HVDC extruded cable

This technical guideline describes the basic design and construction requirements Svenska kraftnät applies to HVDC extruded cables for submarine and underground installations. The guideline shall be used when purchasing and designing extruded HVDC cables.
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1 References

The cable design shall be such that it fulfils the requirements for extruded HVDC cables in the following references.

IEC 60228 Conductors of insulated cables
IEC 62067 Power cables with extruded insulation and their accessories for rated voltages above 150 kV (Um = 170 kV) up to 500 kV (Um = 550 kV) – Test methods and requirements
IEC 60287 Electric cables - Calculation of the current rating
IEC 60853 Calculation of the cyclic and emergency current rating of cables
Cigré TB No 623 Recommendations for mechanical testing of submarine cables
Cigré TB No 496 Recommendations for Testing DC Extruded Cable Systems for Power Transmission at a Rated Voltage up to 500 kV
Cigré TB No 490 Recommendations for testing of long AC submarine cables with extruded insulation for system voltage above 30 (36) to 500 (550) kV
Cigré TB No 194 Construction, laying and installation techniques for extruded and self contained fluid filled cable systems
2 Definitions and abbreviations

Definitions and abbreviations used in this technical guideline, as well as in all other TR14 documents, can be found in a separate document in the TR14 series, TR14-01-2E.

3 General

3.1 Manufacturer’s prequalification
Manufacturers shall have expertise and substantial experience in designing, manufacturing and installing submarine and underground HVDC extruded cables for the specified (or higher) rated voltage level and current. The manufacturer shall be able to present two successful reference projects as a basis for a prequalification.

3.2 Lifetime
The cable design with respect to used materials, manufacturing techniques as well as electrical, thermal and mechanical stresses shall have the theoretical lifetime of at least 50 years.

3.3 Materials
The materials used in delivery cable shall be of the same type and designation as for the qualification tests and type tests. The materials shall not be changed during the project.

3.4 Power flow changes
The design has to withstand change of loads and power flow directions several times every day for the planned lifetime of the cable in all operational and environmental conditions.

3.5 Electrical stresses
The manufacturer shall show that electrical stresses in the insulation do not exceed well-established stresses during normal operation, transient conditions and during a fault. The electrical stress shall be calculated for the most severe cases at the specified ambient conditions for underground, submarine and open air installation.

If one cable pole fails by grounding of conductor due to internal insulation failure or external damages the remaining healthy pole shall withstand the stresses that result
thereof. The cable shall be designed to withstand specified withstand voltages as well as temporary over voltages to which the cable can be subjected to in service.

3.6 Mechanical requirements
The cable system has to withstand all tension, bending, bending fatigue, sidewall pressure, torsion and abrasion that it will experience during the lifetime of the cable, including repair operations.

4 Cable construction

4.1 Conductor
The cable shall have copper or aluminium conductor. The conductor shall be made of compacted stranded or profiled wires (also called keystone wires).

The compacted stranded conductor shall comply with IEC 60228.

The profiled conductor shall follow the designation of conductor cross-section with relation to conductor resistance according to IEC 60228 for stranded conductors. The profiled conductor shall have the filling grade of at least of 96%.

The conductor shall contain swelling agents to make it longitudinally water tight.

On top of the conductor a water swelling tape shall be applied to make it longitudinally water tight.

4.2 Insulation system
The insulation system consists of a conductor screen, insulation and insulation screen.

The insulation system shall be applied in a triple extrusion process. The insulation and semi-conductive layers shall be cross-linked. Insulation material shall be unfilled cross-linked polyethylene suitable for DC applications (DC-XLPE). Unloading of the extrusion materials into an extruder shall be performed in a cleanroom environment.

The cross-linking shall be performed by dry-curing with nitrogen gas.

On top of the outer semi-conductive layer (but under the water barrier sheath), a swelling tape shall be applied to make the cable core longitudinally water tight.
4.3 Water barrier sheath
The water barrier sheath shall effectively block water ingress to the cable core and shall be designed to meet mechanical and electrical conditions during manufacturing, testing, laying, retrieving and daily loading variations under its lifetime.

For a submarine cable design, the radial water barrier shall consist of a lead sheath.

For an underground cable design the radial water barrier sheath shall consist of an aluminium laminate.

The design of the water barrier sheath shall be sturdy and well proven. It shall be able to withstand and maintain integrity at all foreseen handling of the cable core and the cable.

Longitudinal water-tightening shall be implemented as swelling tapes under water barrier sheath.

4.4 Anti-corrosion sheath
A lead sheath shall be protected by an extruded anti-corrosion layer/sheath. This layer shall be designed to assure that the lead sheath and other layers are protected against corrosion, mechanical and electrical damages under its lifetime. The anti-corrosion sheath shall be made of semi-conductive material. Metallic connections between a lead sheath and armouring wires are not accepted.

4.5 Wire armouring
The submarine cable design has to be such that it is resistant to forming loops during cable laying and repair. If the manufacturer can demonstrate its appropriateness single wire armour may be acceptable.

If a submarine cable with a copper conductor is to be coiled, this shall be demonstrated in type testing.

The submarine cable with an aluminium conductor shall be handled during all phases so that the cable meets only minimum torsion, in other words storage requires turntable, any type of coiling is not acceptable.

The steel wires shall be galvanized. The armouring wires shall be flooded with bitumen.
4.6 Outer serving and markings
The wire armouring shall be covered by an outer serving. The outmost serving shall be resistant against biological decomposition and UV radiation.

If polypropylene yarns are to be used as outer serving on the cables, the outmost layer shall be mainly black, but with white or yellow stripes for easier visual detection. The complete cable length shall have the same stripe configuration and colour. Both plus and minus cable poles shall have the same stripe configuration and colour. If the cable has integrated FIMT this cable part containing FIMT shall have an additional blue stripe.

The inner serving layer/layers shall be flooded with bitumen.

Above the outer serving the submarine cable shall be fitted with the markings. The markings shall mark the locations of:

- Cable length marked at 100 m intervals. The marking shall state the cable length in meters at particular location.
- Flexible joints
- Non-conformances

4.7 Metallic screen
The underground cable design shall have a metallic screen of copper wires. The total area of screen copper wires shall be a minimum of 100 mm².

The underground cable shall be made longitudinally watertight by applying water swelling tape layers, one under and one above the metallic screen.

4.8 Outer sheath
The underground cable design shall have an outer sheath made of HDPE. The nominal thickness shall be 5 mm.

A thin semi-conductive layer shall be applied for testing purposes on the outer surface of the outer sheath.

Every metre the outer sheath shall have embossed markings stating the manufacturer’s name, year of manufacture, insulation material (DC-XLPE), rated voltage, conductor material, conductor cross-section, unique identification number of particular cable delivery length and metre marking.
5 Accessories

Accessories to be used in extruded HVDC cable systems are covered in Svenska kraftnät technical guideline TR14-02-5E.

6 Testing

Testing of extruded HVDC cable systems are covered in Svenska kraftnät technical guideline TR14-04-1E.

7 Documentation

The cable design, calculations, life-time estimations, testing etc. shall be documented according to document list described in TR08-05.

Documentation shall comply with requirements in TR08-01 and TR08-02.