Close and Return



# DC extruded Cable System design and its main characteristics

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# Cable system design
# AC versus DC

**Advantage of AC vs DC**

easier to change the voltage level
⇨ decreasing of the losses by
increasing the voltage
⇨ AC networks

**Advantages of DC vs AC**

No reactive power – Electrical losses are smaller (no skin effect).
Main application
⇨ Long distance transmissions

**Cable system**

- ✓ Cable
- ✓ Joint
- ✓ Termination

**Land links**

- ➢ Transportation of long length of cable is difficult
- ➢ In case of breakdown = repair of the link is easy

**Submarine links**

- ➢ Easy to transport long length of cable
- ➢ In case of breakdown = difficult to repair the link

**One single joint design:**

- ➢ Field joint

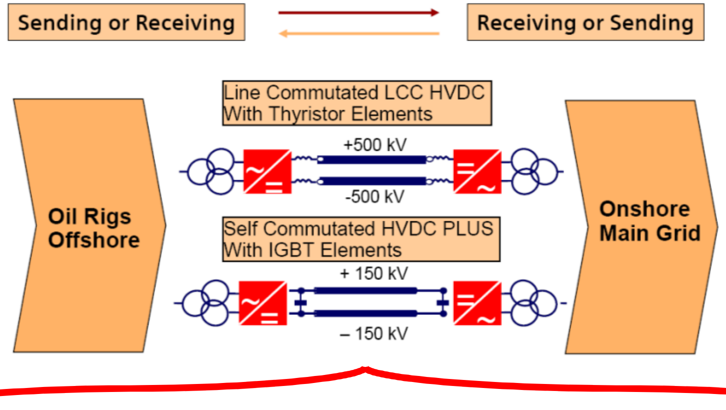
**Two dedicated joints :**

- ➢ Factory joint
- ➢ Repair joint

# Long length AC link can be achieved through shunt compensation

# Converter technologies for DC links

*Convertor station at both ends*

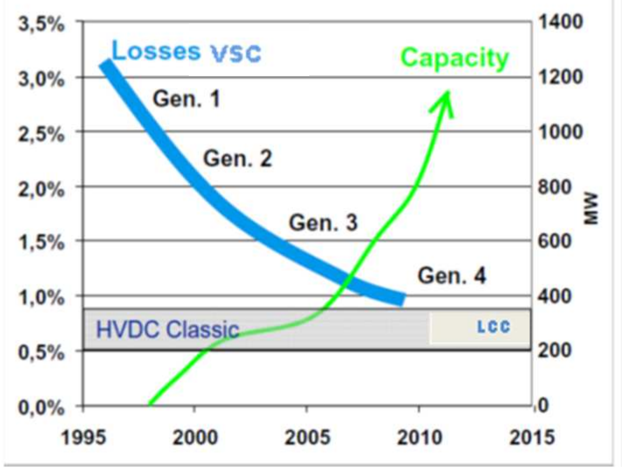



## LCC technology (thyristors)

- Reversal of the power flow ⇨ polarity on the cable system is reversed
- Used up to very high powers (800 kV - 5000 MW)
- Site area relatively large

## VSC technology (transistors)

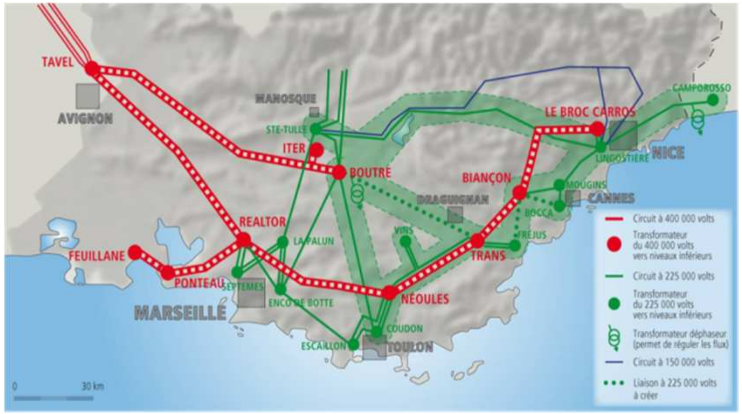
- Allows to reverse the power flow without changing the polarity of the cable system
- Gives more flexibility to network operators
- Currently used up to 320 kV




