Testing of High Voltage Cable Systems

Introduction

This technical guideline states the requirements Svenska kraftnät applies to testing of high voltage cable systems to be installed in the Swedish national grid.

This guideline shall be the basis for any technical specification issued by Svenska kraftnät when purchasing high voltage cable systems. There may however be specific requirements and adaptions in the technical specifications for each single project.
# Revision notes

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1 References

The following list of references, standards and guidelines shall apply for testing of HV cable systems addressed in this technical guideline. If there is any reference, standard or guideline that should apply in addition, the supplier shall inform Svenska kraftnät immediately.

Where a note with publishing year is given, this version will apply for this technical guideline, even if later versions have been published. Possible Amendments, Addenda, Corrigenda or Errata given for this specific version shall however apply.

IEC 60060 : 2010 High Voltage Test Techniques.
IEC 60229 : 2007 Tests on cable oversheaths which have a special protective function and are applied by extrusion.
IEC 60230 : 1966 Impulse tests on cables and their accessories.
IEC 60332-3 : 2000 Test on electrical cables under fire condition.
IEC 60529 : 1989 Degrees of protection provided by enclosures (IP code).
IEC 62067 : 2011 Power cables with extruded insulation and their accessories for rated voltage above 150 kV ($U_{m}=170$ kV) up to 500 kV ($U_{m}=550$ kV) – Test methods and requirements.
IEC 62271-203 : 2003 High-voltage switchgear and control gear – Part 203: Gas-insulated metal-enclosed switchgear for rated voltage above 52 kV.
IEC 62155:2003 Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1 000 V.
IEC 621462:2007 Composite hollow insulators - Pressurized and unpressurized insulators for use in electrical equipment with rated voltage greater than 1 000 V - Definitions, test methods, accept criteria and design recommendations.
Cigré Electra 189 : 2000  Recommendations for test of power transmission DC cables for a rating up to 800 kV.

Cigré TB 303 : 2006  Revision of Qualification Procedures for HV and EHV AC extruded UG Cable Systems.

Cigré TB 415 : 2010  Test Procedures for HV Transition Joints for Rated Voltages 30 kV up to 500 kV.

Cigré TB 490 : 2012  Recommendations for Testing of Long AC Submarine Cables with Extruded Insulation for System Voltage above 30 (36) to 500 (550) kV.

Cigré TB 496 : 2012  Recommendations for Testing of DC Extruded Cable Systems for Power Transmission at Rated Voltage up to 500 kV.

Cigré TB 622 : 2015  Recommendations for Testing DC Transition Joints for Power Transmission at a Rated Voltage Up To 500 kV.


Svk TR08-05E  Svenska kraftnät Technical guideline – Svenska kraftnät’s requirements for documentation in cable projects.
2 Scope

This technical guideline states the testing requirements Svenska kraftnät applies to high voltage (HV) cable systems to be installed in the Swedish national grid. For submarine cables some requirements are put on installation methods. The guideline covers requirements on prequalification tests, type tests, routine tests, sample tests as well as tests during installation and tests after installation or repair.

This technical guideline does not address tests of measuring and monitoring equipment/systems or tests performed to verify optical fibre systems.

3 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, Definitions and abbreviations in TR14 technical guidelines.

4 General

In general testing of HV cable systems to be used in the Swedish national grid shall follow applicable IEC standards and Cigré recommendations. The purpose of this technical guideline is to provide a general overview of the requirements related to the testing of high voltage cable systems. Where applicable or needed, some specific requirements (not in the applicable standards or recommendations) are stated.

Tests described in this technical guideline are divided into the following categories:

- Prequalification tests.
- Type tests.
- Routine tests during manufacturing.
- Sample tests during manufacturing.
- Tests of installation methods.
- Tests during installation.
- Tests after installation.
Tests after repair.

The categories of cable systems addressed in this technical guideline are:

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<td>Yes</td>
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<tr>
<td>Underground MI</td>
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There may be tests requested for specific projects that are in addition to the ones described in this technical guideline. This is specifically the case for tests (and inspections) during installation.

5 General requirements on tests

5.1 Testing prerequisites

5.1.1 General requirements
All requirements and tests in a standard shall apply, unless it is evidently not applicable. If a supplier believes a test is not applicable, he shall confer with Svenska kraftnät, who will decide whether the test shall be performed or not.

