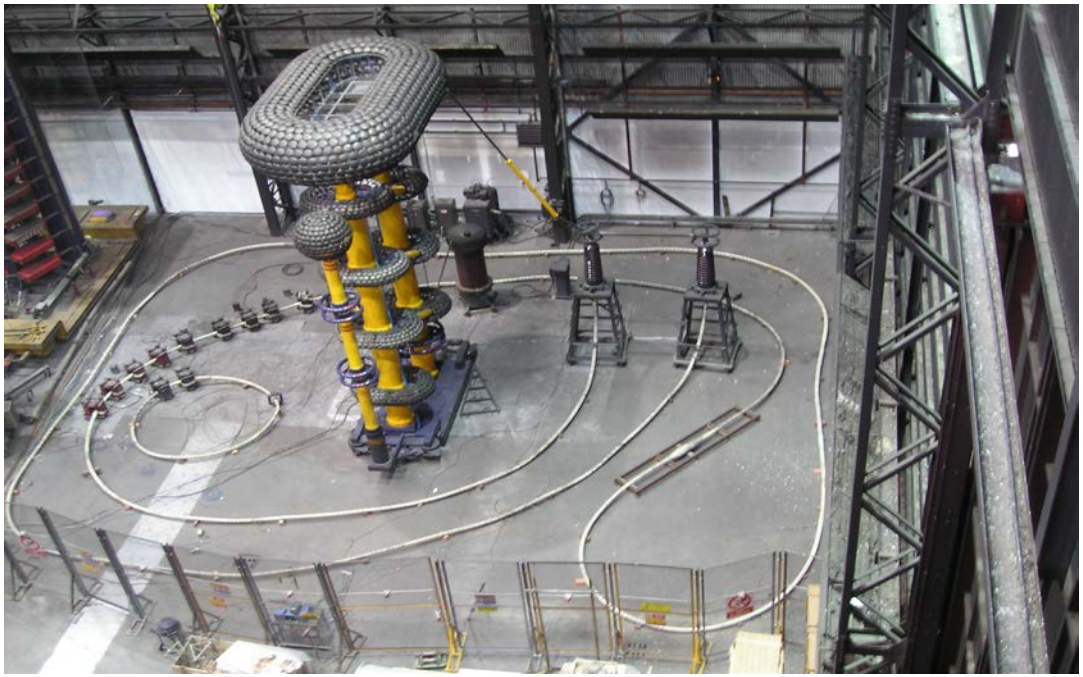
RECOMMENDATIONS FOR TESTING HVDC CABLE SYSTEMS



Ernesto Zaccone

PRYSMIAN POWERLINK
SUBMARINE AND HV CABLES & SYSTEMS

AVAILABLE RECOMMENDATIONS

- **CIGRE WG 21.02 - Recommendations for tests of power transmission DC cables for rated voltage up to 800 kV – Electra No 189 April 2000**

- **CIGRE WG 21.01 - Recommendations for testing DC extruded cable systems for power transmission at a rated voltage up to 250 kV – Technical Brochure 219 – 2003**

- **Cigre WG B1.32 - Recommendations for testing DC extruded cable systems for power transmission at a rated voltage up to 500 kV – 2012 Technical Brochure 496 – 2012 (replace the TB 219)**

The CIGRE recommendations are applicable to land and submarine projects. No international (IEC) standards are available because the HVDC projects in the past have been very limited and specific applications

Note: All the CIGRE members can download these documents free of charge at the following link: *http://www.e-cigre.org/*.

General definitions

Development tests: Tests made during the development of the cable system.

Prequalification test: Test made before supplying on a general commercial basis a type of cable system covered by this recommendation, in order to demonstrate satisfactory long term performance of the complete cable system.

Type tests: Tests made before supplying on a general commercial basis a type of cable system covered by this recommendation, in order to demonstrate satisfactory performance characteristics to meet the intended application.

Routine tests: Tests made by the manufacturer on each manufactured component (length of cable or accessory) to check that the component meets the specified requirements.

Sample tests: Tests made by the manufacturer on samples of complete cable or components taken from a complete cable or accessory, at a specified frequency, so as to verify that the finished product meets the specified requirements.

Tests after installation: Tests made to demonstrate the integrity of the cable system as installed.

Other definitions

Uo: Rated DC voltage between conductor an screen

Manufacturing length: One continuous production length without factory joints.

Delivery length: Is a shipping length that may contain factory joints (i.e. long submarine cables).

Factory joint: A factory joint is a joint between manufacturing lengths that is manufactured under controlled factory conditions.

Repair joint: A repair joint is a joint between two cables that are completed with all construction elements.

Field joint: A field joint is a joint between two cables that are completed with all construction elements and in a state as installed in the field in the actual cable system.

Transition joint: A transition joint connects cable having different origin.

LCC: (Line Commutated Converters) → Classic HVDC, thyristor technology, cable system subjected to polarity reversals

VSC: (Voltage Source Converters) → New generation conversion technology based on IGBT electronics, cable system not subjected to polarity reversals

LAMINATED DIELECTRICS (Electra 189-2000)

These recommendations are applicable to the following types of HVDC cables up to the voltage of 800 kV:

- **Mass impregnated**
- **Oil filled**
- **Gas filled**
- **And covers all types of paper lapped insulation**

The recommendations cover:

- **Routine tests**
- **Type tests**
- **Tests after installations**

Routine tests

High voltage test at works: this test is optional (even if generally recommended), the manufacturing length may be submitted to the negative DC test voltage of 1.8 Uo for 15 minutes.

Conductor resistance test: the DC resistance of the conductor at 20 C° shall be in accordance with the IEC 228 or the declared value.

Capacitance tests: test to be carried out on cable samples at least 10 m long excluding terminations. This test is carried out in AC in conjunction with the power factor test, the measured value shall not be greater than 8 percent of the declared.

