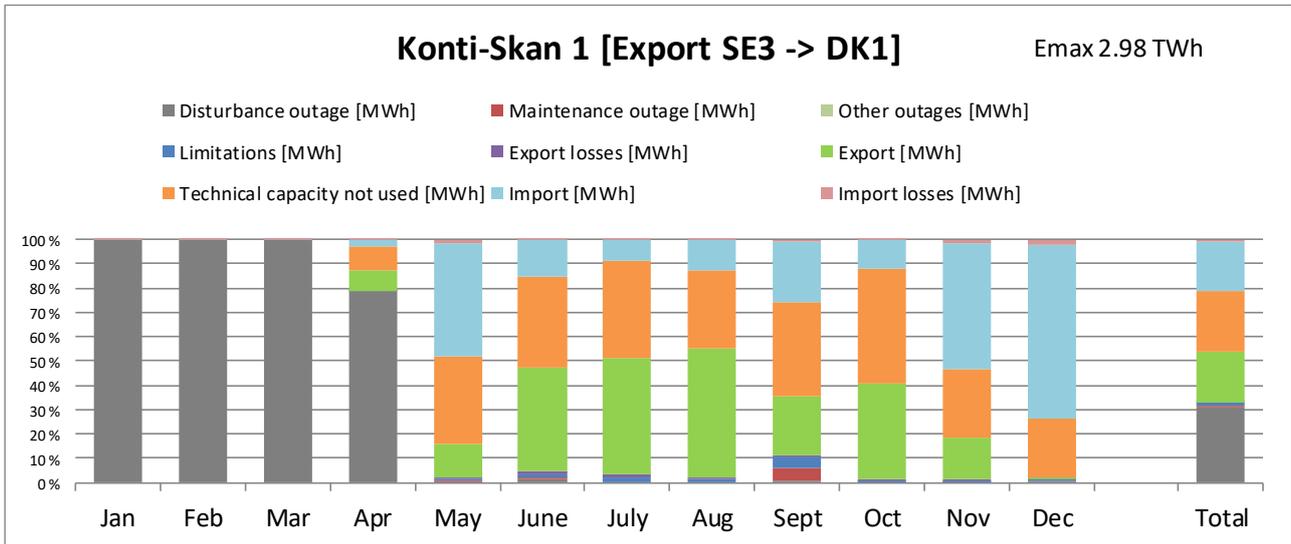


FIGURE 6.3.7 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR KONTI-SKAN 1 IN 2015

In 2015, Konti-Skan 1 had an available technical capacity of 67 % and the technical capacity not used was 25 %. Totally, 0.6 TWh (21 % of the technical capacity) was exported from Sweden to Denmark and 0.6 TWh (21 % of the technical capacity) was imported to Sweden. The available technical capacity of the link was 5 percentage points lower in comparison with 2014. Table 6.7 presents the numerical values behind Figure 6.3.7.

There were 8 disturbance outages on Konti-Skan 1, of which the most severe was due to a transformer failure in Sweden which started in November 2014 and ended 24 April 2015. The annual maintenance was performed in September.

TABLE 6.7 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR KONTI-SKAN 1 IN 2015

Konti-Skan 1 [SE3 -> DK1]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of Emax)
Import losses [MWh]	16	12	9	169	3431	1053	551	883	1889	815	3622	5201	0.6
Export losses [MWh]	1	0	0	377	876	2180	2344	2832	1381	1982	859	38	0.4
Technical capacity not used [MWh]	0	0	0	24294	94761	92721	102353	82598	95339	121888	71966	62927	25.1
Import [MWh]	16	12	9	6285	120717	37519	22461	32345	62967	29647	129678	188118	21.1
Export [MWh]	0	0	0	20818	35915	106208	122248	134992	60468	99598	42940	2328	20.9
Limitations [MWh]	0	0	0	344	914	3004	5935	3275	12484	2314	1097	1251	1.0
Disturbance outage [MWh]	252944	228468	252611	193097	0	3859	0	0	1642	24	1081	1697	31.3
Maintenance outage [MWh]	0	0	0	0	2839	2034	0	0	12707	0	0	0	0.6
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
P_r (370 MW)	252960	228480	252620	244837	255146	245346	252997	253211	245607	253471	246762	256321	101.0

6.3.8 KONTI-SKAN 2

Figure 6.3.8 presents the availability and utilisation of Konti-Skan 2 for 2015. 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.

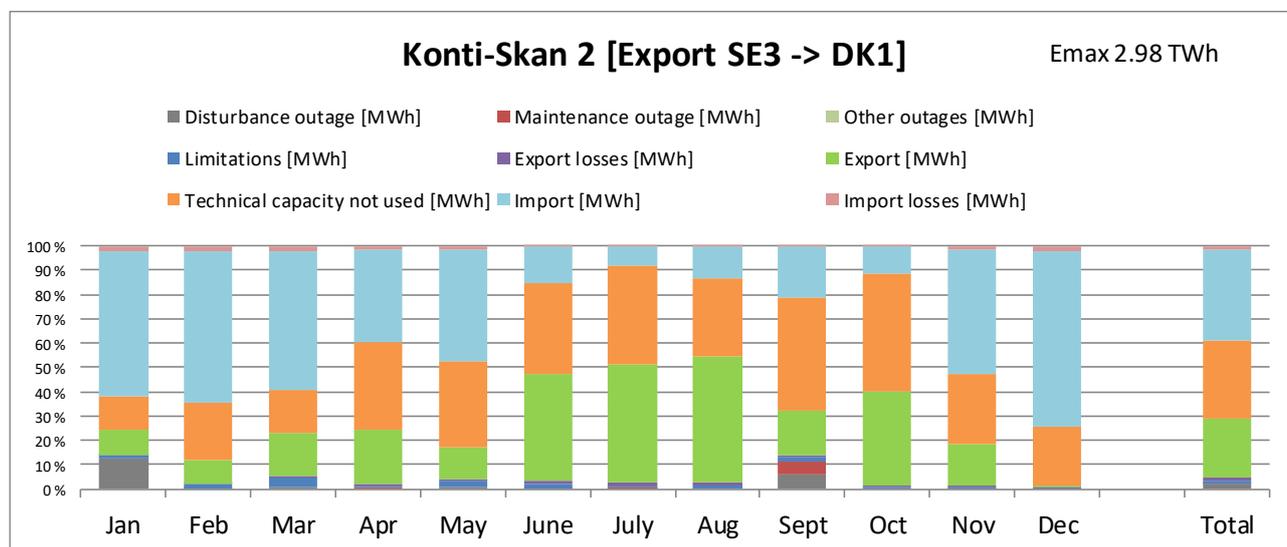


FIGURE 6.3.8 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR KONTI-SKAN 2 IN 2015

In 2015, Konti-Skan 2 had an available technical capacity of 96 % and the technical capacity not used was 33 %. Totally, 0.7 TWh (25 % of the technical capacity) was exported from Sweden to Denmark and 1.2 TWh (39 % of the technical capacity) was imported to Sweden. The available technical capacity of the link was 17 percentage points higher in comparison with 2014. Table 6.8 presents the numerical values behind Figure 6.3.8.

There were 10 disturbance outages on Konti-Skan 2 of which the longest lasted three days in January. The annual maintenance was performed in September.

TABLE 6.8 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR KONTI-SKAN 2 IN 2015

Konti-Skan 2 [SE3 -> DK1]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	(of Emax)
Import losses [MWh]	6294	5833	5863	3613	3207	965	460	860	1365	647	3322	4859	1.2
Export losses [MWh]	1051	847	1728	1873	973	2992	3338	3876	1254	2649	1156	49	0.7
Technical capacity not used [MWh]	35679	55043	45726	90264	92979	93491	103791	82110	116010	124915	72243	62921	32.6
Import [MWh]	155677	146516	149142	96431	119909	37551	21016	34113	50526	28543	129802	188837	38.7
Export [MWh]	26584	22420	46204	55562	34431	109841	124508	134458	46685	98775	42514	2229	24.9
Limitations [MWh]	2177	4247	10109	1821	6852	4545	1053	2970	5431	1375	1346	1160	1.4
Disturbance outage [MWh]	33211	481	2013	0	2372	0	928	0	14379	0	975	0	1.8
Maintenance outage [MWh]	0	0	0	1360	0	419	1930	0	12915	0	0	0	0.6
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
P_r (370 MW)	253328	228708	253193	245437	256544	245848	253225	253652	245946	253607	246880	255147	102.0

6.3.9 NORNED

Figure 6.3.9 presents the availability and utilisation of NorNed for 2015. 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.