*Losses of VSC and LCC*

# Example of long length AC cable system

## XLPE Land cable system 500MW 225kV PACA




*Map of the underground 225kV links (green) and OHL (red)*

*2500mm² enamelled copper 225 kV XLPE Cable*

Reinforcement of the unique 400kV OHL to supply the South East of France area is made using 225kV underground cables

↓

3 links:

- Boutre-Trans: 65 km
- Biançon-Fréjus: 25 km
- Biançon-La Bocca: 20 km

↓

- Total number of joints = 3x68
- Drums are up to 50 T (≈1400 m)
- Conductor cross sections: 2000 and 2500mm² depending on the thermal environment.
- 2500mm² cable has a diameter ≈ 130 mm, weight ≈ 33 kg/m.

↓

Shunt reactor at each substation (160MVAR)

# Examples of long length DC cable systems

## Mass Impregnated 400MW +/- 250kV Cometa link


*Cometa link between Spain and Mallorca*

*750 mm² Cu +/- 250 kV Mass Impregnated cable*
*Deep water*

Connection between Spain and Mallorca

↓

(250km) in one laying campaign (7000T)

↓

- MI cable ⇨ copper cross section of 750 mm².
- Cable with a single layer of flat armour wires for the shallow part of the route up to 200 m water depth.
- For the deeper water middle section, a double flat wire armour layer was used

↓

LCC converter station at each end of the link

# Examples of long length DC cable systems

## XLPE 400MW +/-200kV Trans Bay Cable

*Submarine cable installation route (blue for shallow waters and yellow for deep waters)*

*1100 mm² Cu +/- 200 kV XLPE cable*

Connection between area of Pittsburg to the city and county of San Francisco

↓

- Copper conductor size of 1100 mm² - Compacted circular design – Filled with water blocking compound.
- Extruded insulation : XLPE for HVDC

↓

Route length : 83 km

↓

- Barge used for the shallow water section of the route
- Cable ship Giulio Verne was used for the deeper water sections

↓

VSC converter station at each end of the link

# Examples of long length DC cable systems

## XLPE 2x 1000MW +/- 320kV France/Spain Interconnection


*INELFE layout*


*2500 mm² Cu +/- 320 kV XLPE cable*

Interconnection between Spain and France across the Pyrenees

↓

Cables and accessories have been subject to long term and short term testing, in accordance with Customer requirements, derived from Cigré Technical Brochure 219

↓

64 km, 2 bipoles (total cable quantity = 256 km)

