SEDIVER

TOUGHENED GLASS INSULATORS FOR HVDC APPLICATIONS

Experts & Pioneers

USA - CANADA - 2025

We are manufacturing
High Resistivity Toughened Glass Insulators (HRTG)

At the end of the 1950s, Sediver® was among the first manufacturers to develop insulators for HVDC overhead transmission line applications.

Thanks to our unique and substantial field experience along with ongoing research programs with utilities and international experts, the Sediver® research team introduced a state-of-the-art new DC insulator using High Resistivity Toughened Glass (HRTG) in the mid 1980s.

This development has strongly contributed to establishing a high performance benchmark in the industry ; this includes specific criteria later on introduced in IEC 61325 - the only international standard describing HVDC performance requirements.

Today, more than 11 million Sediver® insulators have been in operation on HVDC lines with great success.

The applications cover all climatic and environmental conditions at up to 800 kV DC.

Why glass?

Glass is fully amorphous, it is a frozen liquid. Therefore, it has no crystallographic structure responsible for aging. Through our manufacturing process it becomes even more reliable, stable, and strong. We have developed decades of knowledge around this material to bring our customers unique benefits that last throughout their installation's life cycle.

Our own distinctive manufacturing process

- Ensures an **outstanding homogeneity in the chemical composition of the glass** and provides **high purity** glass.
- Our unique know-how enables us to create **complex glass shapes** and products up to 16½" (420 mm) in diameter and weighing more than 22 lbs. (10 kg).
- The toughening process developed by Sediver® generates a compressive pre-stress on the surface of the glass shells which confers to the glass : high mechanical strength, high resistance to thermal shocks and mechanical impacts, and an immunity to the effects of aging.
- A highly automated manufacturing process, perfected through the years by Sediver® , guarantees a consistent high level of quality in the materials and the final product remove.
- **Very stringent quality system** comprises systematic controls and inspection of the insulators during manufacturing. The entire process is **constantly automaticaly monitored** and supervised by qualified inspectors.
- **Our process is standardized across all our production facilities, with a guaranteed consistency of our product performance worldwide.** Our QA system and individually marked units grants the full traceability of our insulators.
- **Low shattering rate:** Guaranteed < 1/10,000 per year due to the high purity of Sediver® glass and outstanding process.

Focus on glass binary nature

Any arcing is guaranteed to occur externally with no risk of passing internally.

Intact shell

- Guaranteed absence of internal cracks or electrical punctures.
- 100% of the mechanical rating guaranteed over prolonged periods of time even in very harsh conditions
- 100% electrical strength

Damaged shell

- Residual mechanical strength: 80% of the mechanical rating guaranteed over prolonged periods of time even in very harsh conditions
- Residual electrical strength: Avoiding internal puncture and forcing overvoltage induced discharges externally

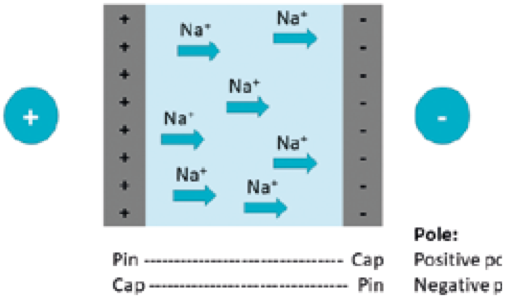
Therefore

- Ease of inspection : no need to climb structures or to use sophisticated instrumentation.
- Enhanced workers' safety in live line operations.
- Very low cost of inspection for the entire service life of the line.
- No risk of separation or line drops.
- No urgency in replacing a unit with broken shell.
- Long-term savings in maintenance operations.

HVDC specific stresses

Insulators used on HVDC lines have to sustain very unique and specific stress conditions associated with the unidirectional e-field and current flow.

IONIC MIGRATION

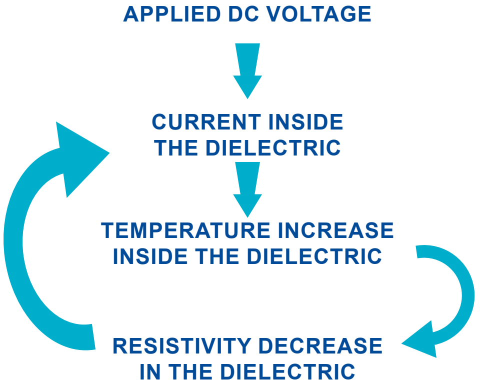


1. Ionic migration

In HVDC lines, the current is unidirectional and the polarity of the poles is constant, resulting in migration of ions.