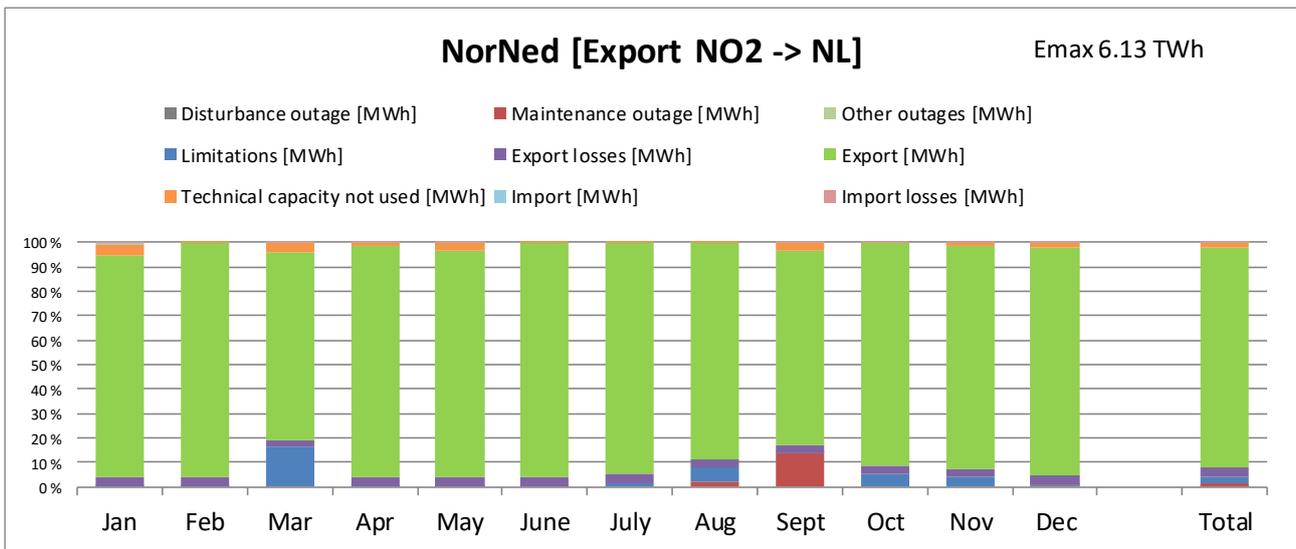


FIGURE 6.3.9 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR NORNED IN 2015

In 2015, NorNed had had an available technical capacity of 96 %. The technical capacity not used was 1.8 %. Totally, 5.8 TWh (94 % of the technical capacity) was exported from Norway to the Netherlands and 11 GWh (0.2 % of the technical capacity) was imported to Norway.

Table 6.9 presents the numerical values behind Figure 6.3.9.

There was 1 disturbance outage on NorNed with minor significance. The annual maintenance outage lasted five days in the beginning of September.

TABLE 6.9 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR NORNED IN 2015

NorNed [NO2 -> NL]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	160	0	70	7	54	0	0	0	2	0	0	77	0.0
Export losses [MWh]	19464	18732	14308	19661	20035	20248	20458	18481	16455	19428	18569	20343	3.7
Technical capacity not used [MWh]	23675	2330	20894	7826	16050	392	481	1280	18535	1885	7223	8159	1.8
Import [MWh]	4830	0	2307	244	1590	0	0	0	4	0	0	2208	0.2
Export [MWh]	492823	469410	410396	497091	504579	505306	515242	478266	414502	494936	477477	508856	93.8
Limitations [MWh]	921	105	87112	528	362	213	7071	32712	1552	27352	20671	351	2.9
Disturbance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	2816	0.0
Maintenance outage [MWh]	0	0	0	0	0	0	0	10500	71355	0	0	0	1.3
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
P_r (700 MW)	522249	471844	520710	505689	522580	505911	522794	522758	505948	524172	505372	522389	103.7

6.3.10 SKAGERRAK 1

Figure 6.3.10 presents the availability and utilisation of Skagerrak 1 for 2015. 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.

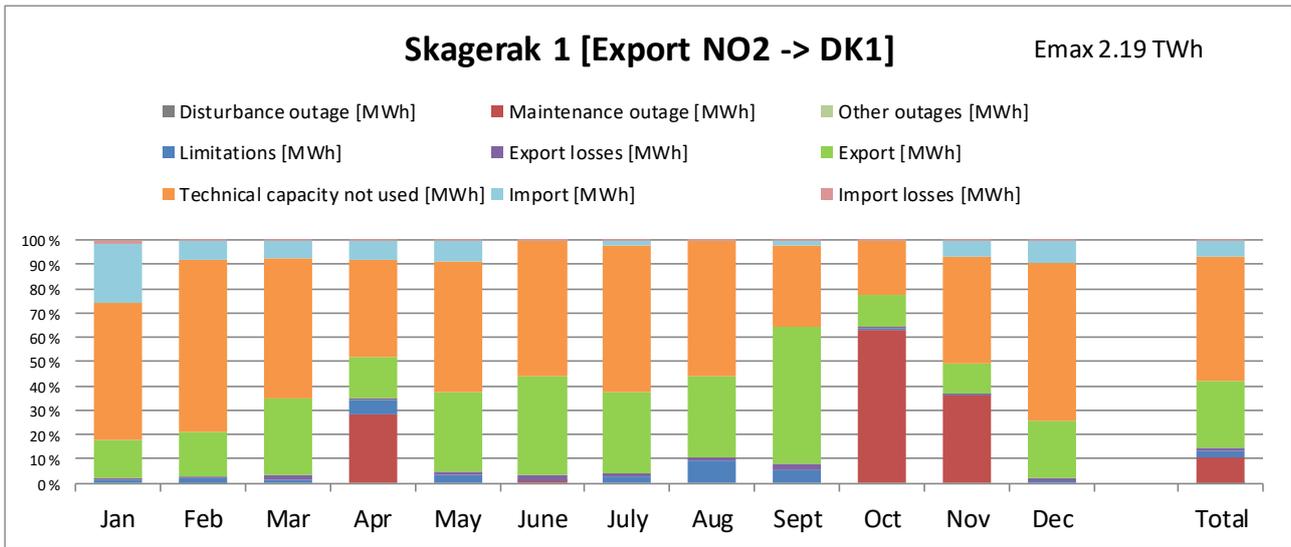


FIGURE 6.3.10 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR SKAGERRAK 1 IN 2015

In 2015, Skagerrak 1 had an available technical capacity of 86 %. The technical capacity not used was 52 %. Totally, 0.6 TWh (28 % of the technical capacity) was exported from Norway to the Denmark and 0.1 TWh (6.3 % of the technical capacity) was imported to Norway. Table 6.10 presents the numerical values behind Figure 6.3.10.

There was 1 disturbance outage with minor significance on Skagerrak 1. There were 3 maintenance outages with the longest lasting from 12 October to 11 November. The annual maintenance was performed in April.

TABLE 6.10 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR SKAGERRAK 1 IN 2015

Skagerrak 1 [NO2 -> DK1]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	2551	789	797	846	835	148	318	111	261	49	660	961	0.4
Export losses [MWh]	1235	1172	2995	1373	3022	3826	3145	3084	5313	1309	1007	2205	1.4
Technical capacity not used [MWh]	107049	120797	108976	72504	102634	102382	114344	106231	61454	42051	80307	123319	52.1
Import [MWh]	46817	12751	13292	14419	15216	741	3988	42	3845	49	11251	16412	6.3
Export [MWh]	29534	30653	60427	30773	62092	74991	62880	62281	104787	25143	22338	44851	27.9
Limitations [MWh]	2600	3343	3054	10940	6058	932	4788	17446	9915	367	764	1418	2.8
Disturbance outage [MWh]	0	456	0	0	0	0	0	0	0	0	0	0	0.0
Maintenance outage [MWh]	0	0	0	51364	0	954	0	0	0	118641	65340	0	10.8
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
P_r (250 MW)	186000	168000	185750	180000	186000	180000	186000	186000	180001	186250	180000	186000	101.7

6.3.11 SKAGERRAK 2

Figure 6.3.11 presents the availability and utilisation of Skagerrak 2 for 2015. 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.

