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UHV AC transmission systems

Part 100: General information

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National foreword

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UHV AC transmission systems –
Part 100: General information

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

UHV AC TRANSMISSION SYSTEMS –

Part 100: General information

FOREWORD

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The technical report IEC 63042-100 was prepared by IEC Technical Committee 122: UHV AC transmission systems.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
122/29/DTR	122/31A/RVC

Full information on the voting for the approval of this technical report 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- withdrawn,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.

INTRODUCTION

UHV AC transmission systems are capable of transmitting large amounts of electric power. However, if a failure occurs in a UHV AC system, the system influence can be severe from the viewpoints of reliability and overall security of the supply of the power system. Most UHV AC substations are located far from city areas, with large equipment in size and mass installed. Equipment is transported over long distances from where it is manufactured and tested to where it is installed and commissioned. Also, the installation time of equipment is generally longer compared with lower voltage classes. For UHV AC transmission lines, the design of insulation is an important aspect due to non-linearity effect.

Therefore, securing the reliability, availability, and environmental aspects are crucial issues. Standards and/or applications guidance, as relevant, in the following aspects of UHV AC transmission systems exceeding 800 kV are necessary:

a) planning (guidance);
b) design;
c) technical requirements (exclusively systems-related);
d) construction;
e) commissioning;
f) reliability;
g) availability (continuity of power supply, % availability);
h) operation;
i) maintenance.

This document describes both specific issues to UHV AC transmission systems and common issues of UHV AC and lower voltage transmission systems because it is very easy to understand UHV AC transmission systems as a whole.

In this Technical Report, minimum items or requirements for the standards and guidelines for each step of UHV AC transmission systems are described.

UHV AC TRANSMISSION SYSTEMS –

Part 100: General information

1 Scope

This part of IEC 63042, which is a Technical Report, specifies the reference for the standards and guidelines for UHV AC transmission systems. This document provides an overview of these standards as well as guidelines.

This document is developed to clarify standardization items and/or guideline items for UHV AC transmission systems. It describes the items to be considered for each stage of planning, design, construction, commissioning, operation, and maintenance during the development of IEC publications for UHV AC transmission systems.

NOTE Based on this IEC/TR 63042-100, TC 122 will prepare the standards and guidelines for UHV AC transmission systems, but it is not limited by the framework of the TR. A systematic approach is necessary for the preparation of systems-oriented specifications such as those for planning, design, technical requirements, construction, commissioning, reliability, availability, operation, and maintenance.

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, *IEC standard voltages*

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
UHV AC
the highest voltage of the AC transmission system exceeding 800 kV

Note 1 to entry: UHV stands for Ultra High Voltage.

4 Planning

4.1 General

Large scale power sources have been developed. It is important to transmit the electric power efficiently from these power sources to consumption areas. Moreover, the network enhancement might decrease the system stability and worsen fault current problems. To prevent such problems in existing high voltage transmission systems, multiple transmission lines and switchyards might be necessary due to the shortage of transmission capacity/improvement of the system stability. As a result, large facility investment will be required and inference of transmission losses will be considerable.

To solve the above-mentioned problems, the UHV AC transmission system was developed, which can transmit a large amount of electric power by minimum transmission lines effectively and in a stable way.

For example, a UHV AC transmission line can transmit three or four times a larger quantity of electric power than a 550 kV transmission line.

The UHV AC transmission system has many advantages such as:

– decrease of right of way (ROW);
– improvement of fault current condition and system stability;
– formulation of network with high reliability;
– increase of redundancy for the system enhancement;
– reduction of environmental impact.

Some countries have introduced a UHV AC system to their grid as follows:

a) Use Case 1

   Case 1 had developed UHV AC transmission systems in the 1980s and started its operation in 2009. UHV AC transmission systems were selected to achieve energy bulk transmission to distant areas to serve a large capacity economically and efficiently.

   To improve the transmission capacity, series capacitors are used. By using them, the transmission capacity is increased from 3 000 MW to 5 000 MW.

b) Use Case 2

   Case 2 has developed UHV AC transmission systems since 1973. The power transmission capability in the power system is often constrained by power system stability because the bulk power transmission is larger than the surge impedance loading (SIL).

   Additionally, special schemes for system control are applied. Problematic contingencies such as a permanent fault on both circuits of a double-circuit transmission line, or delays in fault clearance for any reason, have a very small probability of occurrence, but have a severe impact on the synchronous stability of a bulk power transmission system. Such severe contingencies may result in a loss of synchronism and the subsequent cascading outages. As a means of preventing such system-wide loss of synchronism, the following emergency relaying schemes are employed in the bulk power transmission system:

   – generator tripping relays for preventing loss of synchronism;
   – load shedding relays for preventing overloading;
   – generation tripping and/or load shedding relays for maintaining system frequency.

4.2 Security and stability

As a UHV AC transmission line has to transmit a large amount of power over a long distance, a disturbance, such as a faulty event, may give significant influence to the whole system. Therefore, the redundancy and stability for the network system should be considered from the operational viewpoint.

4.3 Transmission systems

It should be determined whether the transmission system is UHV AC or UHV DC, considering the benefit of the transmission system. In general, UHV AC is used in power grids.

