IEC TS 63042-101

Edition 1.0 2019-01

TECHNICAL SPECIFICATION

colour inside

UHV AC transmission systems –
Part 101: Voltage regulation and insulation design



IEC TS 63042-101:2019-01(en)



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2019 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
67 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC TS 63042-101

Edition 1.0 2019-01

TECHNICAL SPECIFICATION



UHV AC transmission systems –
Part 101: Voltage regulation and insulation design

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.240.01

ISBN 978-2-8322-6456-0

Warning! Make sure that you obtained this publication from an authorized distributor.

® Registered trademark of the International Electrotechnical Commission

CONTENTS

FOREWORD 4
INTRODUCTION 6
1 Scope 7
2 Normative references 7
3 Terms and definitions 7
4 Reactive power compensation for UHV AC transmission systems 8
4.1 General principles 8
4.2 Configuration of reactive power compensation – consider placing after general functions 8
4.3 Determining reactive power compensation 9
4.3.1 Reactive compensation at UHV side 9
4.3.2 Compensation at tertiary side of UHV transformers 9
4.3.3 Reactive power compensation at UHV side 10
4.3.4 Shunt capacitor configuration at tertiary side of UHV transformers 11
4.3.5 Shunt reactor configuration at tertiary side of UHV transformers 12
4.4 Controllable shunt reactor at UHV side 13
4.4.1 General 13
4.4.2 Capacity selection 13
4.4.3 Tap-changer 13
4.4.4 Response speed of CSR 13
4.4.5 Control mode 14
4.5 Other requirements for compensation at tertiary side of UHV transformers 14
4.5.1 Configuration of shunt compensator banks 14
4.5.2 Connection 14
4.5.3 Dynamic reactive compensation 14
5 Voltage regulation 15
5.1 General 15
5.2 Voltage regulation for UHV transformers 15
5.2.1 Voltage regulation via transformer tap changes 15
5.2.2 Selection of transformer taps 15
5.2.3 Voltage selection for transformers 15
5.2.4 Types of tap-changers 15
5.2.5 UHV transformer tap range 15
5.2.6 Selection of transformer tap position during operation 15
6 Generator reactive power control 16
6.1 General 16
6.2 Coordination among reactive devices 17
7 Insulation design and coordination procedure for transmission line and substation design 17
7.1 General 17
7.2 Insulation design procedure 18
7.3 UHV AC system overvoltage 18
7.3.1 General 18
7.3.2 Temporary overvoltage (TOV) 19
7.3.3 Switching overvoltage (slow-front overvoltage) 19
7.3.4 Lightning overvoltage (fast-front overvoltage) 20
7.3.5 Very fast front overvoltage (VFFO) 21

7.4 Reduction of insulation levels using overvoltage suppression measures 21
7.4.1 General 21
7.4.2 Overvoltage suppression using surge arrester with low protective level 21
7.4.3 Resistor-fitted circuit-breakers with closing/opening resistor 21
7.4.4 Damping effect of resistor-fitted disconnectors employed in GIS to suppress VFFO 22
7.4.5 Damping effect of AIS for suppressing VFFO 22
7.4.6 Fast insertion of switchable or controllable shunt reactors 22
7.4.7 Controlled switching 22
7.5 Coordination of design requirements 22
7.5.1 General 22
7.5.2 Transmission line 22
7.5.3 Substation 23
Annex A (informative) UHV multi-stage controllable shunt reactor 24
Annex B (informative) General procedure for the selection of transformer tap positions 26
Bibliography 29

Figure 1 – Flowchart for reactive power compensation configuration 9
Figure 2 – Flow chart for rational insulation specification for UHV 18
Figure 3 – Overvoltage categorized by time domain 18
Figure 4 – Overvoltage mechanism caused by back-flashover and direct lightning 20
Figure A.1 – Illustrative example of a UHV project with an MCSR 24
Figure B.1 – Schematic diagram of UHV transmission line 26
Figure B.2 – Voltage profile of UHV line A-B while energized at substation 27

Table A.1 – Impact of MSCR switching on voltage at station B 25
Table B.1 – Lower limits of operating voltage for UHV substations 28

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

UHV AC TRANSMISSION SYSTEMS –

Part 101: Voltage regulation and insulation design

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a Technical Specification when

- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical Specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 63042-101, which is a Technical Specification, has been prepared by IEC technical committee 122: UHV AC transmission systems.

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

Enquiry draft	Report on voting
122/60/DTS	122/70A/RVDTS

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

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

A list of all parts in the IEC 63042 series, published under the general title *UHV AC transmission systems*, can be found on the IEC website.

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

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

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Large-scale power sources including renewable energy have recently been developed. To meet the requirements for large power transmission capacity, some countries have introduced, or are considering introducing, ultra high voltage (UHV) transmission systems, overlaying these on the existing transmission systems at lower voltages such as 420 kV and 550 kV.