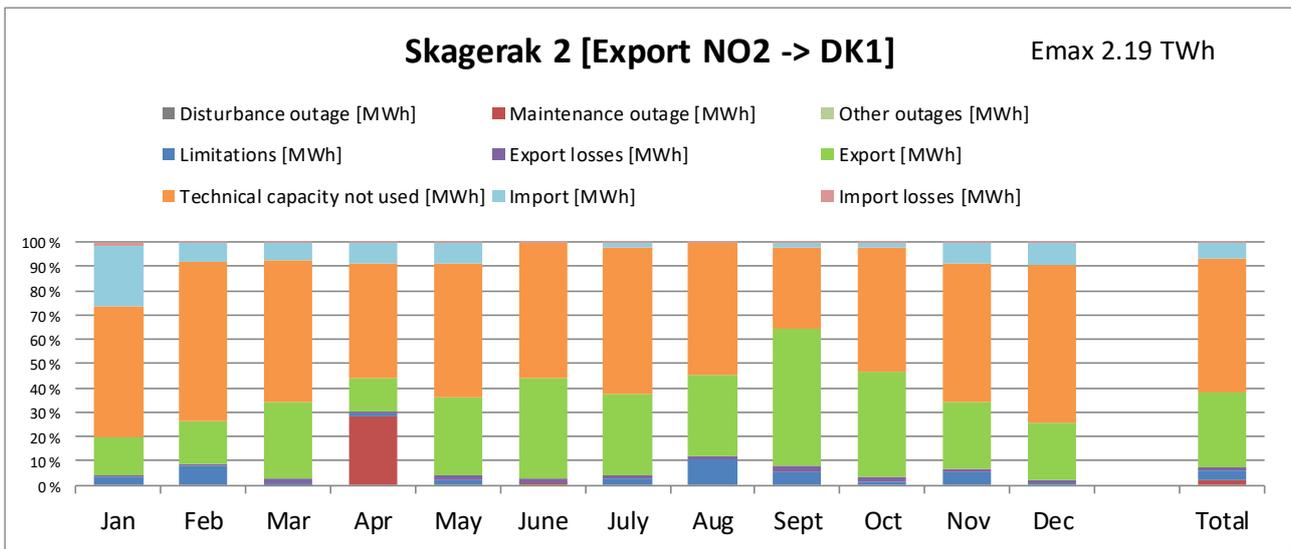


FIGURE 6.3.11 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR SKAGERRAK 2 IN 2015

In 2015, Skagerrak 2 had an available technical capacity of 94 %. The technical capacity not used was 56 %. Totally, 0.7 TWh (32 % of the technical capacity) was exported from Norway to the Denmark and 0.1 TWh (6.7 % of the technical capacity) was imported to Norway. Table 6.11 presents the numerical values behind Figure 6.3.11.

There were no disturbance outages with minor significance on Skagerrak 2. There were 3 maintenance outages. The annual maintenance was performed between 22–30 April.

TABLE 6.11 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR SKAGERRAK 2 IN 2015

Skagerrak 2 [NO2 -> DK1]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	%(of E_{max})
Import losses [MWh]	2604	817	795	863	899	143	289	82	256	281	908	994	0.4
Export losses [MWh]	1249	1176	3044	1088	2967	3809	3127	3059	5096	4366	2576	2267	1.5
Technical capacity not used [MWh]	101804	110822	110362	86807	104576	102441	114397	103607	61733	98335	104598	123166	55.8
Import [MWh]	47513	13286	13374	14544	15229	741	3976	17	3870	3560	15014	16509	6.7
Export [MWh]	29892	30793	60295	24451	62031	75113	62978	62329	104898	81910	50283	45089	31.5
Limitations [MWh]	6791	13110	1064	2202	4164	751	4650	20047	9499	2641	10104	1236	3.5
Disturbance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Maintenance outage [MWh]	0	0	660	51997	0	954	0	0	0	0	0	0	2.4
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
P_r (250 MW)	186000	168010	185755	180000	186000	180000	186001	186001	180001	186446	180000	186001	102.0

6.3.12 SKAGERRAK 3

Figure 6.3.12 presents the availability and utilisation of Skagerrak 3 for 2015. 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.

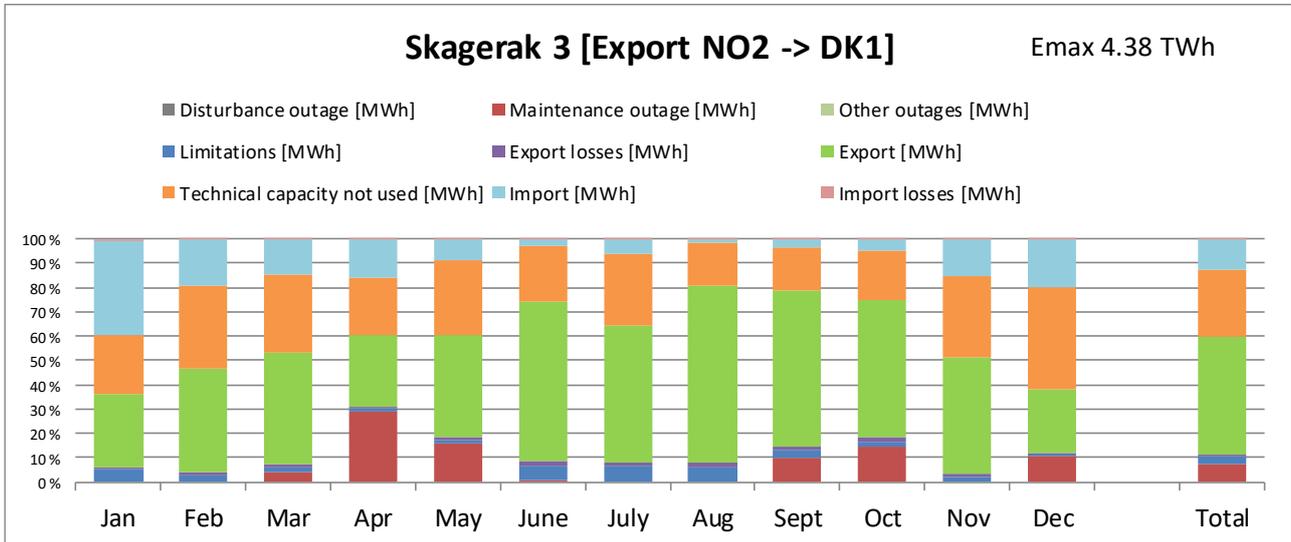


FIGURE 6.3.12 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR SKAGERRAK 3 IN 2015

In 2015, Skagerrak 3 had an available technical capacity of 89 %. The technical capacity not used was 28 %. Totally, 2.2 TWh (49 % of the technical capacity) was exported from Norway to Denmark and 0.6 TWh (13 % of the technical capacity) was imported to Norway. Table 6.12 presents the numerical values behind Figure 6.3.12.

There were no disturbance outages on Skagerrak 3. There were 10 maintenance outages, which mainly aimed to improve bipolarity capabilities with Skagerrak 4. The annual maintenance was performed between 22 April and 5 April.