5.1.2 Approval of tests
A test is not completed until the test procedure has been approved, the actual test has successfully been performed in accordance with the test procedure and in accordance with the success criteria, a visual inspection has been performed (as applicable), and a test report is issued and approved. Svenska kraftnät and its representatives shall be authorised to witness any test.
5.2 Testing of transition joints

5.2.1 Joints between MI and XLPE - HVAC
All tests of HVAC transition joints between paper-lapped and extruded insulations are to be performed in accordance with Cigré TB 415.

5.2.2 Joints between MI and XLPE - HVDC
All tests of HVDC transition joints between paper-lapped and extruded insulations are to be performed in accordance with Cigré TB 622.

5.2.3 Joints between different conductor cross sections - HVAC
All tests of HVAC transition joints between different conductor cross sections are to be performed in accordance with Cigré TB 415.

5.2.4 Joints between different conductor cross sections - HVDC
Tests of HVDC transition joints between different conductor cross sections are covered by Cigré TB 496.

5.3 Testing of cable termination insulators
Cable termination porcelain insulators shall be tested in accordance with IEC 62155.

Cable termination composite insulators shall be tested in accordance with IEC 61462.

5.4 Inspection and test plan, ITP

5.4.1 References to international standards et cetera
All testing of cables, accessories and link boxes to be performed in a project shall be summarised in an inspection and test plan, ITP. For each test that shall be performed, the ITP shall give a reference to a contract clause, an IEC standard, a Cigré Recommendation or another appropriate international test standard.

5.4.2 Requirements
Sequence of tests shall be apparent, test conditions shall be summarised, and acceptance criteria shall be stated in the ITP.

5.4.3 Approval of the ITP
The ITP shall be completed well in advance, subject to Svenska kraftnät review and approval, before any test is allowed to start.
5.5  Test methods

5.5.1  Preparations
The supplier shall prepare procedures for all tests described in the ITP. For each test, a
written detailed instruction shall be presented that covers description of the test, test
requirements, test object(s), test circuit and equipment, measuring circuit, measuring
equipment, assembling, calibration, test procedures and parameters, reference
documents, standards, et cetera.

5.5.2  Approval of test circuit
Prior to start of any test the test circuit shall be well defined, subject to Svenska
kraftnät approval. The supplier shall also prepare a list of Witness Points (WP) and
Hold Points (HP), subject to Svenska kraftnät approval.

5.5.3  Calibration and validation
The test and measuring equipment used during all testing shall have valid calibration
certificates, and have a range and accuracy as per top range of industrial practice.
All certificates shall be available for Svenska kraftnät review at site of testing.

5.5.4  Measurement documentation
Measurements shall be performed and recorded continuously during all the type t
ests. All measurements shall be recorded in such a way that later computer evaluation and
analysis may be easily performed. It shall also be possible for Svenska kraftnät to have
access to the obtained raw data.

5.6  Witnessing of tests
Svenska kraftnät shall well in advance be given the opportunity to witness all tests.

5.7  Visual inspection
All test objects shall be subject to visual inspection after a completed test, or if the test
is disrupted by a failure of test object.

5.7.1  Scope of inspection
Visual inspection is the process to disassemble a test object to inspect and record
dimensional characteristics, insulation characteristics or flaws, degree of water ingress
(if applicable), irregularities and (if applicable) break-down characteristics.

5.7.2  Requirements
Requirements as per IEC 62067, section 12.4.8 shall apply in addition to cable type
specific methods.
5.7.3 Svenska kraftnät witnessing
Svenska kraftnät shall well in advance be given the opportunity to witness all visual inspections.

5.8 Test reports

5.8.1 Content
All tests shall be reported in test reports. A test report shall be issued within three weeks (15 working days) after test completion. The test report shall contain at least the following:

- Clear reference to applicable section in the ITP.
- Clear identification (serial No., batch No., metre marking on cable et cetera) of object(s) under test (for traceability purposes).
- Dates (periods) of test.
- Name(s) of Svenska kraftnät representative(s) witnessing.
- Description of test arrangements (test circuit, equipment, calibration certificates et cetera).
- Graphs, if applicable.

5.8.2 Language and requirements
The test reports shall be complete and cover all results and outcome of the tests. English or Swedish language shall be used in graphs, routine test protocols et cetera if they constitute a part of the test report.