Power factor test: test to be carried out at ambient temperature on cable samples at least 10 m long excluding terminations. The power factor (tan delta) shall be measured and shall not be higher that the indicated value for the specific type of cable insulation (MI or FF). For MI cable tan delta is measured @ the maximum gradient of 2kV/mm and 8kV/mm.

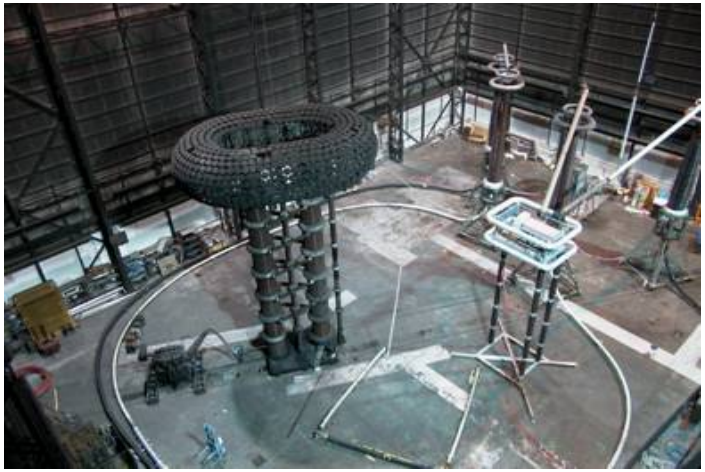
Factory acceptance test: Each delivery length of cable shall be submitted to the negative DC test voltage of 1.8 Uo for 15 minutes.

Type tests

Type test shall be carried out on a minimum 30 m long cable sample, at least one accessory per type shall be included in the test circuit.

The following tests shall be carried out in sequence:

1. Mechanical test
2. Loading cycle test
3. Polarity reversal test
4. Superimposed impulse voltage test

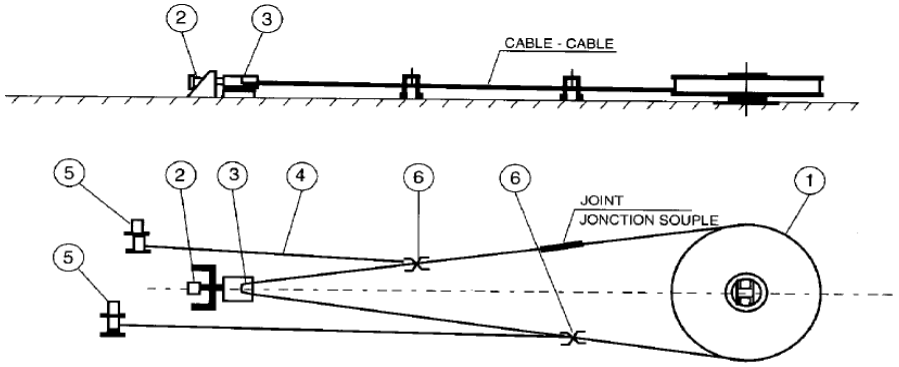


1 – Mechanical test

The cable sample (without joints and terminations) shall be subjected to the following mechanical tests:

- If land cable
  - Bending tests according to the procedures of the equivalent AC applicable standard (for MI or FF)

- if submarine cable
  - Coiling test (when requested)
  - Tensile bending test



1 *ROTATING DRUM* – TOURET TOURNANT
2 *HYDRAULIC PULLING CYLINDER* – CYLINDRE HYDRAULIQUE D'ESSAI DE TRACTION
3 *TRACTION PULLEY* – POULIE DE TRACTION
4 *STEEL WIRE ROPE* – FILIN D'ACIER
5 *WINCH* – TREUIL
6 *CABLE HEAD* – EXTRÉMITÉ DU CÂBLE

2 – Loading Cycle Test

The cable sample with the relative accessories (joints and terminations) shall be subjected to a total of 20 loading cycles. A loading cycle shall consist of 8 hours of heating by circulating current in the conductor followed by a 16 hours cooling without circulation of current. During the heating period the temperature of the conductor shall state at the maximum rated cable temperature with a tolerance of -0+5 K for at least 1 hour. The heating circulating current shall not be less than the nominal current. The test ambient temperature shall take into account the relevant ambient temperature of the installation.
The test procedure is the following:

- Apply 10 daily loading cycles at the positive polarity voltage of 1.8 Uo
- Apply a rest discharge period without voltage and heating of at lest 8 hours
- Apply 10 daily loading cycles at the negative polarity voltage of 1.8 Uo
- Apply a rest discharge period without voltage and heating of at lest 8 hours

3 – Polarity reversal test

After the loading cycle test the object shall be subjected to 10 cycles of polarity reversal test according to the following procedure:

- The object shall be subjected to 8 hours of heating followed by 16 hours cooling as for the previous loading cycle test.
- A positive voltage of 1.4 Uo shall be continuously applied and the polarity shall be continuously reversed every four hours for the duration of the 10 cycles.
- The reversal shall coincide with the cessation of loading current in every loading cycle.
- The recommended time duration for a polarity reversal is 2 minutes
- At the end of the test apply a rest discharge period without voltage and heating of at least 8 hours

