IEC TS 63042-201

Edition 1.0 2018-12

TECHNICAL SPECIFICATION

colour inside

UHV AC transmission systems –
Part 201: UHV AC substation design

IEC TS 63042-201:2018-12(en)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.240.01; 29.240.10

ISBN 978-2-8322-6330-3

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

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

IEC TS 63042-201, 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
122/64/DTS	122/71A/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- withdrawn,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.

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UHV AC TRANSMISSION SYSTEMS –

Part 201: UHV AC substation design

1 Scope

This part of 63042, which is a Technical Specification, provides common rules for the design of substations with the highest voltages of AC transmission systems exceeding 800 kV, so as to provide safety and proper functioning for the intended use.

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 60038:2009, *IEC standard voltages*

IEC 60044 (all parts), *Instrument transformers*

IEC 60059:1999, *IEC standard current ratings*
IEC 60059:1999/AMD1:2009

IEC 60071-1:2006, *Insulation co-ordination – Part 1: Definitions, principles and rules*
IEC 60071-1:2006/AMD1:2010

IEC 60071-2, *Insulation co-ordination – Part 2: Application guide*

IEC 60076 (all parts), *Power transformers*

IEC 60068-3-3, *Environmental testing – Part 3: Guidance – Seismic test methods for equipments*

IEC 60137*, Insulated bushings for alternating voltages above 1000 V*

IEC 60168, Tests on indoor and outdoor post insulators of ceramic material or glass for systems with nominal voltages greater than 1000 V

IEC 60196:2009, IEC standard frequencies

IEC 60255-26, *Measuring relays and protection equipment – Part 26: Electromagnetic compatibility requirements*

IEC TS 60479-1, *Effects of current on human beings and livestock – Part 1: General aspects*

IEC 60721-2-4, *Classification of environmental conditions – Part 2-4: Environmental conditions appearing in nature – Solar radiation and temperature*

IEC TS 60815 (all parts), *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions*

IEC 60865 (all parts), *Short-circuit currents*

IEC 60871 (all parts), *Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V*

IEC 60909 (all parts), *Short-circuit currents in three-phase a.c. systems*

IEC TS 61463, *Bushings – Seismic qualification*

IEC 61850 (all parts), *Communication networks and systems for power utility automation*

IEC 61936-1:2010, *Power installations exceeding 1 kV a.c. – Part 1: Common rules*
IEC 61936-1:2010/AMD1:2014

IEC 62231, *Composite station post insulators for substations with AC voltages greater than 1 000 V up to 245 kV – Definitions, test methods and acceptance criteria*

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 62271-207, *High-voltage switchgear and controlgear – Part 207: Seismic qualification for gas-insulated switchgear assemblies for rated voltages above 52 kV*

IEC TR 62271-300, *High-voltage switchgear and controlgear – Part 300: Seismic qualification of alternating current circuit-breakers*

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
UHV AC
highest voltage of AC transmission system exceeding 800 kV

Note 1 to entry: UHV stands for "ultra high voltage".

3.2
high-voltage side of transformer
highest voltage among two or three voltages on each side of the main transformer

3.3
intermedium voltage side of transformer
second highest voltage among three voltages on each side of the main transformer

3.4
low-voltage side of transformer
lowest voltage among two or three voltages in the apparatus or installation

Note 1 to entry: In this document, the definition is modified as the lowest voltage among two or more voltages on each side of main transformer.

4 UHV AC substation requirement

4.1 General requirement

The UHV AC substation should withstand the electrical, mechanical, climatic and environmental influences anticipated on site.

In the design of the UHV AC substation, several factors should be taken into account: system demands, operation and maintenance requirements, construction requirements, site condition, environmental impact and economy.

To meet the requirements above, the design should also be performed in consideration of the following characteristics of the UHV AC substation:

- high importance of the UHV AC substation;
- high transmission capacity;
- high overvoltage;
- high secondary arc current;
- high electric and magnetic field strength;
- large dimension and weight of the UHV AC equipment;
- large dimension of the UHV AC substation.

A typical design of a UHV AC substation is shown in Figure 1.