TABLE 6.12 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR SKAGERRAK 3 IN 2015

Skagerrak 3 [NO2 -> DK1]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	4099	1690	1487	1573	877	257	609	127	342	532	1521	1981	0.3
Export losses [MWh]	2741	3390	4068	2592	3724	5951	5178	6718	5763	5576	4474	2285	1.2
Technical capacity not used [MWh]	92639	117312	119632	87289	115639	84855	112376	68404	65291	75733	122428	155755	27.8
Import [MWh]	145704	63519	54141	55484	32250	10024	22352	5315	11783	18866	53756	73822	12.5
Export [MWh]	114539	145156	173758	107685	158572	240553	212834	275389	234544	214692	176798	99058	49.2
Limitations [MWh]	19158	10012	9680	4761	6240	22659	24440	22893	11658	7703	7019	3426	3.4
Disturbance outage [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Maintenance outage [MWh]	0	0	14289	104780	59300	1909	0	0	36724	55885	0	39938	7.1
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
P_r (500 MW)	372040	336000	371500	360000	372000	360000	372002	372000	360000	372881	360000	372000	101.5

6.3.13 SKAGERRAK 4

Figure 6.3.13 presents the availability and utilisation of Skagerrak 4 for 2015. Skagerrak 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 700 MW.

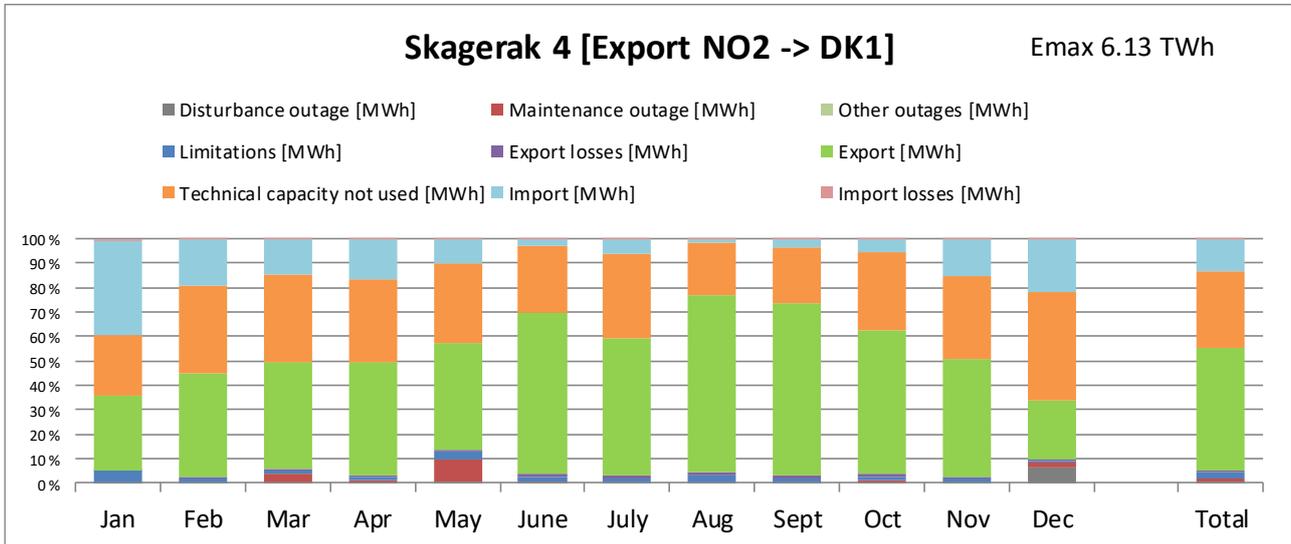


FIGURE 6.3.13 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR SKAGERRAK 4 IN 2015

In 2015, Skagerrak 4 had an available technical capacity of 96 %. The technical capacity not used was 32 %. Totally, 3.1 TWh (51 % of the technical capacity) was exported from Norway to the Denmark and 0.8 TWh (13 % of the technical capacity) was imported to Norway. Table 6.13 presents the numerical values behind Figure 6.3.13.

There were 3 minor disturbance outages Skagerrak 4. There were 10 maintenance outages, which mainly aimed to improve bipolarity capabilities with Skagerrak 3. The annual maintenance was performed 24 April and 5–8 May.

TABLE 6.13 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR SKAGERRAK 4 IN 2015

Skagerrak 4 [NO2 -> DK1]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	%(of E_{max})
Import losses [MWh]	4972	2178	1910	2080	1281	372	819	183	416	671	1883	2696	0.3
Export losses [MWh]	3031	3704	4182	4402	4160	6263	5381	6959	6666	5253	4317	2334	0.9
Technical capacity not used [MWh]	128677	169715	189995	173246	174536	140946	182715	112491	115940	170888	174732	233944	32.1
Import [MWh]	204632	89915	75165	82853	49995	14327	31913	7626	16572	27035	75646	110393	12.8
Export [MWh]	161643	202701	228416	234826	229289	336109	295455	383311	362687	309250	245144	127441	50.8
Limitations [MWh]	25682	8069	6375	6106	13953	9968	10717	17372	8802	8595	8478	4593	2.1
Disturbance outage [MWh]	456	0	0	0	4832	0	0	0	0	0	0	33420	0.6
Maintenance outage [MWh]	0	0	20148	6969	48195	2649	0	0	0	6258	0	11009	1.6
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
P_r (700 MW)	521091	470400	520100	504000	520800	504000	520800	520800	504000	522026	504000	520800	101.2

6.3.14 STOREBAELT

Figure 6.3.14 presents the availability and utilisation of Storebaelt for 2015. 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.

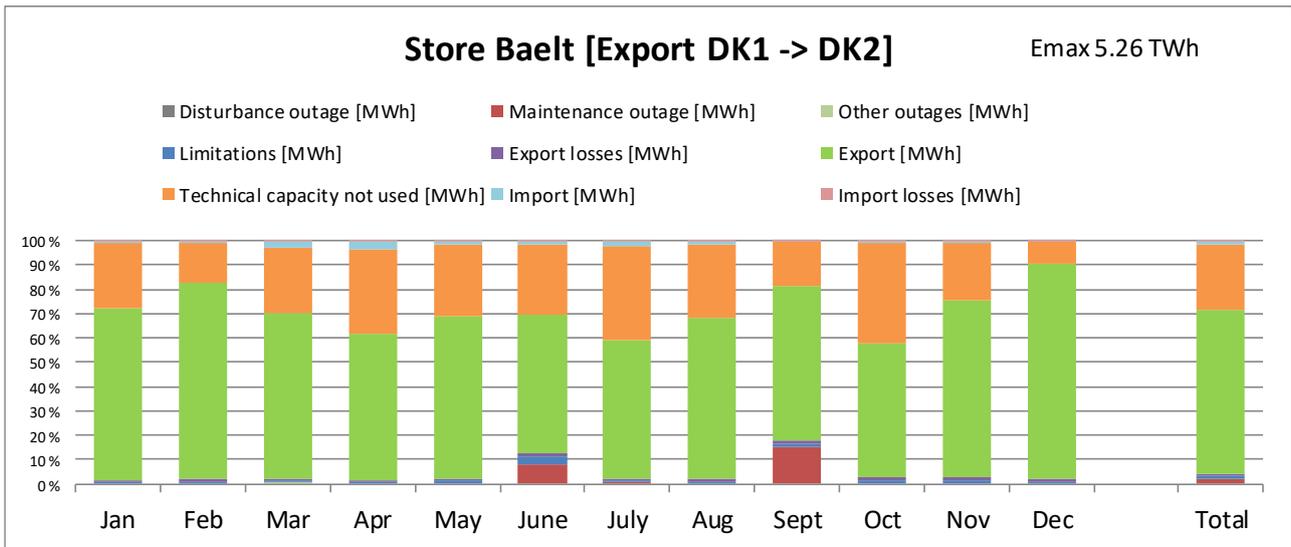


FIGURE 6.3.14 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR STOREBELT IN 2015

In 2015, Storebaelt had an available technical capacity of 97 %. The technical capacity not used was 28 %. Totally, 3.6 TWh (68 % of the technical capacity) was exported from Jutland to Zealand and 0.1 TWh (1.4 % of the technical capacity) was imported to Jutland. Table 6.14 presents the numerical values behind Figure 6.3.14.

There were no disturbance outages and 5 maintenance outages on Storebaelt. Faulty cooling was replaced in June and generic maintenance was done in September.

