

SEDIVER

TOUGHENED GLASS INSULATORS FOR HVDC APPLICATIONS



Experts & Pioneers

WORLDWIDE - 2024

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 this unique and substantial field experience and 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, including specific criteria later on introduced in IEC 61325, which still is 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



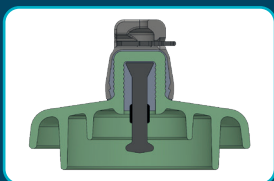
- Ensures an **outstanding homogeneity in the chemical composition of the glass** and provides **high purity** glass.
- Our unique know-how enables us to create **complex glass shapes** and products up to 16½" (420 mm) in diameter and weighing more than 22 lbs. (10 kg).
- The toughening process developed by Sediver® generates a compressive pre-stress on the surface of the glass shells which confers to the glass : a high mechanical strength & high resistance to thermal shocks and mechanical impacts as well as an immunity to the effects of aging.
- A highly automated manufacturing process, perfected along the years by Sediver®, guarantees consistent high level of quality in the materials and the final product assembly.

- **Very stringent quality system** comprises systematic controls and inspection of the insulators during manufacturing.

The entire process is **constantly automatically monitored** and supervised by qualified inspectors.

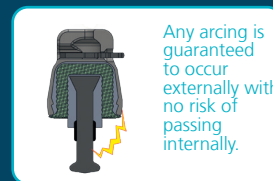
- **Our process is standardized across all our production facilities, with a guaranteed consistency of our product performance worldwide.** Our QA system and individually marked units grants the full traceability of our insulators.
- **Low shattering rate:** Guaranteed < 1/10 000 per year due to the high purity of Sediver® glass and outstanding process.

Focus on glass binary nature



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.

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.

2. Thermal runaway

In HVDC applications, the **unidirectional current can generate a significant increase of temperature locally in the dielectric**. This effect is named 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, lead to a steady build-up of pollutants on the insulator surface.

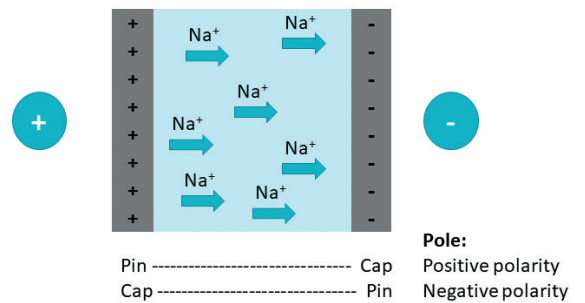
This pollution accumulation can be up to 10 times more severe than that on comparable HVAC insulators in the same environment.

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.

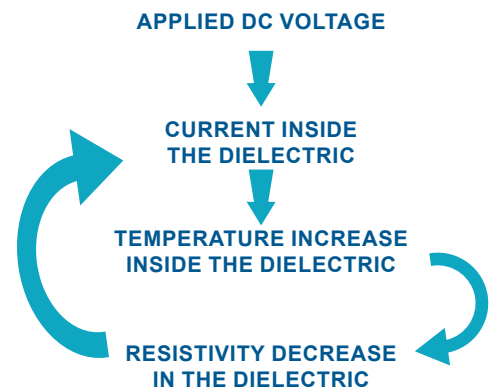
4. Metal part corrosion

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

IONIC MIGRATION



THERMAL RUNAWAY CONCEPT

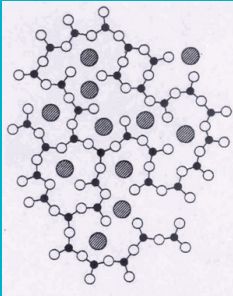


To achieve an **optimal performance in DC and to cope with these 4 additional constraints**, Sediver® developed the **High Resistivity Toughened Glass (HRTG)** insulator, having a **special type of glass and an adapted insulator design**.

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

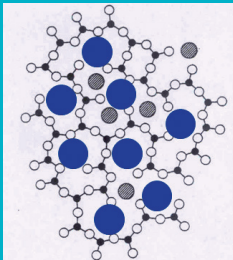
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AC glass
chemical composition

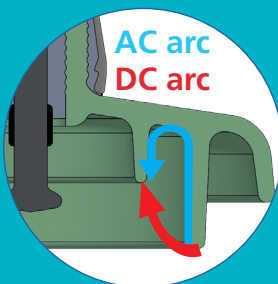


Si⁴⁺ O²⁻ Na⁺

DC glass
chemical composition



Si⁴⁺ O²⁻ Na⁺ K⁺



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.

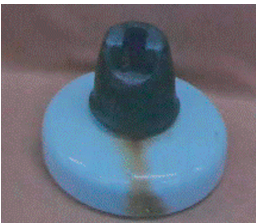
Cap protection

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.

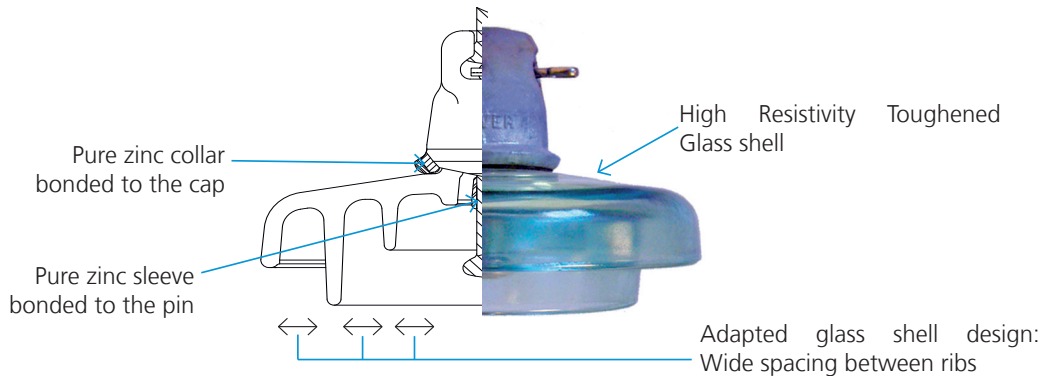
In order to avoid this type of corrosion, Sediver®, went beyond the IEC specification in the early 80s and patented a specific zinc collar design to protect the cap.

Field observations



Rust appears on cap due to surface current

Sediver® HRTG features and User benefits



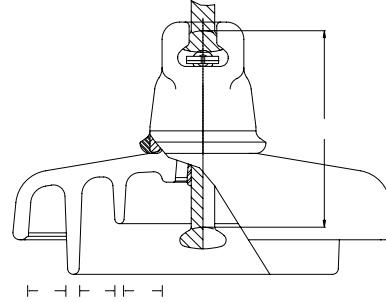
	HVDC stress consequence	Risk	Sediver® HRTG solution	User benefit
Internal current	Ionic migration	Dielectric breakdown	High Resistivity Toughened Glass coping with ion flow stresses	No puncture = less maintenance
	Thermal runaway	Dielectric breakdown	High Resistivity Toughened Glass with high purity 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

IEC



OLD CATALOG N° NEW CATALOG N°	DC Fog type Profile					
	F160P/C170DR F160PS/C170DC	F210P/C170DR F210PP/C170DC	F300PU/C195DR F300PU/C195DC	F420P/C205DR F420PQ/C205DC	F550P/C240DR F550CT/C240DC	
IEC class ⁽¹⁾	U160BL	U210BP	U300BP			
Metal fitting size ⁽²⁾	20	20	24	28	32	
MECHANICAL CHARACTERISTICS						
Combined M&E strength	kN	160	210	300	420	550
Impact strength	N-m	45	45	45	45	45
Tension proof	kN	80	105	150	200	275
DIMENSIONS						
Diameter (D)	mm	330	330	360	380	360
Spacing (S)	mm	170	170	195	205	240
Leakage distance	mm	550	550	635	630	635
ELECTRICAL CHARACTERISTICS⁽³⁾						
DC withstand voltage						
- Dry one minute ±	kV	150	150	170	170	170
- Wet one minute ±	kV	65	65	65	70	70
Dry lightning impulse withstand	kV	140	140	140	140	150
DC SF6 puncture withstand voltage	kV	225	225	225	225	255
PACKING AND SHIPPING DATA						
Approx. net weight per unit	kg	8.8	9.9	13.4	14.7	17.5
No of insulators per crate		6	6	5	4	2
Volume per crate	m ³	0.062	0.062	0.135	0.132	0.063
Gross weight per crate	kg	31.7	34.6	78	82	43

Custom products, not shown here are also available.

