

# TECHNICAL SPECIFICATION

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**Joint commissioning for grid-connection of offshore wind farms using VSC  
HVDC transmission**

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## Joint commissioning for grid-connection of offshore wind farms using VSC HVDC transmission

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The text of this Technical Specification is based on the following documents:

Draft	Report on voting
8A/210/DTS	8A/223/RVDTS

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

The language used for the development of this Technical Specification is English.

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## INTRODUCTION

This document addresses the joint commissioning of grid-connection of offshore wind farms (GCOWF) using the voltage source converter based high voltage direct current (VSC HVDC) transmission system. The test purpose, test preconditions, test procedures and methods, and test acceptance criteria for joint commissioning are introduced in this document. The scope of the document covers the commissioning of offshore wind farms, testing of the onshore DC energy dissipation device, special test items for transmission test, coordination function testing among the VSC HVDC system, DC energy dissipation device, offshore wind farm and automatic generation control (AGC). The conventional commissioning test items of the VSC HVDC system are out of scope.

Due to the advantages of abundant and highly qualified wind resources, offshore wind farms have become the development trend of wind power generation. Currently, the VSC HVDC power transmission technology provides a solution for grid connection of the large-scale and long-distance offshore wind power farms since it can achieve power supply for a passive system, long-distance power transmission, and flexible and independent control for active and reactive power. In this context, a number of large-scale and long-distance wind power farms, connected with power grid using VSC HVDC power transmission, have been put into commercial operation around the world, such as China, Germany, and the UK.

More and more offshore wind farms will be integrated into the onshore AC power grid using VSC HVDC power transmission. The commissioning is the final on-site test for grid-connection of offshore wind farms using VSC HVDC power transmission, to help ensure that the whole system can safely and reliably operate, and meet the grid connection requirements, as well as the relevant contracts and specifications.

Compared with the commissioning of conventional VSC HVDC projects, the joint commissioning procedures, methods, and grid-connection requirements of the VSC HVDC projects with integration of offshore wind farms are different, due to the special offshore operating conditions, as well as the existence of onshore DC energy dissipation device and the offshore wind farms. Therefore, it is important to draft a technical specification on joint commissioning for grid-connection of offshore wind farms using VSC HVDC power transmission.

The purpose of this document is to elaborate on the commissioning procedures, test items, conditions, methods, and special requirements of grid-connection of offshore wind farms to help ensure the integrity and correctness of the commissioning. It is possible that the document is not applicable to all projects but represents a range of possible system tests which should be considered. The commissioning requirements and procedures provided in this document are not for any specific project and these should be considered according to the agreement between the purchaser and supplier and as applicable.

## 1 Scope

This document serves as a specification for the joint commissioning of grid-connection of offshore wind farms (GCOWF) using the voltage source converter based high voltage direct current (VSC HVDC) transmission system.

This document provides the technical specification on the commissioning precondition, objectives, procedures, items, methods and requirements of grid-connection of offshore wind farms using the VSC HVDC power transmission, particularly focusing on the special test items of offshore wind farms.

This document covers the commissioning of offshore wind farms, testing of onshore DC energy dissipation device, special test items for transmission test, coordination function testing among VSC HVDC, DC energy dissipation device, offshore wind farm and automatic generation control (AGC). However, the conventional commissioning test items of the onshore VSC HVDC system are out of scope.

## 2 Normative references

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.

IEC 60050-811, *International Electrotechnical Vocabulary - Part 811: Electric traction*, [www.electropedia.org](http://www.electropedia.org)

IEC 60270, *High-voltage test techniques - Charge-base measurement of partial discharges*

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

IEC 61400-3-1, *Wind energy generation systems - Part 3-1: Design requirements for fixed offshore wind turbines*

IEC 61400-3-2, *Wind energy generation systems - Part 3-2: Design requirements for floating offshore wind turbines*

IEC 62747:2014, *Terminology for voltage-sourced converters (VSC) for high-voltage direct current (HVDC) systems*  
IEC 62747:2014/AMD1:2019

IEC 62934, *Grid integration of renewable energy generation - Terms and definitions*

IEC TS 63336:2024, *Commissioning of VSC HVDC systems*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-811, IEC 60270, IEC 60633, IEC 61400-3-1, IEC 61400-3-2, IEC 62747, IEC 62934, IEC TS 63336 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

#### 3.1

##### **control mode**

manner in which a converter unit, pole, or VSC HVDC converter station is controlled in order to maintain one or more electrical quantities at desired values

[SOURCE: IEC 60633:2019, 10.1, modified - Updated to VSC HVDC transmission.]