If a type test consists of essentially separated test sequences (such as mechanical preconditioning and electrical testing), these shall be reported individually within three weeks (15 working days) after each test is completed.

5.8.3 Consolidated reports
In addition, consolidated reports (referring to issued test reports) for each type test object, delivery length of, for example, submarine cable, tunnel cable and underground cable on delivery drums (consolidated for instance by batch) shall be submitted.
6 Prequalification tests

6.1 Prequalification tests - general and common

6.1.1 Purpose of prequalification tests
The purpose of a prequalification test is to demonstrate satisfactory long term performance of the complete cable system to be supplied.

6.1.2 Basic requirements
To be a supplier of HV cable systems to Svenska kraftnät, the supplier shall have performed prequalification (PQ) tests in accordance with applicable standards.

To be a supplier of HVAC 400 kV cable systems, the supplier shall be approved according to Svenska kraftnät prequalification system for procurement of 400 kV HVAC cables. This is a general and separate prequalification process.

6.1.3 Complementary testing
In exceptional cases minor complementary PQ testing may be required as part of the PQ testing requirements in a specific contract.

6.2 PQ tests of HVAC XLPE cable systems

6.2.1 PQ tests of HVAC XLPE land cable systems
PQ tests for HVAC XLPE cable systems to be installed on land (direct buried, tunnel, trough, ducts et cetera) shall be performed in accordance with IEC 62067, section 13. The conditions specified in the standard shall apply.

6.2.2 PQ tests of HVAC XLPE submarine cable systems
HVAC XLPE submarine cable systems shall further be pre-qualified in accordance with Cigré TB 490, section 9.

6.3 PQ tests of HVDC cable systems

6.3.1 PQ tests of HVDC XLPE cable systems
HVDC XLPE cable systems shall be pre-qualified in accordance with Cigré TB 496, section 3, with the following additional conditions:

Any change of materials or design in the cable system requires a new PQ test.

The supplier may ask Svenska kraftnät for approval to relieve from the PQ test if the test is already performed on almost identical cable system. Prerequisites are:

- Requirements in Cigré TB 496, section 3 shall be fulfilled.
A written report shall be submitted containing explanation of the changes with detailed drawings.

Additionally Svk may require demonstration of assembly, dissection and investigation of cable system parts.

6.3.2 PQ tests of HVDC MI cable systems
There are no specific PQ test requirements for MI cable systems. A qualified good operational experience, and record of type tests, will validate the competence and capacity for design, production, installation and operation of HVDC MI cable systems.

7 Type tests

7.1 Type tests - general and common for all types of cable system

7.1.1 General
The whole cable system shall pass all type tests in the type test programme.

Purpose of type tests
The purpose of a type test is to demonstrate satisfactory performance characteristics and lifetime operation of the cable system to be supplied. The performance of the cable system shall meet the intended application. The type test does not mimic actual operation, real external stresses or actual ambient conditions. Standardisation bodies have spent a lot of effort to formulate test set-ups, sequences and margins, to make reasonably acceptable representations from all parties of the life of the cable system.

Different manufacturing plants
The type test of a cable system in one plant does not automatically qualify for approval of cable manufactured in another plant.

Ambient thermal conditions
In practical terms, the ambient thermal test conditions shall represent the real foreseen “worst case” conditions when it implies the most onerous stresses for the cable system.

Scope of type tests
The type tests shall comprise the electrical type tests (sometimes preceded by some mechanical preconditioning), water integrity type tests, mechanical type tests, and non-electrical type tests.
Approval of type tests
Svenska kraftnät shall have the right to reject the design of a cable system if any type test has failed. Type tests are not approved until all individual type tests have passed.

A type test is not approved until Svenska kraftnät has approved all applicable test reports.

7.1.2 Acceptance of pre-contract type tests
Subject to the following conditions, the supplier may refer to previously performed type tests in scope of type testing, subject to Svenska kraftnät approval:

- The supplier has within the last five years completed type tests on identical (or close to identical) cable systems with corresponding mechanical and electrical stresses as for the designs proposed.
- The constructional elements are identical.
- The materials and supplier used for the insulation system are identical.
- No significant change has been introduced in the manufacturing processes.

All requirements as per IEC 62067, section 12.2, shall apply.

