HVDC mass-impregnated cable

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

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

IEC 60228    Conductors of insulated cables.
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 ÉLECTRA No 189 Recommendations for tests of power transmission DC cables for a rated voltage up to 800 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 MI 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 for 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. It shall be possible to use MI cables with either Line Commutated Converters (LCC) or Voltage Source Converters (VSC).

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 conductor in accordance with IEC Publication 60228. The conductor shall be made of profiled wires in order to achieve a metallic cross section ratio of at least 96%. Aluminium conductor may be considered for some special cases or special installations.

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

4.2.1 Material requirements
The cable shall have mass-impregnated paper insulation. Only insulation materials and cable impregnation oil that have previously been shown as having satisfactory DC performance will be accepted. The insulation system shall be designed with consideration taken to the electrical stresses at any load and temperature conditions. Insulation thickness, paper lapping and impregnation are especially important parameters and processes to consider.

4.2.2 Oil hydrodynamics
The hydrodynamic system (conductor, paper insulation, lead sheath and tape armouring layers) shall be designed in order to control the risk of cavitation within the insulation system to a minimum. The supplier shall be able to account for all relevant insulation status considering temperature gradients, load cycling et cetera, in terms of dielectric strength.

4.3 Lead sheath
The lead sheath shall be designed to meet mechanical and electrical conditions during manufacturing, testing, laying, retrieving, and daily loading variations under its lifetime.
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 Tape reinforcement
The submarine and underground cables shall be furnished with steel tape reinforcement layer in order to withstand the internal pressure and handle the pressure variations during any operation condition. The function and design of the tape reinforcement shall consider all pressure conditions for both land and sea.

4.6 Wire armouring
MI insulation is not as mechanically sturdy as XLPE insulation. As a result MI cable has lower tolerance to twisting as compared to XLPE cables. The MI cable design shall be such that it is resistant to forming loops during cable laying and repair.

The cable shall have a double-layer counter-helical tensile armouring. The armouring wires shall be made of steel. The steel wires shall be galvanized. The armouring wires shall be flooded with bitumen.

The armour layers shall be designed in such a way that an appropriate balance of tensional strength and minimum torsion is achieved during cable laying at the deepest portion of the cable route. The cable shall be handled during all phases so that it meets only minimum torsion. In other words, storage requires turntable, any type of coiling is not acceptable.

For underground MI cables the tensile armour layers shall reflect the mechanical forces during cable pulling/pushing. In general the steel wires offers some additional sturdiness to the design, but underground cables without tensile armouring may be considered.
4.7 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

4.8 Outer sheath
In case the underground MI cable design is without tensile wire armouring it shall have an outer sheath made of HDPE. The nominal thickness shall be 5 mm.

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

Every metre of the outer sheath shall have embossed markings stating the manufacturer's name, year of manufacture, insulation material (MI), 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 MI HVDC cable systems are covered in Svenska kraftnät technical guideline TR14-02-5E.
6 Testing

Testing of MI 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.