# Sediver® High Resistivity insulators for HVDC applications

Experts & Pioneers

# Introduction to Sediver® HRTG insulators

At the end of the 1950's 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 1980's.
This development has largely contributed to establish 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 9.5 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.

# 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

Electrical conduction in insulating materials is the result of the movement of ions through the material.
During the life of insulators on a DC line, certain units can be exposed for extended periods to a combination of a high voltage - due to non-uniform voltage distribution - and high temperatures arising from ambient conditions and solar heating.
In DC applications, the unidirectional current can generate a significant increase of temperature locally in the dielectric.
Ionic migration is also sensitive to the purity of the dielectric material.
The effect of ionic migration on dielectric materials not specifically designed for DC application, or having an improper formulation, is a risk of formation of depletion layers resulting in a weakening of the dielectric itself.
This can lead to puncture for porcelain or shattering for toughened glass.

## 2. Thermal runaway

Thermal runaway can occur in insulators with a low resistivity material when the temperature of the dielectric is much higher than the ambient temperature, or when ionic currents flow in the vicinity of internal discontinuities of the dielectric. The temperature rise associated with the local heating increases the current which increases the temperature in a runaway spiral and finally leads to puncture for porcelain or shattering for toughened glass.

## 3. Pollution accumulation

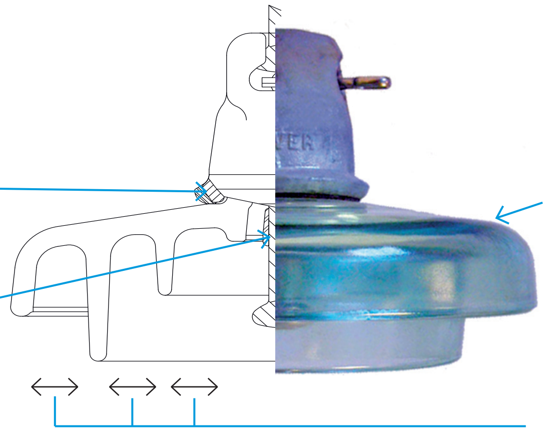
Under HVDC, the electrostatic field along the length of an insulator string, in conjunction with the wind, lead to a steady build-up of pollutants on the insulator surface. This pollution accumulation can be as high as
10 times more severe than that on comparable HVAC insulation in the same environment.
Therefore, while for high voltage alternating current (HVAC) systems, switching and lightning performance are the dominant factors influencing the overall length of insulation, for HVDC systems the length of the string is more often controlled by the level of pollution.

## 4. Metal part corrosion

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

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

To achieve an optimum 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.

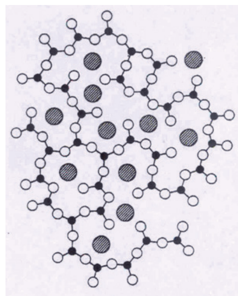



## 1. High Resistivity Toughened Glass to solve internal current effects

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 for acheving 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.

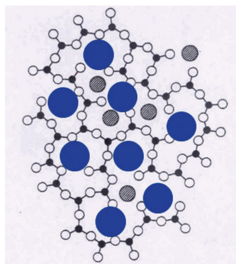
AC glass chemical composition




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.
The electrical resistivity of the glass is therefore increased by a factor of about 100, eliminating the risk of failure due to ionic migration or 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.

DC glass chemical composition



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

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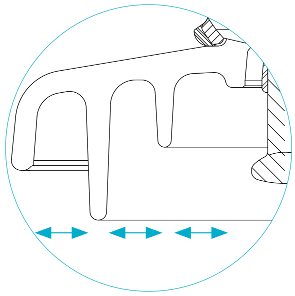
## 2. Adapted glass shell design to prevent pollution accumulation

The specific pollution conditions of DC applications require that the insulators be designed with care to reduce 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 specifics, made possible thanks to the glass pressing and toughening processes which:

- avoids arc bridging,
- reduces dust accumulation,
- maintains self-cleaning.



## 3. 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 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.

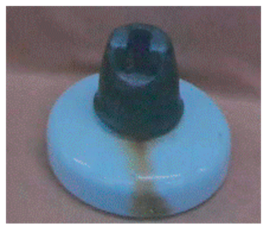
### Cap protection

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 80's and patented a specific zinc collar design to protect the cap.