If the supplier wants to refer to a previously performed type test, a proposal shall be made in writing with detailed technical justification for the proposal.

7.1.3 Acceptance of accessory representation in type tests
All accessory designs to be used in a specific cable installation shall be type tested.

For HVAC cables, in exceptional cases, the supplier may however propose relief in number of varieties of accessories to be included in type testing, if the accessories are in all essential aspects equal (e.g. supplier of insulation system materials is considered as an essential aspect, as well as rubber sleeve pressure). Such a proposal shall be performed in writing, argumentation shall be clearly substantial, and it will be subject to Svenska kraftnät approval. The type test shall anyway include as a minimum one accessory.

7.1.4 Cable repairs during manufacturing and installation

Methods and approval
During cable manufacturing and installation it is sometimes necessary to do repairs on cables. Methods for such a repair shall be declared and described in advance by the supplier, subject to Svenska kraftnät review and approval. Repairs shall be performed in accordance with approved procedures according to the supplier QA system.
Permanent local deviations
If a repair method leaves a permanent local deviation in the cable, that deviation shall be represented in type testing.

7.1.5 Type test objects
Type test objects shall be clearly identified and defined before the start of testing.

All type test objects shall have been successfully subjected to routine test prior to being subjected to type test.

The following items are to be subjected to type test(s):

➢ All cable designs.
➢ All cable joint designs.
➢ All cable termination designs (including corona ring(s) and, if applicable, bolt/stud for temporary earthing).
➢ Link boxes and bonding leads.

7.1.6 Disruptions and failures in type test

Test disruptions not caused by the test object itself
A test disruption that is not caused by a test object itself may not necessarily disqualify the type test. If an external disruption has caused a defect to a test object, this part may be cut out from the test circuit and the test may be restarted, subject to that the minimum length or quantity requirements are still met. If not, the test shall be redone completely. The defect test object needs to be replaced by a new test object, which shall be subject to a new type test.

Test disruptions that do not affect the test object itself
If the test object is not affected by the disruption, the test may be resumed. However, if the disruption has provided a rest period for the test object, which offsets the effect of continuity, Svenska kraftnät may require retesting completely, or partially. The supplier shall warrant that the test object has not been affected by the disruption before resuming type test. If supplier cannot do this, the test object shall be treated as defect (see section above).

Failure in components that in all essential can be regarded as a test object
A failure of a component or part of a test circuit that is not defined as a test object, but is in all essential parts equal to a test object, is regarded as a serious incident. It will not be regarded as a type test failure, but a thorough investigation of the cause of the failure shall be undertaken, and the corrective actions shall be taken to avoid recurrence. The investigation shall be reported in writing and presented to the satisfaction of Svenska kraftnät, in order to achieve approval of applicable type test.
Failure in a test object
A failure in a type test object calls for a repeated type test of a new type test object of the same kind. If a test fails due to causes within the test object, the supplier may not continue testing until a thorough technical investigation on cause of failure has been performed. Svenska kraftnät shall have full insight in such an investigation. Based on this investigation, the supplier shall propose what actions to take. This proposal shall be discussed with Svenska kraftnät, and shall be subject to Svenska kraftnät’s approval.

Repetition of type tests
If a type test fails due to reasons found within the test object, and following the technical investigation described above, the supplier may repeat the complete type test (that failed). If the repeated type test fails, the supplier may repeat the complete test once more. Three disqualified type tests shall reject the design.

7.1.7 Link boxes
Each design of link box with mounted bonding leads shall be type tested in accordance with IEC 60529, with the following modifications:

- Water immersion for five days with a water column exceeding 2 m.
- Subsequent DC tests 20 kV for 1 minute.
- Examination, there shall be no traces of water inside the link box.

7.2 Type tests of HVAC XLPE cable systems

7.2.1 Type tests of HVAC XLPE cable systems – general and common
Type tests of HVAC XLPE cable systems shall be performed in accordance with IEC 62067, sections 12, 14 and 15.

All electrical type tests shall be performed. All non-electrical type tests shall be performed as applicable. For tests under fire conditions, refer to section 7.2.3.

If GIS terminations are to be used, these shall be type tested in accordance with IEC 62271-203, section 6.

