



Extruded Cables for HVDC Power Transmission

System Solutions and Innovation

HV land and submarine cable systems are the backbone of all power transmission networks.

The greater and ever-increasing demand for power, the need for larger bulks of power and for the transmission of such bulks over longer and longer distances, the localization of the sufficient or even exceeding existing power generation capacity far from the requiring use and consumption centers are the main reasons for the realization of interconnections among power networks of various and different types.

In addition, the involvement of new players other than the traditional operators and asset owners (e.g. Merchant Lines) in the electricity market requires an increasingly stricter control of the power flows.

HVDC cable systems offer a technologically advanced and reliable instrument to address these issues.



Power transmission cable systems

AC transmission is used on short distances because it is more cost effective as it does not require converter stations.

DC transmission is used for long lengths.

For bulk power transmission, mass impregnated cables still prove to be the most suitable solution because of their capacity to work up to 600 kV DC.

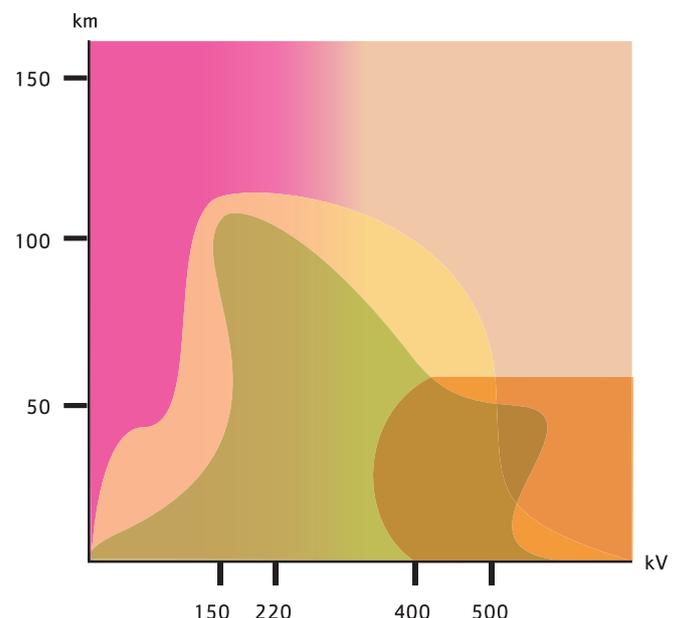
Recent developments on converters technology have lead to the adoption of extruded insulation cables for DC transmission systems up to 300 kV.