The effect of ionic migration is a risk of formation of depletion layers in dielectric materials not specifically designed for DC application, or having an improper formulation. These depletion layers can weaken the dielectric and lead to puncture for porcelain or shattering for toughened glass.

THERMAL RUNAWAY CONCEPT



APPLIED DC VOLTAGE

CURRENT INSIDE THE DIELECTRIC

TEMPERATURE INCREASE INSIDE THE DIELECTRIC

RESISTIVITY DECREASE IN THE DIELECTRIC

2. Thermal runaway

In HVDC applications, the **unidirectional current can generate a significant increase of temperature locally in the dielectric**. This effect is called the Joule effect and is accentuated in hot environments

When the temperature increases inside the dielectric, its resistivity decreases. These two phenomena can enter into a loop where the loss of resistivity allows more current to flow through the insulator and the temperature to rise higher and higher.

This loop is called **thermal runaway** and can lead to puncture for porcelain or shattering for toughened glass.

3. Pollution accumulation

Under HVDC, the electrostatic field along the length of an insulator string, in conjunction with the wind, leads to a steady build-up of pollutants on the insulator surface.

This pollution accumulation can be up to 10 times more severe than that on comparable HVAC insulators in the same environment.

For HVDC systems, the length of the string is more often controlled by the level of pollution than the switching and lightning performance as applied for HVAC.

4. Metal part corrosion

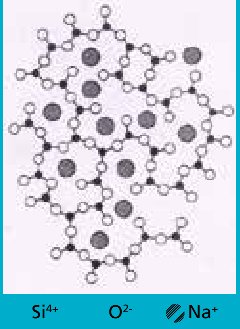
Additionally, direct current, when associated with humid conditions, accelerates the corrosion of the metal parts due to electrolytic effects.

To achieve an **optimal performance in DC and to cope with these 4 additional constraints**, Sediver® developed the **High Resistivity Toughened Glass (HRTG)** insulator, having a **special type of glass and an adapted insulator design.**

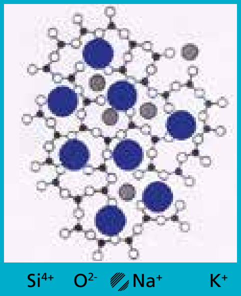
Sediver® HRTG insulator design: **the answer for HVDC T/L reliability**

To achieve an optimal performance in DC and to cope with these 4 additional constraints, Sediver® developed the **High Resistivity Toughened Glass (HRTG) insulator,** having a special type of glass and an adapted insulator design.

AC glass
chemical composition



DC glass
chemical composition



1. High Resistivity Toughened Glass to solve internal current effects

Glass is an amorphous material. Its atomic structure is a basic Silica/Oxygen network in which several other oxides are added, either for processing or to achieve specific properties depending upon the final application.

In AC glass chemistry, oxides such as Sodium are used.

In this case Sodium, which is not linked to the structural atomic backbone, can move under an electric field leading to ionic conductivity.

In DC, such ionic conductivity has to be inhibited.

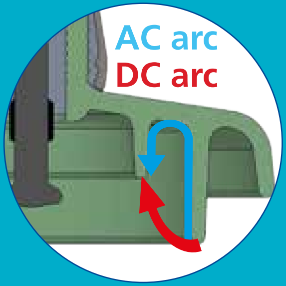
In order to reduce ionic migration, the atomic network is modified by replacing part of the sodium ions with bigger cations or other cations having lower mobility.

The resulting glass material (HRTG) is characterized by a **reduced mobility of sodium which is hindered by the addition of bigger cations, eliminating the risk of failure due to ionic migration.**

2. High Resistivity Toughened Glass to prevent thermal runaway

The **chemistry of the high resistivity toughened glass** results in a higher electrical resistivity of glass, about 100 times higher compared to AC glass, **eliminating the risk of failure due to thermal runaway**.

