



BSI Standards Publication

High-voltage direct current (HVDC) installations — System tests

National foreword

This British Standard is the UK implementation of EN 61975:2010+A2:2022. It is identical to IEC 61975:2010, incorporating amendment 1:2016 and amendment 2:2022. It supersedes BS EN 61975:2010+A1:2017, which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to IEC text carry the number of the IEC amendment. For example, text altered by IEC amendment 1 is indicated by **A1** **A1**.

The UK participation in its preparation was entrusted to Technical Committee PEL/22, Power electronics.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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30 April 2017	Implementation of IEC amendment 1:2016 with CENELEC endorsement A1:2017
31 December 2022	Implementation of IEC amendment 2:2022 with CENELEC endorsement A2:2022

**High-voltage direct current (HVDC) installations -
System tests
(IEC 61975:2010)**

Installations en courant continu
à haute tension (CCHT) -
Essais système
(CEI 61975:2010)

Anlagen zur
Hochspannungsgleichstromübertragung
(HGÜ) -
Systemprüfungen
(IEC 61975:2010)

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 22F/221/FDIS, future edition 1 of IEC 61975, prepared by SC 22F, Power electronics for electrical transmission and distribution systems, of IEC TC 22, Power electronic systems and equipment, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61975 on 2010-09-01.

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at national level by publication of an identical
national standard or by endorsement (dop) 2011-06-01
- latest date by which the national standards conflicting
with the EN have to be withdrawn (dow) 2013-09-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61975:2010 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC/TR 60919-1	NOTE	Harmonized as CLC/TR 60919-1.
IEC 61000-4-3	NOTE	Harmonized as EN 61000-4-3.
IEC 61803	NOTE	Harmonized as EN 61803.

Foreword to amendment A1

The text of document 22F/375/CDV, future IEC 61975:2010/A1, prepared by SC 22F "Power electronics for electrical transmission and distribution systems" of IEC/TC 22 "Power electronic systems and equipment" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61975:2010/A1:2017.

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publication of an identical national
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- latest date by which the national (dow) 2020-02-10
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European foreword to amendment A2

The text of document 22F/670/CDV, future IEC 61975/AMD2, prepared by SC 22F "Power electronics for electrical transmission and distribution systems" of IEC/TC 22 "Power electronic systems and equipment" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61975:2010/A2:2022.

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Annex ZA (normative)

Normative references to international publications with their corresponding European publications

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

The Annex ZA of EN 61975:2010 applies with the following changes:

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
<i>Replace the reference to IEC 60633 with the following new reference:</i>				
IEC 60633	2019	High-voltage direct current (HVDC) transmission - Vocabulary	EN IEC 60633	2019

¹⁾ At draft stage.

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INTRODUCTION

 The standard is structured in eight clauses:

Clause 1 – Scope

Clause 2 – Normative references

Clause 3 – Terms and definitions

Clause 4 – Objectives of system tests

This clause addresses the purpose of this standard, the HVDC system structure, the control and protection structure, the logical steps of commissioning, the structure of the system test and that of the system commissioning standard.

Clause 5 – Converter station test

This clause addresses the commissioning of converter units and verifies the steady state performance of units as well as switching tests.

Clause 6 – Power transmission tests

This clause concerns the commissioning of the transmission system, and verifies station coordination, steady-state and dynamic performance, interference, as well as interaction between the DC and AC systems.

Clause 7 – Trial operation

After completion of the system test, the period of trial operation is normally specified to verify the normal transmission.

Clause 8 – System test plan and documentation

Clauses 5 to 7 comprise individual sections providing an introduction and covering objectives, preconditions and procedures and general acceptance criteria as well as detailed descriptions of the individual tests. 

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HIGH-VOLTAGE DIRECT CURRENT (HVDC) INSTALLATIONS – SYSTEM TESTS

1 Scope

This International Standard applies to system tests for high-voltage direct current (HVDC) installations which consist of a sending terminal and a receiving terminal, each connected to an A_1 AC A_1 system.

The tests specified in this standard are based on bidirectional A_1 monopolar A_1 and bipolar high-voltage direct current (HVDC) installations which consist of a sending terminal and a receiving terminal, each connected to an A_1 AC A_1 system. The test requirements and acceptance criteria should be agreed for back-to-back installations, while multi-terminal systems and voltage sourced converters are not included in this standard. For monopolar HVDC installations, the standard applies except for bipolar tests.

For the special functions or performances that are claimed by specific projects, A_1 Text deleted A_1 extra test items not included in this standard should be added according to the technical specification requirements.

This standard only serves as a guideline to system tests for high-voltage direct current (HVDC) installations. The standard gives potential users guidance, regarding how to plan commissioning activities. The tests described in the guide may not be applicable to all projects, but represent a range of possible tests which should be considered.