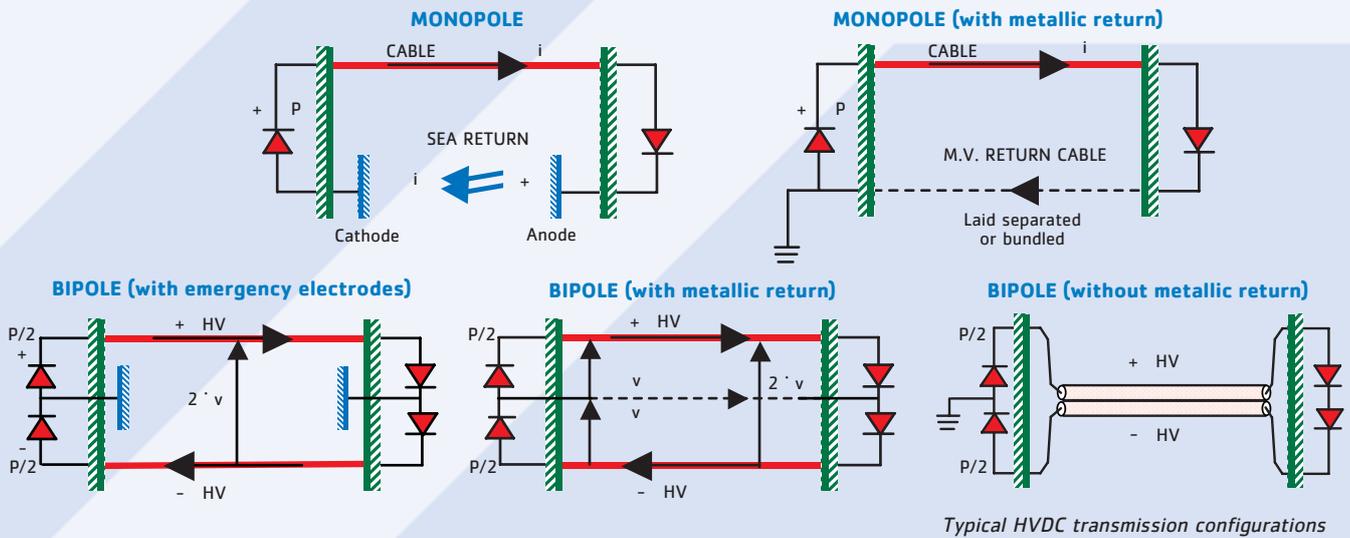
AC CABLES SYSTEMS

- **AC extruded:**
 - > up to 500 kV
 - > typical length: up to 60 km at 400 kV over 100 km at 150 kV
- **AC fluid filled:**
 - > up to 525 kV
 - > typical length: up to 50 km at 400-500 kV

DC CABLES SYSTEMS

- **DC extruded:**
 - > up to 300 kV
 - > power: up to 800 MW
- **DC mass-impregnated:**
 - > up to 600 kV
 - > power: up to 2500 MW
- **DC fluid filled:**
 - > up to 600 kV
 - > typical length: used for short circuits





> A new generation of cables for a new generation of converters

In recent years HVDC power transmission systems have gone through a remarkable development because of the increasing need for the transmission of larger and larger bulks of power over longer and longer distances with the purpose of optimising the energy resources available worldwide.

The new generation of converters (VSC – Voltage Source Converters) use IGBT (Insulated Gate Bipolar Transistors) which allow the power to be transmitted as it is in both directions without requiring polarity reversal.

This has allowed re-introducing the use of extruded cables in DC power transmission as, with the polarity reversal being no longer required, the problem of space charges that can arise with an extruded insulation and create excessive dielectric stress within the cable in the case of sudden polarity reversal does not exist any longer.

Peculiarities of power transmission

Transmission Solution	Advantages	Drawbacks/Limitations
<p>AC</p>	<ul style="list-style-type: none"> Simple No maintenance High Availability 	<ul style="list-style-type: none"> Heavy cable Length (50-150 km) Rigid connection/Power control Require compensation reactance
<p>DC Conventional</p>	<ul style="list-style-type: none"> Less cables (n.), lighter No limits in length Low cable and conversion losses Power flow control Very high transmission power 	<ul style="list-style-type: none"> Strong AC networks needed Cannot feed isolated loads Polarity reversal required Large space occupied Special equipment required (transformer, filters)
<p>DC 'New'</p>	<ul style="list-style-type: none"> Can feed isolated loads (oil platforms, wind parks, small islands, etc.), medium power Modularity, short delivery time Small space and environmental impact No polarity reversal Standard equipment 	<ul style="list-style-type: none"> Higher conversion losses Reduced experience Limited power

About us

Prysmian is a world leader in the energy and telecommunication cables industry with a strong market position in higher added value market segments.

It is organised in two business sectors: Energy Cables and Systems (submarine and underground cable systems for power transmission and distribution, cabling solutions for residential and infrastructure buildings and cabling systems for signalling, control and power feeding for a wide range of industrial applications) and Telecom Cables and Systems (optical fibres, optical cables and copper cables for voice, video and data transmission). The Prysmian Group has a global presence in 34 countries with 54 plants, 7 international R&D Centers and more than 12,000 employees.

Specialising in the development of bespoke products and systems, Prysmian's main competitive strengths include: focus on research and development, ability to innovate in terms of both products and processes, and the use of advanced proprietary technologies.