TABLE 6.14 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR IN 2015

Storebaelt [DK1 -> DK2]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	62	41	178	248	140	117	150	98	27	140	82	13	0.0
Export losses [MWh]	5291	5493	5087	4328	5034	4218	4274	5016	4768	4099	5399	6922	1.1
Technical capacity not used [MWh]	121271	68350	123217	152496	134572	126432	175659	136860	79564	185704	102499	41099	27.5
Import [MWh]	3659	2645	11501	15759	6783	5593	9137	5611	764	4979	5190	459	1.4
Export [MWh]	319184	328420	305620	260893	299565	250593	256335	300728	279112	249091	319050	401572	67.9
Limitations [MWh]	2649	4157	3324	3160	5843	13760	3141	3515	6024	7402	5442	3760	1.2
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	35967	2320	0	67077	0	0	0	2.0
Other outages [MWh]	0	0	2420	0	0	0	0	0	0	0	0	0	0.0
P_r (600 MW)	446764	403572	446082	432307	446763	432345	446592	446715	432541	447177	432181	446889	101.2

6.3.15 SWEPOL

Figure 6.3.15 presents the availability and utilisation of SwePol for 2015. 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 Stårnö and in Poland (bidding zone PL) to Slupsk. The transmission capacity is 600 MW.

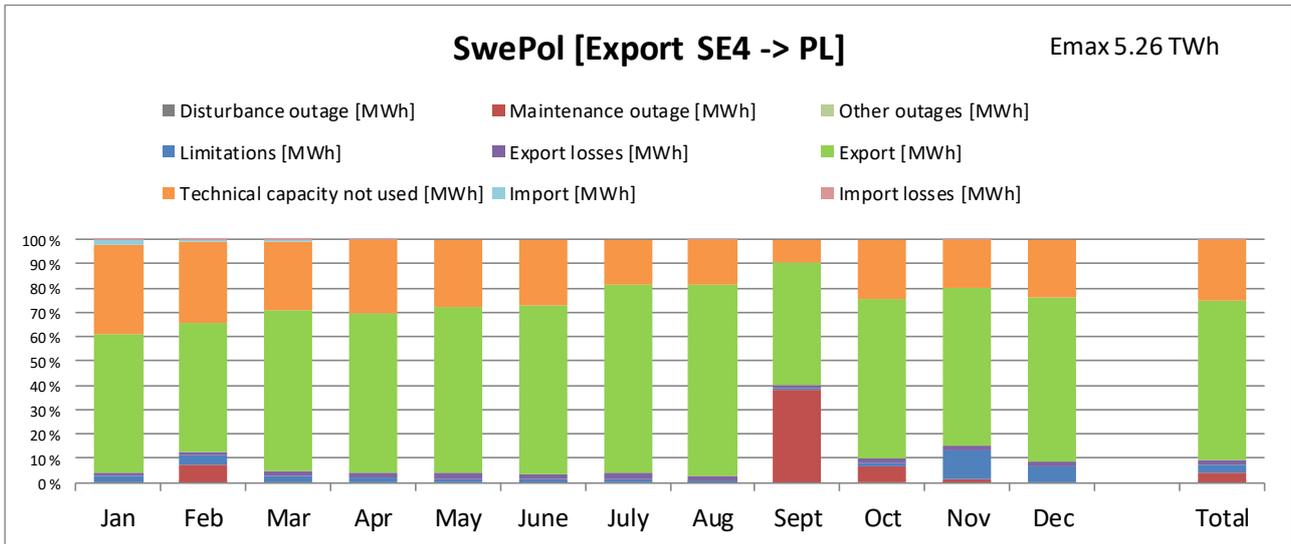


FIGURE 6.3.15 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR SWEPOL IN 2015

In 2015, SwePol had an available technical capacity of 92 %. The technical capacity not used was 25 %. Totally, 3.5 TWh (67 % of the technical capacity) was exported from Sweden to Poland and 20 GWh (0.4 % of the technical capacity) was imported to Sweden. Table 6.15 presents the numerical values behind Figure 6.3.15.

There were 8 disturbance outages with minor significance on SwePol. There were 4 maintenance outages of which the annual maintenance was the longest one and was performed between 19 September and 2 October. There was also maintenance on the Polish side during February.

TABLE 6.15 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR SWEPOL IN 2015

SwePol [SE4 -> PL]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [MWh]	200	84	87	52	0	0	0	6	0	0	25	0	0.0
Export losses [MWh]	7310	6033	8733	8356	9080	8891	10038	10353	6184	8440	7762	8402	1.9
Technical capacity not used [MWh]	168426	135663	126609	130196	127185	118123	84174	84470	40621	112632	85841	108516	25.2
Import [MWh]	8880	3714	4010	2205	0	0	0	246	0	0	1139	0	0.4
Export [MWh]	257125	218323	302067	289875	311199	306327	354847	358915	221251	298068	285862	307823	66.8
Limitations [MWh]	11969	16010	13128	9724	8023	7548	7402	2817	2107	7005	52984	30060	3.2
Disturbance outage [MWh]	0	693	0	0	0	33	0	14	72	0	790	0	0.0
Maintenance outage [MWh]	0	28797	0	0	0	0	0	0	168000	29295	5385	0	4.4
Other outages [MWh]	0	0	0	0	0	0	0	0	0	0	0	0	0.0
P_r (600 MW)	446400	403200	445814	432000	446407	432031	446424	446463	432051	447000	432000	446400	101.9

6.3.16 VYBORG LINK

Figure 6.3.16 presents the availability and utilisation of the Vyborg Link for 2015. 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.

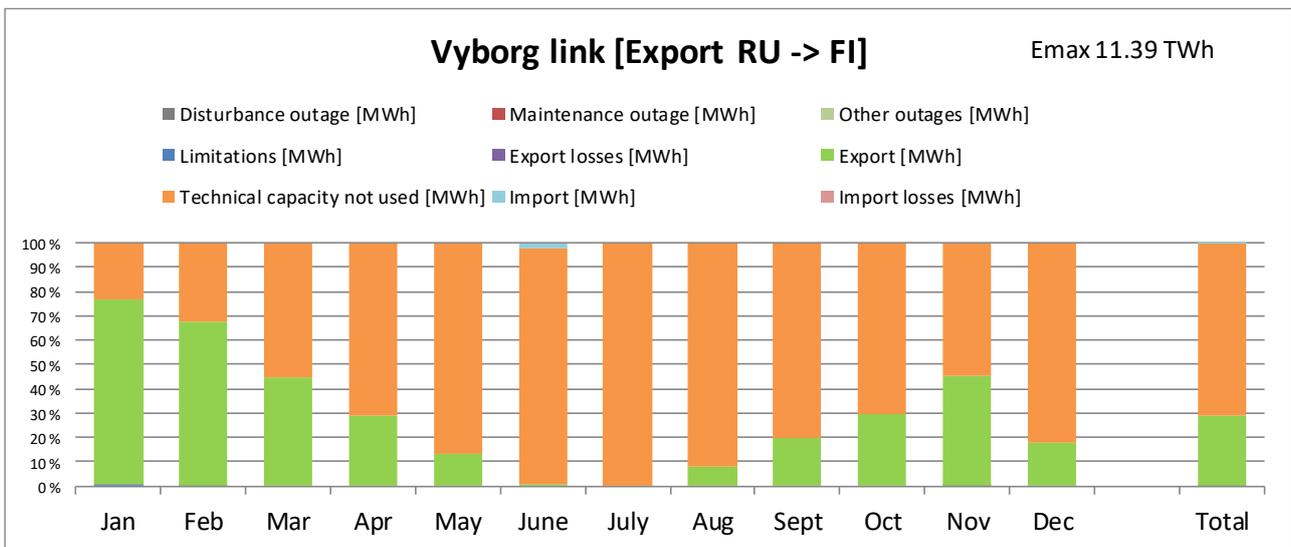


FIGURE 6.3.16 PERCENTAGE DISTRIBUTION OF THE AVAILABILITY AND UTILISATION CATEGORIES DEFINED IN CHAPTER 4 ACCORDING TO MONTH FOR VYBORG LINK IN 2015

In 2015, the Vyborg Link had an available technical capacity of 100 %. The technical capacity not used was 71 %. Totally, 3.3 TWh (29 % of the technical capacity) was exported from Russia to Finland and 22 GWh (0.2 % of the technical capacity) was imported to Russia. Table 6.16 presents the numerical values behind Figure 6.3.16.