Therefore, it is preferable that the project organization establishes the individual test program based on this standard and in advance assigns responsibilities for various tasks/tests between involved organisations (e.g. user, supplier, manufacturer, operator, purchaser etc.) for each specific project.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For A_1 undated A_1 references, the latest edition of the referenced document (including any amendments) applies.

A_2 IEC 60633:2019, *High-voltage direct current (HVDC) transmission – Vocabulary* A_2

IEC/TR 60919-2:2008, *Performance of high-voltage direct current (HVDC) systems with line commutated converters – Part 2: Faults and switching*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60633 as well as the following terms and definitions apply.

3.1 Test classification terms

A_1 converter station tests

converter station system test including items which verify the function of individual equipment of the converter station in energized state A_1

3.1.2**system test**

test verifying functions and performances of HVDC system as a whole as well as the interaction with adjacent A_1 AC A_1 systems

3.1.3**transmission tests**

test verifying functions and performances of HVDC system when transmitting power between both terminals

NOTE It is also referred to as an “end to end test”.

 A_1 **3.1.4****on-site tests**

tests which are performed at the final construction site consisting of converter station test and transmission test A_1

3.2 Operation state terms

A_1 NOTE There are five defined states in the HVDC system: earthed, stopped, standby, blocked, de-blocked. A_1

3.2.1**earthed**

state in which the pole or converter is isolated and earthed on the A_1 AC A_1 and A_1 DC A_1 sides and no energizing of the pole or converter equipment is possible

NOTE The earthed state provides the necessary safety for carrying out maintenance work, and is the only one that permits the pole or converter maintenance. In this state maintenance work is possible on the converter transformers, the isolated and earthed part of the A_1 AC A_1 high voltage bus equipment, A_1 DC A_1 and valve hall installed equipment of this pole or converter.

3.2.2**stopped/isolated**

state in which the pole or converter is isolated from the A_1 AC A_1 and A_1 DC A_1 side, but all the earthing switches are open

NOTE In this state the A_1 DC A_1 yard can be prepared for power transmission (earth electrode line, pole and A_1 DC A_1 line connect).

3.2.3**standby**

state which is to be used when the A_1 HVDC A_1 system is not being utilized but is ready for power transmission

NOTE In this state the converter transformer is to be ready; tap-changer is automatically brought to the start position, which ensures that the transformer will be energized with minimum voltage to minimize the inrush current. The disconnector of the A_1 AC A_1 bay should be closed, but the circuit breakers in the feeding bay of the converter transformer should be open. In this state the A_1 DC A_1 configuration can still be changed (earth electrode line, pole and A_1 DC A_1 line connect). A_1 The standby state is also referred to as “Ready for energization”. A_1

3.2.4**blocked**

state in which the pole is prepared to transmit power at a moment's notice

NOTE The converter transformer is connected to the energized A_1 AC A_1 bus by means of closing of the respective circuit breaker. A_1 The valve cooling system is in operation, and the cooling water conductivity, flow rate and water temperature are within the specified limits. A_1 A defined A_1 DC A_1 configuration shall have been established. Further changes are not possible in this state. The thyristor pre-check is carried out after the converter transformer has been energized. The pre-check is considered as passed when in every valve the redundancy is not lost. To change the blocked state, the states stopped, standby and de-blocked are selectable. A_1 The blocked state is also referred to as “Ready for operation”. A_1

3.2.5

de-blocked

state representing the following two operating modes: power transmission and open line test

NOTE Power transmission is the normal operating mode. In the de-blocked status the pole transmits power in normal operating mode if both terminals are in the deblocked stage and there is a voltage difference between the terminals. A minimum number of A_1 AC A_1 filters should be available.

3.2.6

off-site tests

tests which are performed before on-site testing

A_1 EXAMPLE Routine and type tests performed at the suppliers' factory. A_1

4 Objectives of system tests

4.1 Categories of system tests

System test completes the commissioning of an HVDC system.

The supplier can verify the suitability of the station equipment installed and the functional completeness of the system. Moreover, adjustments and optimizations can be made.

It is shown for the user that the requirements and stipulations in the contract are met and that there is correlation with studies and previous off-site tests.

For the user, the completion of system A_1 testing A_1 marks the beginning of commercial operation of the HVDC system.

When adapting the HVDC system to the connected A_1 AC A_1 systems, there may be various constraints which require coordination within the economic schedules of the A_1 AC A_1 system operators. System tests prove to the public that tolerable values of phenomena concerning the public interest are not exceeded.

Five major aspects are subject to system tests:

- a) HVDC station equipment and A_1 DC A_1 line/cable/bus including earth electrode, if any;
- b) HVDC control and protection equipment and their settings;
- c) environmental considerations;
- d) A_1 AC A_1 / A_1 DC A_1 system interaction;
- e) system performance when jointly operated with a connected A_1 AC A_1 system.

The interrelation between these aspects is shown in Figure 1.