However, the introduction of UHV AC also presents many challenges to planners and operators. One of the major challenges is the management and control of system voltage and reactive power control. Reactive power control is normally used to address power frequency voltage requirements and maintain the voltage under transient conditions. Suitable insulation designs and coordination procedures are adopted in order to control transient overvoltages and prevent damage to equipment.

The objective of UHV AC power system design is to achieve both economic efficiency and high reliability, considering its impact on systems at lower voltages such as 420 kV and 550 kV. Long-distance transmission lines in particular generate a large amount of charging reactive power (Mvar) that could cause the system voltage to rise significantly. For example, when energizing a transmission line, the terminal voltage at the remote end could reach an unacceptable level. Reactive power compensation is implemented to ensure that the UHV AC system operates within an adequate voltage range under normal conditions and any contingency conditions that the system is designed to withstand.

Moreover, effective insulation design that limits internal electric field stress is important for minimizing and optimizing the size and structure of UHV AC transmission lines and substation apparatus. This document provides technical specifications on insulation design and coordination, reactive power compensation design and voltage regulation that are essential for maintaining UHV AC transmission systems so that they operate safely and efficiently.

UHV AC TRANSMISSION SYSTEMS –

Part 101: Voltage regulation and insulation design

1 Scope

This part of IEC 63042 specifies reactive power compensation design, voltage regulation and control, and insulation design for the coordination of UHV AC transmission systems.

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 60071-1, *Insulation co-ordination – Part 1: Definitions, principles and rules*

3 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
voltage deviation
difference between the actual voltage and nominal system voltage under continuous operating conditions

3.2
network node
<in power networks> any point where two or more transmission lines meet

3.3
controllable shunt reactor
CSR
high voltage shunt reactor whose capacity can be adjusted

3.4
continuous controllable shunt reactor
CCSR
high voltage shunt reactor whose capacity can be adjusted continuously

3.5
multi-stage controllable shunt reactor
MCSR
type of controllable shunt reactor, based on the principle of high impedance transformers whose reactive power output usually varies in discrete stages and is achieved by controlling transistors, circuit-breakers and other devices

4 Reactive power compensation for UHV AC transmission systems

4.1 General principles

An appropriate amount of reactive power supply should be planned and installed in UHV AC systems to meet the system voltage regulation requirements and reduce the amount of unintended reactive power transfers between different network nodes/voltage levels.

A sufficient amount of reactive power supply with flexible capacity, including an adequate amount of reactive power reserve, should be maintained.

The capacity, type and location of reactive power compensators should be selected to improve power transmission capabilities and enhance system stability limits.

Planning and design of reactive power compensators for UHV AC systems should meet the overvoltage limit requirements for UHV AC systems.

A compensation ratio of between 90 % to 110 % is considered reasonable in planning reactive compensation to minimize the reactive power exchange between UHV and lower voltage level systems. The compensation should be judiciously implemented between line and bus reactive compensation so that it is able to control voltage during various switching operations and to prevent oscillations due to high levels of compensation.

4.2 Configuration of reactive power compensation – consider placing after general functions

In general, reactive power compensation should be distributed at the primary, secondary and tertiary side of the UHV transformer based on the overall requirements for voltage regulation and to minimize the overall cost. The principle of locating reactive power compensation at the primary and secondary sides of the UHV transformer is the same except for the cost of reactive power compensation and its effectiveness in regulating voltage at the primary side of the UHV transformer. In this way, they are treated in the same manner.

The major processes in configuring reactive power compensation for UHV AC systems are as follows:

a) Identify the range of likely active power flow across the UHV line, then calculate and analyse the characteristics of reactive power and voltage profiles along the UHV line, taking into account charging reactive power produced by UHV lines and reactive power loss under different power flow conditions. Simulations need to be repeated for each scenario to determine the compensation that keeps the voltage within acceptable limits. One of the methods for this is to determine the compensation required at each bus by using a static Var compensator (STATCOM) with a large range. The calculated output of the STATCOM that maintains bus voltage at 1,0 p.u. is the required compensation at that bus.

b) Select UHV transformer tap positions to avoid overvoltage under a range of operating conditions taking into account UHV substation location, number of transmission lines connected, and system operation mode.

c) Select capacity and location of UHV line shunt reactors with the following considerations:

   1) limiting temporary overvoltage and reducing secondary arc current;

   2) balancing charging power of lines and flexibly controlling bus voltage.

d) Identify total and unit capacity of compensators installed on the tertiary side of the transformer. Total capacity should be selected to reduce the reactive power exchange between different voltage levels and maintain bus voltage within the admissible range; the selection of single bank capacity should take into account the maintaining of voltage fluctuations induced by the switching of a single capacitor bank or reactor within a reasonable range. Set the dynamic reactive power limits provided by generators within the desired capability range.