



BSI Standards Publication

# HVDC Grid Systems and connected Converter Stations – Guideline and Parameter Lists for Functional Specifications

---

Part 2: Parameter Lists

## National foreword

This Published Document is the UK implementation of CLC/TS 50654-2:2018.

The UK participation in its preparation was entrusted to Technical Committee GEL/8, Systems Aspects for Electrical Energy Supply.

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

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2018  
Published by BSI Standards Limited 2018

ISBN 978 0 580 99257 5

ICS 29.240.01

**Compliance with a British Standard cannot confer immunity from legal obligations.**

This Published Document was published under the authority of the Standards Policy and Strategy Committee on 30 April 2018.

### Amendments/corrigenda issued since publication

Date	Text affected
------	---------------

---

ICS 29.240.01

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

This Technical Specification was approved by CENELEC on 2018-01-22.

CENELEC members are required to announce the existence of this TS in the same way as for an EN and to make the TS available promptly at national level in an appropriate form. It is permissible to keep conflicting national standards in force.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.



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

**CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels**

## Contents

	Page
European foreword .....	5
Introduction .....	6
1 Scope .....	7
1.1 General.....	7
1.2 About the present release .....	7
2 Normative references .....	7
3 Terms, definitions and abbreviations .....	8
3.1 Terms and definitions .....	8
3.2 Abbreviations.....	10
4 Coordination of HVDC Grid System and AC Systems.....	11
4.1 Purpose of the HVDC Grid System and Power Network Diagram .....	11
4.2 Hybrid AC/DC Power Flow Optimization.....	12
4.3 Basic Operation Functions – Converter Normal Operation State .....	14
4.3.1 General.....	14
4.3.2 AC System Frequency by a Frequency / Power Droop .....	15
4.3.3 DC Voltage / DC Power Droop .....	15
4.4 Basic Operation Functions – Converter Abnormal Operation State .....	15
4.4.1 General.....	15
4.4.2 Network Conditions and Power Flow Requirements .....	16
4.4.3 Abnormal AC Voltage Conditions .....	16
4.5 Ancillary Services.....	18
4.5.1 General.....	18
4.5.2 Frequency Control Related Services .....	18
4.5.3 AC Voltage Control Related Services .....	20
4.5.4 Power Oscillation Damping Services .....	20
4.5.5 System Restoration Services .....	20
5 HVDC Grid System Characteristics .....	21
5.1 HVDC Circuit Topology .....	21
5.1.1 Basic Characteristics and Nomenclature .....	21
5.1.2 Attributes of HVDC Grid Systems or HVDC Grid Sub-Systems .....	21
5.1.3 Attributes of a Converter Station .....	21
5.2 Grid Operating States .....	22
5.2.1 Normal State .....	22
5.2.2 Alert State .....	22
5.2.3 Emergency State.....	22
5.2.4 Blackout State .....	23
5.2.5 Restoration .....	23
5.3 DC Voltages .....	23
5.3.1 General.....	23
5.3.2 Nominal DC System Voltage .....	24
5.3.3 Steady-State DC Voltage .....	24
5.3.4 Temporary DC Voltage .....	24
5.4 Insulation Coordination .....	25

5.5	Short-Circuit Characteristics .....	25
5.5.1	General Remarks .....	25
5.5.2	Calculation of Short-Circuit Currents in HVDC Grid Systems.....	25
5.5.3	Short Circuit Current Design Requirements.....	27
5.6	Steady-State Voltage and Current Distortions .....	27
6	HVDC Grid System Control.....	27
6.1	Closed-Loop Control Functions.....	27
6.1.1	General.....	27
6.1.2	Core Control Functions .....	27
6.1.3	Coordinating Control Functions .....	28
6.2	Controller Hierarchy .....	28
6.2.1	General.....	28
6.2.2	Internal Converter Control.....	28
6.2.3	DC Node Voltage Control.....	28
6.2.4	Coordinated System Control.....	28
6.2.5	AC/DC Grid Control.....	30
6.3	Propagation of Information .....	31
6.4	Open-Loop Controls .....	34
6.4.1	Operating Sequences for Grid Installations .....	34
6.4.2	Operating Sequences for the Return Path.....	35
6.4.3	Recovery .....	35
7	HVDC Grid System Protection .....	36
7.1	General.....	36
7.2	DC Fault Separation.....	36
7.3	Protection System Related Installations and Equipment .....	36
7.3.1	AC/DC Converter Station.....	36
7.3.2	HVDC Grid System Topology and Equipment.....	36
7.4	HVDC Grid System Protection Zones.....	36
7.4.1	General.....	36
7.4.2	Permanent Stop P.....	38
7.4.3	Permanent Stop PQ.....	38
7.4.4	Temporary Stop P.....	39
7.4.5	Temporary Stop PQ.....	39
7.4.6	Continued Operation.....	39
7.4.7	Example of Protection Zone Matrix.....	39
7.5	DC Protection.....	39
7.5.1	General.....	39
7.5.2	DC Converter Protections .....	40
7.5.3	HVDC Grid System Protections .....	40
7.5.4	HVDC Hub Respective HVDC Node Protections .....	40
7.5.5	DC Grid Protection Communication.....	40
8	AC/DC Converter Stations .....	40
8.1	General.....	40
8.2	AC/DC Converter Station Types .....	40
9	HVDC Grid System Installations .....	40
10	Models and Validation .....	40
10.1	Introduction.....	40
10.2	HVDC Grid System Studies .....	40
10.2.1	Type of Studies .....	40

10.2.2	Tools and Methods.....	41
10.3	Model General Specifications .....	41
10.3.1	Model Capability.....	41
10.3.2	Model Format and Data Type .....	41
10.3.3	Model Aggregation .....	41
10.4	Model Specific Recommendations.....	42
10.4.1	Load Flow Models .....	42
10.4.2	Short-Circuit Models.....	42
10.4.3	Protection System Models .....	42
10.4.4	Insulation Coordination Related Models .....	42
10.4.5	Electromechanical Transient Models .....	43
10.4.6	Electromagnetic Transient Models.....	44
10.4.7	Power Quality Models .....	49
10.5	Model Validation.....	50
10.6	Compliance Simulation .....	51
10.7	Outputs/Results.....	51
10.7.1	Model Data .....	51
10.7.2	Model Documentation .....	51
10.7.3	Model Example .....	51
10.7.4	Model Compliance Documentation .....	51
10.7.5	Model Validation Documentation – Model Final Version .....	51
10.7.6	Model Guarantee .....	51
11	HVDC Grid System Integration Tests .....	51
	Bibliography.....	52

## European foreword

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

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.

Currently in preview, click buy full version

## 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)*