#### 3.2

##### **converter station tests**

tests verifying functions and performances of the converter unit disconnected from the VSC HVDC transmission line on-site

[SOURCE: IEC TS 63336:2024]

#### 3.3

##### **converter starting resistor**

resistor temporarily connected in series with the converter to vary the voltage applied and limit the current during starting

[SOURCE: IEC 60050-811:2017, 811-27-01]

#### 3.4

##### **DC energy dissipation device**

device used to achieve the conversion of electric energy into thermal energy non intended to be used

Note 1 to entry: This is also referred to as a DC braking chopper.

#### 3.5

##### **on-site equipment tests**

electrical and mechanical tests which are performed on-site on a single equipment to verify that no equipment damage has occurred during transport and site assembly, and that installation has been correctly performed

[SOURCE: IEC TS 63336:2024]

#### 3.6

##### **high power transmission tests**

tests verifying functions and performances of the whole system at a high power transmission level. The power value should be higher than 0.3 pu. Some test items can be carried out during the trial operation

[SOURCE: IEC TS 63336:2024]

### 3.7

#### **interface transformer**

transformer (if any) through which power is transmitted between the AC system connection point and one or more VSC units

[SOURCE: IEC 62747:2014]

### 3.8

#### **joint commissioning**

final test before putting into commercial operation, aimed at verifying that the functionality and performance of the system meet the design requirements

### 3.9

#### **low power transmission tests**

tests verifying functions and performances of the offshore wind farms and VSC HVDC system at a low power transmission level

Note 1 to entry: The power value depends on the grid connection and output conditions of offshore wind farms.

[SOURCE: IEC TS 63336:2024]

### 3.10

#### **local workstation**

##### **LWS**

local workstation near the control and protection devices of VSC HVDC, which can monitor, control, and manage the system

### 3.11

#### **offshore wind farm**

sea-based renewable energy facility using wind turbine generator systems to generate electricity for the grid

### 3.12

#### **operator workstation**

##### **OWS**

remote control centre where operators monitor, control, and manage the system

Note 1 to entry: The operator workstation provides a graphical interface for real-time data visualization and system operation.

### 3.13

#### **point of common coupling**

##### **PCC**

point of interconnection of the onshore converter station to the adjacent AC system, or point of interconnection of wind farms to the offshore converter station

### 3.14

#### **reactive power control mode**

control of the reactive power exchanged between a converter unit, or a HVDC substation, and the connected AC network

[SOURCE: IEC 60633:2019, 10.5]

### 3.15

#### **submodule**

part of the VSC valve comprising controllable switches and diodes connected to a half bridge or full bridge arrangement, together with their immediate auxiliaries, storage capacitors, if any, where each controllable switch consists of only one switched valve device connected in series

[SOURCE: IEC 62501:2024, 3.4.7]

### 3.16

#### **STATCOM operation**

##### **static synchronous compensator operation**

operation mode of the converter that can continuously generate or absorb reactive power for the power grid

### 3.17

#### **subsystem test**

test which is performed on-site to prove the correct interconnection and functioning of all individual items of equipment within a functional group (or subsystem) and that these items operate and interact correctly

[SOURCE: IEC TS 63336:2024, 3.1.3]

### 3.18

#### **trial operation**

<VSC HVDC systems> period following the completion of the commissioning

[SOURCE: IEC TS 63336:2024, 4.4]

### 3.19

#### **end-to-end tests**

tests verifying functions and performances of the VSC HVDC system when transmitting power between both converter stations on-site

[SOURCE: IEC TS 63336:2024, 3.1.6, modified - Term "transmission tests" removed, abbreviated term "VSC" added, and note to entry removed.]

### 3.20

#### **islanded network operation mode**

control mode in which the VSC HVDC substation controls the frequency and the voltage of the connected islanded AC network

[SOURCE: IEC 62747:2014, 11.6, modified - Abbreviated term "VSC" added.]

### 3.21

#### **wind turbine generator system**

##### **WTGS**

system which converts the kinetic wind energy into electric energy

[SOURCE: IEC 60050-415:1999, 415-01-02]

### 3.22

#### **zero power transmission tests**

tests verifying the functions and performance of the VSC HVDC system without transmitting power

## 4 General

Joint commissioning consists of on-site tests for the grid connection of offshore wind farms using VSC HVDC power transmission systems. This comprehensive assessment covers all system aspects, including the control and protection system, converter valves with valve controls, transformers, valve cooling systems, and equipment in the AC and DC fields. The primary objective of joint commissioning is to validate subsystem coordination and help ensure compliance with both design specifications and performance indicators defined in equipment technical specifications. During commissioning, coordinated optimization among different equipment and subsystems is performed to improve the overall operational performance of the GCOWF using the VSC HVDC power transmission system. Additionally, essential data and parameters are collected to help ensure the economic and stable operation of the system in the future. Upon successful commissioning, the GCOWF using the VSC HVDC power transmission system is validated for operational deployment. Typical topologies for GCOWF using the VSC HVDC power transmission system can refer to APPENDIX A.

