SEDIVER

TOUGHENED GLASS INSULATORS FOR HVDC APPLICATIONS

Experts & Pioneers

WORLDWIDE - 2024

We manufacture
High Resistivity Toughened Glass (HRTG) insulators

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 programmes 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 then introduced in IEC 61325, which remains the only international standard describing HVDC performance requirements.

More than 11 million Sediver® insulators have now been used in HVDC lines, with great success.

Applications cover all climatic and environmental conditions up to 800 kV DC.

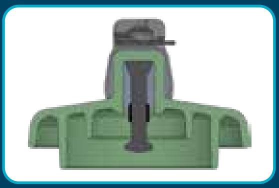
Why glass?

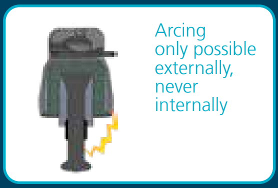
Glass is fully amorphous, it is a frozen liquid. This means it has no crystallographic structure responsible for ageing. Our manufacturing process makes it even more reliable, stable and strong. We have decades of knowledge of this material, enabling us to provide our customers with unique benefits throughout the life cycle of their installation.

Our own distinctive manufacturing process

- A **high-purity** glass with an **outstandingly homogeneous chemical composition.**
- A unique know-how enabling us to create **complex glass shapes** and products up to 16½” (420 mm) in diameter and weighing more than 22 lbs (10 kg).
- A toughening process developed by Sediver® that generates a compressive pre-stress on the surface of the glass shells, giving the glass a high mechanical strength and increasing its resistance to thermal and shocks and mechanical impacts and its immunity to the effects of ageing.
- A highly automated manufacturing process perfected over the years by Sediver®, guaranteeing consistently high levels of quality in terms of materials and final product assembly.
- A **very stringent quality system** comprising systematic controls and inspection of insulators during manufacturing, all **constantly and automatically monitored** and supervised by qualified inspectors.
- **A standardised process across all production facilities, guaranteeing consistent product performance worldwide.** A QA system and individually marked units that ensure full traceability of all insulators.
- **A low shattering rate,** guaranteed <1/10 000 per year due to the high purity of our Sediver® glass and outstanding process.

Focus on binary glass





Intact shell	Damaged shell
• Guaranteed absence of internal cracks and electrical punctures. • 100% mechanical rating guaranteed over prolonged periods, even in very harsh conditions. • 100% electrical strength.	• Residual mechanical strength: 80% mechanical rating guaranteed over prolonged periods, even in very harsh conditions. • Residual electrical strength: no internal puncture and forcing overvoltage induces discharges externally.

Therefore

- Easier inspection: no need to climb structures or use sophisticated instruments.
- Greater worker safety in live-line operations.
- Very low-cost inspection throughout the service life of the line.
- No risk of separation or line drops.
- No urgency in replacing a unit with a broken shell.
- Long-term savings in maintenance operations.

HVDC specific stresses

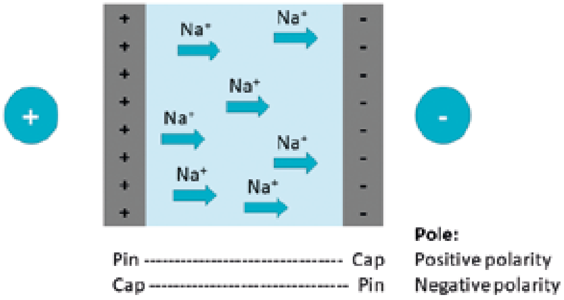
Insulators used on HVDC lines must withstand unique and specific stress conditions associated with the unidirectional e-field and current flow.

1. Ionic migration

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

Ionic migration creates a risk of depletion layer formation in dielectric materials not specifically designed for DC application, or with an improper formulation. These depletion layers can weaken the dielectric and cause porcelain to puncture or toughened glass to shatter.

IONIC MIGRATION



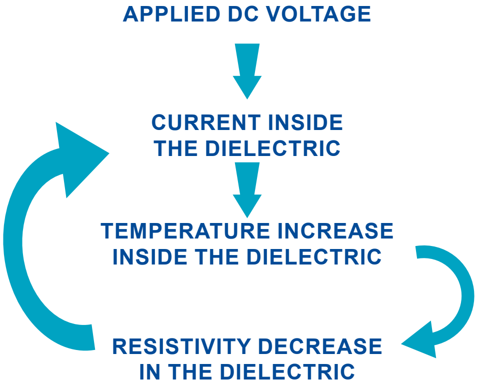
2. Thermal runaway

In HVDC applications, the **unidirectional current can cause a significant rise in temperature locally in the dielectric**. This 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 create a loop where loss of resistivity allows more current to flow through the insulator and the temperature to rise higher and higher.

This is called **thermal runaway,** it can cause porcelain to puncture or toughened glass to shatter.

THERMAL RUNAWAY CONCEPT



APPLIED DC VOLTAGE

CURRENT INSIDE
THE DIELECTRIC

TEMPERATURE INCREASE
INSIDE THE DIELECTRIC

RESISTIVITY DECREASE
IN THE DIELECTRIC

3. Pollution accumulation

Under HVDC, the electrostatic field along the length of an insulator string combined with the effects of the wind cause a steady build-up of pollutants on the insulator surface.

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

In HVDC systems, the length of the string is more often controlled by the level of pollution than by switching and lightning performance.

4. Metal part corrosion

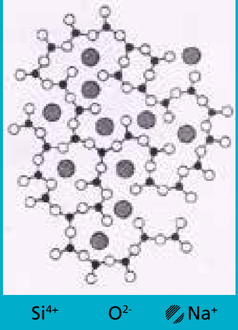
Direct current combined with humid conditions also accelerate corrosion of metal parts due to electrolytic effects.

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

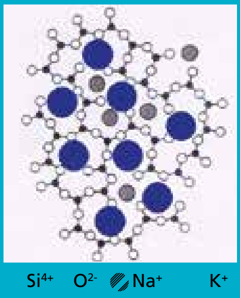
Sediver® HRTG insulator design:
the answer to HVDC T/L reliability

To achieve optimum performance in DC and to cope with these four additional constraints, Sediver® has developed a **High Resistivity Toughened Glass (HRTG) insulator,** with a special type of glass and 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 to which other oxides are added, either for processing or to achieve specific properties depending on the final application.

In AC glass chemistry, oxides like sodium can be used.

In this case, sodium, which is not linked to the structural atomic backbone, can move under an electric field and result in ionic conductivity.

In DC, this ionic conductivity must be inhibited.

To reduce ionic migration, the atomic network is modified by replacing some sodium ions with bigger cations, or other cations having lower mobility.

Sodium mobility in the resulting glass material (HRTG) is **hindered by these bigger cations, eliminating risk of failure due to ionic migration.**

2. High Resistivity Toughened Glass to prevent thermal runaway

The **chemistry of High Resistivity Toughened Glass** increases the electrical resistivity of the glass, which is about 100 times higher compared to AC glass, **avoiding 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, having a lower impact on ionic accumulation.

3. New glass shell design to offset pollution accumulation

The **specific pollution conditions in DC applications require insulators capable of reducing 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.

Sediver® has successfully adapted the shape of its glass shell to DC requirements, by using specific glass moulding and toughening processes which reduce the risk of arc bridging.

4. Protection of metal end fittings against corrosion

Pins from service insulators

Corroded pin without zinc sleeve

Pin with zinc sleeve

Pin protection

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

To prevent such 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

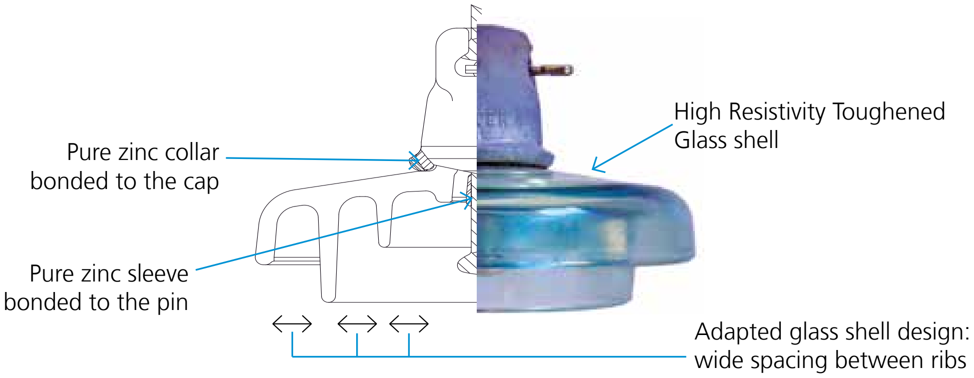
Cap protection

In HVDC, arcing activity and corrosion can also occur around the cap, creating rust deposits on the top surface of the skirt.

