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INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

Installations en courant continu à haute tension (CCHT) – Essais systèmes

IEC 61975:2010

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

FOREWORD

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International Standard IEC 61975 has been prepared by subcommittee 22F: Power electronics for electrical transmission and distribution systems, of IEC technical committee 22: Power electronic systems and equipment.

This first version of IEC 61975 cancels and replaces IEC/PAS 61975 published jointly in 2004 by IEC and CIGRÉ. It constitutes a technical revision incorporating engineering experience.

This bilingual version (2012-09) corresponds to the monolingual English version, published in 2010-07.

The text of this standard is based on the following documents:

FDIS	Report on voting
22F/221/FDIS	22F/227/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

The French version of this standard has not been voted upon.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

The standard is structured in eight clauses:

a) Clause 1 – Scope

b) Clause 2 – Normative references

c) Clause 3 – Definitions

d) Clause 4 – General

e) 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.

f) Clause 5 – Converter station test

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

h) Clause 6 – Power transmission tests

i) 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 d.c. and a.c. systems.

j) Clause 7 – Trial operation

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

l) Clause 8 – System test plan and documentation

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

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.c. system.

The tests specified in this standard are based on bidirectional and bipolar high-voltage direct current (HVDC) installations which consist of a sending terminal and a receiving terminal, each connected to an a.c. 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, some 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 updated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60633:1998, *Terminology for high-voltage direct current (HVDC) power transmission*

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 classifications terms

3.1.1
station test
converter system test including items which verify the function of individual equipment of the converter staton in energized state

3.1.2
system test
test verifying functions and performances of HVDC system as a whole as well as the interaction with adjacent a.c. 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”.

3.2 Operation state terms

In the d.c. system, there are 5 defined states: earthed, stopped, standby, blocked, de-blocked.

3.2.1
earthed
state in which the pole or converter is isolated and earthed on the a.c. and d.c. 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.c. high voltage bus equipment, d.c. 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.c. and d.c. side, but all the earthing switches are open

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

3.2.3
standby
state which is to be used when the d.c. 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.c. bay should be closed, but the circuit breakers in the feeding bay of the converter transformer should be open. In this state the d.c. configuration can still be changed (earth electrode line, pole and d.c. line connect).

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.c. bus by means of closing of the respective circuit breaker. The valve cooling system is ready for operation if the cooling water conductivity, flow and temperature are within the specified limits. A defined d.c. 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.

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.c. filters should be available.

3.2.6
off-site tests
tests which are performed before on-site testing

4 General

4.1 Purpose

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 test marks the beginning of commercial operation of the HVDC system.

When adapting the HVDC system to the connected a.c. systems, there may be various constraints which require coordination within the economic schedules of the a.c. 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 d.c. line/cable/bus including earth electrode, if any;
b) HVDC control and protection equipment and their settings;
c) environmental considerations;
d) a.c./d.c. system interaction;
e) system performance when jointly operated with a connected a.c. system.

The interrelation between these aspects is shown in Figure 1.