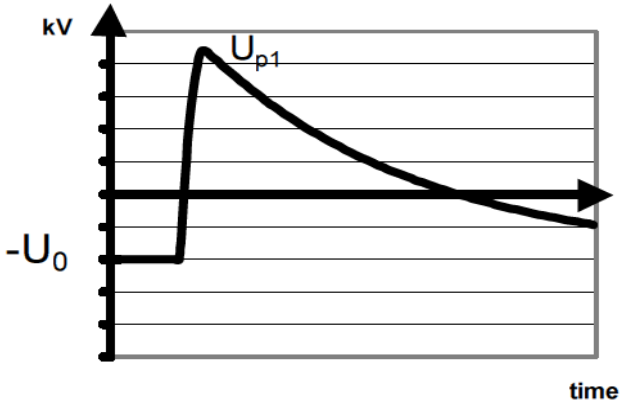
4 – Super imposed impulse voltage test

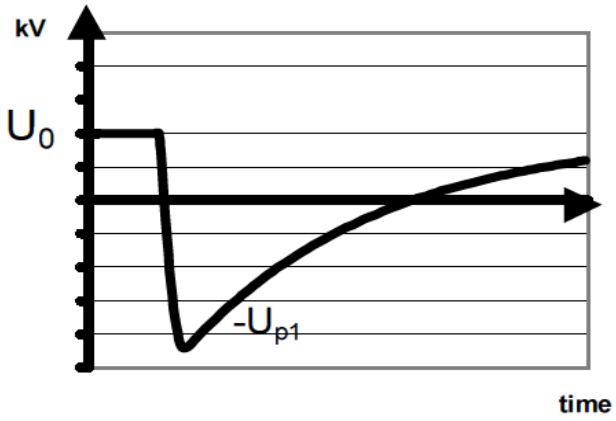
After the polarity reversal the object shall be subjected to the superimposed switching and lightning (if relevant) impulse test.

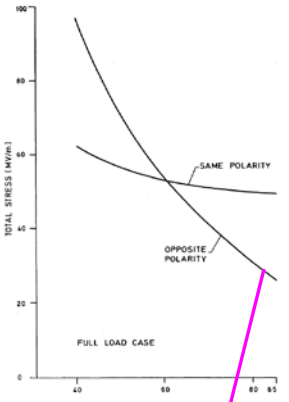
- **Switching impulse test sequence**
  - The object shall be conditioned with the conductor at the maximum rated cable temperature with a tolerance of -0+5 K for at least 1 hour.
  - A negative voltage of Uo shall be applied for 2 hours
  - 10 superimposed positive switching impulse shall be applied
  - A positive voltage of Uo shall be applied for 2 hours
  - 10 superimposed negative impulses shall be applied

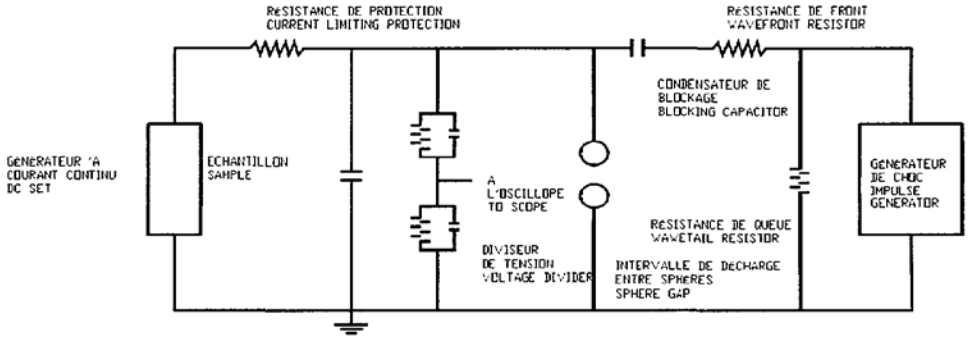
- **Lightning impulse test sequence**
  - The object shall be conditioned with the conductor at the maximum rated cable temperature with a tolerance of -0+5 K for at least 1 hour.
  - A negative voltage of Uo shall be applied for 2 hours
  - 10 superimposed positive switching impulse shall be applied
  - A positive voltage of Uo shall be applied for 2 hours
  - 10 superimposed negative impulses shall be applied

Super imposed impulse voltage test configuration









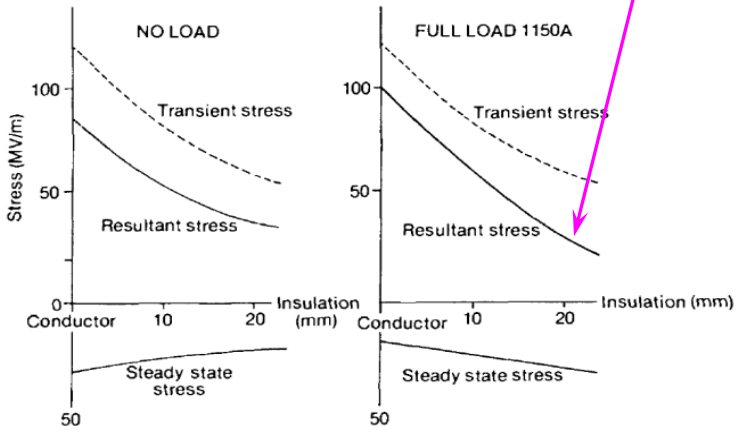


Fig. 38.3 Stress distribution in a 600 kV, 1000 mm², paper insulated d.c. cable with a positive impulse superimposed on negative operating voltage

Ref. Insulation design of self contained oil-filled cables for d.c. operation - C.A. Arkell, et al - IEEE Transactions on Power Apparatus and Systems, vol. pas -101, no. 6 june 1982

Test after installation

The installed cable system shall be subjected to a negative polarity d.c. voltage 1.4 Uo applied for a duration of 15 minutes.

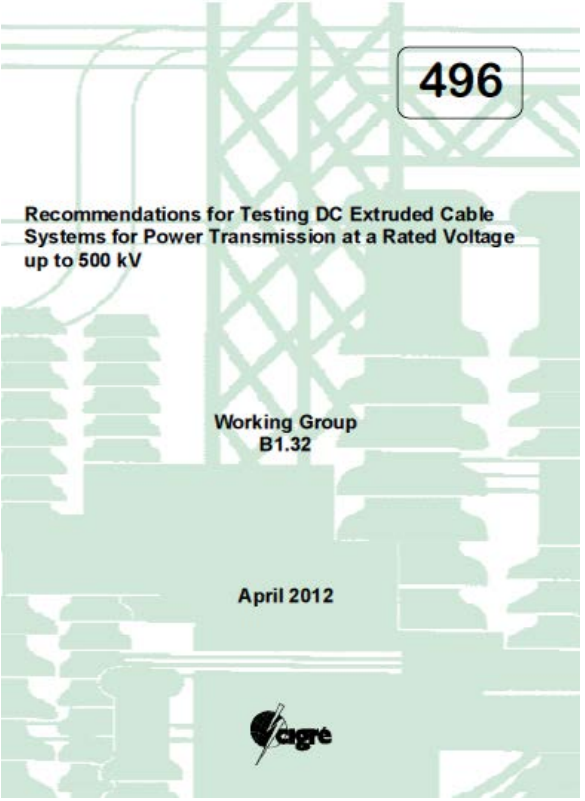
EXTRUDED DIELECTRICS
(CIGRE TB 219 & TB 496)

These recommendations are applicable to the following types of HVDC cables and their accessories up to the voltage of 500 kV:

- **Filled and unfilled extruded insulations**
- **Thermoplastic and thermoset (crosslinked)**
- **Different recommendations for LCC and VSC systems**

The recommendations cover:

- **Development tests**
- **Prequalification tests**
- **Type tests**
- **Routine tests**
- **Sample tests**
- **Tests after installations**



Development tests

The manufacturer should complete all analyses and development testing prior to commencing the prequalification test. The precise nature and extent of development work and analyses shall be left to the discretion of the manufacturer, but may include the following:

- An evaluation of the materials and processes employed. Such evaluations would normally include electrical resistivity assessments, breakdown tests and space charge measurements.
- An analysis of the electric stress distribution within the cable system insulation for a range of typical installation and loading conditions.
- An assessment of the long-term stability, possibly involving factory experiments to assess the ageing effects of various parameters, e.g., electrical stress, temperature, environmental conditions etc.
- An assessment of the sensitivity of the electric stress distribution to the expected variations in cable dimensions, material composition and process conditions (extrusion, post extrusion treatments and finishing).

Note: the development tests are not mandatory but are necessary for the design of the proper cable system

Prequalification tests

Prequalification test shall be carried out on a 100 m approximate length of cable sample, at least one accessory per type shall be included in the test circuit.

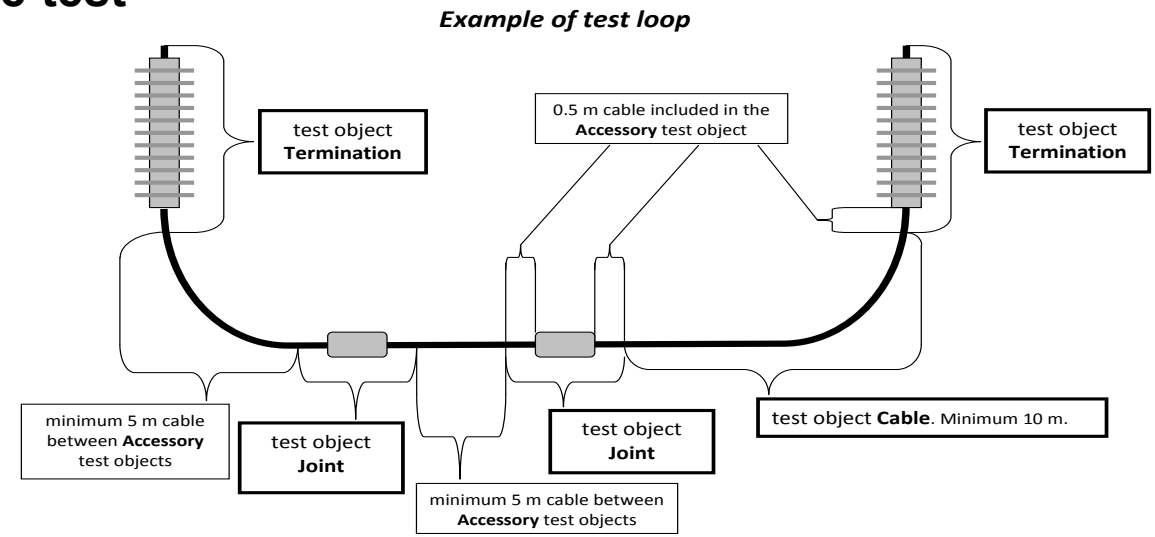
The following tests shall be carried out in sequence:

1. **Long duration voltage test**

2. **Superimposed impulse voltage test**

3. **Examination**

Configuration of the test loop - courtesy CIGRE TB 219.



1. Long duration voltage test

The minimum duration is 360 days.
Conductor temperature and temperature difference across the insulation shall both be controlled to the design level. Design levels in accessories and adjacent cables may differ.
The test sequence and requirements for the LCC and VSC systems are different

A) Line commutated converter, LCC

	LC	**LC**	**LC+PR**	**HL**	**HL**	**ZL**	**LC**	**LC**	**LC+PR**	**S/IMP**
Number of cycles or days	30 cycles	30 cycles	20 cycles	40 days	40 days	120 days	30 cycles	30 cycles	20 cycles	Not applicable
Test Voltage	**+**	**-**		**+**	**-**	**-**	**+**	**-**		$U_{P2,O} = 1.2\ U_0$ $U_{P1} = 2.1\ U_0$*
	1.45 Uo	1.45 Uo	1.25 Uo	1.45 Uo	1.45 Uo	1.45 Uo	1.45 Uo	1.45Uo	1.25 Uo	

B) Voltage source converter, VSC

	LC	**LC**	**HL**	**HL**	**ZL**	**LC**	**LC**	**S/IMP**
Number of cycles or days	40 cycles	40 cycles	40 days	40 days	120 days	40 cycles	40 cycles	Not applicable
Test Voltage	**+**	**-**	**+**	**-**	**-**	**+**	**-**	$U_{P2,O} = 1.2\ U_0$ $U_{P1} = 2.1\ U_0$*
	1.45 Uo	1.45 U0	1.45 Uo	1.45 Uo	1.45 Uo	1.45 Uo	1.45 Uo	

LC=Load Cycle, HL=High Load, PR=Polarity Reversal, ZL=Zero Load, S/IMP=Superimposed Impulse Test.* If required

1. Long duration voltage test conditions

"24 hours" load cycles (for prequalification and type tests) consist of at least 8 hours of heating followed by at least 16 hours of natural cooling. During at least the last 2 hours of the heating period, a conductor temperature ≥ Tcond,max and a temperature drop across the insulation ≥ ΔTmax shall be maintained.

High Load consists of a continuous heating period. Within the first 8 hours of the heating period conductor temperature ≥ Tcond,max and temperature drop across the insulation ≥ ΔTmax shall be achieved and maintained for the rest of the High Load test.
If, for practical reasons, the specified temperatures can not be reached within the first 8 hours, a longer time can be used. This additional time shall not be constituted as being part of the test period.

A minimum rest period of 24 hours without voltage, but with heating, is recommended between blocks of different polarities. This does not apply to the individual polarity reversals in the PR blocks of the LCC test scheme

1. Long duration voltage test conditions

Polarity reversal test (PR) for LCC systems only

Starting with positive voltage, the voltage polarity shall be reversed three times every “24 hours” load cycle (evenly distributed) and one reversal shall coincide with the cessation of loading current in every “24 hours” load cycle. The recommended time duration for a polarity reversal is within 2 minutes.

If, for practical reasons, polarity reversals cannot be achieved within 2 minutes, the duration for polarity reversals shall be agreed between customer and supplier.

2. Superimposed impulse voltage test

Prior to the first impulse of each test the test object shall be heated so that the temperature conditions are achieved for at least 10 hours and the test object shall have been subjected to Uo (of the relevant polarity) for at least 10 hours. These conditions have been selected to reflect the electrical dynamics present within extruded insulations used for HVDC. Superimposed switching impulse voltage of opposite polarity shall be applied according to the stated procedure.
Ten positive switching impulses superimposed to the negative polarity followed by ten negative impulses superimposed to the positive polarity shall be applied. The impulse amplitude shall be 1.2 Uo.

If required by agreement the superimposed lightning impulse voltage of opposite polarity at the voltage of 2.1 Uo may also be applied

The aim of the superimposed impulse test after the long duration test is only to check the integrity of the insulation system.
Project specific requirements regarding impulse levels should be covered by the electrical type test.
The test shall be performed according on one or more cable samples, with a minimum total active length of 30 m cut from the assembly. *As an alternative, the test may be carried out on the whole test assembly.*

3. Examination

Examination of the cable by dissection of a sample and, whenever possible, of the accessories by dismantling, with normal or corrected vision without magnification, shall reveal no signs of deterioration (e.g., electrical degradation, leakage, corrosion or harmful shrinkage) which could affect the system in service operation.

Prequalification test evaluation and repetitions:

If there is a breakdown in a test object the complete prequalification test shall be repeated for that particular test object.
If a breakdown of a test object occurs, causing an interruption to the ongoing testing of connected test objects, the test may be resumed after the failed test object is removed. The actual load cycle or impulse during which the failure occurred shall be repeated for the remaining test objects. If breakdown occurs during a constant load period the time elapsed without voltage applied shall be added to the remaining test period. After any interruption, for example an interruption caused by external factors the test may be resumed. If the interruption is longer than 30 minutes, the specific lost load cycle shall be repeated. If the interruption occurs during a constant load period and is longer than 30 minutes, the day the interruption occurred shall be repeated.

Prequalification test range of type approval

The prequalification test qualifies the manufacturer as a supplier of cable systems provided that the following conditions are fulfilled:

- The rated voltage Uo is not more than 10% higher than that of the tested cable system.
- The calculated average electrical stress in the insulation (given by Uo divided by the nominal insulation thickness) is less than or equal to that of the tested system.
- The calculated Laplace electrical stress at Uo (using nominal dimensions) at the cable insulation screen is less than or equal to that of the tested system.
- The maximum conductor temperature $T_{cond,max}$ is less than or equal to that of the tested system.
- The maximum temperature drop across the insulation layer ΔT_{max} (excluding the semiconducting screens) is less than or equal to that of the tested system.
- A cable system prequalified according to this recommendation for LCC is also prequalified for VSC. A cable system prequalified according to this recommendation for VSC is not prequalified for LCC.
- An unarmoured cable prequalified according to this recommendation prequalifies an armoured cable and vice versa.

Type Tests

The electrical type test shall be carried out on a 10 m minimum length of cable sample, at least one accessory per type shall be included in the test circuit.

The non electrical type test shall be carried out on cable samples that may be different from that subjected to the electrical type tests.

Electrical type tests

- Mechanical preconditioning
- Load cycles tests
- Superimposed impulse voltage test
- Test of outer protection for joints
- Examination

Non electrical type tests

- Test on cable components
- Water penetration test for land cables (when applicable)
- Water integrity testing for submarine cables
- Testing of the intermediate earthing connection of long submarine cables

Electrical type tests - Mechanical preconditioning

The intent of mechanical preconditioning is to subject the test objects to the maximum mechanical stress that the cable system will experience during handling, installation and recovery. Consequently the factory joints and repair joints for submarine cables shall be included, but field joints for land cables are not to be included.

Cable systems to be installed on land shall be subjected to mechanical preconditioning (bending) as specified in the relevant standards applicable to equivalent AC cables (IEC 62067).

Cable systems intended to be installed as submarine cables shall be subjected to mechanical tests as specified in the Electra 171.

Electrical type tests – Loading cycle

Load cycle test for cable system to be qualified for VSC

The test objects shall be subjected to:

- Twelve “24 hours” load cycles at negative polarity at 1.85 Uo
- Twelve “24 hours” load cycles at positive polarity at 1.85 Uo
- Three “48 hours” load cycles at positive polarity at 1.85 Uo

A minimum rest period of 24 hours without voltage but with heating is recommended between blocks of different polarities

Load cycle test for cable system to be qualified for LCC

The test objects shall be subjected to the following conditions

- Eight “24 hours” load cycles at negative polarity at 1.85 Uo
- Eight “24 hours” load cycles at positive polarity at 1.85 Uo
- Eight “24 hours” load cycles with polarity reversal cycles at 1.45 Uo
- Three “48 hours” load cycles at positive polarity at 1.85 Uo

A minimum rest period of 24 hours without voltage but with heating is recommended between blocks of different polarities. This does not apply to the individual polarity reversals in the PR blocks.

Electrical type tests – Loading cycle conditions

"24 hours" load cycles (for prequalification and type tests) consist of at least 8 hours of heating followed by at least 16 hours of natural cooling. During at least the last 2 hours of the heating period, a conductor temperature ≥ Tcond,max and a temperature drop across the insulation ≥ ΔTmax shall be maintained

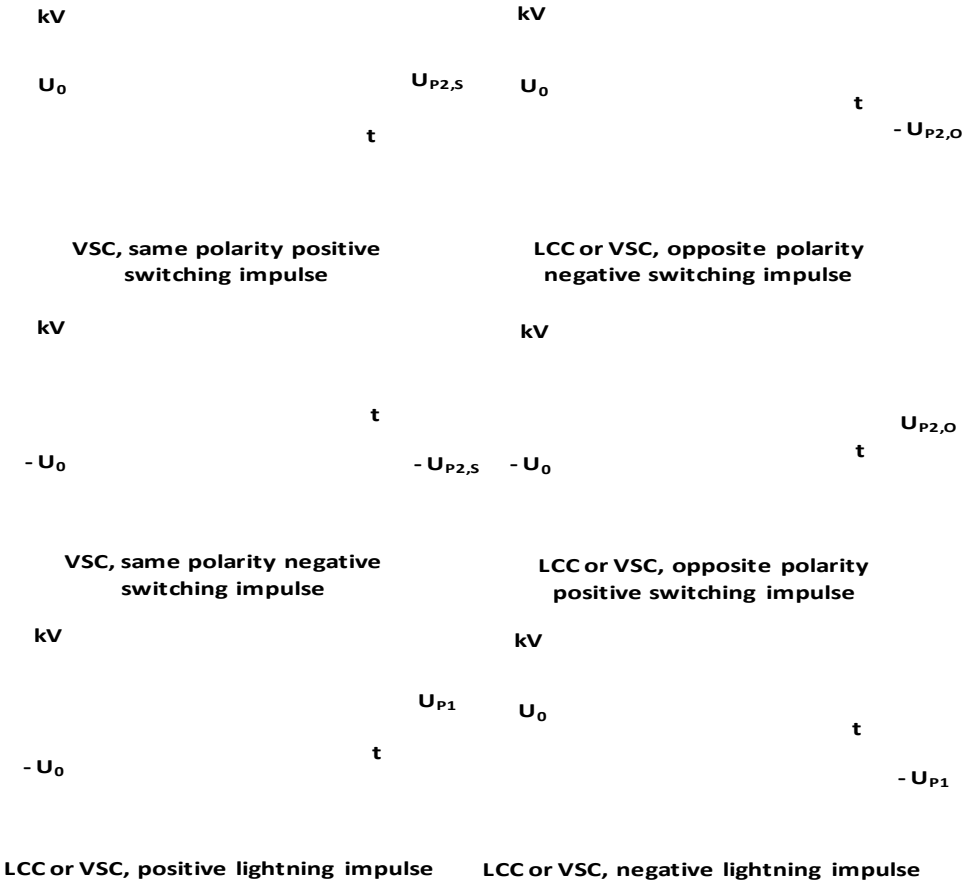
"48 hours" load cycles (for type test only) consist of at least 24 hours of heating followed by at least 24 hours of natural cooling. During at least the last 18 hours of the heating period, a conductor temperature ≥ Tcond,max and a temperature drop across the insulation ≥ ΔTmax shall be maintained. 48 hour load cycles are only required as part of the type test procedure to ensure that electrical stress inversion is well advanced within the cycle.

Positive polarity was selected for the "48 hours" load cycles as this is believed to be the most stringent condition for accessories.

Polarity reversal test (for LCC only) the procedure of the test is the same of that of the prequalification but the number of cycles is lower and the voltage higher

Electrical type tests – Superimposed impulse test

The superimposed impulse voltage test is to be performed on test objects that have successfully passed the load cycle test. The test switching impulse levels are those relative to the system augmented of 15%



Lightning impulse withstand test - If the intended installation of the cable system is such that it is not exposed to lightning strikes (direct or indirect), these tests need not be done.

Subsequent DC test

After the successful completion of the series of 10 impulses each polarity the test object shall be subjected to 2 hours at a negative DC voltage of 1.85 Uo, no heating. A rest period prior to this test is acceptable.

