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HVDC Grid Systems and connected Converter Stations - Guideline and Parameter Lists for Functional Specifications - Part 1: Guidelines

Hochspannungsgleichstrom-Netzsysteme - Leitfaden und Parameter-Listen für funktionale Spezifikationen - Teil 1: Leitfaden

Réseaux CCHT et stations de conversion connectées - Lignes directrices et listes de paramètres pour les spécifications fonctionnelles - Partie 1: Lignes directrices

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Contents

Page

European foreword

This document (CLC/TS 50654-1:2020) has been prepared by CLC/TC 8X "*System aspects of electrical energy supply*".

This document supersedes CLC/TS 50654-1:2018.

CLC/TS 50654-1:2020 includes the following significant technical changes with respect to CLC/TS 50654-1:2018:

— new content concerning AC/DC converter stations;

— new content concerning HVDC Grid System installations, including DC switching stations;

— new content concerning HVDC Grid System integration tests.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights.

Introduction

HVDC Grid Systems are a new field of technology. There are very few systems with a small number of converter stations in operation; some more are in execution or in detailed planning.

The Guidelines and Parameter Lists to Functional Specifications are presented featuring planning, specification and execution of multi-vendor HVDC Grid Systems in Europe. Being elaborated by a team of experts from leading vendors of HVDC technology, Transmission System Operators (TSO's), Academia and Institutions in Europe, the present document provides a commonly agreed basis for an open market of compatible equipment and solutions for HVDC Grid Systems. Executing such systems and gaining operational experience is seen an important prerequisite for developing corresponding technical standards in the future.

By elaborating this document, special care has been taken to as far as possible describe the requirements in a technologically independent way. In order to achieve that, a function of interest is described by a comprehensive set of parameters. The parameters are selected based on a systematic analysis of physical phenomena relevant to achieve the requested functionality. The physical phenomena are categorized in order to show the mutual dependence of the individual parameters and ensure completeness of the physical aspects to be considered. Based on a clearly defined common language describing the functionalities requested, existing technologies can be applied, or new dedicated technical solutions can be developed.

Reflecting the early stage of technology, these Guidelines and Parameter Lists to Functional Specifications need comprehensive explanations and background information for the technical parameters. This dual character of the content will be represented by two corresponding parts:

- Part I “Guidelines” containing the explanations and the background information in context with the Parameter Lists.
- Part II “Parameter Lists” containing the essential lists of parameters and values describing properties of the AC respectively DC system (operating conditions) and parameters describing the performance of the newly installed component (performance requirements).

1 Scope

1.1 General

These Guidelines and Parameter Lists to Functional Specifications describe specific functional requirements for HVDC Grid Systems. The terminology “HVDC Grid Systems” is used here describing HVDC systems for power transmission having more than two converter stations connected to a common DC circuit.

While this document focuses on requirements, that are specific for HVDC Grid Systems, some requirements are considered applicable to all HVDC systems in general, i.e. including point-to-point HVDC systems. Existing IEC, Cigré or other documents relevant have been used for reference as far as possible.

Corresponding to electric power transmission applications, this document is applicable to high voltage systems, i.e. having typically nominal DC voltages higher than 50 kV with respect to earth are considered in this document.

NOTE While the physical principles of DC networks are basically voltage independent, the technical options for designing equipment get much wider with lower DC voltage levels, e.g. in case of converters or switchgear.

Both parts have the same outline and headlines to aid the reader.

1.2 About the Present Release

The present release of the Guidelines and Parameter Lists for Functional Specifications describes technical guidelines and specifications for HVDC Grid Systems which are characterized by having exactly one single connection between two converter stations, often referred to as radial systems. When developing the requirements for radial systems, care is taken not to build up potential showstoppers for meshed systems. Meshed HVDC Grid Systems can be included into this specification at a later point in time.