Although this poses no mechanical risk, generation of a conductive path on the insulators can substantially reduce the overall leakage distance of the entire string and therefore its electrical performance.

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

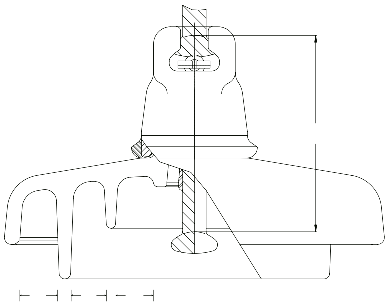


	HVDC stress consequence	Risk	Sediver® HRTG solution	User benefit
Internal current	**Ionic migration**	Dielectric breakdown	**High Resistivity Toughened Glass** coping with ion flow stresses	No puncture = less maintenance
	Thermal runaway	Dielectric breakdown	**High Resistivity Toughened Glass** with high purity offering high resistance to localised thermal stresses	No puncture = less maintenance
External current	**Pollution accumulation**	String flashover	**HVDC specific glass shell design** for improved performance in presence of pollution	High pollution efficiency = less maintenance
	Metal part corrosion	String flashover Mechanical failure	**Protection of 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. Millions of Sediver® HRTG insulators have already proven their outstanding performance and reliability under all kinds of environmental conditions.

Sediver® toughened glass suspension insulators
Ball & Socket type - DC Fog profile

IEC



		DC Fog type Profile				
OLD CATALOG N°		**F160P/C170DR**	**F210P/C170DR**	**F300PU/C195DR**	**F420P/C205DR**	**F550P/C240DR**
NEW CATALOG N°		**F160PS/C170DC**	**F210PP/C170DC**	**F300PU/C195DC**	**F420PQ/C205DC**	**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	m³	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 to international standardisation committees

Sediver® contributes actively to the following committees and working groups:

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
- ANSI NEMA 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, 12-15 Nov. 2023, Bangkok, Thailand

George JM, Lepley D, "AC and DC pollution testing methods: accuracy and limitations", 2022 INMR World Congress, 16-19 Oct. 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, 24 Aug.-3 Sep. 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 Jul. 2018, Acapulco, Mexico

George JM, Brocard E, Virlogeux F, Lepley D, "DC pollution performance: current approximations & future needs" INMR 2017 World Congress, 5-8 Nov. 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 JM, "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, 5-8 Nov. 2017, Barcelona, Spain

George JM, "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

Nolasco JF, Ferreira LFP, "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

George JM, "Long term Performance Evaluation of Toughened Glass Insulators and the consequences for UHV and DC Applications", International Conference on UHV Transmission, Beijing, China, 21-22 May 2009

Ferreira LF, George JM, "HVDC Toughened Glass Insulators", INMR Rio de Janeiro 2007

George JM, Del Bello E, "Assessment of electrical and mechanical performance of Toughened Glass Insulators removed from existing HV Lines", CIGRE Regional Meeting 27-28 Aug. 2007, Calgary Canada

Dumora D, Parraud R, "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 Apr. 2002, New Delhi, India

Parraud R, Dumora D, Joulie R, Lumb C, "Improvement in the Design and the Reliability of Toughened Glass Insulators for AC and DC Transmission Lines", CEPSI, 21-25 Oct. 1996

O'Brien M, Burleigh C, Gleadow J, "New Zealand ± 250 KV 600 MW HVDC Link Reliability, Operating Experience and Improvements", CIGRE Colloquium on HVDC, New Delhi, 9-11 Sep. 1991

Pargamin L, "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

Pargamin L, De Decker D, Dumora D, "Improvement of the Performances of HVDC Toughened Glass Insulators", HVDC Insulator Symposium Los Angeles, 19-21 Nov. 1985

Sediver®

Extensive HVDC experience worldwide

- Over 11 million toughened glass DC insulators
- More than 50 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

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