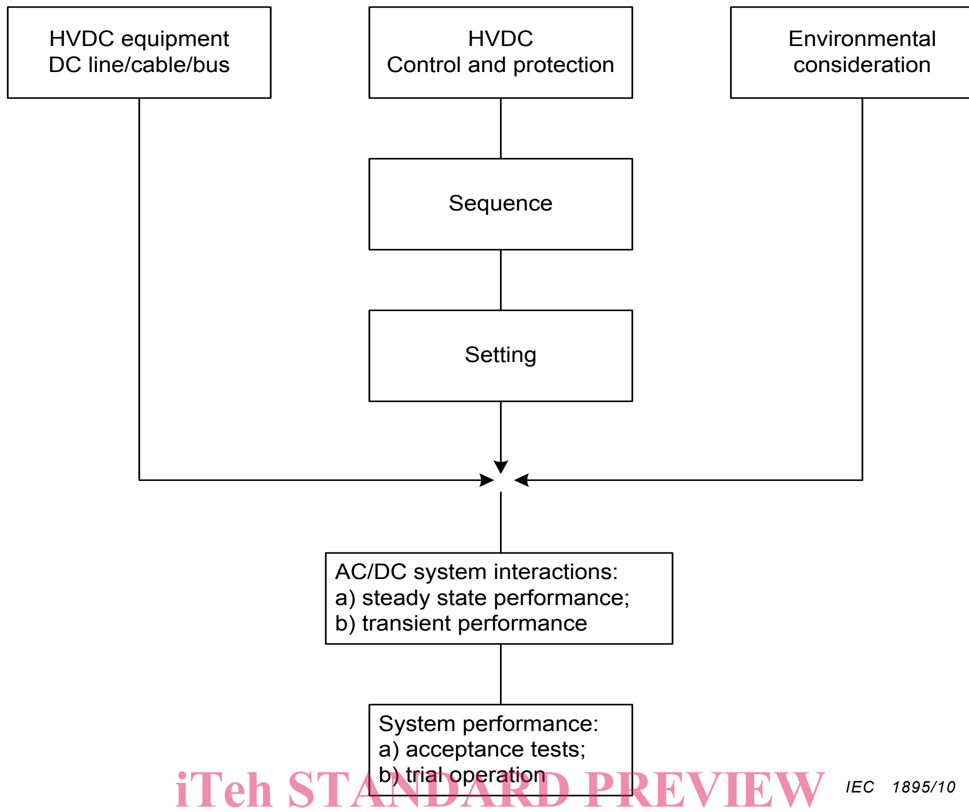

Figure 1 – Relation among five major aspects of system test

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

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 a.c. system. The two terminals have one or several converters connected in series on the d.c. side and in parallel on the a.c. side. The terminals are connected by a transmission line or cable or a short piece of busbar (back-to-back station). Multi-terminal systems are not addressed in this standard.