7.2.2 Type tests of HVAC XLPE underground cable systems
Water penetration tests shall be performed in accordance with IEC 62067, Annex E. All requirements and conditions shall apply, but the height of the water in the tube shall be 2 m above the cable centre (Figure E.1 in Annex E).

No further additional requirements beyond those given in section 7.2.1.
7.2.3 Type tests of HVAC XLPE tunnel cable systems
For cables to be installed in tunnels, shafts, bridges or similar installation spaces, tests under fire conditions shall be performed. These tests shall be performed in accordance with IEC 60332-3, fire condition cat A.

Water penetration tests (if applicable) shall be performed in accordance with IEC 62067, Annex E. All requirements and conditions shall apply, but the height of the water in the tube shall be 2 m above the cable centre (Figure E.1 in Annex E).

7.2.4 Type tests of HVAC XLPE submarine cable systems
Type tests for HVAC XLPE submarine cable systems shall be performed in accordance with Cigré TB 490, section 8.

Mechanical preconditioning and mechanical tests shall be performed in accordance with Cigré TB 623.

Svenska kraftnät will for specific projects specify which tests in Cigré TB 623, section 6 that shall be included as type tests.

Physical and mechanical representation in type tests
A submarine cable system test object shall represent a long cable without any end effects (e.g. twisting of armour wires).

Consequently the following implications shall be addressed in type testing:

- The distribution of tensile force between conductor and armour layers shall be demonstrated before start of testing. It shall be possible to control the conductor share of the total applied tensile force in the test object.
- Joints in coil tests shall be separated by at least two complete turns, or in accordance with Cigré TB 623, section 5.1.2.

7.3 Type tests of HVDC cable systems
7.3.1 Type tests of HVDC XLPE cable systems
Type tests of HVDC XLPE cable systems shall be performed in accordance with Cigré TB 496 section 4.

For submarine HVDC XLPE cable systems the mechanical preconditioning and mechanical tests shall be performed in accordance with Cigré TB 623.

Svenska kraftnät will for a specific project specify which tests in Cigré TB 623, section 6 that shall be included in the type test programme.
Cable joints intended for burial on land shall be subjected to the tests of outer protection for joints in accordance with IEC 62067, Annex G.

Water penetration tests (land cables) shall be performed in accordance with IEC 62067, Annex E. All requirements and conditions shall apply, but the height of the water in the tube shall be 2 m above the cable centre (Figure E.1 in Annex E).

All cable types (submarine, tunnel and underground) shall be subject to non-electrical tests as per Cigré TB 496, except those for EPR and/or PVC. Tunnel cables shall also be subject to fire propagation test, in accordance with IEC 60332-3, fire condition cat A.

**Physical and mechanical representation in type tests**

A submarine cable system test object shall represent a long cable without any end effects (e.g. twisting of armour wires).

Consequently the following implications shall be addressed in type testing:

- The distribution of tensile force between conductor and armour layers shall be demonstrated before start of testing. It shall be possible to control the conductor share of the total applied tensile force in the test object.
- Joints in coil tests shall be separated by at least two complete turns, or in accordance with Cigré TB 623, section 5.1.2.

### 7.3.2 Type tests HVDC MI cable systems

Type tests of HVDC MI cable systems shall be in accordance with Cigré Electra 189.

For submarine HVDC MI cable systems the mechanical preconditioning and mechanical tests shall be performed in accordance with Cigré TB 623.

Svenska kraftnät will for a specific project specify which tests in Cigré TB 623, section 6 that shall be included in the type test programme.

**Physical and mechanical representation in type tests**

A submarine cable system test object shall represent a long cable without end effects (e.g. twisting of armour wires).

Consequently the following implications shall be addressed in type testing:

- The distribution of tensile force between conductor and armour layers shall be demonstrated before start of testing. It shall be possible to control the conductor share of the total applied tensile force in the test object.
- The test setup shall be performed so that oil balance cannot be influenced by the cable test terminations.
8 Routine tests

8.1 Routine tests - general and common for all types of cable system

8.1.1 General and purpose of routine tests
All cable lengths and all cable joints and conductor joints, cable terminations, and link boxes that will be supplied shall be subjected to routine tests. The purpose of a routine test is to check that the component to be delivered meets the specified requirements.

All routine tests shall be reported in routine test reports.

8.1.2 Routine tests - Factory acceptance test, FAT
The final routine test that releases a cable, accessory or link box to be shipped, are referred to as Factory acceptance tests, FAT. These tests shall clearly be identified in the ITP. The FAT constitutes a sub-group of all routine tests.

8.1.3 Dielectric losses and leakage current
Dielectric losses of HVAC cables and leakage current (A/m) of HVDC cables shall be measured and recorded on all delivery lengths. A theoretic model shall be developed on how to correlate the measured values in factory with actual losses as a function of the temperature gradient in the insulation.

8.1.4 Integrated optical fibres
If there are optical fibres (for DTS) integrated in the cable, these fibres shall be checked for fibre breaks. The attenuation of the fibres shall be measured, and no excessive attenuation increases shall be measured. OTDR measurements shall be made and recorded. This shall be considered as part of the FAT.

8.1.5 Resistance of conductor and metallic sheath
Electric resistance of conductor and metallic screen(s)/sheath(s) shall be measured on each delivery length (for land cables, typically a completed cable length on a drum). The supplier shall clearly demonstrate what the effective average temperature of the cable is at testing. For underground cable on drums, testing shall be performed in accordance with IEC 62067, section 10.5.

8.1.6 TDR fingerprinting
All delivery lengths of submarine cables shall be subjected to TDR fingerprinting. This is considered as part of the FAT.
8.1.7 Failures in routine tests

General
All cables and accessories to be used in a specific project (including spares) shall have passed all applicable routine tests.

Quality report
If a routine test fails, the supplier shall issue a quality report.

Technical investigation
The supplier shall investigate a failure in a routine test. The result of the investigation shall be presented to and discussed with Svenska kraftnät, before any possible retest of the failed object is performed. The quality report shall as a minimum clarify what caused the failure, what damage was caused by the failure, and it shall also describe the measures to be taken not to let failure of same kind or reason be repeated.

Failure in an accessory (test object)
An accessory that has failed in routine test may not be repaired or delivered.

Failure in a cable (test object)
A cable that has failed in a routine test may be repaired (subject to that a qualified repair method previously presented and accepted by Svenska kraftnät is used) and retested.

Repetitive routine test failures
Repetitive failures of same kind or reason, implies that applicable production and shipping has to be stopped, until a full investigation has been performed by the supplier. The investigation shall be reported and discussed with Svenska kraftnät before shipping may continue.

8.2 Routine tests of HVAC XLPE cable systems

8.2.1 Routine tests of HVAC XLPE cable systems – general and common
Routine tests of HVAC XLPE cable systems shall be performed in accordance with IEC 62067, section 9.

If GIS terminations are used, these shall be routine tested in accordance with IEC 62271-203, section 7.

8.2.2 Routine tests of HVAC XLPE underground cable systems
No additional requirements beyond those given in sections 8.1 and 8.2.1.

8.2.3 Routine tests of HVAC XLPE tunnel cable systems
No additional requirements beyond those given in sections 8.1 and 8.2.1.
8.2.4 Routine tests of HVAC XLPE submarine cable systems
Routine tests of HVAC XLPE submarine cable systems shall be performed in accordance with Cigré TB 490, section 6.

8.3 Routine tests of HVDC cable systems

8.3.1 Routine tests of HVDC XLPE cable systems
Routine tests of HVDC XLPE cable systems shall be performed, and it shall be performed in accordance with Cigré TB 496, section 5.

Sheath integrity testing in accordance with IEC 60229 is required.

For underground cable lengths and cable accessories AC voltage test and PD measurement as mentioned in Cigré TB 496, section 5 is strongly recommended.

8.3.2 Routine tests of HVDC MI cable systems
Routine tests of HVDC MI cable systems shall be in accordance with Cigré Electra 189.

9 Sample tests

9.1 Sample tests - general and common for all types of cable system

9.1.1 General requirements
Sample tests are extra tests performed on a limited number of samples taken from regular production. Svenska kraftnät shall have the right to select the samples. The supplier shall for each sample occasion notify in advance (four weeks in advance of testing) what the latest date is for Svenska kraftnät selection to be performed. When the supplier is notifying he shall also provide information on the objects to choose between, such as production sequence, any deviations or non-conformances et cetera.

9.1.2 Dimensional checks on accessories
One complete cable joint of each design shall be subjected to a complete dimensional check, and adherence to drawing. This is a destructive inspection. Svenska kraftnät shall be allowed to choose the test object in a batch for delivery.