The Guidelines and Parameter List to the Functional Specification of HVDC Grid Systems cover technical aspects of:

- coordination of HVDC grid and AC systems
- HVDC Grid System characteristics
- HVDC Grid System control
- HVDC Grid System protection
- AC/DC converter stations
- HVDC Grid System installations, including DC switching stations
- models and validation
- HVDC Grid System integration tests

Beyond the present scope, the following content is proposed for future work:

- transmission lines and transition stations
- DC/DC converter stations
- DC line power flow controllers

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.

EN 60909 (series), *Short-circuit currents in three-phase AC systems*

EN 61660-1:1997, *Short-circuit currents in DC auxiliary installations in power plants and substations — Part 1: Calculation of short-circuit currents*

IEC 60050, *International Electrotechnical Vocabulary*

IEC/TR 60919-1:2010[1], Performance of high-voltage direct current (HVDC) systems with line-commutated converters – Part 1: Steady-state conditions

IEC 62271-100, *High-voltage switchgear and controlgear - Part 100: Alternating-current circuit-breakers*

IEC 62271-102, *High-voltage switchgear and controlgear - Part 102: Alternating current disconnectors and earthing switches*

IEC 62747:2014[2], *Terminology for voltage-sourced converters (VSC) for high-voltage direct current (HVDC) systems*

IEV 351-45-27, *International electrotechnical vocabulary, control technology*

[1] As impacted by IEC/TR 60919-1:2010/A1:2013, IEC/TR 60919-1:2010/A2:2017.

[2] As impacted by IEC 62747:2014/A1:2019.

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply. ISO and IEC maintain terminological databases for use in standardization at the following addresses:

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

3.1.1
AC/DC converter unit
indivisible operative unit comprising all equipment between the PoC-AC and the PoC-DC, essentially one or more converters, together with converter transformers, control equipment, essential protective and switching devices and auxiliaries, if any, used for conversion

[SOURCE: EN 62747:2014[2], modified – The definition was neutralised with respect to technology (not only VSC converters) and uses the terms PoC as defined in the present document]

3.1.2
AC/DC converter station
part of an HVDC system which consists of one or more AC/DC converter units including DC switchgear, if any, DC fault current controlling devices, if any, installed in a single location together with buildings, reactors, filters, reactive power supply, control, monitoring, protective, measuring and auxiliary equipment

[SOURCE: EN 62747:2014[2], modified – The definition was made specific with respect to AC/DC converter units, differentiating from DC/DC converter units. Furthermore, only the term AC/DC converter station is used in the present document]

3.1.3
point of connection-DC
PoC-DC
electrical interface point at DC voltage as shown in Figure 1

3.1.4
point of connection-AC
PoC-AC
electrical interface point at AC voltage as shown in Figure 1

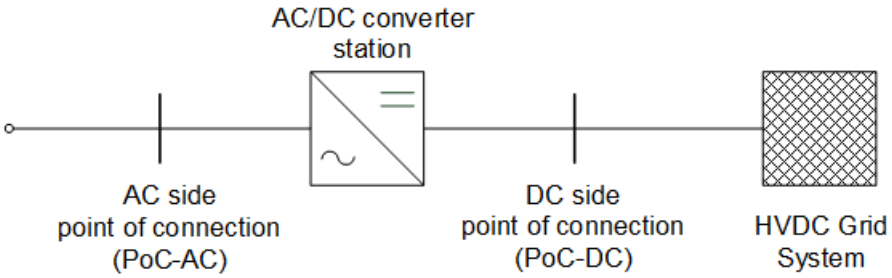

Figure 1 — Definition of the Point of Connection-AC and the Point of Connection-DC at an AC/DC converter station

3.1.5
DC/DC converter unit
indivisible operative unit comprising all equipment between the points of connection to the HVDC Grid System, essentially one or more converters, together with converter transformers, if any, control equipment, essential protective and switching devices and auxiliaries, if any, used for conversion

