

## Study Committee B4

HVDC and Power Electronics

Paper B4-11135

# A SURVEY OF THE RELIABILITY OF HVDC SYSTEMS THROUGHOUT THE WORLD DURING 2019 – 2020

M.G. BENNETT L. Crowe P.V.I. Tairaro  
On behalf of B4 AG04

### CIGRE B4 – AG04

- HVDC reliability surveys since 1968 starting with mercury arc valves
- LCC Thyristor systems since 1972
- VSC IGBT systems since 2013
- Paper published every two years

### Reports are Made to a Protocol



### Key Measures

- Energy Availability
- Forced Energy Unavailability
- Scheduled Energy Unavailability
- Forced Outages

### Key Measures

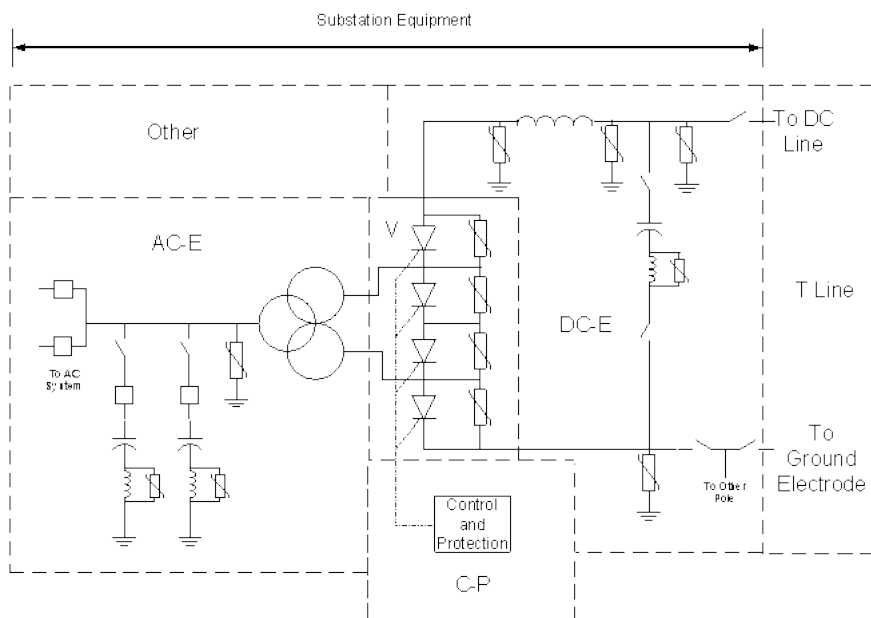
- Thyristor or IGBT failures
- Number and cause of commutation failures (LCC)
- Data is concentrated on converter equipment
- Minimal data on transmission lines or cables

### Fault Classifications by Area

- **AC-E** - AC Equipment
- **V** - Valve equipment and valve cooling
- **C-P** - Control and protection
- **DC-E** - DC Equipment

### Fault Classifications by Area

- **Other** - Human error, unknown
- **TL** - DC transmission line or cable
- **Ext** - External



## Study Committee B4

HVDC and Power Electronics

Paper B4-11135

# A SURVEY OF THE RELIABILITY OF HVDC SYSTEMS THROUGHOUT THE WORLD DURING 2019 – 2020 continued

### Survey for 2019 and 2020

- In 2019
  - 50 LCC systems reported
  - 6 VSC system reported
- In 2020
  - 50 LCC systems reported
  - 7 VSC systems reported

### Survey for 2021 and 2022

In progress.

Your system can participate and help expand this important work.  
Ask how to get involved!

**Table 1 - System Energy Availability, Energy Utilization and Converter Station Energy Unavailability**

System	Year Commissioned	Maximum Continuous Capacity MW	Energy Availability percent		Energy Utilization percent (1)		Forced Energy Unavailability percent (2)		Scheduled Energy Unavailability percent (2)	
			2019	2020	2019	2020	2019	2020	2019	2020
Skagerrak 1 & 2	1976/77	550	77.5	45.4	40.4	35.2	6.21	0.71	16.28	1.82
Skagerrak 3 & 4 (3)	1993/15	1215	67.3	75.9	45.4	45.3	9.63	0.04	6.09	0.00
Shin-Shimano 1	1977	300	98.2	93.8	0.4	0.1	0.00	0.00	1.79	6.22
Shin-Shimano 2	1992	300	97.6	93.6	89.9	79.4	0.00	0.00	2.35	6.42
Nelson River BP1	1973/04	1855	93.8	90.4	53.3	55.3	1.75	5.35	4.41	4.28
Nelson River BP2	1978/83	2000	88.0	79.9	47.0	46.9	7.49	19.29	4.52	0.80
Nelson River BP3	2018	2500	88.9	98.4	27.3	48.7	2.40	0.09	8.69	1.47
Hokkaido-Honshu	1979/93	600	89.0	80.6	17.6	17.7	0.00	0.00	10.96	19.41
New Hokkaido-Honshu (6)	2019	300	96.3	96.9	46.5	38.4	0.06	0.00	3.62	3.11
CU	1996	1000	88.8	95.8	74.0	75.8	0.14	0.00	11.02	4.19
Gotland 2 & 3	1983/87	320	98.5	99.1	19.5	17.7	0.94	0.07	0.58	0.80
Itaipu BP1	1984/85	3150	92.0	93.8	43.7	35.4	0.36	0.26	7.59	5.98
Itaipu BP2	1987	3150	89.9	85.1	43.7	35.4	2.06	0.05	8.03	14.83
Highgate	1985	225	98.7	98.7	93.9	94.0	0.00	0.06	1.28	1.20
Virginia Smith	1988	200	92.2	-	13.6	-	4.83	-	3.01	-
Kontj Skan 2	1988	300	83.9	95.7	50.1	55.6	1.02	2.83	15.05	15.50
Vindhyachal	1989	500	96.1	93.3	65.2	55.0	0.69	0.20	3.22	6.46
McNeill	1989	150	78.9	97.2	22.0	29.9	0.78	0.03	20.28	2.81
Femto-Skan 1	1990	400	98.2	98.3	95.2	97.6	0.06	0.14	1.75	1.52
Femto-Skan 2	2011	830	98.6	99.6	74.4	78.3	0.13	0.08	1.31	0.33
Rihand-Dadi	1991	1650	98.4	97.4	74.3	73.5	0.06	0.66	1.56	1.87
SACOU (4)	1992	300/50/50	74.5	66.6	45.4	52.2	6.55	2.38	7.71	7.98
New Zealand Pole 2 (5)	1992	500	99.8	86.8	41.4	30.8	0.05	0.05	0.17	13.14
New Zealand Pole 3 (5)	2013	700	99.6	91.5	31.5	24.5	0.00	0.02	0.42	8.49
Sakuma	1965/93	300	97.6	98.0	0.0	0.0	0.00	0.00	2.42	2.01
Konck	1998	600	97.5	69.2	68.6	47.4	0.00	0.01	2.51	5.05
Haenam-Jeju 1	1997	300	60.8	94.8	17.5	25.2	0.16	0.12	39.05	5.09
Jindo-Jeju 2	2014	400	99.7	97.0	40.1	30.9	0.00	0.05	0.32	2.91
Chandrapur	1998	1000	91.4	94.8	58.3	64.5	5.18	5.11	3.41	0.05
Mimami-Fukushima	1999	300	92.7	84.1	1.7	7.1	0.00	0.00	7.28	15.91
Vizag I East-South	2000	500	99.8	99.2	45.0	43.1	0.05	0.42	0.12	0.33
Vizag II East-South	2005	500	99.7	99.9	54.3	43.7	0.03	0.03	0.29	0.04
Kii Channel	2000	1400	92.0	95.9	72.7	81.2	0.12	0.10	7.83	3.98
Malaysia-Thailand	2001	300	96.6	96.1	10.8	10.0	1.65	0.71	1.80	3.19
Genz	2001	500	94.4	89.9	69.0	67.2	0.05	0.21	5.55	9.87
Talcher-Kolar	2003	2000	98.4	97.1	74.8	83.5	0.09	1.61	1.43	1.22
Sasaram	2003	500	99.7	98.3	34.0	59.4	0.26	0.04	0.00	1.65
Higashi-Shimizu	2006	300	95.8	93.3	68.4	57.9	0.00	0.41	1.18	6.25
Basslink	2006	500	89.5	99.2	48.5	62.0	0.54	0.10	4.05	0.73
Estlink 1 (6)	2007	350	98.4	97.4	23.0	56.8	0.03	0.04	1.49	2.59
Estlink 2	2013	450	97.5	97.5	60.4	86.1	2.49	1.05	0.80	1.46
AI Fudhail	2009	1800	98.7	96.5	4.4	8.2	0.25	2.44	1.03	1.06
Cahora Bassa	1977/2009	1920	70.6	-	59.0	-	26.11	-	3.26	-
SAPEI	2009	1000	96.0	91.7	38.0	30.7	0.04	0.27	3.94	7.99
Capivi (6)	2009	300	33.2	96.0	37.1	66.0	66.79	2.25	0.00	1.80
Storebølt	2010	600	98.7	99.8	58.4	70.7	0.00	0.21	1.29	0.01
Batha-Bhivadi	2010	2500	99.1	98.7	18.7	17.1	0.04	0.01	0.87	1.23
Bothled	2011	1000	98.6	91.1	72.4	59.8	0.06	1.22	1.38	1.28
WATL	2016	1000	95.3	97.5	20.9	18.8	0.04	0.00	4.67	2.48
EATL	2016	1000	95.6	91.0	15.4	17.2	1.62	1.58	2.79	7.38
Nemo Link (6)	2019	1000	-	99.2	-	66.7	-	0.05	-	0.77
NER-Agra BP1	2017	6000	97.1	97.4	18.0	20.0	0.04	0.56	2.78	1.86
NER-Agra BP2	2017	6000	98.1	99.9	15.9	16.1	0.09	0.03	1.75	0.00
Champa Kunkakshetra 1	2017	3000	89.9	98.7	35.8	98.7	0.34	0.94	9.70	0.03
AI Fudhail	2017	3000	-	94.9	-	21.7	-	0.71	-	3.95
NordBalt (6, 7)	2016	700	97.6	98.6	62.9	90.6	0.05	0.00	2.32	1.36
LiPol	2016	500	98.0	93.2	61.8	58.9	0.00	0.03	2.03	6.77
Rio Madeira BP2	2018	3150	97.9	98.5	-	-	0.14	0.06	2.01	1.48
Cobra (6)	2019	700	93.8	72.9	67.7	50.6	0.28	0.24	5.89	0.00
MONITA Pole1 (5)	2019	600	-	92.2	-	40.3	-	0.23	-	7.55
MONITA Pole2 (5)	2019	600	-	69.4	-	10.5	-	22.75	-	7.87

(1) Based on maximum continuous capacity (2) Converter station outages only (3) One pole VSC (4) Three terminal monopole system (5) Bipole reporting as two poles (6) VSC system (7) Lithuania station

## Study Committee B4

HVDC and Power Electronics

Paper B4-11135

### A SURVEY OF THE RELIABILITY OF HVDC SYSTEMS THROUGHOUT THE WORLD DURING (2019 – 2020 continued

Table II A - Number of Forced Outages and Equivalent Outage Hours - 2019

System	AC-E		V		C & P		DC-E		O		TL		TOTAL	
	No.	Hours	No.	Hours	No.	Hours	No.	Hours	No.	Hours	No.	Hours	No.	Hours
Skagerrak 1 & 2	5	1308	0	0.0	0	0.0	2	205.4	0	0.0	0	0.0	7	544.2
Skagerrak 2 & 4 (1)	1	13.0	0	0.0	2	2.5	9	796.7	0	0.0	3	1890.1	16	2333.8
Shin-Shimano 1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Shin-Shimano 2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nelson River BP1	20	92.0	0	0.0	13	36.0	0	0.0	0	0.0	0	0.0	42	152.9
Nelson River BP2	6	1.3	4	6.1	15	491.6	3	156.8	2	0.7	0	0.0	30	656.5
Nelson River BP3	4	16.9	0	0.0	1	0.2	0	0.0	1	0.8	0	0.0	9	210.1
Hokkaido-Honshu	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
New Hokkaido-Honshu	0	0.0	1	5.5	0	0.0	0	0.0	0	0.0	0	0.0	1	5.5
CU	1	102.2	0	0.0	1	1.8	0	0.0	0	0.0	0	0.0	2	12.0
Gotland 2 & 3	5	75.4	0	0.0	1	0.5	0	0.0	8	6.3	0	0.0	14	82.2
Itaipu BP1	1	9.8	1	4.4	2	2.3	1	12.1	1	3.1	3	1.4	9	33.1
Itaipu BP2	1	0.4	3	27.3	0	0.0	3	153.1	0	0.0	3	0.0	10	180.9
Highgate	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Virginia Smith	7	120.1	1	1.5	2	65.0	0	0.0	1	236.5	0	0.0	11	423.1
Kont-Skan 2	3	28.2	3	23.4	5	41.6	0	0.0	0	0.0	2	4.5	13	93.7
Vindhyachal	4	8.8	2	1.6	18	29.6	4	20.1	0	0.0	0	0.0	28	60.2
McNeill	5	42.8	1	25.7	0	0.0	0	0.0	0	0.0	0	0.0	6	68.5
Fernos-Skan 1	0	0.0	0	0.0	0	0.0	0	0.0	3	5.0	0	0.0	3	5.0
Fernos-Skan 2	0	0.0	0	0.0	0	0.0	0	0.0	3	11.6	0	0.0	3	11.6
Roland-Dadré	1	1.6	1	3.0	1	0.3	0	0.0	0	1.0	0.4	4	5.3	
SACO(1)	6	20.1	1	0.4	5	20.9	0	0.0	6	522.2	2	989.0	20	1562.5
New Zealand Pole 2	0	0.0	0	0.0	1	1.0	0	0.0	2	2.2	5	6.3	7	9.5
New Zealand Pole 3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.7	1	0.7
Sakuma	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Konks	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Haeunam-Jeju 1	0	0.0	0	0.0	0	0.0	1	0.4	0	0.0	0	0.0	1	0.4
Haeunam-Jeju 2	0	0.0	0	0.0	0	0.0	0	0.0	2	14.4	0	0.0	2	14.4
Chandrapur	5	207.2	0	0.0	6	246.6	0	0.0	0	0.0	0	0.0	11	453.8
Mirama-Fukushima	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Vizag II East-South	0	0.0	0	0.0	1	4.8	0	0.0	0	0.0	0	0.0	1	4.8
Vizag II East-South	0	0.0	0	0.0	0	0.0	0	0.0	1	2.3	0	0.0	1	2.3
Kai-Chuan	0	0.0	1	10.6	0	0.0	0	0.0	0	0.0	0	0.0	1	10.6
Malaysia-Thailand	0	0.0	11	144.3	1	0.1	0	0.0	0	0.0	0	0.0	12	144.4
Gria	0	0.0	0	0.0	2	3.8	0	0.0	1	0.2	0	0.0	4	4.0
Fachou-Kolar	0	0.0	0	0.0	5	2.6	0	0.0	3	3.6	11	11.3	19	18.5
Sasaram	1	3.8	0	0.0	5	18.9	0	0.0	0	0.0	0	0.0	6	22.7
Hgashi-Shimizu	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Basind(1)	1	2.0	0	0.0	3	44.9	0	0.0	0	0.0	1	864.2	5	911.1
Estlink 1	1	2.6	0	0.0	0	0.0	0	0.0	0	0.0	1	5.0	2	7.6
Estlink 2	0	0.0	2	107.4	1	10.5	1	100.0	0	0.0	4	217.9	7	427.9
AI Fadhibi	12	7.2	2	10.5	2	4.0	0	0.0	0	0.0	0	0.0	16	21.7
Cabora Bassa (3)	31	1378.6	59	580.1	11	60.9	37	339.6	4	3.0	0	0.0	114	2287.3
SAPCI	1	1.2	0	0.0	1	2.0	0	0.0	0	0.0	0	0.0	2	3.2
Capriv(2)	1	9.4	1	584.1	0	0.0	0	0.0	0	0.0	2	5850.8	4	6435.3
Storöback	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Bafra-Binwahdi	1	0.8	0	0.0	0	0.0	6	3.0	0	0.0	4	3.1	11	6.8
BritNed	0	0.0	2	2.5	0	0.0	0	0.0	2	2.5	0	0.0	4	5.0
WATL	1	3.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	3.5
EATL	0	0.0	0	0.0	0	0.0	1	141.9	0	0.0	0	0.0	1	141.9
NER-Agra BP1	0	0.0	0	0.0	0	0.0	0	0.0	2	3.9	10	7.0	12	10.9
NER-Agra BP2	3	4.0	2	1.2	0	0.0	0	0.0	1	2.4	3	1.9	9.4	
Champa Kankshetra 1	1	4.4	3	4.4	2	19.1	2	6.5	0	0.0	5	2.2	37	32.1
Nordbalt	0	0.0	1	4.3	0	0.0	0	0.0	0	0.0	0	0.0	1	4.3
Lafra	0	0.0	0	0.0	0	0.0	0	0.0	1	0.1	0	0.0	1	0.1
Rio Madeira BP1	1	2.1	2	11.1	18	1.7	5	6.2	2	1.0	0	0.0	28	12.1
Cobra	1	3.7	2	7.1	0	0.0	0	0.0	1	13.8	0	0.0	4	24.6

Table II B - Number of Forced Outages and Equivalent Outage Hours - 2020

System	AC-E		V		C & P		DC-E		O		TL		TOTAL	
	No.	Hours	No.	Hours	No.	Hours	No.	Hours	No.	Hours	No.	Hours	No.	Hours
Skagerrak 1 & 2 (1)	3.0	7.2	0.0	0.0	1.0	7.7	3.0	47.1	0.0	0.0	0.0	0.0	5.0	459.3
Skagerrak 2 & 4 (1)	0.0	0.0	0.0	0.0	1.0	3.1	0.0	0.0	0.0	0.0	0.0	0.0	5.0	2195.3
Shin-Shimano 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shin-Shimano 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nelson River BP1	16.0	274.7	4.0	9.1	19.0	184.1	0.0	0.0	6.0	6.0	0.0	0.0	2.0	474.0
Nelson River BP2 (1)	1.0	3.0	1.0	3.4	4.0	37.7	11.0	1645.3	1.0	0.4	3.0	0.3	21.0	1690.2
Nelson River BP3	10.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.1	0.0	0.0	11.0	8.1
Hokkaido-Honshu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Hokkaido-Honshu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gotland 2 & 3	6.0	1.9	1.0	0.5	4.0	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.0
Itaipu BP1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	23.0	4.0	0.6	5.0	23.6
Itaipu BP2	0.0	0.0	1.0	0.1	2.0	3.7	0.0	0.0	2.0	0.3	0.0	0.0	5.0	4.1
Highgate	0.0	0.0	1.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	5.0
Kont-Skan 2	1.0	0.4	0.0	0.0	2.0	2.0	1.0	244.2	1.0	1.7	0.0	0.0	5.0	248.3
Vindhyachal	0.0	0.0	1.0	1.9	9.0	15.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0
McNeill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.9	0.0	0.0	1.0	2.9
Fernos-Skan 1	2.0	9.4	0.0	0.0	0.0	0.0	1.0	3.2	0.0	0.0	0.0	0.0	3.0	12.5
Fernos-Skan 2	0.0	0.0	0.0	0.0	0.0	0.0	1.0	7.4	0.0	0.0	0.0	0.0	1.0	7.4
Roland-Dadré	3.0	52.2	0.0	0.0	3.0	3.5	1.0	1.8	0.0	0.0	0.0	0.0	2.0	100.0
SACO(1)	1.0	1.8	2.0	109.5	5.0	93.1	0.0	0.0	1.0	4.2	10.0	20.0	10.0	222.9
New Zealand Pole 2	4.0	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	5.6
New Zealand Pole 3	0.0	0.0	1.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.6
Sakuma	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Konks(1)	1.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6
Haeunam-Jeju 1	0.0	0.0	0.0	0.0	2.0	8.5	0.0	0.0	1.0	2.3	0.0	0.0	3.0	10.8
Haeunam-Jeju 2	1.0	0.7												