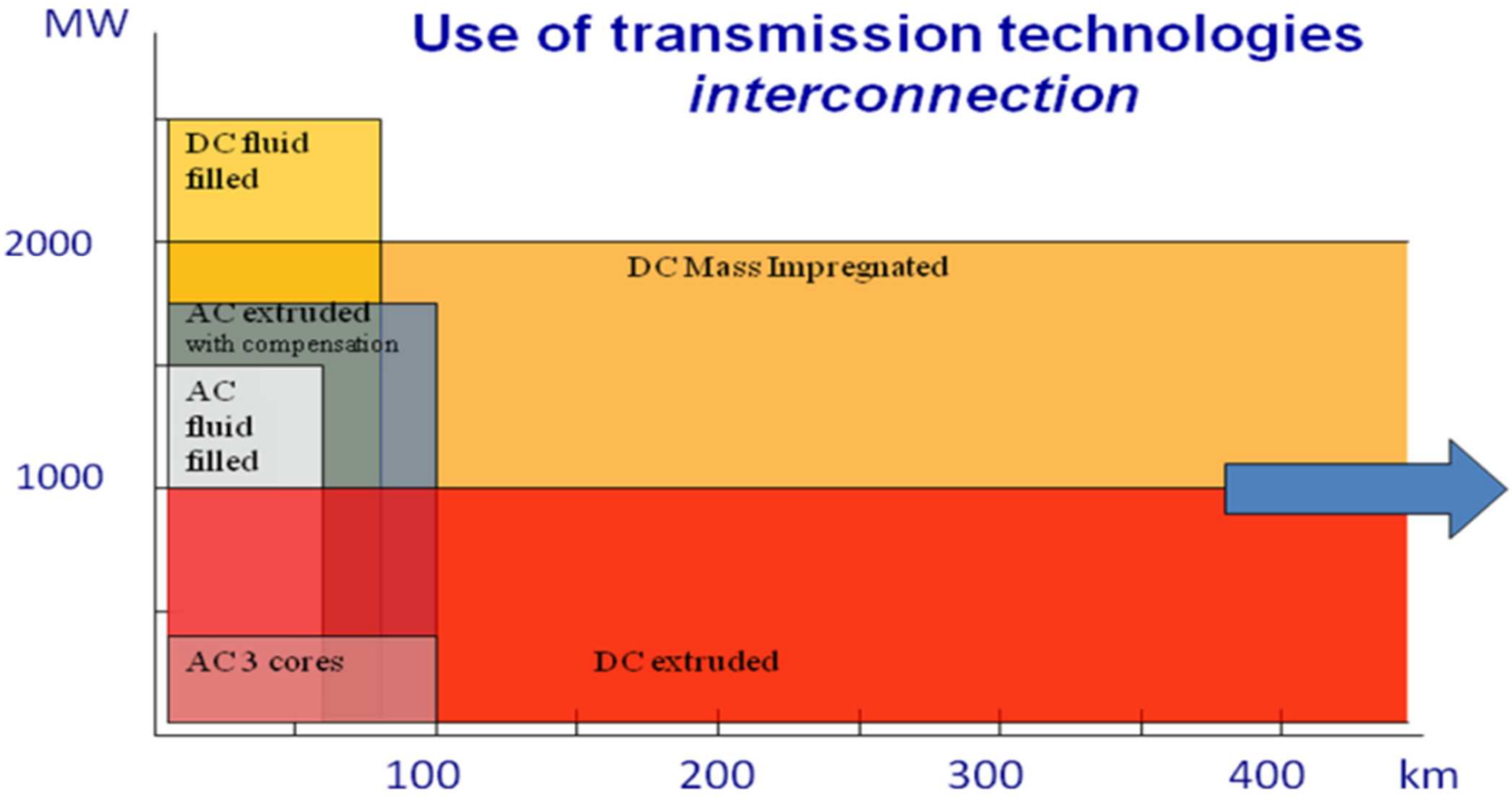
↓

- 2500 mm² copper conductor
- Extruded insulation
- Longitudinally welded aluminium sheath
- Plastic over sheath

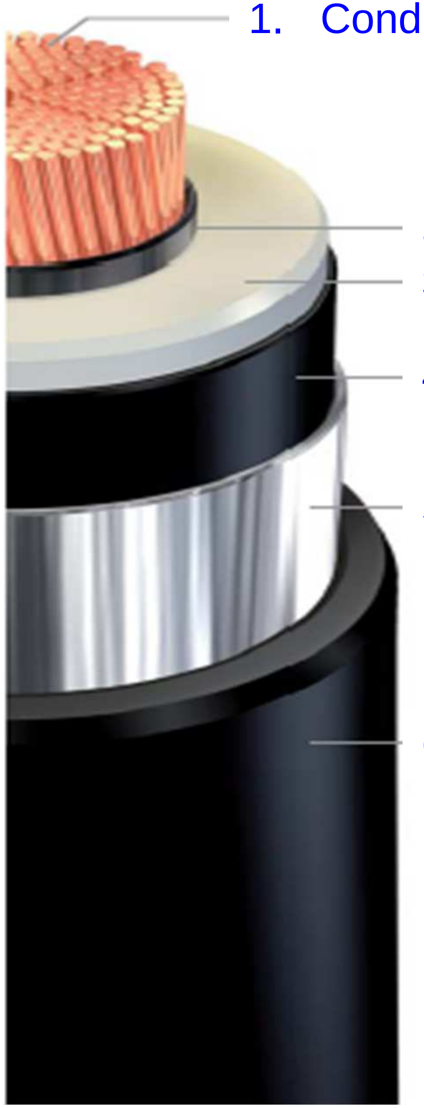
↓

VSC converter station at each end of the link

# Use of power transmission technologies



# HVDC cable design



1. Conductor
2. Inner semi-conducting conductor screen
3. Cross-linked polyethylene (XLPE)
4. Outer semi-conducting core screen
5. Metal screen
6. Outer Sheath

DC extruded cable design is similar to AC extruded cable design.

The main difference between DC vs AC design is the use of dedicated compounds not only for insulation but also for semi-conducting screens.