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

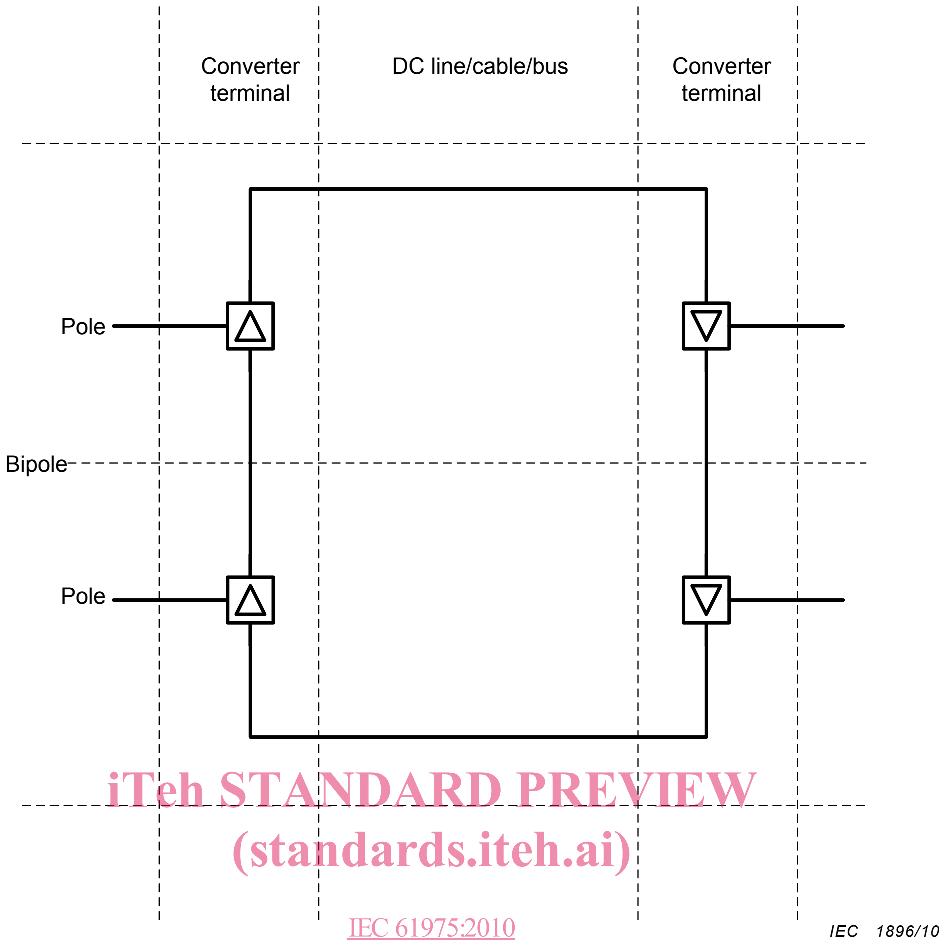

Figure 2 – Structure of the HVDC system

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:

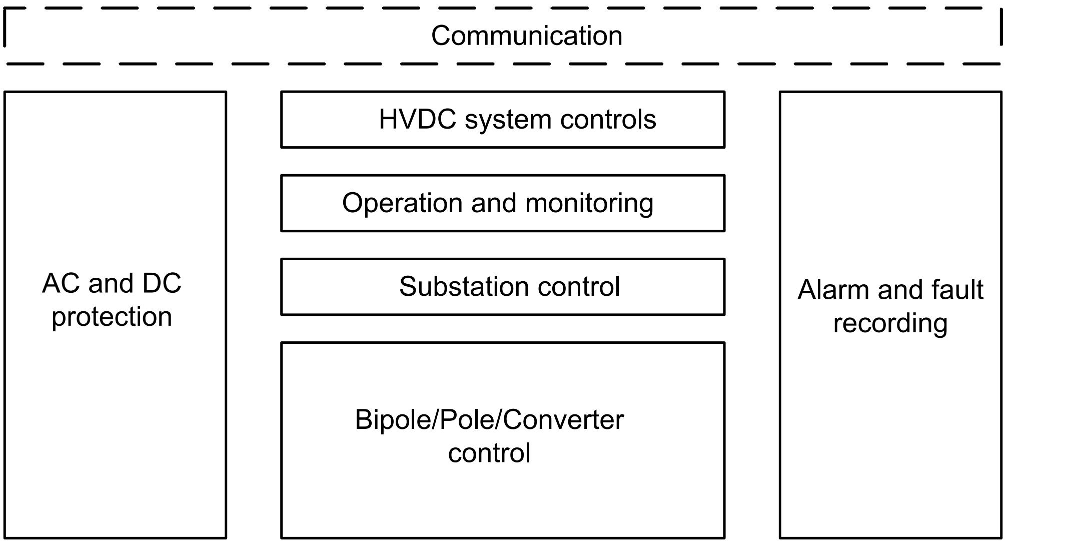

Figure 3 – Structure of the HVDC control and protection

4.4 Logical steps of system test

To ensure proper functioning, the type test and functional performance test should 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 should 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 test 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 should be fulfilled concerning subsystem tests, operator training and safety instructions, system test plan and test procedures, and all necessary test equipment.

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

Site system tests should 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 should 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 should be conducted and begin from the converter unit test, including energizing of a.c. filter and d.c. yard, electrical magnetic interference, trip test, changing the d.c. system configuration, open line test, and so on.

The power transmission (also called end-to-end) test should start on a monopolar basis, with bipolar operation, with full power 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 d.c. side of the system as well as in the a.c. 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.

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 should be given in advance as to when acceptance tests are carried out.

If acceptance tests are still outstanding or acceptance tests have to be repeated due to modifications, they should be performed during the transmission testing, or following trial operation, if appropriate.

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.

4.5 Structure of system test

The structure of the system test is shown in Figure 4.

4.6 Precondition for site test

4.6.1 Factory system test

This subclause describes site tests and the commissioning 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.

In the factory system test the complete control system 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 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 before site system test

If the a.c. network condition in commissioning stage is different from that in the HVDC design stage, the additional simulation test should be conducted, if specified by the user.