3.1.6
DC/DC converter station
part of an HVDC Grid System which consists of one or more DC/DC converter units including DC switchgear, if any, DC fault current controlling devices, if any, installed in a single location together with buildings, reactors, filters, control, monitoring, protective, measuring and auxiliary equipment, if any

3.1.7
DC switching unit
indivisible operative unit comprising all equipment between the DC busbars and the terminals (HV poles and neutral, if any) of one point of connection on the DC side, comprising, if any, one or more switches, control, monitoring, protective, measuring equipment and auxiliaries

3.1.8
DC switching station
part of an HVDC Grid System which consists of one or more DC switches, but no AC/DC or DC/DC converter units, installed in a single location together with buildings, reactors, filters, control, monitoring, protective, measuring and auxiliary equipment, if any

3.1.9
HVDC Grid System
high voltage direct current transmission network connecting more than two AC/DC converter stations transferring energy in the form of high-voltage direct current including related transmission lines, switching stations, DC/DC converter stations, if any, as well as other equipment and sub-systems needed for operation

3.1.10
meshed HVDC Grid System
HVDC Grid System having more than one direct current connection between at least two converter stations

3.1.11
radial HVDC Grid System
HVDC Grid System having exactly one direct current connection between two arbitrary converter stations

3.1.12
DC protection zone
physical part of a HVDC Grid System with a distinct DC fault handling sequence

3.1.13
rigid bipolar (HVDC) system
bipolar (HVDC) system without dedicated return path or electrodes as illustrated in Figure 2

NOTE 1 to entry Monopolar operation is possible by means of bypass switches during a converter pole outage, but not during an HVDC conductor outage. A short bipolar outage will follow a converter pole outage before bypass operation can be established.

[SOURCE: IEC/TR 60919-1:2010][1]

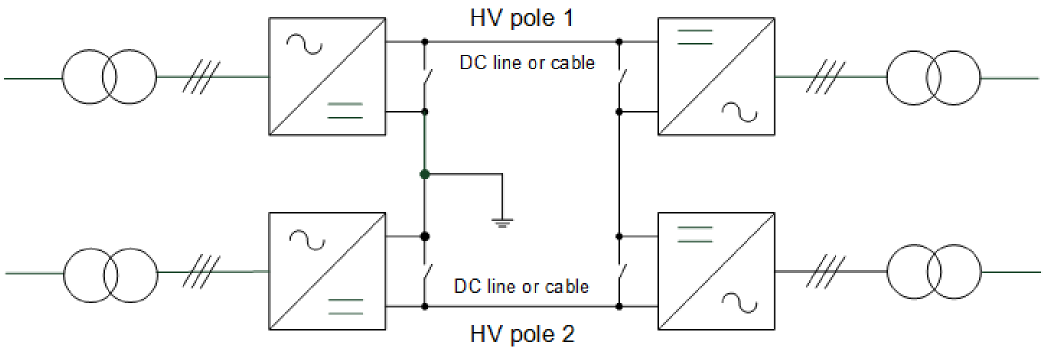

Figure 2 — Rigid Bipolar HVDC system

3.2 Abbreviations

AC/DC	alternating current / direct current (conversion)
BB	bus bar
CB	circuit breaker
CLES	converter local earthing switch
CU	converter unit
C&P	control and protection
DC/DC	direct current / direct current (conversion)
DPS	dynamic performance studies
DPT	dynamic performance tests
EMT	electromagnetic transients
ENTSO-E	European Network of Transmission System Operators for Electricity
ERTS	earth return transfer switch
FAT	factory acceptance tests
FCR	frequency containment reserve
FRR	frequency restoration reserve
FSD	fault separation device
GOOSE	generic object-oriented substation events
HSS	high-speed switches
HV	high voltage
HVDC	high-voltage direct current
IEEE	Institute of Electrical and Electronics Engineers
LAT	laboratory acceptance test
MMC	modular multilevel converter
MRTS	metallic return transfer switch
NBGS	neutral bus grounding switch
NBS	neutral bus switch
NC	Network Code
OHL	overhead line
OP	operating point
OPF	optimum power flow
OVRT	over-voltage ride through
PoC	point of connection
POD	power oscillation damping
STATCOM	static synchronous compensator
SRAS	System Recovery Ancillary Service
T	terminal
THD	total harmonic distortion
TSO	transmission system operator