Field observations



Rust appears on cap due to surface current

# User benefits

**Sediver® HRTG features and User benefits**

| | HVDC stress consequence | Risk | Sediver HRTG solution | User benefit |
|---|---|---|---|---|
| **Internal current** | **Ionic migration**<br>**Thermal runaway** | Dielectric breakdown | **High Resistivity Toughened Glass** imparting high resistance to localized thermal stresses and ion flow | No puncture<br>= less maintenance |
| **External current** | **Pollution accumulation** | String flashover | **Adapted glass shell design** with wide spacing between ribs and increased leakage distance | High pollution efficiency<br>= less maintenance |
| | **Metal parts corrosion** | String flashover<br>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 |

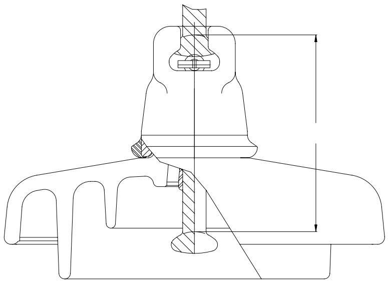
**The condition of Sediver® DC insulators after 30 years in service has been monitored jointly with Utilities. Today millions of Sediver® HRTG insulators have proven their outstanding performance and reliability under all kinds of environmental conditions.**

# Sediver® toughened glass suspension insulators

**IEC**

## Ball & Socket type

## DC Fog type



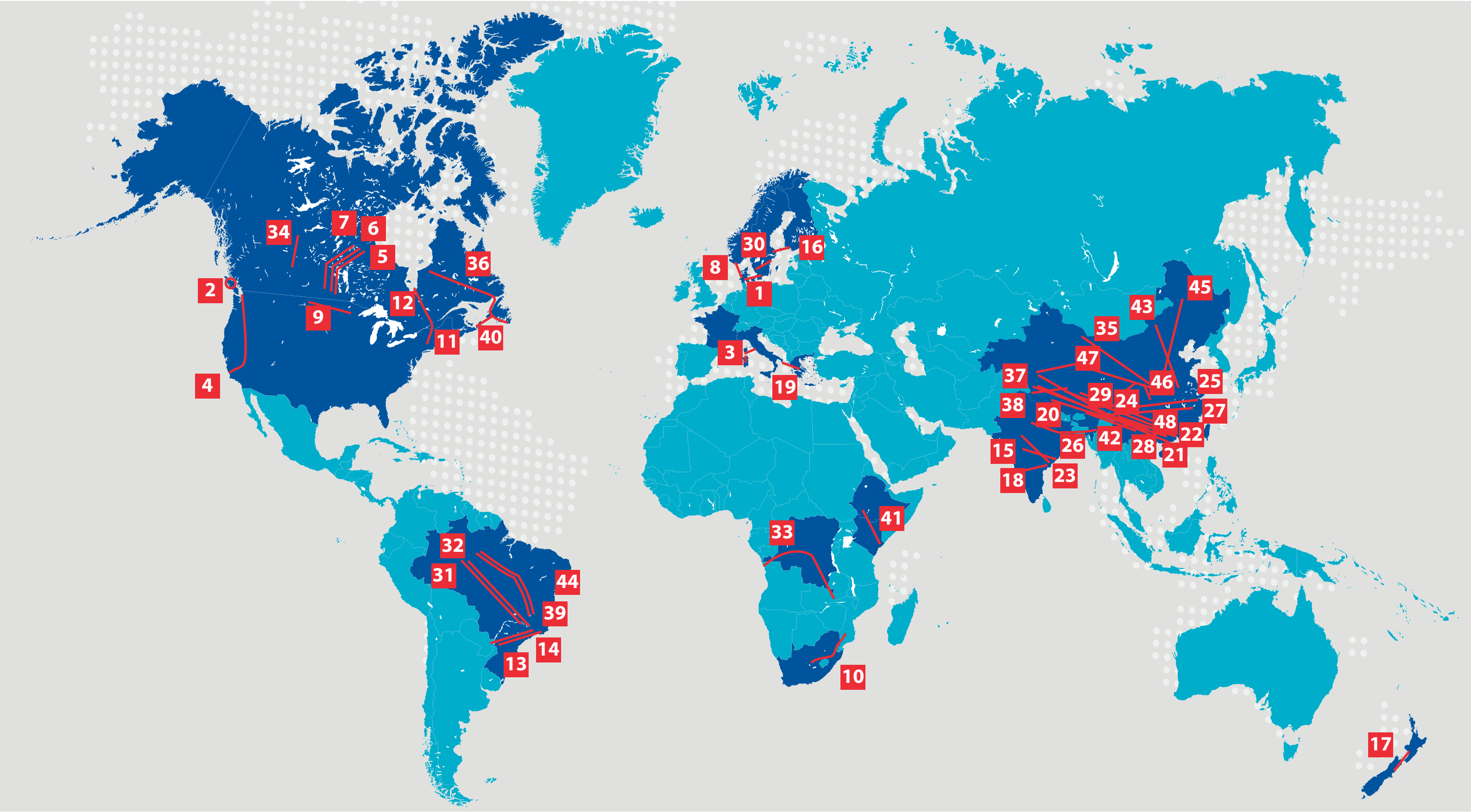
| CATALOG N° | | DC Fog type Profile F160P/ C170DR | F210P/ C170DR | F300PU/ C195DR | F420P/ C205DR | F550P/ C240DR |
|---|---|---|---|---|---|---|
| IEC class [(1)] | | U160BL | U210BP | U300BP | | |
| Metal fitting size [(2)] | | 20 | 20 | 24 | 28 | 32 |
| **MECHANICAL CHARACTERISTICS** | | | | | | |
| 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 | 645 | 670 | 635 |
| **ELECTRICAL CHARACTERISTICS[(3)]** | | | | | | |
| DC withstand voltage | | | | | | |
| - Dry one minute ± | kV | 150 | 150 | 150 | 150 | 170 |
| - Wet one minute ± | kV | 65 | 65 | 65 | 65 | 75 |
| Dry lightning impulse withstand | kV | 140 | 140 | 140 | 140 | 140 |
| DC SF6 puncture withstand voltage | kV | 225 | 225 | 225 | 225 | 255 |
| **PACKING AND SHIPPING DATA** | | | | | | |
| Approx. net weight per unit | kg | 9.7 | 10.2 | 15.3 | 18.7 | 18 |
| No of insulators per crate | | 3 | 3 | 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 on HVDC T/L in the World