- a) Joint commissioning for GCOWF using the VSC HVDC power transmission system begins upon completion and verification of both on-site equipment tests and subsystem tests.
- b) For different topologies or specialized equipment in GCOWF using the VSC HVDC power transmission system, the special function/performance can be changed according to the requirements of the engineering design specifications. For typical topologies of GCOWF using VSC HVDC, refer to informative Annex A.
- c) To protect the system against the potential risk of wide-band oscillation during the joint commissioning process, impedance matching verification for offshore and onshore transmission sections should be conducted based on accurate system simulation, including representation of valve and control system time delays before the tests. For the introduction to system simulation, refer to Annex B.
- d) Joint commissioning should consider the black start capability of offshore wind farms. The designs and procedures of tripping tests, disturbance tests, and dynamic performance tests should fully consider the time required for recovery following the disconnection of offshore wind farms.
- e) It is advisable to conduct the offshore converter station system test via the DC submarine cable power supply upon completion of the first part of the onshore converter station system test.
- f) During commissioning, all operational data (steady-state, dynamic, and transient) from converter stations and offshore wind farms should be monitored and recorded by the commissioning contractor. The functionality and performance of the overall system should be verified and meet the design specifications, as much as possible.
- g) The joint commissioning test items are listed in Figure 1, while the test process can be referred to Figure 2.