UVRT	under-voltage ride through
VSC	voltage-sourced converter

4 Coordination of HVDC Grid System and AC Systems

4.1 General

The HVDC Grid System connects several AC/DC converters via their respective PoC-DC to a common DC circuit as shown in Figure 3. The HVDC Grid System can consist of one or more of the following installations:

- DC switching station
- transmission line (overhead line, cable or combinations thereof)
- DC/DC converter station
- DC line power flow controller.

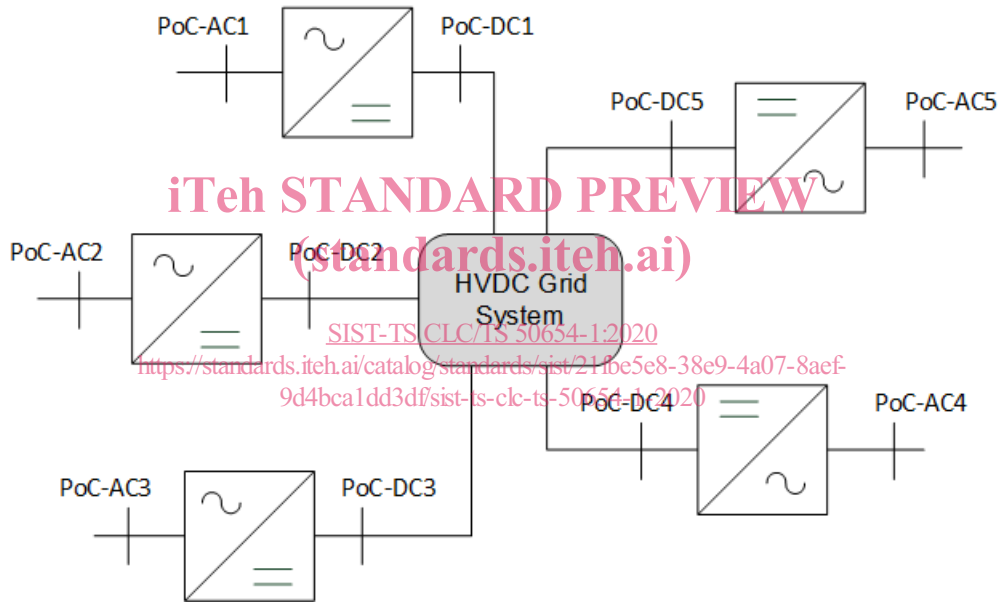

Figure 3 — Principle structure of an HVDC Grid System

The topologies of the AC/DC converter stations as well as the various installations of the HVDC Grid System shall be coordinated and specified as described in chapter 5.1 “HVDC Circuit Topologies”.

Within the boundaries of the given topologies, each AC/DC converter station or HVDC Grid System installation can be operated in different DC connection modes as described for AC/DC converter stations in chapter 8.4.2.1 “DC Connection” and for DC switching stations in chapter 9.2.2.2.1 “DC Connection”. The individual connection modes and their application needs to be coordinated throughout the HVDC Grid System any time when operating.

4.2 Purpose of the HVDC Grid System and Power Network Diagram

To provide an overall understanding of the HVDC Grid System, the purposes and basic functions of the HVDC Grid System including all AC/DC converter stations shall be explained.

To explain the AC and HVDC Grid System structure a network diagram shall be specified showing the grid topology including the installations and their connections. This diagram shall contain information such as: