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HVDC Grid Systems and connected Converter Stations - Guideline and Parameter Lists for Functional Specifications - Part 2: Parameter Lists

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English Version

HVDC Grid Systems and connected Converter Stations - Guideline and Parameter Lists for Functional Specifications - Part 2: Parameter Lists

Réseaux CCHT et stations de conversion connectées - Lignes directrices et listes de paramètres pour les spécifications fonctionnelles - Partie 2: Listes de paramètres

Hochspannungsgleichstrom-Netzsysteme - Leitfaden und Parameter-Listen für funktionale Spezifikationen - Teil 2: Parameter-Listen

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European foreword

This document (CLC/TS 50654-2:2018) has been prepared by CLC/TC8X/WG 06 “System Aspects of HVDC Grid”.

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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 manufacturers 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 a.c. respectively d.c. 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 d.c. 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. .only nominal d.c. voltages equal or higher than 50 kV with respect to earth are considered in this document.

NOTE While the physical principles of d.c. networks are basically voltage independent, the technical options for designing equipment get much wider with lower d.c. 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 show-stoppers 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 a.c. Systems
- HVDC Grid System Characteristics
- HVDC Grid System Control
- HVDC Grid System Protection
- Models and Validation
- Beyond the present scope, the following aspects are proposed for future work:
- AC/DC converter stations
- HVDC Grid System Equipment
- HVDC Grid System Integration Tests

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

EN 61660-1:1997, *Short-circuit currents in d.c. auxiliary installations in power plants and substations — Part 1: Calculation of short-circuit currents (IEC 61660-1:1997)*

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 http://www.iso.org/obp

3.1.1
AC/DC converter unit
indivisible operative unit comprising all equipment between the point of connection on the a.c. side and the point of connection on the d.c. side, 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, 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 d.c. switchgear, d.c. 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, 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 d.c. voltage

3.1.4
Point of connection-AC (PoC-AC)
electrical interface point at a.c. voltage

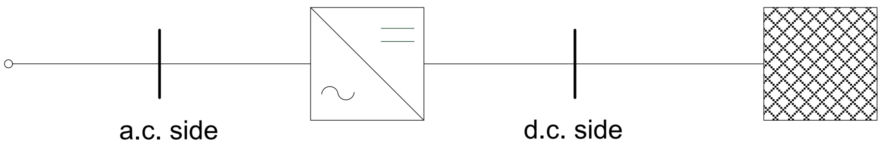

Figure 1 — Definition of the Point Of Connection-AC and the Point Of Connection-DC at an AC/DC converter station

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 d.c. switchgear, d.c. fault current controlling devices, if any, installed in a single location together with buildings, reactors, filters, control, monitoring, protective, measuring and auxiliary equipment

3.1.7
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

3.1.8
meshed HVDC Grid System
HVDC Grid System having more than one direct current connection between at least two converter stations

3.1.9
DC protection zone
physical part of a HVDC Grid System with a common response to d.c. faults

3.1.10
radial HVDC Grid System
HVDC Grid System having exactly one direct current connection between two arbitrary converter stations

3.1.11
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: IEEE P1899]

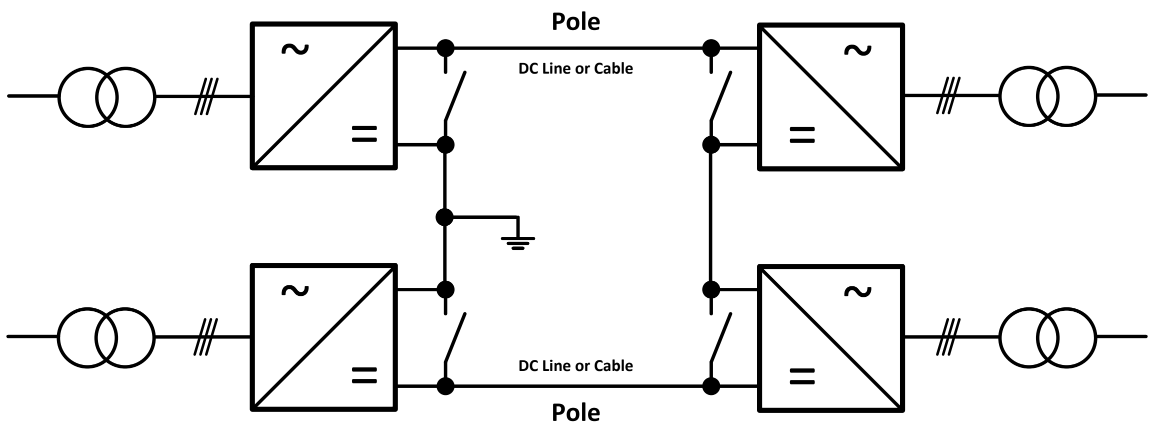

Figure 2 — Rigid Bipolar HVDC system

3.2 Abbreviations

AC/DC	alternating current / direct current (conversion)
DC/DC	direct current / direct current (conversion)
DPT	dynamic performance tests
ENTSO-E	European Network of Transmission System Operators for Electricity
FAT	factory acceptance tests
FCR	frequency containment reserve
FRR	frequency restoration reserve
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
LVRT	low-voltage ride through
MMC	modular multilevel converter
NC	Network Code
OHL	overhead line
OP	operating point
OPF	optimum power flow
OVRT	over-voltage ride through
PoC-AC	point of connection on a.c. side

PoC-DC	point of connection on d.c. side
POD	power oscillation damping
STATCOM	static synchronous compensator
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 Purpose of the HVDC Grid System and Power Network Diagram

The following information shall be provided

- HVDC Transmission System, d.c. lines
- HVDC Grid System topology and converter station topology for each AC/DC converter station as well as each DC/DC converter station according to the nomenclature given in Table 1. In case of an isolated HVDC Grid System, the number of series connected converter units between poles (one or two) shall be specified
- DC earthing impedances at each AC/DC converter station and DC/DC converter station
- HVDC switchyard
- Surge Arresters
- DC breakers
  - o Mechanical HVDC breakers
  - o Semiconductor based HVDC breakers (breaking device is a semiconductor, e.g. IGBT valve)
  - o Hybrid HVDC breakers (combination of mechanical and semiconductor breaking device)
- Disconnecting switches
  - o High speed switches (HSS), i.e. mechanical breakers
  - o Disconnectors and earthing switches
- DC/DC Converter Station
  - o With d.c. fault current breaking capability
  - o Without d.c. fault current breaking capability
- Measurement equipment
- Transition between a cable and d.c. overhead line, i.e. d.c. transition station.

Table 1 — Nomenclature of HVDC circuit topologies
(Please refer to CLC/TS 50654-1:2018, 5.1, for details of the nomenclature)

Characteristics of the HVDC Grid System			**-**	**Characteristics of a converter station**		
Number of HV poles	DC	d.c. earthing	-	connection to pole	neutral return path	station earthing
1 2	DC	“z” isolated “e” **e**ffectively earthed	-	“1” pole **1** “2” pole **2** “B” b**o**th	“O” n**o**ne “R” **r**eturn conductor “E” earth or sea **e**lectrode	“O” n**o**ne “Z” impedance “E” dir**e**ct

4.2 Hybrid AC/DC Power Flow Optimization

To provide a basis for the AC/DC power flow optimization the purpose and the operational strategy of the hybrid AC/DC system needs to be described. The objectives of the optimization are to be expressed by objective functions and boundary conditions.

The interface points between the HVDC grid and a.c. systems are the Points of Connection (PoC-AC or PoC-DC respectively).

The parameters needed to perform a power flow calculation for hybrid a.c. and d.c. system both in normal or in abnormal operating state are listed in the following table.

Table 2 — Parameters for a.c. and d.c. static power flow calculation

Symbol	Parameter	Characteristic	Value	Unit
U_{XACmax_ss}		maximum steady-state voltage at each station defined at the PoC-AC, a station being identified by X = A, B, …Z		kV
U_{XACmin_ss}		minimum steady-state voltage at each station defined at the PoC-AC, a station being identified by X = A, B, …Z		kV
P_{XACmax_ss}	maximum active power	maximum steady-state active power exchange between a.c. and d.c. network at each station defined at the PoC-AC, a station being identified by X = A, B, …Z [1]		MW
P_{XACmin_ss}	minimum active power	minimum steady-state active power exchange between a.c. and d.c. network at each station defined at the PoC-AC, a station being identified by X = A, B, …Z [2]		MW

[1] Instead of P_{XACmax_ss}, the rated active power P_{XDCmax_ss} may be defined at the PoC-DC.

[2] Instead of P_{XACmin_ss}, the rated active power P_{XDCmin_ss} may be defined at the PoC-DC.

Symbol	Parameter	Characteristic	Value	Unit
P_{XACmax_temp}	maximum active power	maximum temporary active power exchange between a.c. and d.c. network at each station defined at the PoC-AC, a station being identified by X = A, B, …Z [3]		MW
P_{XACmin_temp}	minimum active power	minimum temporary active power exchange between a.c. and d.c. network at each station defined at the PoC-AC, a station being identified by X = A, B, …Z [4]		MW
t_{XP_ACtemp}	time	time, for which limits of temporary maximum and minimum active power apply		s
P_{Xloss_rat}	power losses of station X	power losses function of each station, a station being identified by X = A, B, …Z [5]		MW
$Q_{Xmax}(.)$	maximum reactive power	maximum steady-state reactive power exchange capability chart (inductive and capacitive) depending on active power and voltage (P_{XAC},U_{XAC}) at the PoC-AC of each station, a station being identified by X = A, B, …Z		Mvar
$Q_{Xmin}(\cdot)$	minimum reactive power	minimum steady-state reactive power exchange capability chart (inductive and capacitive) depending on active power and voltage (P_{XAC},U_{XAC}) at the PoC-AC of each station, a station being identified by X = A, B, …Z		Mvar
$Q_{Xmax}(.)$	maximum reactive power	maximum temporary reactive power exchange capability chart (inductive and capacitive) depending on active power and voltage (P_{XAC},U_{XAC}) at the PoC-AC of each station, a station being identified by X = A, B, …Z		Mvar

[3] Instead of P_{XACmax_temp}, the rated active power P_{XDCmax_temp} may be defined at the PoC-DC.

[4] Instead of P_{XACmin_temp}, the rated active power P_{XDCmin_temp} may be defined at the PoC-DC.

[5] Instead of P_{Xloss_rat}, power losses P_{Xloss_OP} at various operating points OP may be given.