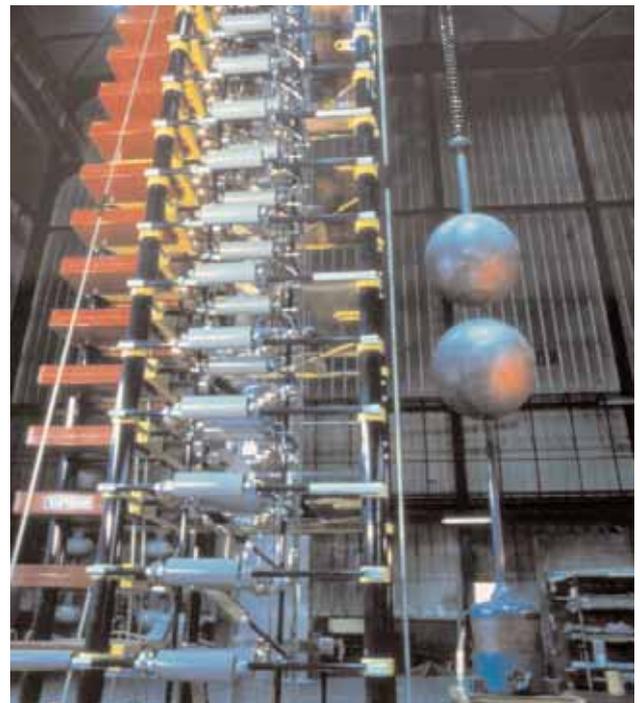


Global Solutions Provider

The energy market has been changing dramatically in recent years, as a result of deregulation and privatisation. To face the challenge of competition, energy transmission and distribution operators are driven towards an optimum use of their existing resources and new investments.

To support its customers, Prysmian has evolved over the years from the traditional role of cable manufacturer to that of a **Global Solutions Provider**. Prysmian focuses on a total system approach, to give its customers the lowest cost of ownership of their new and installed cable networks.

This "Total System" approach is, at all voltages, the ultimate solution to provide power utilities with real advantages in terms of asset optimisation. Besides an increasing activity on product innovation to lower investment costs, Prysmian is developing additional pre and post sales services for its customers - e.g. network services, enhanced logistics, engineering studies - to optimise asset management and give the best possible exploitation of transmission and distribution networks.



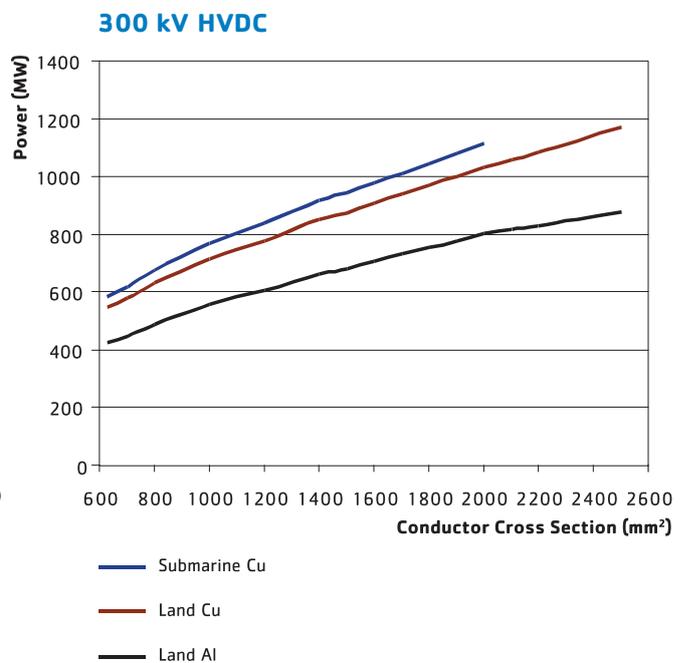
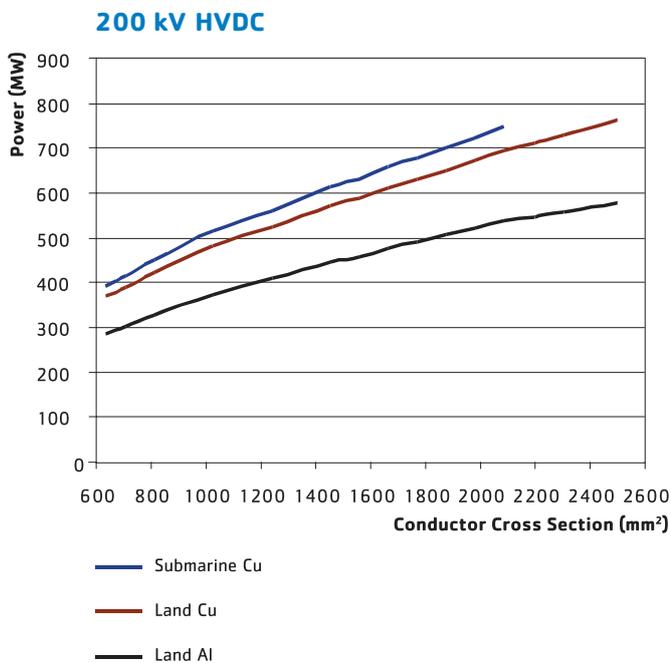
Product Range

So far, Mass Impregnated cables (high-density paper tapes impregnated with a high-viscosity compound) have proven suitable allowing these cables to be installed in HVDC links in very long lengths, up to several hundreds of kilometers. However, where remarkable advantages and makes for lighter and easier-to-handle cables, which can operate at high temperatures and at high

Thanks to recent technology improvement, extruded cables are presently adopted for voltages up to 300 kV DC. Recent studies have demonstrated that the extruded technology proves suitable for HVDC links, in particular when associated with Impregnating fluids and/or pressure feeding reduced cable weight and dimensions and relative ease of jointing are the key features in terms of total system costs.