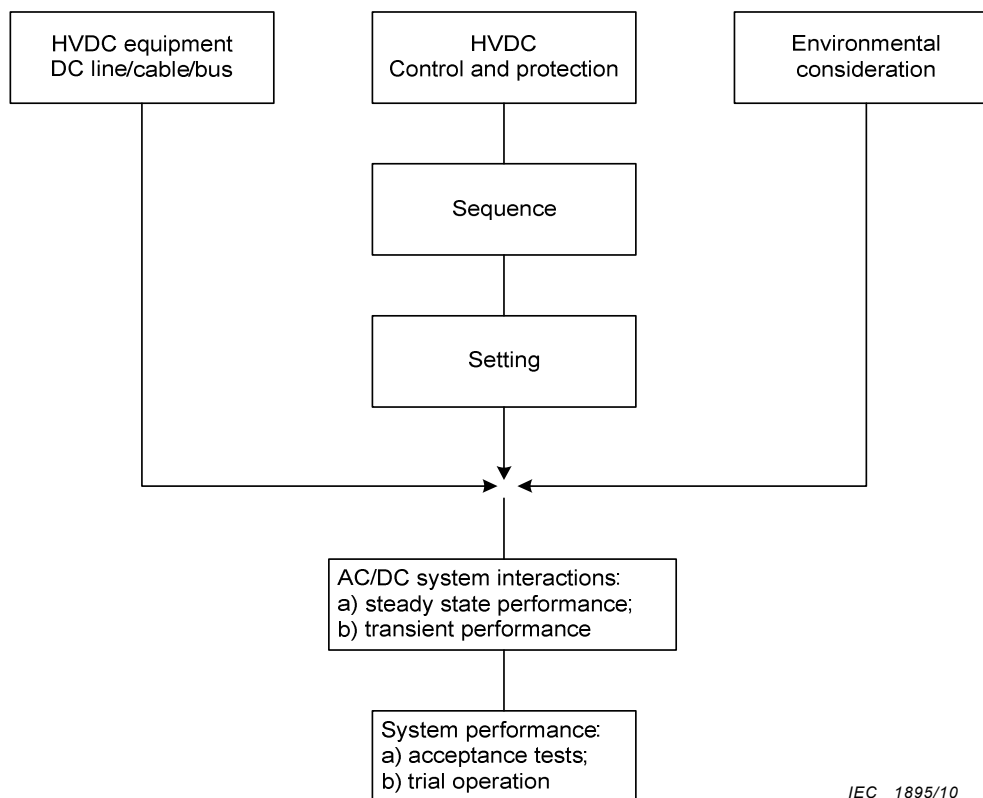


Figure 1 – Relation among five major aspects of system test

Thorough and complete system test of the above components can be achieved with the tests described in the standard.

A1 Acceptance tests are the acceptance requirements for a successful completion of works and a basis for the final acceptance of the HVDC system by its users. **A1**

Acceptance tests shall be defined between supplier and user in advance and may be performed at an appropriate time during the test schedule.

System tests may affect more than the actual contract parties. Those parties shall be informed in time.

The complexity and the diversified areas concerned during system test require thorough planning and scheduling, cooperation of all involved parties, as well as complete and organized documentation.

NOTE The suggested “Test Procedures” are recommendations and alternative test procedures may be used subject to the agreement between supplier and user.

4.2 Structure of the HVDC system

From a functional point of view an HVDC system consists of a sending terminal and a receiving terminal, each connected to an **A1** AC **A1** system. The two terminals have one or several **A1** converter units **A1** connected in series on the **A1** DC **A1** side and in parallel on the **A1** AC **A1** side. The terminals are connected by a transmission line or cable or a short piece of busbar (back-to-back station). **A1** Two terminals in connection constitute a HVDC system. If the configuration comprises a single pole, it is defined as a monopolar HVDC system. If the configuration comprises two poles of opposite polarities with respect to earth, it is called a bipolar HVDC system. **A1** Multi-terminal systems are not addressed in this standard.

The structure of the HVDC system is shown in Figure 2.