Test of outer protection for joints

Cable joints intended for burial on land shall be subjected to the outer protection test specified in § 12.4 in IEC 62067. The test can be carried out o a separate joint

Examination

Examination of the cable by dissection of a sample and, whenever possible, of the accessories by dismantling, with normal or corrected vision without magnification, shall reveal no signs of deterioration (e.g. electrical degradation, leakage, corrosion or harmful shrinkage) which could affect the system in service operation.

Cables with a longitudinally applied metal tape or foil, bonded to the oversheath
A 1 m sample shall be taken from the cable length and subjected to the tests and requirements in IEC62067.

Success criteria, re-testing and interruptions

The criteria for a successful outcome to the type test are that all tests have been performed without breakdown of that test object and that all other non-electrical requirements have been complied with.
After any interruption, for example an interruption caused by external factors the test may be resumed. If the interruption is longer than 30 minutes, the specific lost load cycle shall be repeated. If the interruption is longer than 24 hours, the actual test block (“24 hours” load cycles block at negative or positive polarity, “24 hours” load cycles block with polarity reversals, “48 hours” load cycles block under positive polarity) shall be repeated.
In case of deviations in test parameters during load cycles or superimposed impulse voltage test, the load cycle or the superimposed impulse in question shall be repeated.

Non-electrical type tests

The cable system shall be subjected to the applicable non-electrical type testing as specified in IEC 62067. The test program shall be agreed between supplier and customer.

Cable systems intended for installation on land where water blocking is included shall be subjected to a water penetration test as specified in IEC 62067.

Cable systems intended to be installed as submarine cables shall be subjected to water integrity testing as specified in Cigre TB 490. This test would also qualify the cable for installation on land.

Submarine cables with metallic earthing connections through plastic sheaths shall be subjected to the specific test in Electra 171

Range of type approval

The type approval shall be accepted as valid for cable systems supplied within the scope of this recommendation if the following conditions are fulfilled:

- The actual designs, materials, manufacturing processes and service conditions for the cable system are in all essential aspects equal.
- All service voltages, rated voltage and impulse (also for return cable), are less than or equal to those of the tested cable system.
- The mechanical stresses to be applied during preconditioning are less than or equal to those of the tested cable system.
- The service maximum conductor temperature Tcond,max is less than or equal to that of the tested cable system.
- The maximum temperature drop across the insulation layer Δ Tmax (excluding the semiconducting screens) is less than or equal to that of the tested cable system.
- The actual conductor cross-section is not larger than that of the tested cable system.
- The calculated average electrical stress in the insulation (given by Uo divided by the nominal insulation thickness) is less than or equal to that of the tested system.
- The calculated Laplace electrical stress (using nominal dimensions) at the cable conductor and insulation screen is less than or equal to that of the tested system.
- A cable system qualified according to this recommendation for LCC is also qualified for VSC provided the switching impulse withstand test at the specified same polarity voltage levels as are carried out. A cable system qualified according to this recommendation for VSC is not qualified for LCC.

Return cable - type test

To verify that the cable system can withstand over-voltages caused by commutation failure an AC voltage test at power frequency shall be performed.

- Mechanical preconditioning (bending)
- Thermo-mechanical preconditioning (24 daily cycles)
- AC voltage test (1,15 The max. ind. voltage comm. failure)
- Lightning impulse withstand test if applicable (to be agreed)

Cable design with integrated return conductor
If the Transmission Cable is such that the return path is integrated, the return path function should be tested together with the Transmission Cable in an integrated test program. The test program shall be agreed between customer and supplier.

ROUTINE TESTS

Routine tests (which include what is in some other documents referred to as Factory Acceptance Test) are made to demonstrate the integrity of the delivery lengths.

Routine tests on transmission cables

Every delivery length of cable shall be submitted to a negative DC voltage of 1.85 Uo applied between conductor and sheath for 1 hour.

The experience of using DC voltage for routine testing of extruded DC cables is limited. In addition to the DC test, testing with AC voltage could be considered provided that the insulation system and the cable design allow AC testing. Long manufacturing lengths and high voltage levels may render AC testing impractical. In the event that AC testing is employed, the voltage level, frequency (power or other frequencies) and time of application shall be agreed between the supplier and customer.

If required for the particular contract or order, the oversheath may be subjected to the routine electrical test specified in IEC 60229.

Routine tests on prefabricated joints and terminations

Prefabricated joints are generally used for the DC land cable connections while the terminations are used for land and submarine connections. This test shall be applied to the main insulation of each accessory:

- DC test at 1.85 Uo for 1 hour

The following additional tests may be carried out according to the quality assurance procedures of the manufacturer:

- AC voltage test, if applicable
- PD measurement, if applicable

Routine tests on factory joints of submarine cables

Factory joints are generally used for long lengths of submarine cable. There are at least four possible methods available today for checking the quality of the factory joint insulation system:

- DC test
- AC voltage test, if applicable
- PD measurement, if applicable
- X-ray inspection

The AC voltage test and the partial discharge measurement may be carried out if applicable to the cable insulation system. The procedure and requirement for these tests will be in accordance with the quality assurance procedures of the manufacturer. X-ray inspection gives additional information regarding the quality of interfaces and possible metallic inclusions. All joints in the complete delivery length shall be DC voltage tested at 1.85 Uo. However, a screening DC or AC voltage test directly after jointing would reduce the time delay in case the joint were to fail at a later stage in the production process. In addition, it is recommended that each welded conductor joint be checked by an X-ray inspection. Even if each factory joint is routine tested, the joint must be installed by experienced personnel. It is recommended that the supplier show qualification records of jointers.

Tests on repair joint for submarine cables

Depending on the joint construction it may be difficult to test the whole joint after installation. If the joint consists of pre-fabricated insulation components for which it is possible to routine test prior to installation, the procedures described for prefabricated joints shall be followed, as closely as possible and according to agreement between manufacturer and customer. If the joint is not built up by any pre-fabricated components, the manufacturer and customer shall agree on the most practical solution, if any, to check the quality of the repair joint after installation.