Additionally, Sediver® has developed a special manufacturing process able to produce glass shells with a very high degree of purity, and therefore having a lower impact on ionic accumulation.



3. Adapted glass shell design to cope with pollution accumulation

The **specific pollution conditions of DC applications** require that the insulators are designed with the goal of **reducing the risk of excessive dust accumulation** resulting from unidirectional electric fields. (See IEC 60815 part 4).

Test laboratory and field experience have largely demonstrated that the bottom of the insulator is of prime importance in this regard. The best insulators will offer an adapted leakage distance distributed in a way that will prevent both dust nests as well as rib-to-rib arc-bridging.

In this regard, Sediver® has been able to adapt the shape of the glass shell to DC requirements, made possible by specific glass moulding and toughening processes which reduce the risk of arc bridging**.**

4. Protection of the metal end fittings against corrosion

Pins from service insulators

Corroded pin without zinc sleeve

Pin with zinc sleeve

Pin protection

Under DC stresses, the galvanized coating of the pin deteriorates over time, leading to the corrosion of the pin itself, which, in the long-term, can lead to a significant reduction of the mechanical strength.

In order to prevent this form of pin damage, Sediver® HVDC insulators are equipped with a corrosion prevention sleeve made of high-purity zinc.

Field observations

Rust appears on cap due to surface current

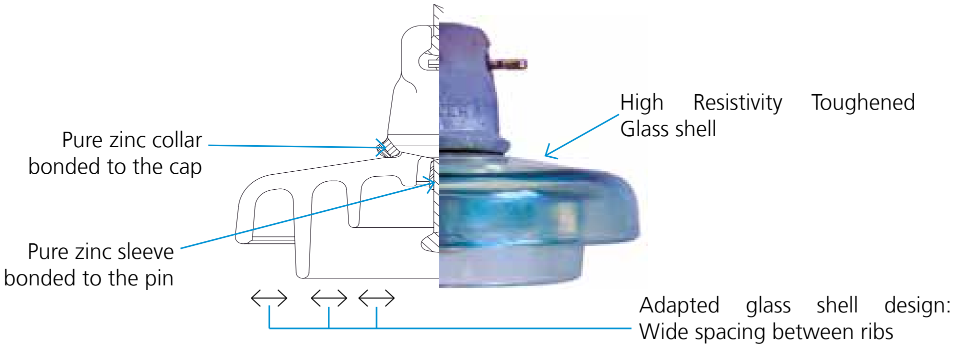
Cap protection

In HVDC, arcing activity and corrosion can also take place around the cap leading to rust deposits on the top surface of the skirt.

While no mechanical risk is expected from this phenomenon the generation of a conductive path on the insulators can substantially reduce the overall leakage distance of the entire string and therefore its electrical performance.

In order to avoid this type of corrosion, Sediver® , went beyond the IEC specification in the early 80s and patented a specific zinc collar design to protect the cap.

Sediver® HRTG features and User benefits



	HVDC stress consequence	Risk	Sediver® HRTG solution	User benefit
Internal current	**Ionic migration**	Dielectric breakdown	**High Resistivity Toughened Glass** coping with ion flow stresses	No puncture = less maintenance
	Thermal runaway	Dielectric breakdown	**High Resistivity Toughened Glass** with high purity imparting high resistance to localized thermal stresses	No puncture = less maintenance
External current	**Pollution accumulation**	String flashover	**HVDC specific glass shell design** dedicated to performance under pollution	High pollution efficiency = less maintenance
	Metal parts corrosion	String flashover Mechanical failure	**Protection of the metal end fittings** with pure zinc collar bonded to the cap and pure zinc sleeve bonded to the pin	Longer life expectancy

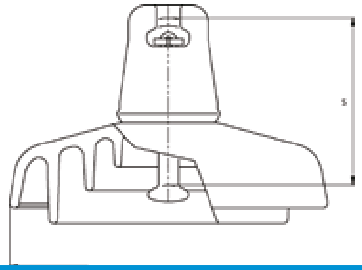
The condition of Sediver® DC insulators after 30 years in service has been monitored jointly with Utilities. Today, millions of Sediver® HRTG insulators have proven their outstanding performance and reliability under all kinds of environmental conditions.