# Electric stress in HVDC cables and accessories

## Resistive field distribution

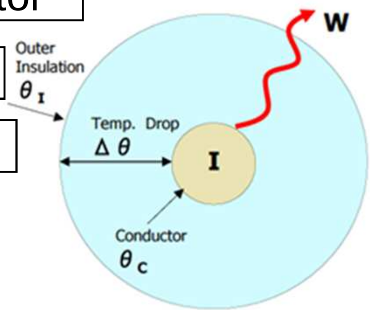
DC voltage is applied

After some time constant ($\tau=\rho\varepsilon$), stress distribution becomes resistive

Circulation of I in the conductor

Joule losses

$\Delta\theta$ across the insulation



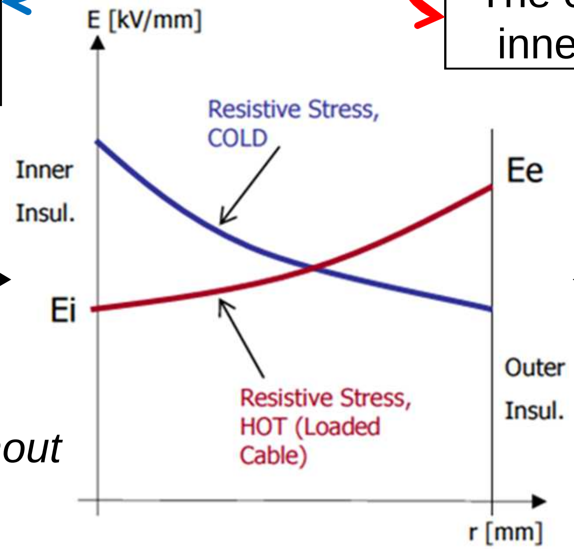

Stress distribution is led by the insulation conductivity

$$\sigma=\sigma_0^{\alpha\theta+\beta E}$$

Where stress is higher, insulation conductivity is better and the charges are moved away from the high stress zone to the low one

Conductivity is increasing with $\theta$

The charges moved away from the inner to the outer insulation layer




*Resistive field distribution with / without temperature gradient*

# Electric stress in HVDC cables and accessories

## Space charge field enhancement

Space charge :

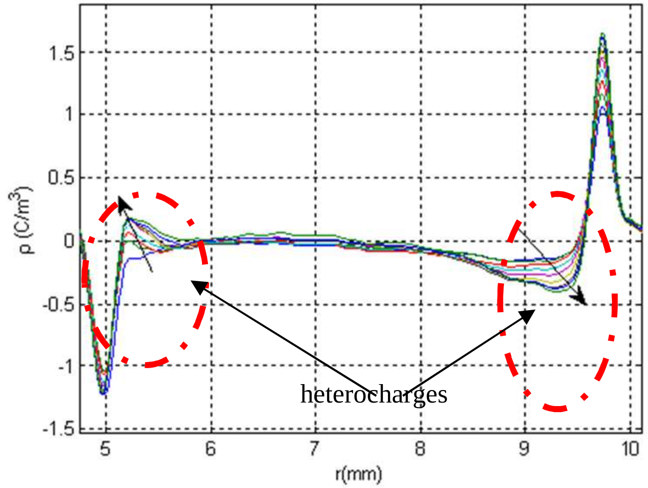
- electronic or ionic in nature
- charges can be injected from the semi-conducting shield used in DC power cable geometry or can be formed by residues dissociation under the action of the electric field

Space charge, is partially fixed inside the bulk of insulation material by traps.

⇨ Charge density measured is in the range of 1 to 10 C /m³ approximately

⇨ It has been found useful to combine the spatial distribution of space charge to the measurement of a parameter known as Field enhancement factor (FEF). FEF is defined as a ratio of the field at a given location as compared to the Laplace field (i.e. field without space charge).
A material with FEF=1 is the preferred choice for DC application.