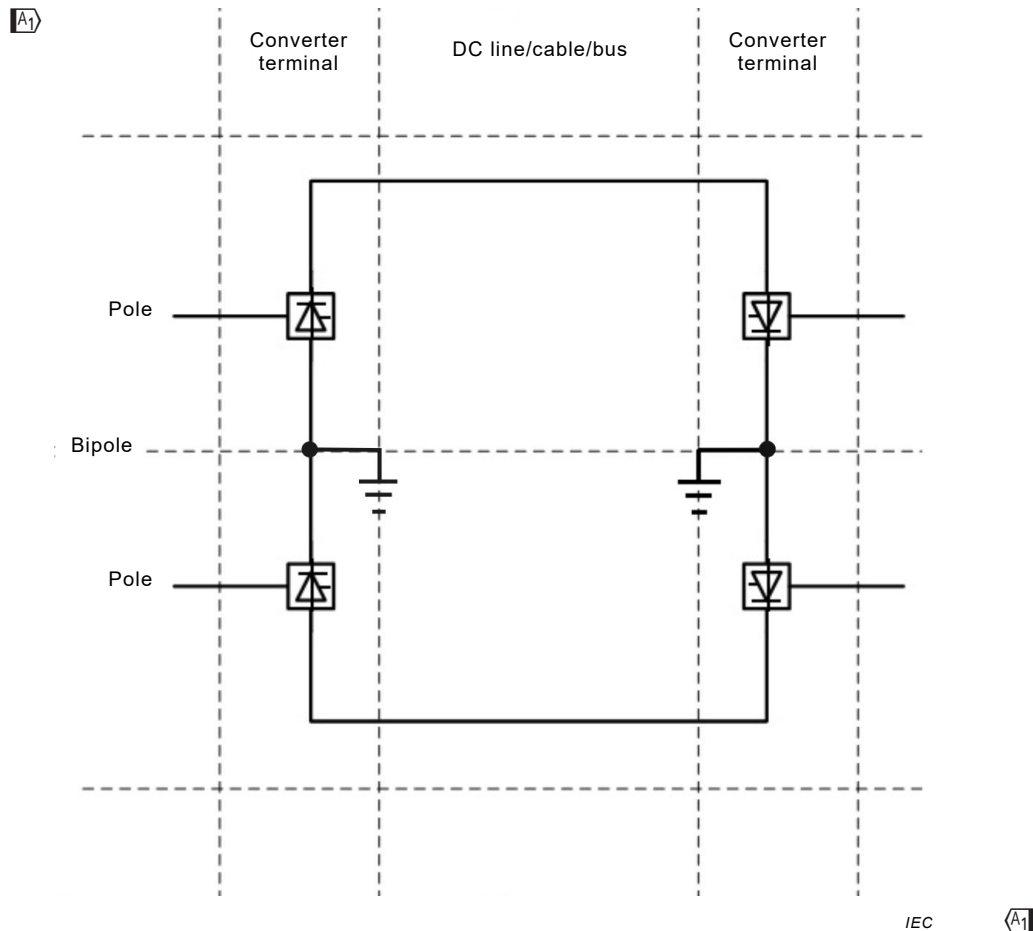


Figure 2 – Structure of the HVDC system

4.3 Structure of the control and protection system

Each of the converter units can be controlled individually. To make the system function correctly as a power transmission system, the converter units should be controlled in a coordinated way by a higher level of the control system. Coordinated controls and protection are essential for the proper functioning of HVDC systems.

The structure of the HVDC control and protection is shown in Figure 3:

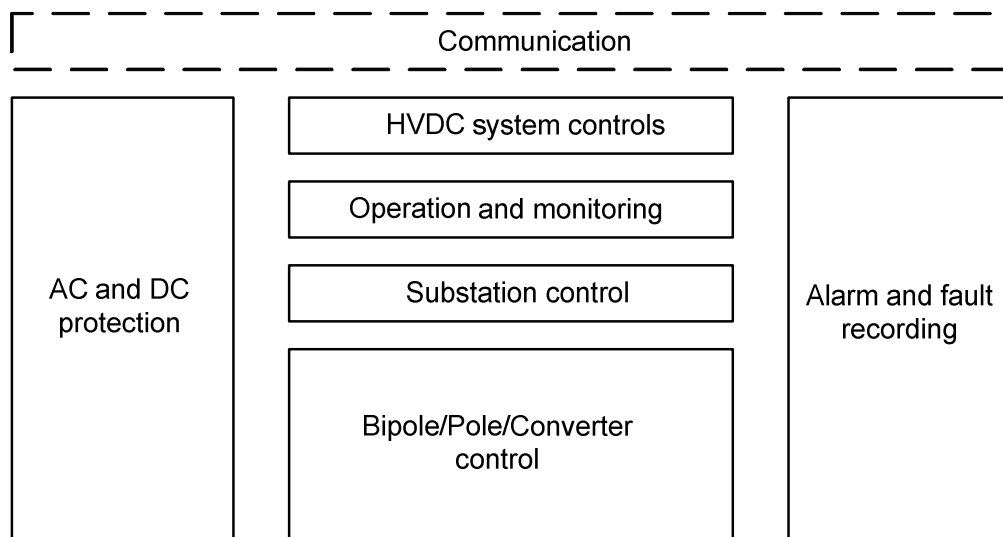


Figure 3 – Structure of the HVDC control and protection

IEC 1897/10

A1 4.4 Logical steps of system test

Replace the existing text by the following new text:

To ensure proper functioning, the type test and functional performance test shall be conducted in factory in order to debug and test the control system before the site test.

In order to provide the power grid data and help to compile the system test plan, the off-line digital simulation shall be conducted before and during the simulation test, especially analysis on the power flow, stability and overvoltage.

Considering the complexity of the HVDC system, all limiting design cases may be conducted on the digital simulator in a similar way to those done on site.

Commissioning an HVDC system may affect more than the actual contract parties. The complexity and the diversified areas concerned during system testing require thorough planning and scheduling, cooperation of all involved parties and complete and structured documentation. Before a system test can begin on site, the following preconditions shall be fulfilled concerning subsystem tests, operator training and safety instructions, system test plan and test procedures, and all necessary test equipment.

- a) All subsystems shall have been tested and commissioned, including AC filters and the converter transformers.
- b) Operating personnel shall be sufficiently trained.
- c) Operating instructions for the station shall be available.
- d) Personnel, plant safety and security instructions shall be available.
- e) System test plan and documentation (Part 8) shall be available and agreed upon.
- f) AC/DC power profiles shall have been agreed for each test.
- g) Any AC/DC system operating restrictions shall have been identified.
- h) Operator voice communications shall be available
- i) All necessary test equipment shall have been calibrated and in service.
- j) Procedures for the preparation and evaluation of test results shall have been agreed upon.

Site system tests shall follow the structure of the HVDC system, starting from the smallest, least complex operational unit, usually a 12-pulse converter, and shall end with the total system in operation. The test sequence shall be scheduled starting at the local level with simple tests before involving additional locations and the transmission system and more complex tests.

After all preconditions are fulfilled, converter station tests shall be conducted and begin from the converter unit test, including the energization of AC filter and DC yard, changing the DC system configuration, electromagnetic interference, trip test, open line test, etc.

The power transmission (also called end-to-end) test shall start on a monopolar basis, continuing with bipolar operation, with full power transmission being the final step.

Having the complete system running properly, performance of the steady state can be verified. With normal operating ramp settings and automatic switching sequences in place, the effect of a number of disturbances on the DC side of the system as well as in the AC systems may be checked, and the transient and fault recovery performances may be verified.

Acceptance tests shall be defined between supplier and user in advance and may be performed at an appropriate time during the test schedule. **A1**

A1 Correct operation of the HVDC system over an extended period of time is checked during the trial operation.

Complete and organized documentation of the system tests, which benefit both the supplier and the user, shall form part of the project documentation and contain all necessary data records, logs, etc, and if necessary a commentary and references.

After all the above HVDC system tests have been completed, all functions have been verified and the HVDC system can be handed over to the users. **A1**

4.5 Structure of system test

A1 The overall structure of the system tests is shown in Figure 4. **A1**

A1 4.6 Precondition for on-site test **A1**

4.6.1 Factory system test

This subclause describes **A1** the off-site tests **A1** and the **A1** partial commissioning **A1** of the HVDC controls at the factory, including real-time simulation test.

Subsequent to the routine test of the HVDC system control and protection equipment, it is normal practice to check the function of the HVDC control and protection equipment in a factory system test (= FST) prior to being shipped to site.

The factory system test provides the opportunity to set up the parameters of the control systems and to obtain a proof on the performance of the equipment relative to the specified requirements.

Performance of the protective functions of the converter, during various simulated faults, can also be checked. This enables the equipment to be partly commissioned off-site. It also provides the opportunity to detect and correct hardware and software errors or deficiencies in the control and protection systems.

The factory system test may use a real-time simulator and/or software models. **A1** Off-line simulation software can be used to analyse short circuit capacity, overvoltage and power flow, while the real-time simulator may be used for the complete functional performance tests of the control system. **A1**

In the factory system test the **A1** complete control and protection system **A1** shall be tested. Fault recorders and sequence of event recorders in case they are “stand alone equipment” may be excluded. If these recorders are not part of the factory system test, the validity of output signals to these equipment would be checked during the tests.

Finding and correcting hardware and software errors in the control **A2** and protection **A2** system is an important function of the off-site test. Such faults are easier to find and correct off-site rather than during site tests and commissioning. Correcting such faults reduces the probability of disturbing the customer power system during the site system test.

4.6.2 Additional simulation test

A1 If the AC network conditions in commissioning stage are different from that in the HVDC design stage, **A1** **A2** any additional simulation tests shall be conducted, if agreed upon between supplier and user. **A2**

A1 Text deleted **A1**

The additional simulations provide opportunities to:

- a) set up the parameters of the control systems and obtain a preliminary check on the performance of the equipment relative to the specified requirements;
- b) check performance of the protective functions of the converter during various simulated faults;
- c) find and correct hardware and software errors in the control **A2** and protection **A2** system which are easier to find and correct off-site rather than during site tests and commissioning, and can reduce the probability of disturbing the customer power system during site system tests.

A1 4.7 Acceptance tests

The acceptance tests necessary to verify whether acceptance criteria have been met may have been performed wholly or in part during the commissioning period. To avoid unnecessary duplication of such tests, careful consideration shall be given in advance as to when acceptance tests are carried out. If acceptance tests are still outstanding or have to be repeated due to modifications, they shall be performed during the transmission test, or following trial operation, if appropriate. **A1**

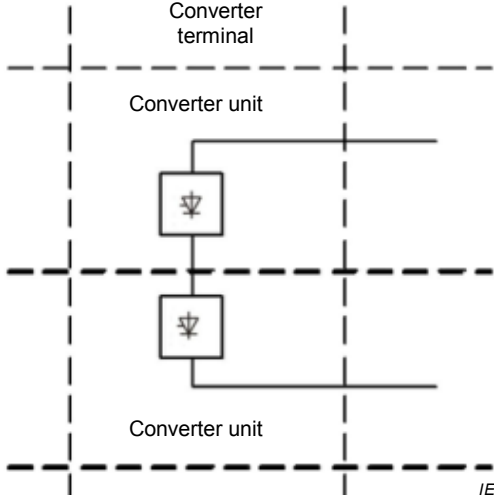
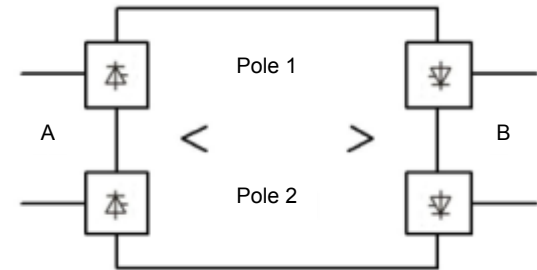
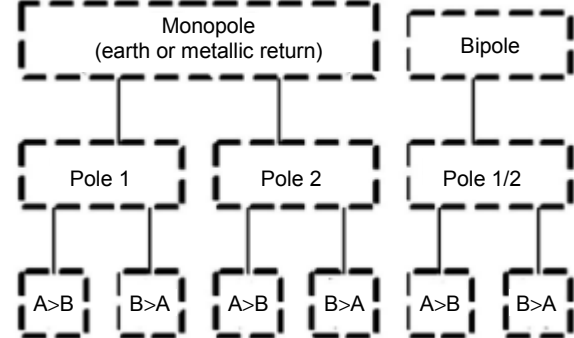
Tests	Configuration
Converter station test 1) Converter unit test 2) Energizing of reactive components • $\overline{A_1}$ AC $\overline{A_1}$ filters • Capacitor banks • Reactors 3) Changing the $\overline{A_1}$ DC $\overline{A_1}$ system configuration 4) Electromagnetic compatibility 5) Trip test 6) Open line test 7) <i>Back-to-back test</i> 8) <i>Short circuit test</i> NOTE Tests in <i>Italic</i> are special load tests as per 5.1.2.5.	 IEC 1898/10
Power transmission test 1) Basic operation • Start and stop sequences and steady state operation • Protective blocking and tripping sequences • Power and current ramping 2) Operator control mode transfer • Control location • Control mode • Reactive power control mode • Operation voltage • $\overline{A_1}$ DC $\overline{A_1}$ power automatic control 3) Changes of $\overline{A_1}$ DC $\overline{A_1}$ configuration 4) Switching of primary equipment • Transformers and tap changers • $\overline{A_1}$ AC $\overline{A_1}$ filters and the reactive power compensation devices • $\overline{A_1}$ DC $\overline{A_1}$ filters 5) Dynamic performance testing 6) $\overline{A_1}$ AC $\overline{A_1}$ and $\overline{A_1}$ DC $\overline{A_1}$ system staged faults 7) Loss of telecom, auxiliaries or redundant equipment 8) Steady state performance • The measurement of the system parameters • $\overline{A_2}$ Reactive power control performance • Overload conditions • Rated load temperature rise $\overline{A_2}$ • Harmonic performance and filter components rating • Audible noise • Loading tests • Electromagnetic interference test • Earth electrode test	 IEC 1899/10 Configuration  IEC 1900/10
Trial operation	

Figure 4 – Structure of system test

5 Converter station test

5.1 General

5.1.1 Environmental specifications

This clause describes the test of each converter station as a unit and the verification of the HVDC transmission line prior to transmitting power. This group of tests precedes the end-to-end test.

During the test program, conformance with environmental specifications should be included where applicable. Preliminary observations of audible noise, radio and PLC interference levels may be made, and temperature rise of major equipment can be monitored as described in Clause 6. However, the actual measurement of the above mentioned quantities should be conducted during end-to-end operation.

5.1.2 General purpose

5.1.2.1 General

The converter station test verifies the correct operation of an individual converter station and the proper insulation of all main circuit equipment before starting the power transmission tests.

The converter station tests may be **A1** divided into trip tests, low voltage energization **A1**, high voltage energizing, open line test and load tests.

5.1.2.2 **A1** Low voltage energizing / Phasing verification **A1**

In order to verify the phasing, the converter main circuit connections and the converter firing control a low voltage energizing test could be conducted prior to high voltage energizing. The test verifies the electrical phasing through the main circuit and the control system.

5.1.2.3 High voltage **A1** energization **A1**

The high voltage energizing verifies that proper voltage insulation is achieved in the AC and **A1** DC **A1** main circuit equipment.