(1) IEC 60305
(2) IEC 60120
(3) IEC 61325

Sediver® contribution within international standardisation committees

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

Committees:

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

Working groups

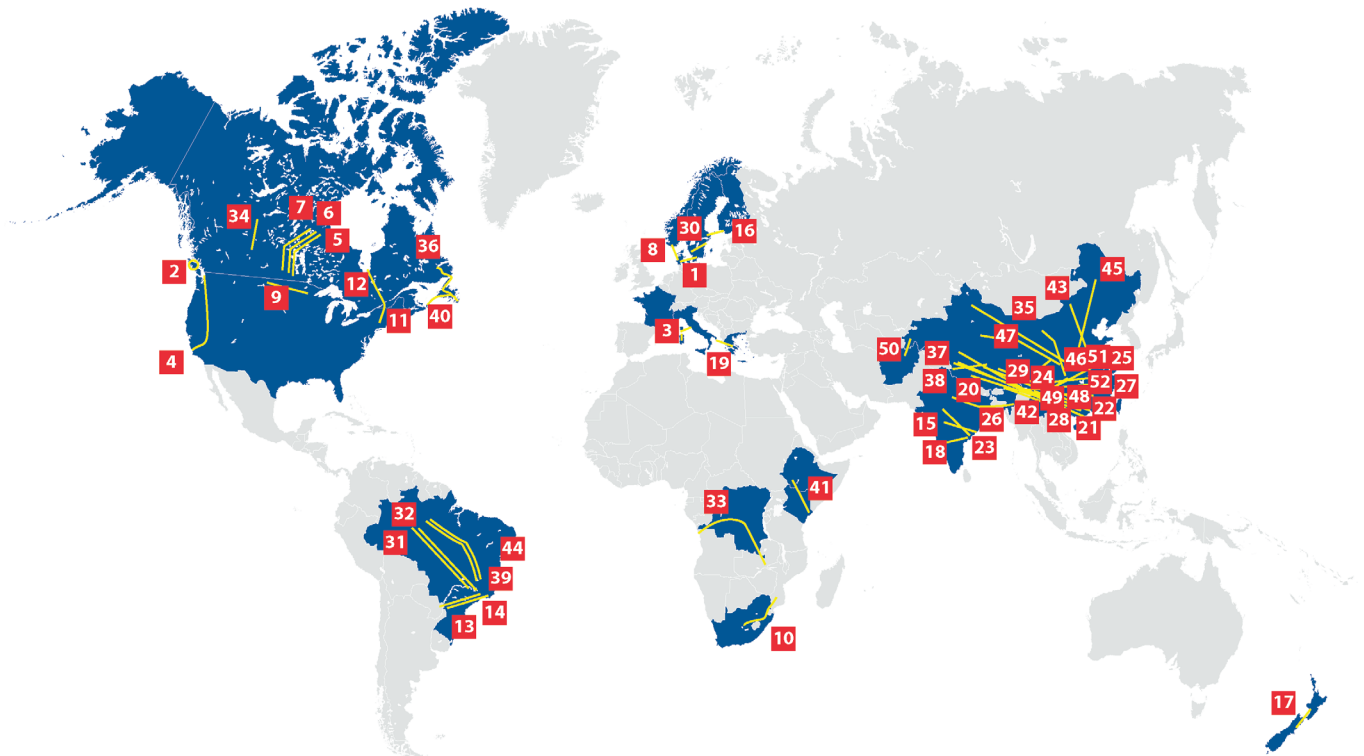
- CIGRE : B2, D1, C4
- IEEE : OHL SC
- CSA 411
- NEMA ANSI C29
- IEC TC36



HVDC international publications and Sediver® research activities on HVDC insulators

- GEORGE JM / LEPLEY D / 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 Technologies 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

extensive HVDC worldwide experience



- 11+ million toughened glass DC insulators
- More than 50 years of experience up to 800 kV DC

