SEDIVER

High Resistivity toughened glass insulators for HVDC applications

Experts & Pioneers

USA/CANADA

Sediver High Resistivity Toughened Glass 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 its 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 6.5 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

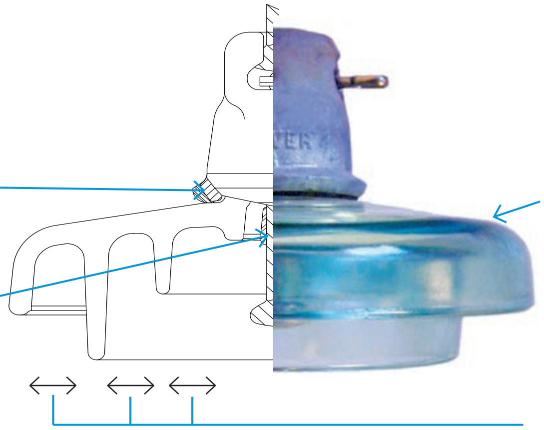
Under HVDC, the electrostatic field along the length of an insulator string, in conjunction with the wind, lead to a steady build-up of pollutants on the insulator surface. This pollution accumulation can be as high as 10 times more severe than that on comparable HVAC insulation in the same environment.
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.



High Resistivity Toughened Glass to solve internal current effects

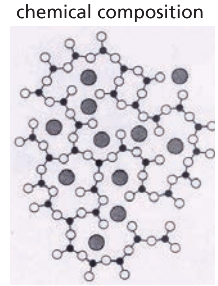
Glass is an amorphous material. Its atomic structure is a basic Silica/Oxygen network in which several other oxides are added, either for processing or for achieving specific properties depending upon the final application.

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.
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.

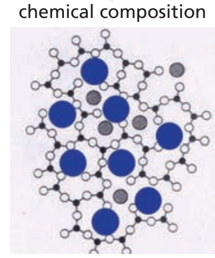
Additionally, Sediver has developed a special manufacturing process able to produce glass shells with a very high degree of purity, and therefore having a lower impact on ionic accumulation.

AC glass chemical composition



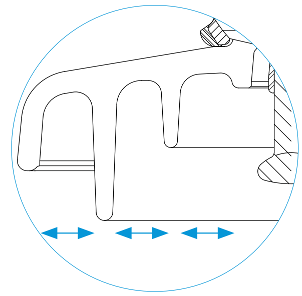
Si^{4+} O^{2-} Na^{+}

DC glass chemical composition



Si^{4+} O^{2-} Na^{+} K^{+}

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.

Protection of the metal end fittings against corrosion

Field observations

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

Field observations

Rust appears on cap due to surface current

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.

User benefits

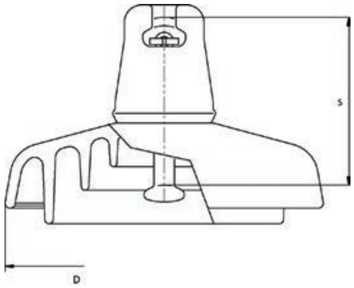
Sediver HRTG features and User benefits

	HVDC stress consequence	Risk	Sediver HRTG solution	User benefit
Internal current	**Ionic migration** **Thermal runaway**	Dielectric breakdown	**High Resistivity Toughened Glass** imparting high resistance to localised thermal stresses and ion flow	No puncture = less maintenance
External current	**Pollution accumulation**	String flashover	**Adapted glass shell design** with wide spacing between ribs and increased leakage distance	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 coupling
DC Fog type



Insulator type		N120PF/ C146DR	N160P/ C170DR	N180P/ C170DR	N220P/ C170DR	F300PU/ C195DR	F400P/ C205DR	F550/ C240DR
		DC Fog type profile						
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 5/8	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	70	70	70
Dry lightning impulse withstand	kV	140	140	140	140	150	150	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	28	34.2	40.1
	kg	*8.4*	*9.7*	*9.7*	*10.5*	*12.7*	*15.5*	*18.2*
No of insulators per crate		6	6	6	6	5	4	4
Volume per crate	ft³	3.92	4.34	4.34	4.34	4.77	3.96	4.63
	m³	*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	ft³	47.11	48.88	48.88	48.88	55.62	47.18	53.57
	m³	*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