5.1.2.4 Open line test

The open line tests of the **A1** DC **A1** switchyard and **A1** DC **A1** transmission circuit verify that proper insulation voltage withstand has been achieved and that the converter firing control and the valve base electronics function properly.

5.1.2.5 Special load test

A load test (back-to-back or short circuit test) may be conducted, if specifically specified by the user, to get a provisional verification of the control system, the valve cooling capability and the main circuit with respect to temperature rise, audible noise and radio interference. Final verification will be made during power transmission test.

5.1.3 General precondition

Before beginning the converter **A1** station **A1** test, the following equipment shall be verified off voltage and be available:

- a) **A1** AC **A1** switchgear;
- a) **A1** AC **A1** filters, capacitor banks and shunt reactors;
- b) **A1** DC **A1** filters and switchgear;

- d) converter transformers;
- e) thyristor valves and cooling system;
- f) station auxiliary service;
- g) fire protection system;
- h) $\boxed{A_1}$ AC $\langle A_1 \rangle$ and $\boxed{A_1}$ DC $\langle A_1 \rangle$ protection systems;
- i) control system;
- j) $\boxed{A_1}$ DC $\langle A_1 \rangle$ line or cable (for open line test);
- k) sequence of event recorder;
- l) alarm system;
- m) transient fault recorders.

Prior to the converter tests, detailed procedures and plans should be prepared. As the tests may involve some disturbance or increased risk to the connected a.c. systems, the operators of the systems should be consulted.

5.2 Converter unit test

5.2.1 Purpose of test

$\boxed{A_1}$ The test verifies that at the first energization of the converter unit the insulation withstand voltage is achieved, and that the electrical phasing is correct. $\langle A_1 \rangle$

5.2.2 Test precondition

Test preconditions are the following:

- a) All controls and protections associated with the high voltage equipment shall be verified and in service. A trip test shall be made shortly before high voltage $\boxed{A_1}$ energization $\langle A_1 \rangle$ (see 5.6).
- b) Monitoring instrumentation shall be connected and ready.
- c) All clamp joints shall have been tightened and the insulators wiped clean.
- d) The HVDC transmission line disconnect switch shall be opened and locked.
- e) All safety procedures shall have been carried out.
- f) A final visual inspection of the high voltage equipment shall be performed and the arrester counter numbers shall be recorded.
- g) The low voltage side of the valves shall be earthed.

5.2.3 Test procedure

5.2.3.1 Low voltage $\boxed{A_1}$ energization $\langle A_1 \rangle$

Test conditions are the following:

- a) During the test, all the internal reference voltages in the controls and the firing pulses of the valve control unit (=VCU) are monitored.
- b) $\boxed{A_2}$ The test may be performed by applying 0,5 kV to 10 kV. $\langle A_2 \rangle$
- c) An appropriate resistor or reactor may serve as a load on the $\boxed{A_1}$ DC $\langle A_1 \rangle$ side.
- d) Each single valve is represented by a single thyristor level. During the low voltage energizing test, the valves are de-blocked and the converter is operating in normal or open line test mode.

NOTE $\boxed{A_2}$ The preferred approach $\langle A_2 \rangle$ to verify the phasing of the converter main circuit connections and the interconnections to the converter transformers is a thorough visual inspection of the interconnection scheme and

comparison with the relevant documentation. This will however include verification that the control sends out a firing pulse to the correct thyristor.

5.2.3.2 High voltage A_1 energization A_1

Test conditions are the following:

- Energize the converter transformer with the valves blocked and check the electrical phasing through the control system.
- A_2 Ensure that the converter transformer tap changers initially at highest position (lowest valve side voltage) and then are stepped to rated voltage. A_2
- Keep the transformer energized for a minimum number of hours as specified by the manufacturer and the local utilities.
- Record A_1 AC A_1 voltage, steady-state and inrush-current, and inspect the equipment for abnormal sounds and corona discharge during the test.

5.2.4 Test acceptance criteria

The test acceptance criteria are the following:

- No abnormal sound or corona discharge shall occur in the energized equipment.
- No protection shall operate improperly.
- Parameters, such as voltage, A_1 shall A_1 be as expected.

5.3 A_1 Energization A_1 of reactive components

5.3.1 A_1 General A_1

Reactive components, such as A_1 AC A_1 filters, capacitor banks and shunt reactors are energized for the first time individually. Combined switching of these elements is described in Clause 6.

5.3.2 Purpose of test

Purposes of the test are the following:

- to verify that proper voltage insulation is achieved;
- to verify that the A_1 AC A_1 filters, capacitor banks and shunt reactors are balanced between the three phases;
- to confirm the no-load currents and voltages of the protections, if any.

5.3.3 Test precondition

Test preconditions are the following:

- All controls and protections (main and backup) associated with the high voltage equipment shall be verified and in service. A trip test shall be made shortly before high voltage A_1 energization A_1 .
- AC filter tuning shall be completed.
- AC filters and shunt capacitors shall have been balanced.
- All clamp joints shall have been tightened and the insulators wiped clean.
- All safety procedures shall have been carried out.
- A final visual inspection of the high voltage equipment shall be performed, and the arrester counter numbers shall be recorded.

5.3.4 Test procedure

Test procedure is the following:

- Energize the A_1 AC A_1 filters, capacitor banks and shunt reactors one by one.

- b) Keep each A_1 AC A_1 filter, capacitor bank and shunt reactor energized for a minimum of 2 h.
- c) Record A_1 AC A_1 voltage, steady-state and inrush current, and inspect the equipment for abnormal sounds and corona discharge during the test.

5.3.5 Test acceptance criteria

The test acceptance criteria are the following:

- a) No abnormal sound or corona discharge shall occur in the energized equipment.
- b) No protection shall operate improperly.
- c) The A_1 AC A_1 filters and capacitor banks shall be balanced within design tolerances.

5.4 Changing the A_1 DC A_1 system configuration

5.4.1 General

Changing the A_1 DC A_1 system configuration can be relatively simple in an end to end or point to point system which has a single converter A_1 unit A_1 per pole. The switching operations become more complicated if the station poles have parallel or series converters. This test demonstrates that equipment, breakers, disconnectors or earthing switches are operated in the correct sequence and, are properly interlocked. Changing the A_1 DC A_1 system configuration on load is described in Clause 6.

Transfers between different A_1 DC A_1 system configurations can be initiated automatically and jointly or manually from local control or from a remote dispatch centre. In manual or separate control, the operators need to coordinate these actions via voice communication.

5.4.2 Purpose of test

- A_1 The test verifies that the different DC system configuration available can be safely changed as specified prior to transmitting power for the first time. A_1

5.4.3 Test precondition

Test preconditions are the following:

- a) Off-site tests verifying A_1 DC A_1 system configuration change shall have been completed.
- b) All necessary A_1 AC A_1 and A_1 DC A_1 switching equipment shall be in service.
- c) Operator instructions and test procedures shall be available.

5.4.4 Test procedure

The transfer between specified A_1 DC A_1 system configurations shall be demonstrated. The changes of configuration should be performed from the initial conditions defined below:

- monopolar earth return;
- monopolar metallic return;
- bipolar operation;
- integration of parallel or series converters.

The tests shall first be performed with telecommunication out of service, and then with telecommunication in service.

- a) Establish voice communication with the operators of the other terminal.
- b) Switch off the telecommunication.
- c) Reset all alarms.

- d) Select the initial $\boxed{A_1}$ DC $\boxed{A_1}$ system configuration in accordance with the operating instructions. The procedure will have to be done in steps involving operators at each terminal.
- e) Verify the appropriate switching action on the operator control interface and sequence of events recorder. Simulate failures in the switching sequence.
- f) Repeat the test for all applicable $\boxed{A_1}$ DC $\boxed{A_1}$ system configurations.
- g) Restore telecommunication.
- h) Repeat the tests, in automatic and joint control mode.

5.4.5 Test acceptance criteria

The test acceptance criteria are the following:

- a) Switching sequences shall correctly transfer between all applicable $\boxed{A_1}$ DC $\boxed{A_1}$ system configurations, with and without telecommunication.
- b) All switching sequences shall be safely and correctly completed.
- c) The interlocking of earthing switches, disconnect switches and breakers of the $\boxed{A_1}$ AC $\boxed{A_1}$ and $\boxed{A_1}$ DC $\boxed{A_1}$ yards shall be in accordance with the technical specifications.
- d) It should be possible to initiate a change of $\boxed{A_1}$ DC $\boxed{A_1}$ system configuration from local and, if available, from remote control locations.
- e) An incomplete sequence shall be terminated in a safe condition.

5.5 Electromagnetic compatibility

5.5.1 $\boxed{A_1}$ Purpose of test $\boxed{A_1}$

The test may be conducted, if specified by user, at each station and each pole individually.

$\boxed{A_1}$ The test verifies that there are no issues with electromagnetic compatibility of the equipment cubicles. $\boxed{A_1}$

5.5.2 Test precondition

Test preconditions are the following:

- a) All primary equipment in the $\boxed{A_1}$ AC $\boxed{A_1}$ and $\boxed{A_1}$ DC $\boxed{A_1}$ yard of the tested station should be off voltage.
- b) All controls and protections (main and backup) associated with the high voltage equipment shall be verified and in service.
- c) All alarm and monitoring (including recording sequence of events) systems shall be verified and in service.

All the cubicles of control and protection system and the devices in them are charged.

All safety procedures shall have been carried out.

A final visual inspection of the high voltage equipment shall be performed, and the arrester counter numbers shall be recorded.

The test equipment, such as walkie talkie or mobile telephones, should be checked and in service. Moreover, the emitting power of the test equipment should be within 3 W to 5 W.

5.5.3 Test procedure

5.5.3.1 General

Electromagnetic compatibility can utilize different interference sources, which are listed as follows.