1. ±300 kV DC, Denmark-Sweden,Konti-Skan 1;2 and 3, 1965/1988	28. ±800 kV DC, China, Nuozhadu-Guangdong 1 413 km, 2012
2. ± 260 kV DC, Canada, Vancouver Islands 42km, 1967	29. ±500 kV DC, China, Xiluodu-Guangdong, 1 251 km, 2012
3. ±200 kV DC, Italy-France, Corsica-Sardinia-Italy 264 km, 1967/1992	30. ±300 kV DC, Sweden, South-West Link – the Southern part, 2012
4. ± 500 kV DC, USA, Pacific Intertie 1 360 km, 1969/2014/2017-2019	31-32. ±600 kV DC, Brazil, Rio Madeira I&II, 2 x 2 500 km, 2012/13
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	33. ±500 kV DC, Congo DR, Inga-Shaba 1 700 km, 2013/2017
8. ± 250&350 kV DC, Denmark-Norway, Skagerrak 217 km, 1&2;3 1975/1993	34. ±500 kV DC, Canada, Eastern Alberta, 500 km, 2013
9. ±500 kV DC, USA, Dickinson - Coal Creek 687 km, 1978	35. ±800 kV DC, China, Hami-Zhengzhou 2 208 km, 2013
10. ±500 kV DC, Mozambique, Cahora Bassa 1 420 km, 1978	36. ± 350 kV DC, Labrador-Newfoundland – Muskrat Falls, 1 300 km, 2014
11. ± 500 kV DC, USA, New England 85 km, 1984	37. ±500 kV DC, China, Jinzhong-Guangxi, 577 km, 2015
12. ± 450 kV DC, Canada, Quebec- New England, 1 100 km, 1988	38. ±500 kV DC, China, Guanyinyan DC, 700 km, 2015
13-14. ±600 kV DC, Brazil, Itaipu 1 & 2, 2 x 800 km, 1984/87	39. ±800 kV DC, Brazil, Belo Monte I, 2 000 km, 2015-17
15. ±500 kV DC, India, Rihand Dadri 814 km, 1987	40. ±200 kV DC, Canada, Maritime link, 2016
16. ±500 kV DC, Finland-Sweden, Fenno Skan 1&2 136 km, 1988/2009	41. ±500 kV DC, Ethiopia-Kenya, Interconnection, 1 045 km, 2016-17
17. ±350 kV DC, New Zealand, North South Island 535 km, 1990	42. ±800 kV DC China, Dianxibei, 1 928 km, 2017
18. ±500 kV DC, India, Chandrapur Padghe, 752 km, 1997	43. ±800 kV DC China, Ximeng-Taizhou, 1 620 km, 2017
19. ±400 kV DC, Italy-Greece Interconnection, 110 km, 1999	44. ±800 kV DC, Brazil, Belo Monte II, 2 300 km, 2017
20. ±500 kV DC, China, Tianshengqiao - Guangzhou, 1 050 km, 2001/2004	45. ±800 kV DC, China, Zhalute-Qingzhou, 1 320 km, 2017
21. ±500 kV DC, China, Guizhou - Guangdong 1 & 2 2007 km, 2003	46. ± 800 kV DC, China, Shaanbei-Wuhan, 1 135 km, 2019
22. ±500 kV DC, China, Yunnan - Guangdong 1 418 km, 2008	47. ±800 kV DC, China, Qinghai-Henan, 1 575 km, 2019
23. ±500 kV DC, India, Ballia Bhiwadi 780 km, 2008/2009	48. ±800 kV DC, China, Wudongde-Guangxi, 1 490 km, 2019
24. ±500 kV DC, China, Deyang - Baoji 534 km, 2009	49. ±500 kV DC, China, Yunnan-Guizhou Interconnection, 1283 km, 2019
25. ±500 kV DC, China, Gezhouba-Shanghai 1 929 km, 2009	50. ±500 kV DC, Tajikistan-Afghanistan, Sangtuda to Deh Salah, 162 km, 2020
26. ±800 kV DC, India, Biswanath Agra 1 825 km, 2010/11/12	51. ±800 kV DC, China, Baihetan-Jiangsu, 2269km, 2021
27. ±800 kV DC, China, Jinping-Sunan 2 089 km, 2011	52. ±800 kV DC, China, Baihetan-Zhejiang, 2193 km, 2021