There were no disturbance outages on the Vyborg link. Maintenance work did not cause any outages but caused minor limitations instead.

TABLE 6.16 MONTHLY DISTRIBUTION OF THE TECHNICAL CAPACITY E_{MAX} FOR VYBORG LINK IN 2015

Vyborg link [RU -> FI]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	% (of E_{max})
Import losses [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	0	0	0	0	0	0.0
Technical capacity not used [MWh]	221699	281565	534200	662530	841450	909347	967200	892420	753720	680380	508765	796843	70.7
Import [MWh]	0	0	0	0	0	21573	0	0	0	0	0	0	0.2
Export [MWh]	740437	591460	431700	273470	125750	5080	0	74780	182280	288120	426835	170357	29.1
Limitations [MWh]	5064	575	0	0	0	0	0	0	0	0	400	0	0.1
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
P_r (1300 MW)	967200	873600	965900	936000	967200	936000	967200	967200	936000	968500	936000	967200	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 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.

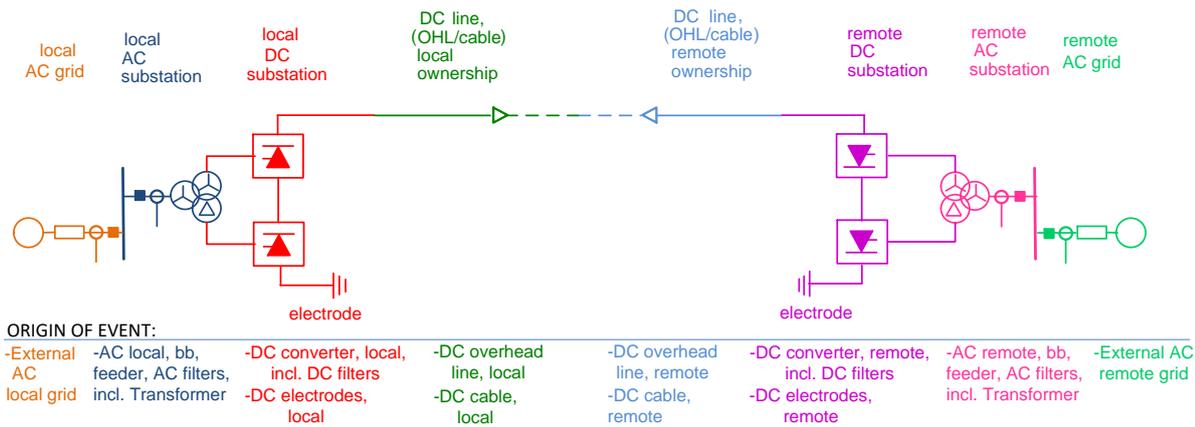


FIGURE A-1 A SCHEMATIC PRESENTATION OF A HVDC LINK WITH LINE COMMUTATED CONVERTERS (LCC)

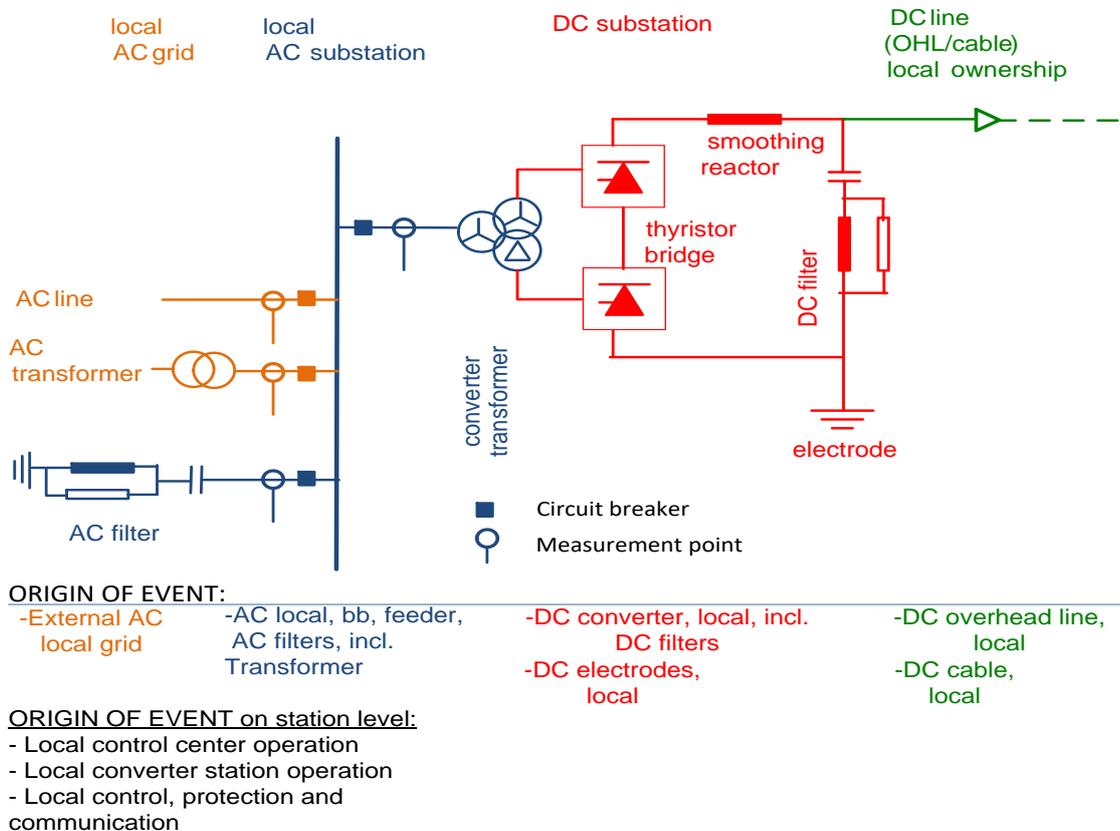


FIGURE A-2 A CONVERTER STATION OF A LINE COMMUTATED CONVERTER HVDC LINK WITH THE CONNECTION TO THE AC GRID

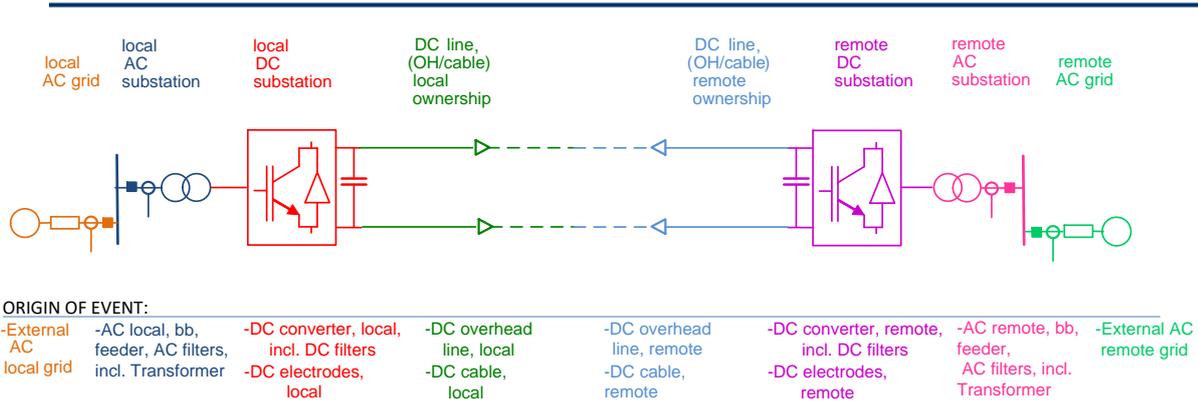


FIGURE A-3 A SCHEMATIC PRESENTATION OF A HVDC LINK WITH VOLTAGE SOURCE CONVERTERS (VSC)