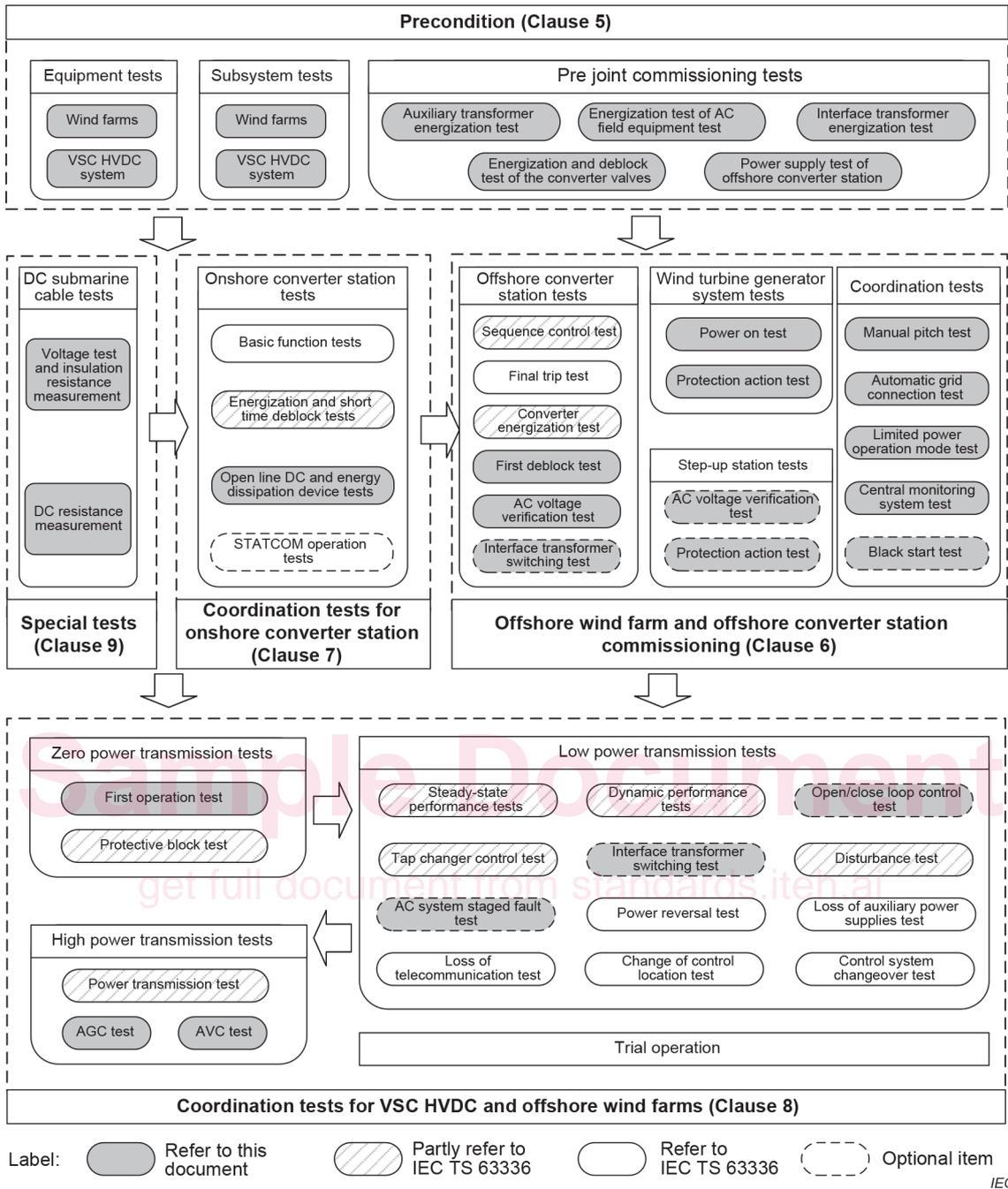


Figure 1 – Test items of the joint commissioning

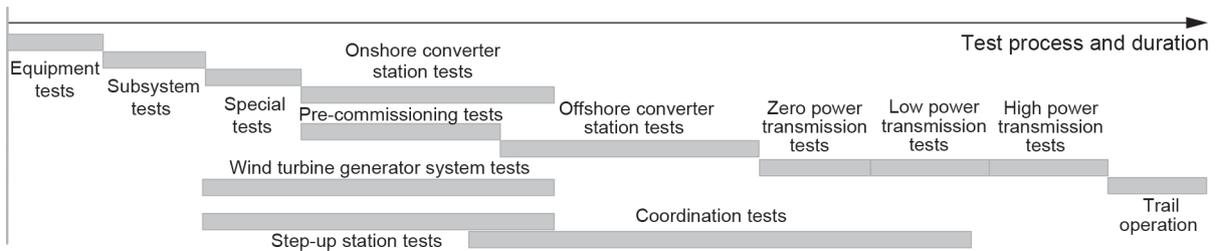


Figure 2 – Test process of the joint commissioning

## 5 Precondition for joint commissioning

### 5.1 General

Before the joint commissioning of GCOWF using the VSC HVDC power transmission system, the preconditions of offshore wind farms, the VSC HVDC system, the offshore high-voltage AC system, and the onshore grid interconnection should be verified. The on-site equipment test, subsystem test, and pre-commissioning tests should be completed. Pre-commissioning tests for the offshore converter station include transformer energization, converter deblocking, and other essential on-site equipment tests that should be carried out in the factory or dock.

The completion and acceptance of the above tests should confirm that the entire system meets all preconditions for the joint commissioning. The relevant joint commissioning tests should be carried out under appropriate offshore weather conditions and permission from the onshore power grid.

In addition, some general requirements of the joint commissioning should address the onshore converter station, offshore converter station, wind turbine generator systems, step-up station, offshore weather, and test instruments.

### 5.2 On-site equipment tests

All equipment and auxiliary devices should have been installed, and preliminary inspections should have been completed. Incorrect installation, missing devices, or unexpected equipment damage should have been resolved by the installation or supervision staff.

The required power supplies should be in place, stable and reliable during on-site equipment tests, with power quality meeting the requirements of the equipment. Their supply systems should have been verified and work correctly for equipment requiring other energy sources such as wind, water, gas, or oil. The following equipment or subsystems should have been tested and verified before joint commissioning.

- a) Switchgear including circuit breakers, isolation switches, earth switches, high-voltage fuses, GIS (gas-insulated switchgear), and other switchgear.
- b) Electrical equipment, including interface transformers, reactors, auxiliary transformers, earth electrodes, lightning arresters, low-voltage distribution devices, feeder lines, high-voltage power lines, and submarine cables.
- c) Control, protection, and automation equipment, including control and protection devices, safety automatic devices, electric energy metering devices, and secondary circuits.
- d) Non-electrical equipment, including insulator strings and insulating oil.

### 5.3 Subsystem tests

Subsystem tests are a critical stage in the integration and operation of the entire system, aimed at conducting thorough validation and optimization of the subsystem to help ensure its optimal performance within the broader engineering project or system while concurrently ensuring the long-term stable operation of the system.

In the converter station, the subsystems include the converter valve subsystem, interface transformer subsystem, AC field subsystem, DC field subsystem, station power supply subsystem, auxiliary subsystem, and control and protection subsystem. The results of the cabinet inspection, secondary circuit inspection, and primary current injection test should meet the design specifications. The valve cooling system, fire protection system, air conditioning system, protection information management substation system, synchronized clock system, fault recording system, phasor measurement unit system, electric energy measurement system, stability control system, fault distance measurement system, integrated power supply system, integrated online monitoring system, and intelligent auxiliary system should work correctly, as applicable. The subsystem test of the VSC HVDC system can refer to IEC TS 63336.