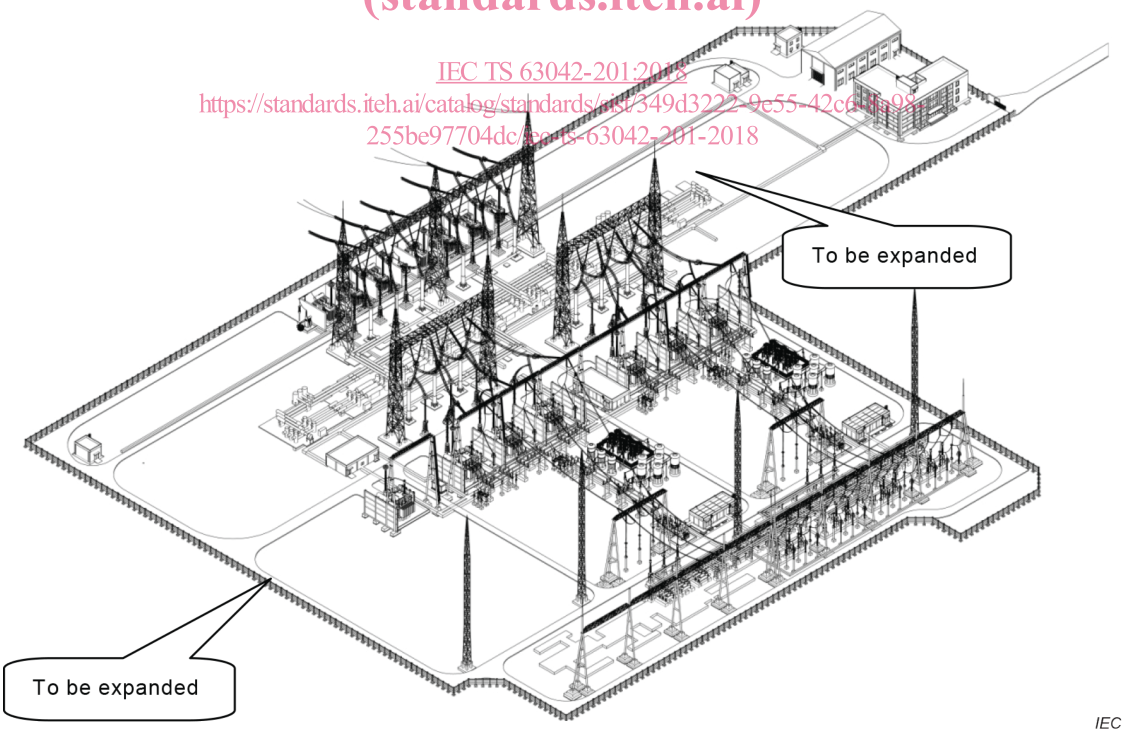


Figure 1 – Bird's-eye view of a typical UHV AC substation

4.2 System demands

The design of the UHV AC substation should meet the AC transmission system demands, including the following items:

a) reliability: the bus scheme and feeder connection, equipment and control protection system of the UHV AC substation should be adopted to meet the requirements of reliability, considering the importance of the UHV AC substation in the AC transmission systems.

b) availability: the selection of the bus scheme and feeder connection, the type and parameters of equipment, equipment layout, control protection and communication system should meet the demands of AC transmission system scale and parameters in the steady-state and transient-state and the possibility of extension (if required). Especially, the demands of the AC transmission system access should be taken into consideration in the design of equipment layout.

c) flexibility: the convenience of switching feeders such as a bank of transformers or a transmission line, switching devices such as circuit breakers, busbars and their relay protection devices in case of maintenance, and the transition from the initial bus scheme and feeder connection to the final bus scheme and feeder connection, should be taken into consideration in the design of bus scheme and feeder connection as well as equipment layout.

4.3 Operation and maintenance requirements

The UHV AC substation with high applied voltage and large dimension plays a significant role in AC transmission systems, which makes the operation and maintenance of these substations very severe. The design of the UHV AC substation should meet the requirements of operation and maintenance, including the following items:

a) The type of bus scheme and feeder connection and equipment should meet the requirements of operation and maintenance as much as possible on premise of meeting the system demands.

b) The design of the UHV AC substation should limit the safety distance and electric field strength to a permissible value in order to ensure the operator safety and to meet the requirements of a daily operation and maintenance, even though the applied voltage of the UHV AC substation is high.

c) The design of the earthing system should meet the requirements of a daily operation and maintenance. Especially, the step potential and touch potential of the earthing system should be limited to permissible value.

d) Control, protection and communication system should meet the requirements of the system architecture and operation mode of AC transmission systems.

4.4 Construction requirements

Large and heavy equipment complicates the construction of the UHV AC substation. The design of the UHV AC substation should meet the requirements of construction, including the following items:

a) The equipment layout and the distance between equipment should meet the requirements of transportation, lifting and installation of the equipment.

b) When selecting the UHV conductors, the effort involved in the structural design shall be taken into account, too, besides the electrical properties such as current-carrying capacity, thermal stability, corona effect, etc.

c) The transportation condition should meet the requirements for large equipment transport.

d) The construction measures should be adopted to meet the requirements of the UHV AC equipment's foundation. Structure construction should be used in order to avoid the temperature cracks generated by the hydration heat impact in mass concrete construction.

4.5 Site condition

The design of the UHV AC substation should meet the requirements of the site condition, including the following items:

a) Hydrological and geological condition. The UHV AC substation should be located in a stable geological region, and the hydrological and geological influence should be considered.

b) Meteorological condition. The type, parameters, and configuration of the UHV AC equipment and conductor should adapt to the meteorological condition such as temperature, humidity, atmospheric pressure, wind velocity, etc.

c) Seismic conditions. The UHV AC substation should avoid being located in a seismically unfavourable site, and electrical facilities should meet the anti-seismic requirements.

d) Altitude. The safety distance, current-carrying capacity of the conductor, and external insulation of the equipment should be corrected according to the altitude on site.