Return cables or conductors

Every delivery length of cable shall be submitted to a voltage test applied between conductor and sheath. AC testing is to be preferred for the testing of return conductors. The voltage level and time of application shall be agreed between the supplier and customer. Long manufacturing lengths and high voltage levels may, however, render AC testing impractical. In this case a suitable DC voltage, agreed between supplier and customer, shall be applied. It is recommended that the DC test voltage be not lower than the highest of either 2.5 x max DC voltage in service, or 25 kV, the voltage shall be applied between conductor and sheath for 1 hour.

SAMPLE TESTS ON TRANSMISSION CABLES

IEC specification for AC extruded power cables shall apply except where not differently specified.

Frequency of tests: The frequency of tests shall be according to IEC standards

- Conductor examination
- Measurement of electrical resistance of conductor
- Measurement of capacitance
- Measurement of thickness of insulation and non-metallic sheath
- Measurement of thickness of metallic sheath
- Measurement of diameters, if required
- Measurement of density of HDPE insulation, if applicable
- Impulse voltage test
- Water penetration test, if applicable
- Tests on components of cables with longitudinally applied metal tape or foil, bonded to the oversheath, if applicable

NOTE: For materials which are not considered by IEC 60840 & 62067, the test program shall be agreed between manufacturer and customer

SAMPLE TESTS ON FACTORY JOINTS FOR SUBMARINE CABLES

For DC submarine cable systems it is recommended to test each manufactured length and each factory joint under the routine tests.
Since routine tests check the quality of the entire submarine cable system itself, the sample tests listed shall be performed on one factory core joint only, prior to starting manufacture of the joints.
A sample of at least 10 m of cable and a factory joint shall be prepared for the tests.
If the factory joint is type tested under the contract, may be omitted.

- Tensile test
- PD measurement and AC voltage test (if applicable)
- Impulse voltage test (same conditions of the type test)
- Hot set test for insulation where applicable

Pass criteria
If a factory joint fails in any of the tests listed above, two additional joints shall be tested successfully.

SAMPLE TESTS ON REPAIR JOINTS AND TERMINATIONS

Sample tests are not applicable for repair joints and terminations for submarine cable systems. The terminations as well as the repair joints will be routine tested.

SAMPLE TESTS ON FIELD MOULDED JOINTS

Field moulded joints may be used for DC cable land connections. This kind of joints cannot be routine tested and the sample test sequence with the frequency and procedure as requested by the IEC 62067 is recommended. The same tests as prescribed for the factory joints of submarine cables are applicable.

AFTER INSTALLATIONS TESTS

High voltage test

The installed HV cable system shall be subjected to a negative polarity DC voltage of 1.45 Uo. The test duration shall be 1 hour.

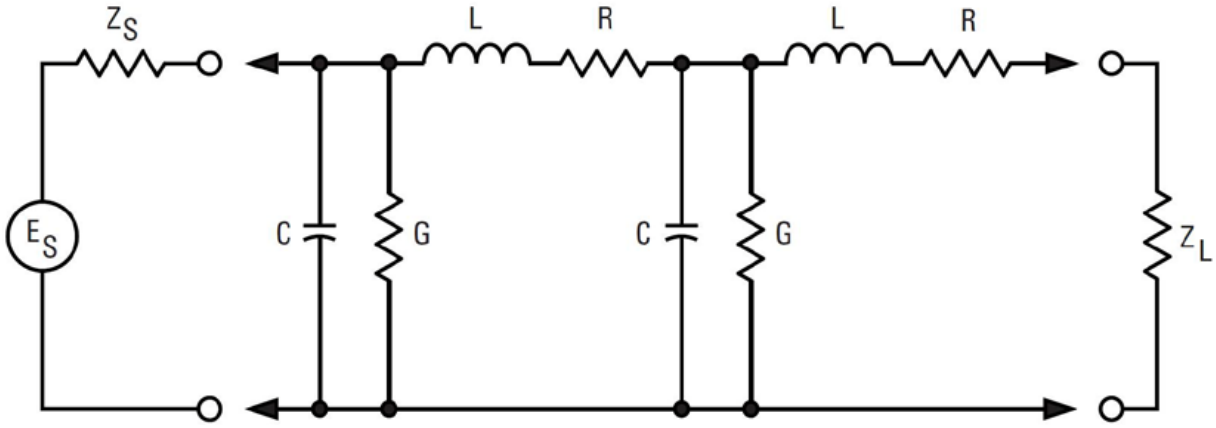
The installed return cable system shall be subjected to a negative polarity DC voltage that has been agreed between the supplier and the customer. The test duration shall be 1 hour. Negative polarity shall be used regardless of the polarity of the pole.

Test on polymeric sheaths

For underground cables electrical testing of the outer sheath subsequent to laying should be considered. If appropriate, the test shall be performed according to IEC60229.

TDR measurement

A TDR (Time Domain Reflectometry) measurement could be performed for engineering information.
If TDR equipment is to be used with the cable link it is advisable to perform a TDR measurement to obtain a “fingerprint” of the wave propagation characteristics of the cable.
The propagation of the pulses used during TDR measurements is dependent upon the per unit length cable parameters. As all electrical signals travel so as to consume a minimum of energy, the pulse propagates where the inductance/resistance is its lowest. Submarine power cables have a metallic screen and the pulses do not propagate outside the screen since the inductance (and impedance) would increase considerably. Hence the pulse is not affected by the coiling on a turntable or after installation.



Circuit diagram for TDR testing, traditional transmission line diagram, π-model

THANK YOU FOR YOUR ATTENTION

any questions?