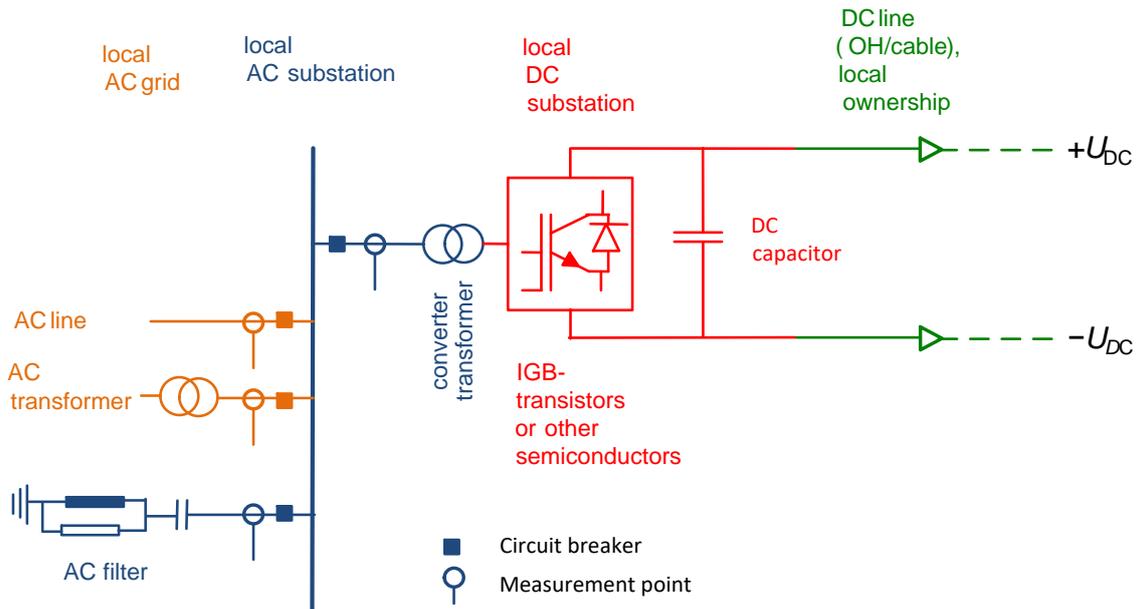


FIGURE A-4 A CONVERTER STATION OF A VOLTAGE SOURCE CONVERTER HVDC LINK WITH THE CONNECTION TO THE AC GRID

Appendix B CONTACT PERSONS

- Denmark: Anders Bratløv
Energinet.dk
Tonne Kjærsvej 65, DK-7000 Fredericia
Tel. +45 51 38 01 31
E-mail: anv@energinet.dk
- Estonia: Kaur Krusell and Raul Uuring
Elering AS
Kadaka tee 42, Tallinn, Estonia
Tel. +372 5648 6011 (K.K)
E-mail: kaur.krusell@elering.ee
Tel. +372 529 6214 (R.U.)
E-mail: raul.uuring@elering.ee
- Finland: Markku Piironen
Fingrid Oyj
Läkkisepäntie 21, P.O. Box 530, FI-00101 Helsinki
Tel. +358 30 395 4172, Mobile +358 40 351 1718
E-mail: markku.piironen@fingrid.fi
- Norway: Jørn Schaug-Pettersen and Christian Melaaen
Statnett SF
Postboks 4904 Nydalen, NO-0423 Oslo
Tel. +47 23 90 35 55, Fax +47 22 52 70 01 (J.S-P)
Tel. +47 23 90 41 53, Mobile +47 91 31 40 58 (C.M)
E-mail: jsp@statnett.no or christian.melaaen@statnett.no
- Sweden: Svenska kraftnät
Sturegatan 1, P.O. Box 1200, SE-172 24 Sundbyberg
Hampus Bergquist
Tel. +46 10 475 84 48, Mobile: +46 72 515 90 70
E-mail: hampus.bergquist@svk.se
Tarek Tallberg
Tel. +46 10 475 86 79, Mobile: Tel. +46 72 244 96 97
E-mail: tarek.tallberg@svk.se
- Production of the report:
Henrik Hillner
Hillner Consulting
Tel. +358 41 505 7004
E-mail: henrik.hillner@hillner.fi