4.6 Environmental impact

The design of the UHV AC substation should reduce the environmental impact, including the following items:

a) Audible noise. The type, parameters, and configuration of the UHV AC equipment and conductor should limit the audible noise strength on the substation boundary that is specified by local regulations to a permissible value.

b) Electric and magnetic field. The type, parameters, and configuration of the UHV AC equipment and conductor should limit the electric and magnetic field strength to a permissible value.

c) Radio Interference. The type, parameters, and configuration of the UHV AC equipment and conductor should limit the radio interference strength to a permissible value.

d) The influence of the potential rising of the earthing system on the outside of the UHV AC substation. The potential rising of the earthing system should avoid being transferred to the outside of the UHV AC substation through metal pipes or cables in the design of the earthing system.

e) Carbon footprint. The design should limit the carbon footprint of the substation (e.g. reduce leakage of total volume of SF_6).

4.7 Economy

The design of the UHV AC substation should strike a balance between performance and cost based on the life-cycle cost analysis, on the premise of meeting functional requirements.

5 Bus scheme and feeder connection

5.1 General

The basic purpose of a chosen bus scheme and feeder connection is to facilitate the operational functions of a substation inside an electrical network. In the past, maintainability and accessibility of high-voltage equipment was very important due to the requirements for frequent maintenance. Different types of circuit breaker design and also the different types of operating mechanisms required regular maintenance with short intervals. These requirements meant that various configurations and arrangements of substations were developed to isolate the circuit breaker and current transformer in a complete bay for maintenance while ensuring availability of supply on adjacent equipment. Disconnectors were required to deal with safety requirements and provide physical isolation during long-term maintenance activities.

Because the latest development in switchgear is aimed at ever longer maintenance intervals, the importance of maintainability in the design of switchgear has changed. At the same time, today's society is getting more and more dependent on electric power supply for all its functions. This results in less tolerance towards quality of power supply issues and black-outs, which will require designers to put more emphasis on high security (i.e. fault tolerance) and availability requirements for substations, especially for UHV AC transmission systems as backbone system.

Summarizing, bus scheme and feeder connection of high voltage substations are strongly influenced by many factors such as operational requirements, security standards, availability, and maintainability, the need for sectionalizing, control and protection systems and regulations. The bus scheme and feeder connection of a UHV AC substation should be determined after comparison of technology and economy according to the importance of the substation in transmission system considering the factors mentioned above.

The configuration for a particular substation depends on its position within a network and also its relative importance.

Because of the generally high importance of UHV AC substations, the following configurations are preferred:

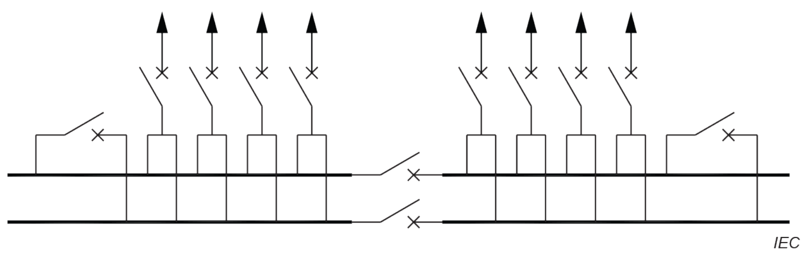
- double busbar (DB);
- one-and-a-half circuit breaker (OHCB);
- two-circuit breaker (2CB).

5.2 Scheme at high-voltage side of main transformer

The DB with a coupler bay as shown in Figure 2 is a substation in which the lines and transformers are connected to either of the two busbars by means of selector disconnectors.

The DB is particularly suitable for highly interconnected power networks in which switching flexibility is important and multiple supply routes are available. The coupler circuit breaker allows the possibility of keeping half of the station in service following a fault on the busbar, a busbar disconnector or any feeder circuit breaker. The configuration provides flexibility by allowing each circuit to be connected to either of the two busbars. It is also possible to move circuits from one busbar to the other while they are energized. Additional flexibility can be provided by adding sectionalised disconnectors into each busbar.

Using a bus section connection arrangement, a higher reliability is provided. This arrangement has the same characteristics and functionality of DB but it is recommended for use when there is a requirement to keep a high number of circuits in service during maintenance or repair of the circuit breaker or the busbar disconnectors.



NOTE The single line diagram only shows circuit breaker and busbar.

Figure 2 – Double busbar (DB) with or without bus section connection

The OHCB as shown in Figure 3 is a double busbar substation where, for two circuits, three circuit-breakers are connected in series between the two busbars, the circuits being connected on each side of the central circuit-breaker. The OHCB is particularly suitable for substations handling large amounts of power, such as those associated with generating stations, and for networks which comprise mainly radial circuits with few mesh connections. The OHCB does not have any separate bus-coupler circuits. Each circuit breaker connecting is acting as a bus-coupler. The design of the bus zone and circuit breaker failure protection systems is simpler than the multiple busbar configurations with selector disconnectors as the systems do not need to select which circuit breakers to trip in response to a busbar fault or a circuit breaker fail situation.