- 9.5 million toughened glass DC insulators are installed all around the world
- 50+ years of experience 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 42km, 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 687km, 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 2007 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, Ge Hu 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, Xiloudu-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, Jingzhong-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, 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 |

# Sediver contribution within international standardisation committees

Since the very beginning of international technical cooperation, Sediver has always been an active member in fields of research and standardisation in international committees and working groups dealing with all aspects of high voltage insulation.

| Committee | International Electrotechnical Commission (IEC) | International Council on Large Electric Systems (CIGRE) | Institute of Electrical and Electronics Engineers (IEEE) |
|---|---|---|---|
| | Main Committees & Working Group in which Sediver is active | | |
| Working Groups | IEC TC 36: Insulators<br>WG 11: Revision of IEC 60815<br>IEC SC 36B: Insulators for overhead lines<br>EC SC 36C: Insulators for substations<br>IEC TC 37: Surge arresters | WG D1.27: Material Properties for New and Nonceramic Insulation<br>WG B2.21: Arc protection and Diagnosis for Composite String Insulators<br>WG B2.41: AC to DC Conversion<br>WG C4.303: Pollution and environmental influence on the electrical performance of power systems | T&D Committee<br>WG Insulator contamination<br>WG Insulator strength<br>WG Application of non ceramic insulators<br>ESMOL |

# HVDC international publications and Sediver research activities on HVDC insulators | Bibliography


GEORGE JM. "Insulator contamination assessment and mitigation for AC and DC overhead lines" 2018 Grid of the Future Symposium, CIGRE US, 28 - 31 October 2018, Reston, Virginia, United States

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 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 – Z. LODI "Design and Selection criteria for HVDC Overhead Transmission Lines Insulators" CIGRE CANADA Conference on Power Systems, Toronto, October 4-6, 2009

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

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