HVDC cable accessories

This technical guideline describes the principal design and construction requirements Svenska kraftnät applies to HV accessories to be used in HVDC cable systems for submarine and underground installations. The guideline shall be used when purchasing and designing extruded HVDC cable systems.
<table>
<thead>
<tr>
<th>Edition</th>
<th>Change notes</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>First edition of this technical guideline</td>
<td>2018-09-21</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Content

1 References ........................................................................................................... 4

2 Definitions and abbreviations ............................................................................ 6

3 General ................................................................................................................ 6

   3.1 Manufacturer’s prequalification .............................................................. 6
   3.2 Lifetime ................................................................................................. 6
   3.3 Materials ................................................................................................ 6
   3.4 Performance ......................................................................................... 6

4 Joints ................................................................................................................... 6

   4.1 Factory joint ........................................................................................ 7
   4.2 Field joint ............................................................................................ 7

5 Termination ......................................................................................................... 8

6 Link box .............................................................................................................. 11

7 Surge arresters .................................................................................................. 12

8 Earthing blade ................................................................................................... 13

9 Discharge resistor ............................................................................................. 13

10 Testing ............................................................................................................... 13

11 Documentation ................................................................................................. 13
1 References

The cable design of cable accessories shall comply with requirements in the following references.

TR14-02-2E  HVDC extruded cable
TR14-02-3E  HVDC mass-impregnated cable
TR14-03-1E  Earthing of HVAC and HVDC Cable Systems
TR01-12E  Self-Contained Surge Arresters 12-420 kV
TR01-13  Stamnätssationer jordning
TR 01-16  Skyttar i ställverk
IEC TS 60815-4  Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 4: Insulators for d.c. systems
IEC 62155  Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1 000 V
IEC 61462  Composite hollow insulators - Pressurized and unpressurized insulators for use in electrical equipment with rated voltage greater than 1 000 V - Definitions, test methods, acceptance criteria and design recommendations
IEC 60099-9  Surge arresters – Part 9: Metal-oxide surge arresters without gaps for HVDC converter stations
SS 421 01 67  Dimensionering av utomhusställverk – Vind- och islaster
SS-EN 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 Recommendation  ÉLECTRA No 189 – Recommendations for tests of power transmission DC cables for a rated voltage up to 800 kV.

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 in and substantial experience of designing, manufacturing and installing underground and submarine HVDC cables for the specified voltage level (or higher) and specified cable technology (extruded or MI). The manufacturer shall be able to present two reference projects as a basis for a prequalification.

3.2 Lifetime
The design of cable accessories 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 accessories must 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 Performance
The cable accessories must fulfil the same electrical, mechanical and thermal performance requirements as the HVDC cable, including static and transient stresses and overloading. Requirements for HVDC cables are described in TR14-02-2E and TR14-02-3E.

4 Joints
Sections of cables incorporating conductor joints must have the same mechanical robustness and handling characteristics as the cable. The cable conductors may not be joined by exothermic welding.
The number of any type of joints in the final installed HVDC link must be mini-
mised.

4.1 Factory joint
A factory joint is defined as a joint made in the factory before armouring of the ca-
ble.

The factory joints must be flexible and meet the same electrical performance re-
quirements as for the cable.

Sections of cables incorporating factory joints must have the same mechanical ro-
bustness and handling characteristics as the cable. This ability is to be proven in
tests by the same mechanical and electrical performance and requirements as is
valid for the cable.

Sections of cable incorporating factory joints must have the same corrosion proper-
ties as the cable itself.

Sections of cable incorporating factory joints must have the same water tightness
properties as the cable itself, except that the joint itself does not need specific
means for longitudinal water blocking.

4.2 Field joint

Submarine cable
A field joint is defined as a joint performed on an already wire-armoured cable and
which is performed in the planned operation of jointing the consecutive cable load-
ing lengths.

Field joints may also be used for repairs, and are then referred to as repair joints.

Field joints for extruded cables may be rigid. Rigid submarine joints may use parts
from the pre-fabricated underground joints.

Underground cable
Field joints for extruded underground cables must be prefabricated.

The earthed joints shall have screen separation. The remaining joints shall be used
without screen separation. The design with screen separation must allow for sheath
testing of cable sections after installation.

Transition joint
Transition joints are joints that connect cables with significant differences in de-
sign. For example, jointing an armoured submarine cable with underground cable
is considered as a transition joint.
Transition joint between submarine and underground cables requires a hang-off of the armour wires.

5 Termination

The termination in this context is considered to consist of: the cable termination, support stands, foundation and all other necessary equipment including link box, earthing conductors and temporary grounding point, in order to have a complete operational installation.

The design of the cable termination shall comply with the following conditions.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air temperature</td>
<td>-40</td>
<td>+35</td>
<td>°C</td>
</tr>
<tr>
<td>Design wind velocity</td>
<td>34</td>
<td></td>
<td>m/s</td>
</tr>
<tr>
<td>Ice layer thickness</td>
<td>20</td>
<td></td>
<td>mm</td>
</tr>
<tr>
<td>Solar radiation</td>
<td>1000</td>
<td></td>
<td>W/m²</td>
</tr>
</tbody>
</table>

The cable termination outer insulators must have a design and material appropriate and qualified for HVDC conditions (composite or porcelain). The colour must be uniform and coordinated with other insulators in the same yard. The insulators shall be maintenance free and shall not require regular cleaning.

The design of porcelain insulators shall comply with IEC 62155.

The design of composite insulators shall comply with IEC 61462.

The profile of the insulators shall comply with IEC 60815-4 Section 10.