Appendix C ANNUAL OVERVIEW OF ALL HVDC DATA WITH SORTED CATEGORIES

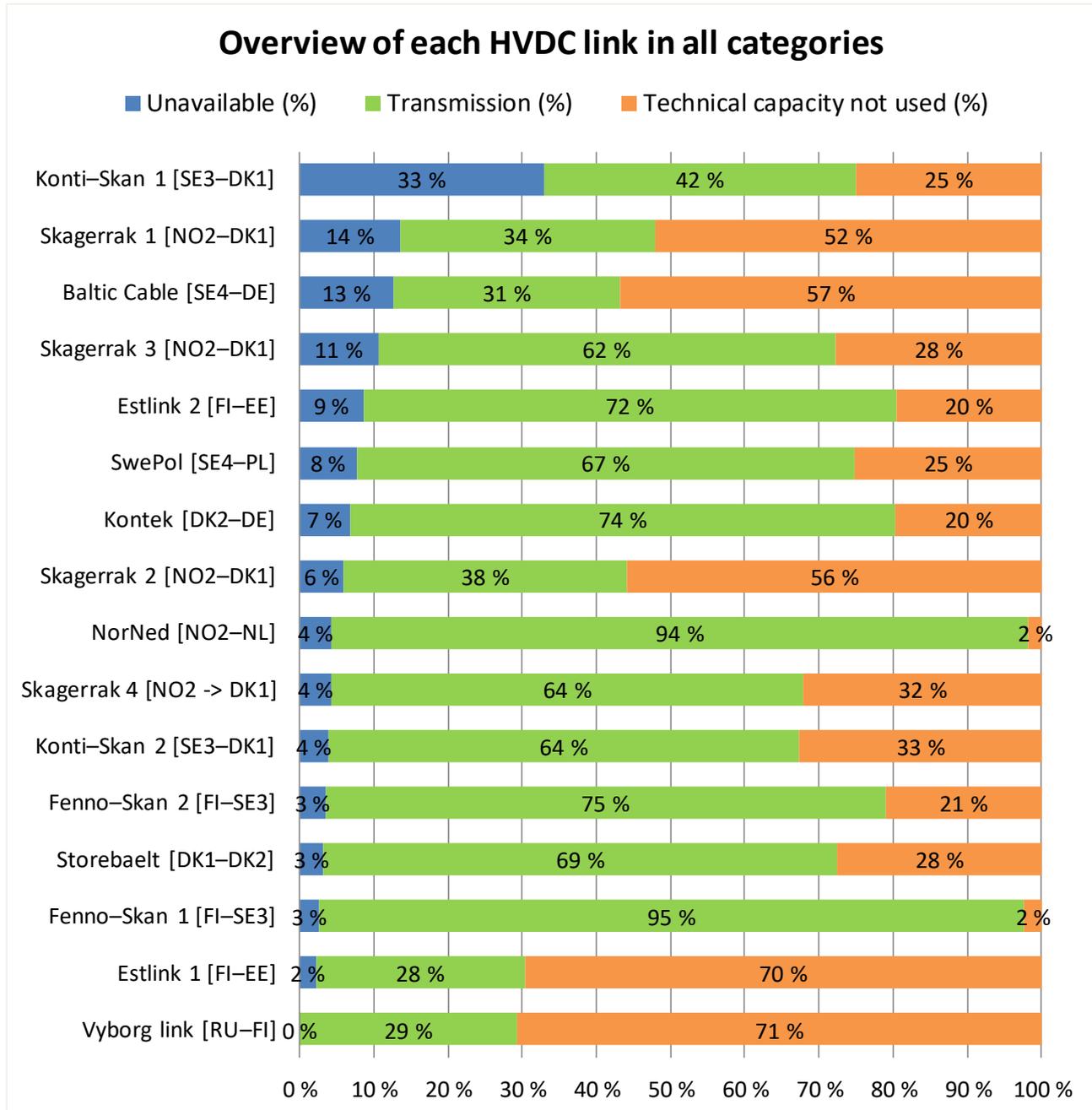


FIGURE C-1 ANNUAL OVERVIEW OF EACH HVDC LINK SORTED BY DESCENDING UNAVAILABLE TECHNICAL CAPACITY (E_U) IN 2015

Overview of each HVDC link in all categories

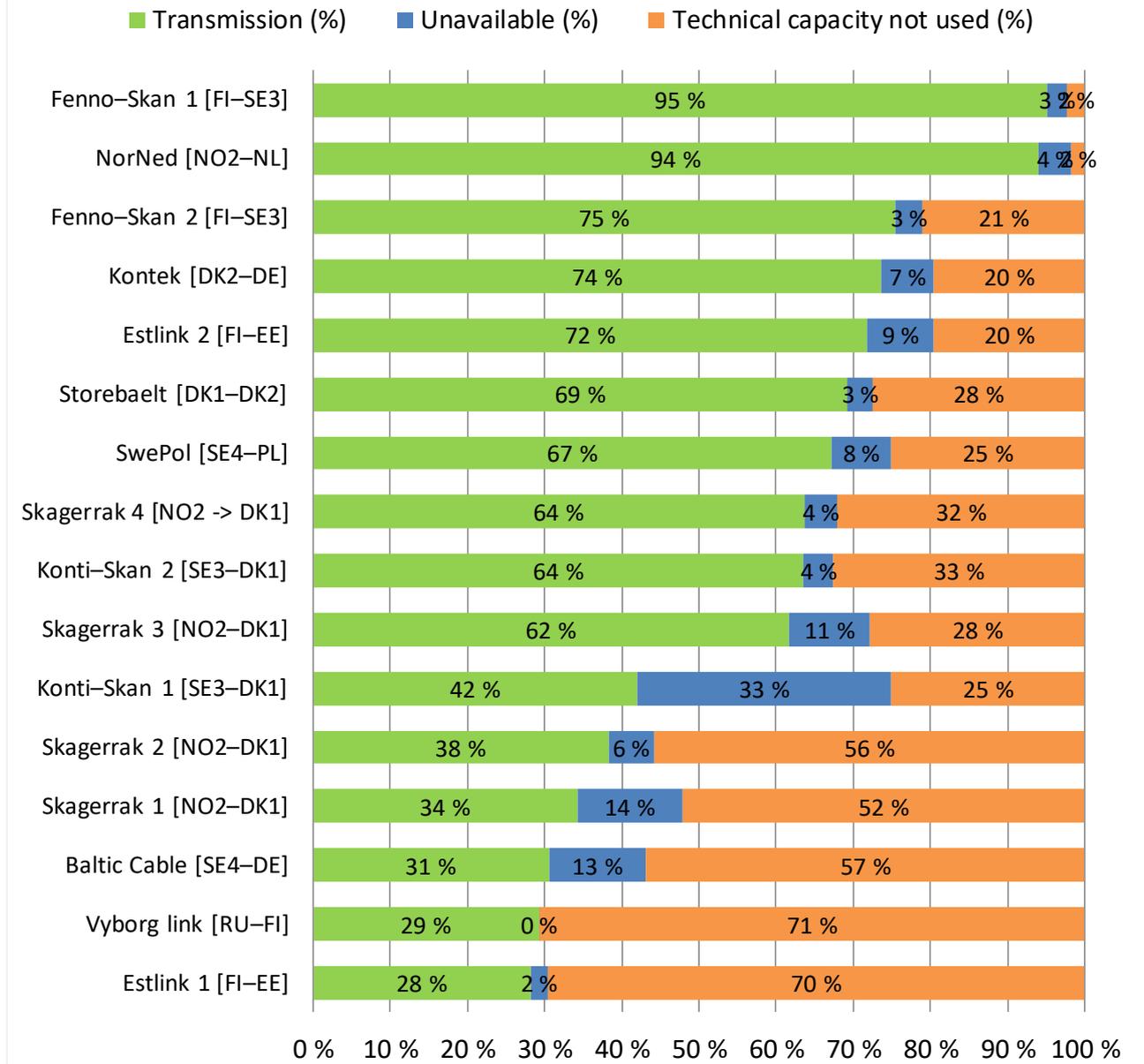


FIGURE C-2 ANNUAL OVERVIEW OF EACH HVDC LINK SORTED BY DESCENDING TRANSMISSION (E_T) IN 2015

Overview of each HVDC link in all categories

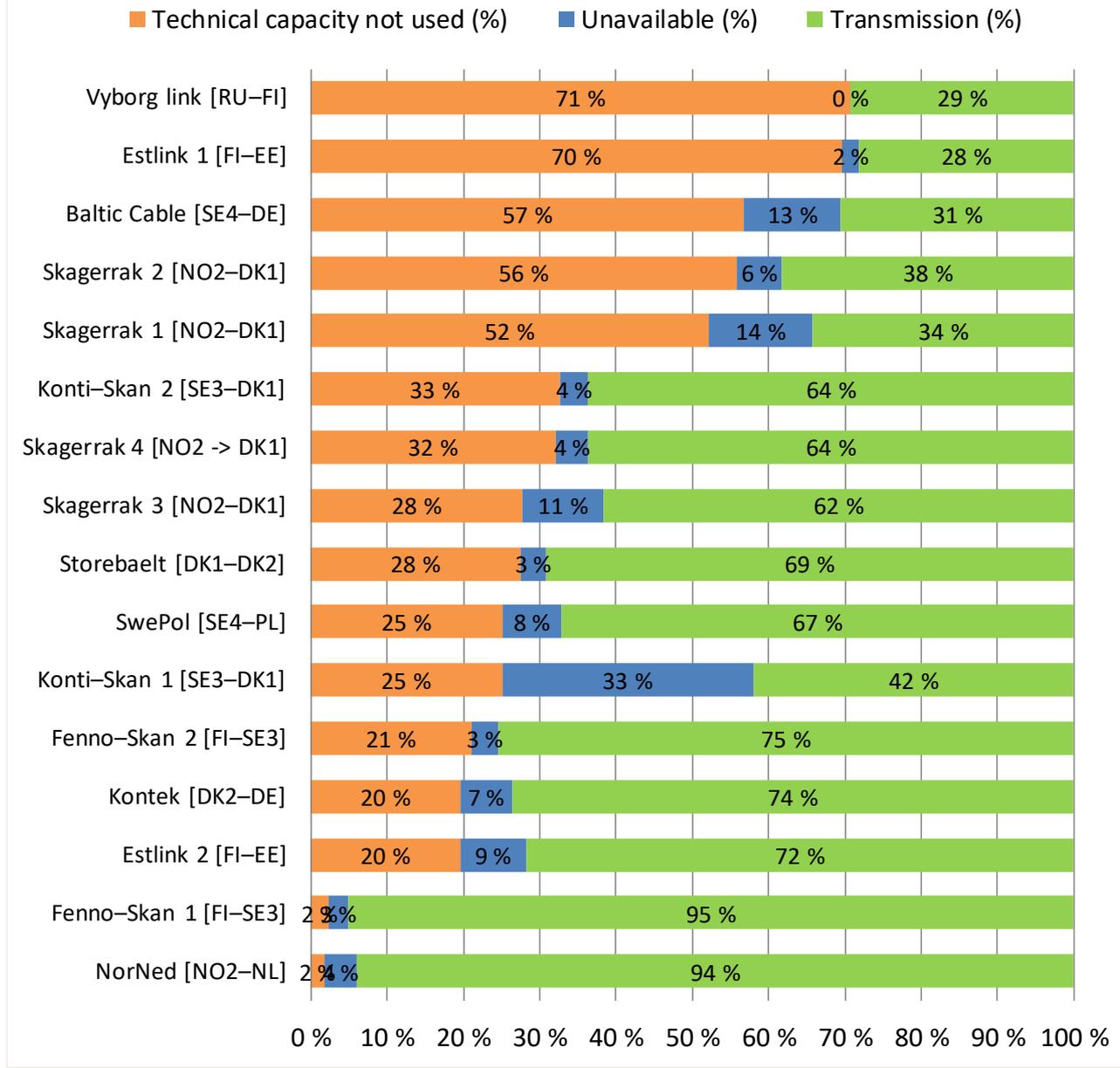


FIGURE C-3 ANNUAL OVERVIEW OF EACH HVDC LINK SORTED BY DESCENDING TECHNICAL CAPACITY NOT USED (E_{TCNU}) IN 2015