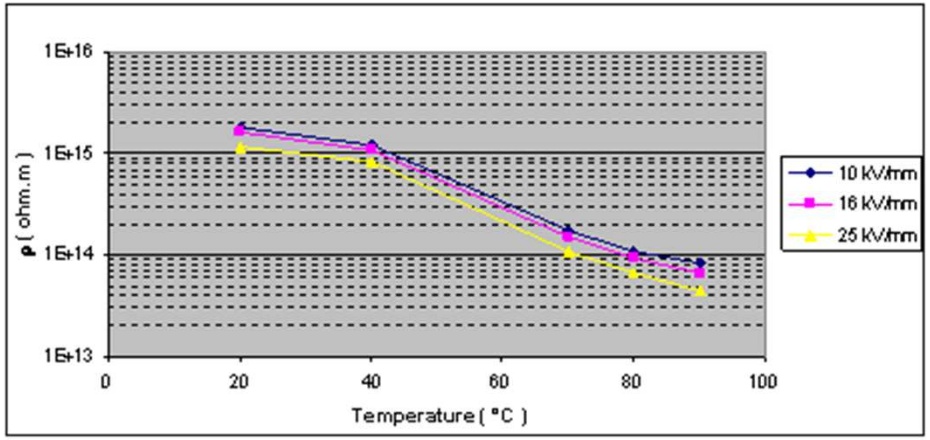
*Voltage-on space charge density in model cable poled at 25 kV/mm at 20° C.*
*Hetero-space charge is accumulated at the anode as well as at the cathode*



# Electric stress in HVDC cables and accessories

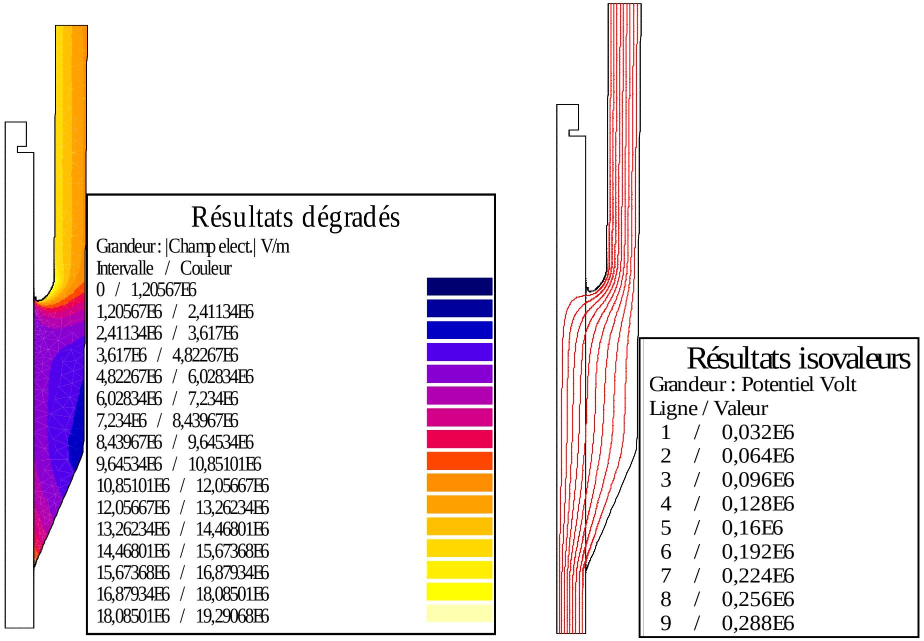
## Space charge field enhancement

Similar to cable insulation, DC insulation resistance (ρ) and space charge properties must be evaluated on insulating material of pre-moulded accessories




*DC resistance properties of EPDM*
*Samples submitted to 8 hours poling*

The electric field distribution in the insulating components of the accessory varies depending also on the shape of electrode and deflector




*Electric field distribution in pre-moulded joint.*

In addition, at each interface where there is a discontinuity of electrical properties (resistivity, permittivity, time constant...) there is a layer of space charges (Maxwell – Wagner effect) which affects the field distribution.

# Rating

Dimensioning of the conductor cross section of HVDC cables takes into account two limiting parameters:

1. The rated maximum conductor temperature
2. The rated maximum $\Delta\theta$ across the insulation.

In cold environmental condition, $\Delta\theta$ is the leading parameter and the maximum conductor temperature may be never reached.

In case of warm environment, the parameter 1 prevails and the maximum temperature gradient across the insulation may be never reached.

These 2 parameters must be also considered when designing the overload conditions. That impacts the way the HVDC cable systems can be used when connected to a generation plant where there is no redundancy.

# Conclusion

The increasing use of VSC technology where the power flow reversal occurs without changing polarity of the cable encourages the use of synthetic insulated cables and both long submarine and underground links are being considered and actively implemented.

The experience of Extruded HVDC cables at transmission voltages is recent (10 years) as compared MI insulation (60 years) and HVAC XLPE (45 years).

There is still a large knowledge to build up specially dealing with the dynamic of space charge under voltage and different temperature profiles over a long period, and the assessment of ageing mechanisms.