The minimum Unified Specific Creepage Distance (USCD) for porcelain and composite insulators shall be according to Figure 1 and Table 1 below:
Figure 1: USCD of insulators for HVDC cable terminations in different pollution areas in Sweden.
Table 1: USCD of insulators for HVDC cable terminations in different pollution areas in Sweden.

<table>
<thead>
<tr>
<th>Area</th>
<th>Label</th>
<th>Distance from sea</th>
<th>USCD DC porcelain (mm/kV)</th>
<th>USCD DC composite (mm/kV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>West coast</td>
<td></td>
<td>0-0.5 km</td>
<td>100</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.5-15 km</td>
<td>75</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15-30 km</td>
<td>50</td>
<td>35</td>
</tr>
<tr>
<td>East coast</td>
<td></td>
<td>0-10 km</td>
<td>50</td>
<td>35</td>
</tr>
<tr>
<td>Skåne, Öland and Gotland</td>
<td></td>
<td>-</td>
<td>50</td>
<td>35</td>
</tr>
<tr>
<td>Inland</td>
<td></td>
<td>-</td>
<td>45</td>
<td>30</td>
</tr>
</tbody>
</table>

If a manufacturer presents positive service experience of similar cable termination in similar environment, lower creepage distance than proposed by technical guidelines could be considered.

The termination shall be insulated from the support stand and shall be connected to earth by a separate earth conductor. All earthing connections including connections from the cable sheath and armouring shall have an electrical and mechanical design that meets any operation condition and failure conditions with respect to ohmic heating. Dimensioning of the earthing conductor shall be according to TR01-13.

The top bolt of the terminations shall be equipped with a grounding ball-stud. It shall be mechanically robust to allow for connection of a grounding clamp with a grounding cable and allow for grounding using an insulated grounding stick from ground level. The grounding ball-stud shall be designed to withstand short circuit current of the link. The grounding ball-stud shall not disturb electric field distribution of corona rings.

Corona rings shall be made of aluminium and shall not be covered/painted with any additional material.

The cable termination is identified by the following data, which also shall be stated on the permanent rating plate:

- Rated continuous voltage pole-ground, $U_0$ (kV)
- Rated DC current, $I_0$ (A)
- Name of manufacturer
- Type designation and identification of the complete cable termination
- Year of manufacture
• Serial number

The rating plate shall be made of corrosion resistant material; preferably stainless steel. The rating plate shall be attached at suitable location on the side of the metallic base of the termination insulation body.

The cable terminations shall be marked with the signs according to TR 01-16.

6 Link box

Link boxes shall be used for earthing purposes at earthed underground cable joint bays, transition joint bays and cable termination stands. The other joint bays shall have no link boxes.

The link boxes shall allow for connecting the screens to local earth wires (insulated or not) from the permanent earthing system. The design of link boxes shall allow for screen separation in order to allow for sheath testing of cable sections. This shall allow for separation between the screens of the jointed cables, and separation between cable screens and the installed earth plane. It shall be possible to reassemble the initial earthing configuration in the link box after screen separation is no longer required.

Earthed underground cable joint bays and transition joint bays shall be equipped with a buried link box. There shall be one link box for both cable poles in symmetrical monopole scheme.

The link boxes for cable terminations shall be fitted on the termination steel stand. There shall be one link box for each cable termination.

The underground link box shall have Intrusion Protection class of IP68. A stainless steel box with the bolted lid is required. The design of the underground link box shall allow reusing the gasket after opening the link box.

The link box for installation on cable termination stand shall have Intrusion Protection class of IP54. The construction of the link-box shall prevent water condensation inside. A stainless steel box with the lockable lid on hinges is required.

All incoming link cables into a link box shall be marked with nametags allowing identifying to which joint screens they are connected. The terminals in the link box shall be logically arranged and consistent in all link boxes (e.g. first link-cable is from positive joint west side, second link-cable from positive joint east side, etc.).
A sign shall be attached on the outside of the underground link box lid. The sign shall be according to the example below and shall contain the following:

- Electric hazard sign
- Text “Warning! Risk för farlig potential. Potentialjorda linkbox med närliggande delar av ledande material och omgivande mark innan arbetet påbörjas”
- Svenska kraftnät’s logo
- Svenska kraftnät’s Littra designation of the cable link
- Joint pit designation

The markings and signs shall have yellow background and black text. The markings shall be made from weather-proof material and shall have the life-length as the cable system.

![Example of a link-box sign](image)

Figure 2: Example of a link-box sign.

### 7 Surge arresters

Every cable termination shall be protected from Switching (SI) and Lightning (LI) impulses with surge arresters. In some cases, if it is found applicable, SvK may relieve from LI protection requirement.

Surge arresters design shall follow TR01-12 in applicable parts and IEC 60099-9.
The surge arrester Protection Level (PL) shall be calculated based on the cable system Withstand Voltage (WV). The relation between the cable system withstand voltage and surge arrester protection level for SI and LI shall be according to the following equations:

\[ \text{SIWV} = 1.15 \times \text{SIPL} \]

\[ \text{LIWV} = 1.15 \times \text{LIPL} \]

8 Earthing blade

At each cable termination an earthing blade shall be installed enabling safe earthing before opening of the cable circuit.

9 Discharge resistor

The cable manufacturer shall state if the cables at floating HVDC potential at SIPL can be discharged instantaneously by direct grounding or a discharge resistor is needed/preferred. In case discharge resistor is needed/preferred the cable manufacturer shall state the safe discharge duration.

10 Testing

Testing of HVDC cable systems and accessories is covered in Svenska kraftnät technical guideline TR14-04-1E.

11 Documentation

The design of accessories, 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.