Power Transmission Capacity

Performances of cables are very much related to environmental conditions. The graphs show typical rating curves in specified conditions.



Submarine installation:

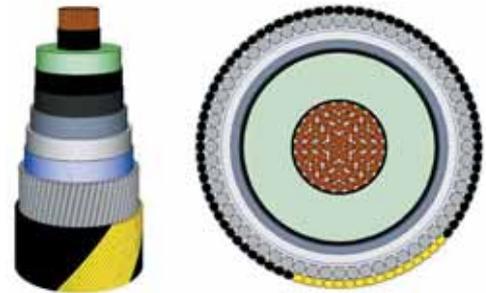
Soil Thermal Resistivity 1.0 K.m/W - Soil Temperature 15°C - Burial Depth 1.2 m - Cables in contact (installation in bundle)

Land installation:

Soil Thermal Resistivity 1.2 K.m/W - Soil Temperature 20°C - Burial Depth 1.4 m - Axial distance between cables 300 mm

For voltages of up to 600 kV DC without requiring fluid pressure feeding, thus the system requirements permit, the use of an extruded insulation offers several advantages in terms of electrical stresses.

Combined with VSC (Voltage Source Converter) technology, the advantages of this technological innovation, which offers also considerable benefits



HDVC submarine cable design

Prequalification of Extruded HVDC Cables

Two electrical prequalification programmes were successfully carried out in accordance to the CIGRE TB 219 document "Recommendations for testing DC extruded cable systems for power transmission".

The first for a rated voltage of 250 kV, the second for a rated voltage of 300 kV. Testing circuits included the cable and all relevant accessories.



The mechanical prequalification procedure according to CIGRE Electra n. 171 consists of:

- > **Tensile bending test** on a real cable sample (at least 30 m) containing at least one flexible joint, with three bending cycles at the same calculated load as during the installation around a drum with the same diameter (or smaller) of the laying ship pay-off wheel. The test is then followed and concluded by the electrical test and the visual inspection.
- > **External water pressure withstand test** carried out on a cable sample (visual examination).

Sea Trial for Submarine Cables

CIGRE Electra n. 171 recommends carrying out this test when laying conditions and/or cable designs differ considerably from previously established practice.

The test is carried out on a sample of cable sufficiently long to reproduce the laying conditions and includes both a factory joint and a repair joint.

The cable sample is laid at the maximum sea depth the cable will reach in real laying conditions and then recovered and subject to electrical tests and visual examination.



Total Quality Commitment

The Prysmian brand has always been a guarantee for the supply of products and services based on worldwide common quality standards. Prysmian has a built-in multi-step quality assurance program, which covers the entire production process from cable design and raw material purchasing, to final inspection and testing documentation.

Prysmian business locations and manufacturing sites as well as operation units are certified according to **ISO 9001 and ISO 14001 Quality Management System standards** for their specific activities and products, and environmental quality standards.

Reference Project

Trans Bay Cable – San Francisco, USA

Route length:	85 km
Transmitted power:	400 MW
Voltage:	± 200 kV



Standards and Recommendations

High Voltage and Submarine cable constructions are not fully covered by national or international standards; Prysmian products are designed to meet the projected service duty and to comply with the applicable specifications. Type approval references are given against each product type available.

Most cable systems are custom designed to suit the specific environmental parameters and operating requirements of a particular route and loading conditions, taking into account the thermal, thermo-mechanical and electrical performance necessary to ensure reliable system operation throughout service life, which naturally will vary considerably between different applications and locations.

Besides, international scientific bodies – like IEC and CIGRE – develop relevant standards, technical recommendations and guidelines within their activities in the field of High Voltage land and submarine cable systems.

Prysmian relies on a long-standing tradition of participation and on a strong presence within such bodies, acquired thanks to its undisputed expertise developed over scores of projects accomplished anywhere in the world.



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