Sediver® toughened glass suspension insulators

Ball & Socket type - DC Fog profile

ANSI

CSA



		DC Fog type profile						
Insulator type		**N120PF/ C146DR**	**N160P/ C170DR**	**N180P/ C170DR**	**N220P/ C170DR**	**F300PU/ C195DR**	**F400P/ C205DR**	**F550/ C240DR**
ANSI CLASS(1) / IEC designation						U300BP	U400B	U530B
CSA Mechanical Class		CSDC-1	CSDC-2		CSDC-3	CSDC-4		
ANSI/IEC Coupling		Type J	Type K	Type K	Type K	24	28	32
MECHANICAL CHARACTERISTICS								
Combined M&E strength	lbs	25.000	36.000	40.000	50.000	66.000	90.000	125.000
	kN	*120*	*160*	*180*	*222*	*300*	*400*	*550*
Impact strength	in-lbs	400	400	400	400	400	400	400
	N-m	*45*	*45*	*45*	*45*	*45*	*45*	*45*
Tension proof	lbs	12.500	18.000	20.000	25.000	33.000	45.000	62.500
	kN	*60*	*80*	*90*	*111*	*150*	*200*	*275*
DIMENSIONS								
Diameter (D)	in	13	13	13	13	14 1/8	14 1/8	14 1/8
	mm	*330*	*330*	*330*	*330*	*360*	*360*	*360*
Spacing (S)	in	5 3/4	6 3/4	6 3/4	6 3/4	7 5/8	8	9 1/2
	mm	*146*	*170*	*170*	*170*	*195*	*205*	*240*
Leakage distance	in	21 1/2	21 5/8	21 5/8	21 5/8	25	24 1/2	25
	mm	*545*	*550*	*550*	*550*	*635*	*625*	*635*
ELECTRICAL CHARACTERISTICS(2)								
DC withstand voltage								
- Dry one minute ±	kV	150	150	150	150	170	170	170
- Wet one minute ±	kV	65	65	65	65	65	70	70
Dry lightning impulse withstand	kV	140	140	140	140	150	160	150
SF6 DC puncture withstand voltage	kV	225	225	225	225	255	255	255
Critical Impulse Flashover Voltage ± (3)	kV	145	150	150	150	170	170	170
PACKING AND SHIPPING DATA								
Approx. net weight per unit	lbs	18.6	21.4	21.4	23.1	29.5	32.4	38.6
	kg	*8.4*	*9.7*	*9.7*	*10.5*	*13.4*	*14.7*	*17.5*
No of insulators per crate		6	6	6	6	5	4	4
Volume per crate	ft^3	3.92	4.34	4.34	4.34	4.77	3.96	4.63
	m^3	*0.11*	*0.12*	*0.12*	*0.12*	*0.14*	*0.11*	*0.13*
Gross weight per crate	lbs	126.21	139.77	139.77	146.83	165.79	152.12	177.91
	kg	*57.25*	*63.4*	*63.4*	*66.6*	*75.2*	*69*	*80.7*
No. of insulators per pallet		54	54	54	54	45	36	36
Volume per pallet	ft^3	47.11	48.88	48.88	48.88	55.62	47.18	53.57
	m^3	*1.334*	*1.384*	*1.384*	*1.384*	*1.575*	*1.336*	*1.517*
Gross weight per pallet	lbs	1192.7	1313.1	1313.1	1377	1530	1411	1653
	kg	*541*	*595.6*	*595.6*	*624.6*	*694*	*640*	*749.8*

Custom products, not shown here are also available

(1) Mechanical rating and couplings

(2) in accordance with IEC publication 61325

(3) in accordance with ANSI publication C29.2B

Sediver® contribution within international standardisation committees

Main Committees & Working Group in which Sediver® is active:

Commitees:

- **IEC**: International Electrotechnical Commission
- **CIGRE**: International Council on Large Electric Systems
- **IEEE**: Institute of Electrical and Electronics Engineers

Working groups

- CIGRE : B2, D1, C4
- IEEE : OHL SC
- CSA 411
- NEMA ANSI C29
- IEC TC36

HVDC international publications and Sediver® research activities on HVDC insulators