One complete cable termination of each design shall be subjected to a complete dimensional check, and adherence to drawing. This is a destructive inspection. Svenska kraftnät shall be allowed to choose the test object in a batch for delivery.
9.1.3  Integrity of the semi-conductive sheath
The supplier shall propose an adequate sample test, to demonstrate the integrity of the semi-conductive PE-sheath during faults, e.g. short circuit.

9.1.4  Failures in sample tests

Investigation and Quality report
If a sample test fails, the supplier shall investigate the failure and issue a quality report.

The result of the investigation shall be presented to and discussed with Svenska kraftnät, before any possible retest of the failed object is performed. A sample test failure leads to the number of samples shall be doubled for test objects like the one that has failed.

Failure in an accessory (test object)
An accessory that has failed in a sample test may not be repaired or delivered.

Failure in a cable (test object)
A cable that has failed in a sample test may be repaired (subject to that a qualified repair method previously presented and accepted by Svenska kraftnät is used) and re-tested.

Repetitive sample test failures
Repetitive failures of same kind or reason, implies that applicable production and shipping has to be stopped, until a full investigation has been performed by the supplier. The investigation shall be reported and discussed with Svenska kraftnät before shipping may continue.

9.2  Sample tests of HVAC XLPE cable systems

9.2.1  Sample tests of HVAC XLPE cable systems – general and common
Sample tests of HVAC XLPE cable systems shall be performed in accordance with IEC 62067, sections 10 and 11.

The lighting impulse withstand test shall be performed in accordance with IEC 62067, section 10.12. It shall be followed by a partial discharge test in accordance with IEC 62067, section 9.2, where the supplier shall determine adequate and appropriate AC voltage levels. The proposed test voltages shall be deduced from insulation material properties, and insulation thickness.

Samples shall be taken from each extrusion length (for submarine cables at least two completed delivery lengths), and 10% of underground cable drums (minimum two).
9.2.2 Sample tests of HVAC XLPE underground cable systems
Water penetration tests (if applicable) shall be performed in accordance with IEC 62067, Annex E. All requirements and conditions shall apply, but the height of the water in the tube shall be 2 m above the cable centre (Figure E.1 in Annex E).

No further additional requirements beyond those given in sections 9.1 and 9.2.1.

9.2.3 Sample tests of HVAC XLPE tunnel cable systems
Water penetration tests (land cables) shall be performed in accordance with IEC 62067, Annex E. All requirements and conditions shall apply, but the height of the water in the tube shall be 2 m above the cable centre (Figure E.1 in Annex E).

No further additional requirements beyond those given in sections 9.1 and 9.2.1.

9.2.4 Sample tests of HVAC XLPE submarine cable systems
Further sample tests shall be performed in accordance with Cigré TB 490, section 7.

9.3 Sample tests of HVDC cable systems

9.3.1 Sample tests of HVDC XLPE cable systems
Sample tests of HVDC XLPE cable systems shall be in accordance with Cigré TB 496 section 6.

Water penetration tests (if applicable) shall be performed in accordance with IEC 62067, Annex E. All requirements and conditions shall apply, but the height of the water in the tube shall be 2 m above the cable centre (Figure E.1 in Annex E).

Resistance of the metallic sheath shall be measured as a part of the sample test, for land cables and for submarine cables (lead sheath).

9.3.2 Sample tests of HVDC MI cable systems
Sample tests of HVDC MI cable systems shall be in accordance with Cigré Electra 189.

Resistance of the metallic sheath shall be measured as a part of the sample test, for land cables and for submarine cables (lead sheath).

10 Tests of marine installation methods

10.1 Purpose of marine installation trials
Installation trials shall demonstrate that machinery, equipment, rigging and methods are suitable for safe handling of the installation processes to be used.
10.2 Marine installation trial cases

Unless the supplier can clearly demonstrate the appropriate installation processes to be used by experience and references, full scale demonstrations or installation trials shall be performed for the following cases:

- Cable Laying Vessel, CLV or critical on board machinery is new.
- Method is new or method experience is poor. Especially laying omega bights and deploying rigid joints shall be considered.
- Cable or joint design brings new challenges.

The installation trials shall be made with a CLV, machinery, equipment and rigging that is representative and similar to the CLV, machinery and rigging that will be used in the actual project. The actual cable and/or joints shall be used.

11 Tests during installation

Some field-tests that in applicable standards are categorised as tests after installation, should also be performed in intermediate tests during the installation phase.

This applies to:

- Phase/pole continuity tests before each jointing.
- Test of integrated or co-installed optical fibres, if available.
- Sheath integrity tests in accordance with IEC 60229.
- Earthing resistance measurements.
- TDR measurements on installed shipping lengths of submarine cables.
- Moisture test on cable ends from submarine cables before offshore jointing.

12 Tests after installation

12.1 After installation tests - Scope

Tests after installation shall include:

- Measurement of cable circuit impedances of complete circuit. For detailed requirements, refer to section 12.1.1 below. (HVAC cable systems)
➢ TDR measurements (for fingerprints) of all cables from cable termination to cable termination (both directions). Features shall be identified in records. (HVAC and HVDC cable systems)

➢ High voltage test. For detailed requirements, refer to section 12.1.2 (HVAC cable systems) and section 12.1.3 (HVDC cable systems) below.

➢ When circuit is energised - Verification of installed PD measurement devices. PD activity shall be measured; all accessories shall be PD free. (HVAC cable systems). This verification should be performed after the circuit has been subjected to some cyclic operation.

➢ Calibration and verification of functionality of temperature monitoring/measurement devices, e.g. DTS systems and PT1000 sensors. (HVAC and HVDC cable systems) Initial verification can be performed before energisation, but final verification should be performed after the circuit has been subjected to some cyclic operation, and still is in operation.

12.1.1 Measurements of cable circuit impedances
Impedance measurements shall be performed when the circuit is ready to be energized, and just before taken it in to operation. Positive sequence impedance and zero sequence impedance shall be measured for the cable circuit installed. All cable metallic sheaths shall be connected to earth as they will be when the circuit is in operation.

If the cable circuit has more than one single-core cable per phase, measurements shall be performed on each single three-phase group as well as on the complete circuit (all single three-phase groups in parallel). For each single three-phase group there shall be two measurements; one measurement having all groups in parallel single end opened, and one measurement having all groups in parallel connected to earth in both ends.

Measurements shall be performed at frequencies 30, 70, 90, 110, 130 Hz. The results applying for 50 Hz shall be interpolated.

Measuring current shall preferably be 50 A or more, in order to keep down noise levels.

12.1.2 High voltage test of HVAC cable systems
For HVAC cable systems Svenska kraftnät requires that the high voltage test after installation shall be performed in accordance with IEC 62067 (2011-11), section 16.3. If this is not practical, a soak test at voltage U₀ is acceptable. Duration of 48 hour is recommended, minimum requirement is 24 hour.

For HVAC submarine cables, refer to Cigré TB 490, section 11.1.
12.1.3 High voltage test of HVDC cable systems
For HVDC cable systems Svenska kraftnät requires that the high voltage test after installation shall be performed in accordance with Cigré TB 496, section 7, with the following additional requirements:

- It is required that all tests in Cigré TB 496 section 7 shall be performed.
- Cable systems to be used in HVDC links with Voltage Source Converters (VSC) shall be tested with positive polarity on the positive polarity pole and with negative polarity on the negative polarity pole.

13 Tests after repair

For a repair of cable or accessory damage/failure after the cable circuit/link has been taken in operation, some verification of the repair work should be performed. Tests after repair shall include the following:

- TDR measurements (finger prints) from both directions (or at least from the direction with closest distance to the fault location) shall be performed. Features shall be identified in records. (HVAC and HVDC cable systems).
- If practical (depending on availability of link boxes or access to metallic sheaths) a sheath test shall be performed, in accordance with IEC 60229. (HVAC and HVDC cable systems).
- For a HVAC cable a soak test in accordance with IEC 62067 section 16.3 shall be performed. Duration of 48 hour is recommended, minimum requirement is 24 hour.
- For a HVDC cable system a 24 hour soak test shall be performed.

14 Documentation

All test reports, test protocols, measuring protocols, inspection and test plans et cetera, produced by test activities described in this technical guideline, shall be included in the as-built documentation within each specific project.

The documentation shall be in accordance with Svenska kraftnät’s technical guideline TR08-05.