HVDC

Sediver extensive HVDC worldwide experience

- Over 6.5 million toughened glass DC insulators
- More than 50 years of experience up to 800 kV DC

1	**±260 kV DC,** Canada, Vancouver Islands 42km, 1967
2-3	**±500 kV DC,** USA, Pacific Inertie 1360 km, 1969/2014
4	**±500 kV DC,** Canada, Eastern Alberta, 500 km, 2013
5	**±500 kV DC,** USA, Dickinson - Coal Creek 687km, 1978
6-7-8	**±450&500 kV DC,** Canada, Bipole I,II & III 2x870 km & 1364 km 1972 & 2014-15
9	**±450 kV DC,** Canada, Quebec- New England, 1100 km, 1988
10	**±500 kV DC,** USA, New England 85 km,1984
11	**±350 kV DC**, Canada, Labrador-Newfoundland – Muskrat Falls, 2014
12-13	**±600 kV DC,** Brazil, Itaipu I & II, 2 x 800 km, 1984/87
14-15	**±600 kV DC,** Brazil, Rio Madeira I & II, 2 x 2500 km, 2012/13
16	**±800 kV DC,** Bresil, Belo Monte I, 2092km, 2015/16
17-18	**±250&350 kV DC,** Denmark-Norway, Skagerrak 217 km, I &II ;III 1975/1993
19-20	**±500 kV DC,** Finland-Sweden, Fenno Skan I & II 136 km, 1988/2009
21-22	**±300 kV DC,** Denmark-Sweden,Konti-Skan I ;II & III, 1965/1988
23	**±300 kV DC,** Sweden, South-West Link – the Southern part, 2012
24	**±200 kV DC,** Italy-France, Corsica-Sardinia-Italy 264 km, 1967/1992
25	**±400 kV DC,** Italy-Greece Interconnection, 110 km, 1999
26	**±500 kV DC,** Congo DR, Inga-Shaba 1700 km, 2013-14
27	**±533 kV DC,** Mozambique, Cahora Bassa 1420 km, 1977/2011/2013
28	**±500 kV DC,** India, Chandrapur Padghe, 752 km, 1997
29	**±500 kV DC,** India, Rihand Dadri 814 km, 1987
30	**±800 kV DC,** India, Biswanath Agra 1825 km, 2010/11/12
31	**±500 kV kV DC,** India, Ballia Bhiwadi 780 km, 2008/2009
32	**±500 kV DC,** China, Tianshengqiao - Guangdong 1050 km, 2001/2004
33	**±500 kV DC,** China, Guizhou - Guangdong I & II 2007 km, 2003
34	**±500 kV DC,** China, Yunnan - Guangdong 1418 km, 2008
35	**±500 kV DC,** China, Deyang - Baoji 534 km, 2009
36	**±500 kV DC,** China, Ge Hu 1929 km, 2009
37	**±800 kV DC,** China, Jinping - Sunan 2089 km, 2011
38	**±800 kV DC,** China, Nuozhadu - Guangdong 1413 km, 2012
39	**±500 kV DC,** China, Xiloudu - Guangdong 1251 km, 2012
40	**±800 kV DC,** China, Hami - Zhengzhou 2208 km, 2013
41	**±500 kV DC,** China, Jinzhong -Guangxi - Zhengzhou 1139 km, 2015
42	**±500 kV DC**, China, Guangyinyan 700 km, 2015
43	**±350 kV DC,** New Zealand, North South Island 535 km, 1990

Sediver contribution within international standardization committees

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

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

HVDC international publications and Sediver research activities on HVDC insulators

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

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

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