George JM, Lepley D, "HVDC overhead line insulators : basics and performance", 2024 CIGRE PARIS, 25 aug. - 30 aug. 2024, Paris, France

George JM, "Pollution of overhead line insulators: update on standards and insulators performance under severe contamination for AC and DC lines, 2024 EDM, International Conference on Overhead Lines, April 15-18, 2024, Fort Collins, U.S.A

GEORGE JM / LEPLEY D / VIRLOGEUX F "POLLUTION AND INSULATORS", 2023 INMR World Congress, Nov 12-15 2023, Bangkok, Thailand

GEORGE JM / LEPLEY D. "AC AND DC POLLUTION TESTING METHODS: ACCURACY AND LIMITATIONS", 2022 INMR World Congress, Oct 16 - 19 2022, Berlin, Germany

MARZINOTTO M / GEORGE JM / PIROVANO G "Field experience and laboratory results on the application of RTV coating on HVDC line" CIGRE 2020 PARIS cigre e-session 48 - Aug 24 - Sep 3 2020

GEORGE JM / FERREIRA LF "HVDC overhead line insulators selection and design update features"RVPAI 2018, XXXI Reunión Internacional de Verano de Potencia, Aplicaciones Industriales y Esposición Industrial IEEE - 15-20 July 2018, Acapulco, Mexico

GEORGE JM. / BROCARD E. / VIRLOGEUX F. / LEPLEY D. "DC pollution performance: current approximations & future needs" INMR 2017 World Congress, nov 5 - 8 2017, Barcelona, Spain

VIRLOGEUX F. / GEORGE JM. "Key parameters for HVDC overhead lines insulators" GCC POWER 2017, 13th International Conference for GCC, 16 - 18 Oct 2017, Muscat, Sultanate of Oman

VIRLOGEUX F. / BROCARD E. / GEORGE J.M. "Correlation assessment between actual pollution performance of insulator strings in DC and theoretical models" INSUCON 2017, 13th International Insulation Conference,16-18 May 2017, Birmingham, UK

GEORGE JM. / BROCARD E. / VIRLOGEUX F. / LEPLEY D. "DC pollution performance: current approximations & future needs" INMR 2017 World Congress, nov 5 - 8 2017, BARCELONA, SPAIN

GEORGE J.M. "HVDC insulators" INMR World Congress 2015, Munich, Germany 2015

KLASSEN D., ZOGHBY E., KIELOCH Z. "Assessment of toughened glass insulators removed from HVDC lines after more than 40 years in service" CIGRE CANADA CONFERENCE 2015

J.F. NOLASCO – L.F.P. FERREIRA "Aspectos especiais de projeto e ensaios de isoladores para LT's de corrente continua" CIGRE XV ERIAC 2013

CIGRE WG C4.303 "Outdoor Insulation in Polluted Conditions : Guidelines for Selection and Dimensioning - Part 2 : The DC Case" CIGRE Technical Brochure 518 - 2012

J.M. GEORGE "Long term Performance Evaluation of Toughened Glass Insulators and the consequences for UHV and DC Applications" International Conference on UHVTransmission , Beijing, China, 21-22 may 2009

L.F. FERREIRA – J.M. GEORGE "HVDC Toughened Glass Insulators" INMR Rio de Janeiro 2007

J.M. GEORGE – E. DEL BELLO "Assessment of electrical and mechanical performance of Toughened Glass Insulators removed from existing HV Lines" CIGRE Regional Meeting August 27-28, 2007 Calgary Canada

D. DUMORA – R. PARRAUD "Reliability of Toughened Glass Insulator on HVAC and HVDC Transmission Lines : Design Improvements, Field Experience and Maintenance" CBIP International Conference Recent Trend in Maintenance Techologies of EHV, 29-30 April 2002, New Dehli, India

R. PARRAUD – D. DUMORA – R. JOULIE – C. LUMB "Improvement in the Design and the Reliability of Toughened Glass Insulators for AC and DC Transmission Lines" CEPSI 21-25 October 1996

M. O'BRIEN – C. BURLEIGH – J. GLEADOW "New Zealand ± 250 KV 600 MW HVDC Link Reliability, Operating Experience and Improvements" CIGRE Colloquium on HVDC New Dehli 9-11, September 1991

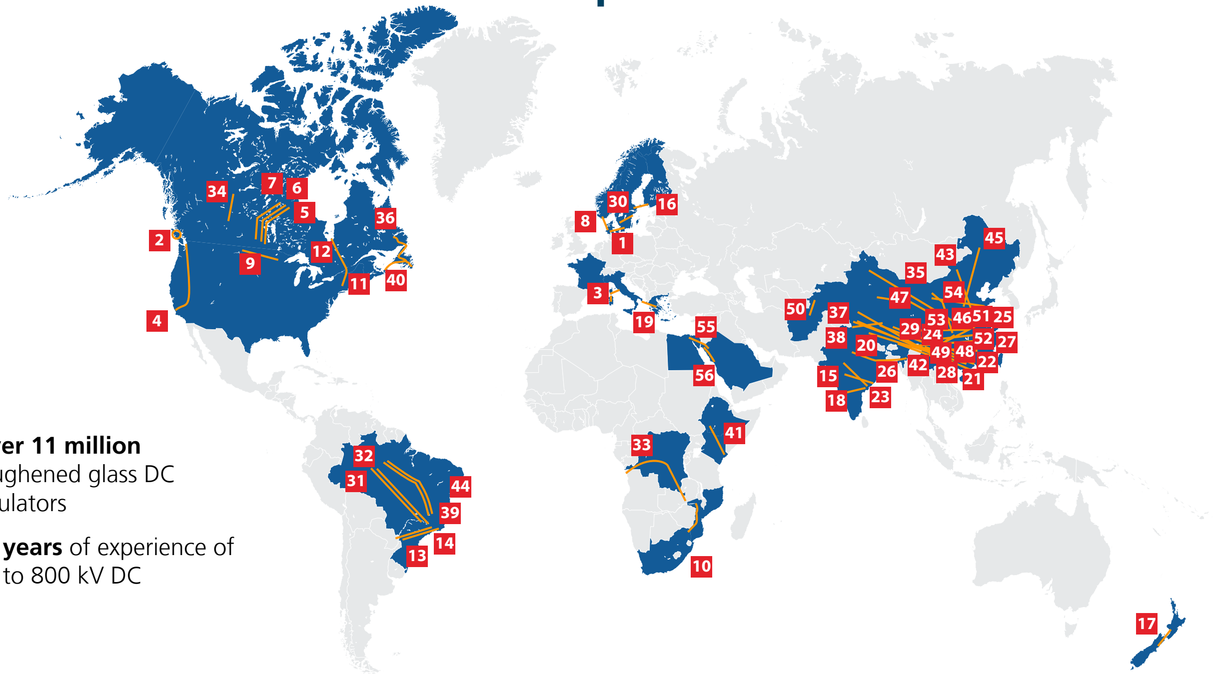
L. PARGAMIN "Contaminated Insulator Performance on HVDC Lines and Substations" IEEE T&D PANEL SESSION 1989

PARGAMIN L.; PARRAUD R.*" A key for the choice of insulators for DC transmission lines"* IEEE HVDC TRANSMISSION MADRAS, 1986

L. PARGAMIN – D. DE DECKER – D. DUMORA "Improvement of the Performances of HVDC Toughened Glass Insulators" HVDC Insulator Symposium Los Angeles November 19-21, 1985

Sediver®

extensive HVDC worldwide experience



- **Over 11 million** toughened glass DC insulators
- **60 years** of experience of up to 800 kV DC

1.	±300 kV DC, Denmark-Sweden, Konti-Skan 1; 2 and 3, 1965/1988
2.	± 260 kV DC, Canada, Vancouver Islands, 42 km, 1967
3.	±200 kV DC, Italy-France, Corsica-Sardinia-Italy, 264 km, 1967/1992
4.	± 500 kV DC, USA, Pacific Intertie, 1 360 km, 1969/2014/2017-2019
5-6-7.	±450&500 kV DC, Canada, Kettle Winnipeg Nelson River, 2x870 km Bipole I, II & Bipole III, 1 364 km, 1972 & 2014-15
8.	± 250&350 kV DC, Denmark-Norway, Skagerrak 217 km, 1&2;3 1975/1993
9.	±500 kV DC, USA, Dickinson - Coal Creek, 687 km, 1978
10.	±500 kV DC, Mozambique, Cahora Bassa, 1 420 km, 1978
11.	± 500 kV DC, USA, New England, 85 km, 1984
12.	± 450 kV DC, Canada, Quebec-New England, 1 100 km, 1988
13-14.	±600 kV DC, Brazil, Itaipu 1 & 2, 2 x 800 km, 1984/87
15.	±500 kV DC, India, Rihand Dadri, 814 km, 1987
16.	±500 kV DC, Finland-Sweden, Fenno Skan 1&2, 136 km, 1988/2009
17.	±350 kV DC, New Zealand, North South Island, 535 km, 1990
18.	±500 kV DC, India, Chandrapur Padghe, 752 km, 1997
19.	±400 kV DC, Italy-Greece Interconnection, 110 km, 1999
20.	±500 kV DC, China, Tianshengqiao-Guangzhou, 1 050 km, 2001/2004
21.	±500 kV DC, China, Guizhou-Guangdong 1 & 2, 2 007 km, 2003
22.	±500 kV DC, China, Yunnan-Guangdong, 1 418 km, 2008
23.	±500 kV DC, India, Ballia Bhiwadi, 780 km, 2008/2009
24.	±500 kV DC, China, Deyang-Baoji, 534 km, 2009
25.	±500 kV DC, China, Gezhouba-Shanghai, 1 929 km, 2009
26.	±800 kV DC, India, Biswanath Agra, 1 825 km, 2010/11/12
27.	±800 kV DC, China, Jinping-Sunan, 2 089 km, 2011
28.	±800 kV DC, China, Nuozhadu-Guangdong, 1 413 km, 2012
29.	±500 kV DC, China, Xiluodu-Guangdong, 1 251 km, 2012

30.	±300 kV DC, Sweden, South-West Link, the Southern part, 2012
31-32.	±600 kV DC, Brazil, Rio Madeira I&II, 2 x 2 500 km, 2012/13
33.	±500 kV DC, Congo DR, Inga-Shaba, 1 700 km, 2013/2017
34.	±500 kV DC, Canada, Eastern Alberta, 500 km, 2013
35.	±800 kV DC, China, Hami-Zhengzhou, 2 208 km, 2013
36.	± 350 kV DC, Labrador-Newfoundland-Muskrat Falls, 1 300 km, 2014
37.	±500 kV DC, China, Jinzhong-Guangxi, 577 km, 2015
38.	±500 kV DC, China, Guanyinyan DC, 700 km, 2015
39.	±800 kV DC, Brazil, Belo Monte I, 2 000 km, 2015-17
40.	±200 kV DC, Canada, Maritime link, 2016
41.	±500 kV DC, Ethiopia-Kenya, Interconnection, 1 045 km, 2016-17
42.	±800 kV DC China, Dianxibei, 1 928 km, 2017
43.	±800 kV DC China, Ximeng-Taizhou, 1 620 km, 2017
44.	±800 kV DC, Brazil, Belo Monte II, 2 300 km, 2017
45.	±800 kV DC, China, Zhalute-Qingzhou, 1 320 km, 2017
46.	± 800 kV DC, China, Shaanbei-Wuhan, 1 135 km, 2019
47.	±800 kV DC, China, Qinghai-Henan, 1 575 km, 2019
48.	±800 kV DC, China, Wudongde-Guangxi, 1 490 km, 2019
49.	±500 kV DC, China, Yunnan-Guizhou Interconnection, 1 283 km, 2019
50.	±500 kV DC, Tajikistan-Afghanistan, Sangtuda to Deh Salah, 162 km,2020
51.	±800 kV DC, China, Baihetan-Jiangsu, 2 269 km, 2021
52.	±800 kV DC, China, Baihetan-Zhejiang, 2 193 km, 2021
53.	±800 kV DC, China, Jinshang-Hubei, 1961km, 2024
54.	±800 kV DC, China, Longdong~Shandong, 1040km, 2024
55.	±500 kV DC, Egypt - KSA, Badr-Tabuk 228 km, 2024
56.	±500 kV DC, KSA, Nic South-Yanbu Central, 604 km, 2024

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