4.4 System voltage

In the case of an installation of the higher voltage class, “twice or three times as high as existing voltage class” is generally selected due to efficiency and expandability. In addition, it is important to consider future demands, power development plans, situation of the site of power plants, and technological, economical, and environmental aspects.

It is especially desirable to choose an existing voltage level in IEC standard voltages, considering the technological and economical aspects. Table 1 shows the highest voltage defined in IEC 60038 standard.

Table 1 – AC three-phase systems having a highest voltage for equipment exceeding 800 kV

Highest voltage for equipment kV
1 100
1 200

In the process of transmission voltage determination, short circuit current, power flow, stability, and voltage control with reactive power compensation are technically investigated confirming the main specifications of the power transmission system. The cost is compared between UHV and other voltage classes, where future system expansion is also considered.

4.5 Reliability and availability

To form the network system, reliability is one of the most important key factors. Particularly, for UHV, high reliability is required because it is used to transmit electric power from an important power source, and it is used as a main transmission system.

Until now, many field tests have been carried out and the reliability of each facility has been sufficiently verified in the countries where UHV AC transmission systems are installed.

As for the operating facilities, various operation records are reported. One circuit fault of a UHV AC transmission line is smaller than two circuit faults of a 550 kV transmission line. In this regard, the UHV AC transmission system also shows high availability. The UHV AC system has a developed technology to keep high reliability.

Table 2 shows the comparison of lightning fault between UHV and 550 kV systems.

Table 2 – Comparison of lightning fault between UHV and 550 kV systems

Unit: Number of fault/year/ 100 km

System	**550 kV double circuits**	**UHV double circuits**
One circuit failure [a]	0,013	Less than 0,001
Two circuit failure [b]	0,005	Less than 0,001
Estimated by the single-phase re-closing: [a] 3 lines to earth fault [b] 4 lines to earth fault		
Reference: this table is calculated by TEPCO Power Grid, Inc.		

4.6 Transmission network

The main objective of UHV AC transmission systems is to transmit a large amount of power over a long distance in a stable way. Various considerations should be taken into account in the network configuration to keep the reliability. In one case, ring transmission route is adopted and internetworking is operated radially to solve the fault current issues and control the power flow easily. In another case, multi-outer ring lines will be planned to supply large amounts of power to distributed load centres.

4.7 Network requirement

As for the formulation of UHV AC transmission systems, it is desirable to clarify the number of transmission routes and the capacity of transmission lines and substations to a certain degree to consider future system configuration. The network components should be determined by considering the long term power development plan as well as system stability, voltage stability, power flow, and fault current.

4.8 Transmission planning

High reliability is one of the most important requirements. The higher the installed voltage level is, the larger the accident influence is. Therefore, a high reliability is expected in the main part of the system.

When the system is enhanced, compliance with the grid code is a requirement. It is also necessary to consider local issues such as the restriction among the regional systems and the basic concept for the redundancy whether one route with two lines or two routes are required.

When UHV AC transmission system is planned to be installed and a grid code must be formulated or revised to meet installation of UHV, it is recommended to refer to the cases used in other countries.

5 System design

5.1 General

The introduction of a higher voltage class has the above-mentioned advantages, but the facilities become large due to the transmission capacity. For example, if the design is based on the conventional concept, the UHV tower would be 1,5 times as high as the 550 kV tower. Then, it is important to reduce the size of the facilities and devices from an economic point of view.

This is realized by suppressing the overvoltage level.

As the UHV AC transmission line has a much larger charging capacity and the unbalance between the charging capacities of each phase also increases, it is necessary to grasp the technical issues and to formulate the plan to solve them.

5.2 System design and solutions

5.2.1 Reactive power compensation

An appropriate amount of reactive power supply should be planned and installed in the UHV AC transmission system to meet the system voltage regulation requirements.

The capacity, type, and location of the reactive power compensator should be selected to improve the power transmission capacity and the system stability.

Based on the study, the appropriate installation of shunt reactor or shunt capacitor should be determined considering the total reactive power balance of the system.

Series capacitors can improve the system stability to increase the transmission capacity.

5.2.2 Protection scheme

The basic concept of the protection scheme is to grasp the fault condition, to remove the fault point as quickly as possible, and then to minimize that influence. Since the UHV AC system requires a high reliability, it is desirable to adopt protection systems with high performance of speed, accuracy, and reliability.

In particular, the following protection systems should be considered:

– transmission line protection relay;
– back-up protection of a transmission line;
– transformer protection relay;
– bus protection relay, etc.

5.2.3 Reclosing scheme

In a UHV AC system forming a skeleton of a bulk power system as well as in an existing bulk power system, the fast multi-phase auto-reclosing scheme is a key technology to minimize the possibility of losing both circuits on the double circuit transmission line.

In a UHV AC system, the fast secondary arc extinction is evaluated as difficult without applying special equipment because higher voltage is induced electrostatically from sound phases.

To reduce the secondary arc, a 4-legged reactor or a high-speed earthing switch (HSES) is recommended as a countermeasure for the secondary arc. In the case of a long line (more than 200 km) that is necessary for compensation by reactor, the 4-legged reactor could make the efficient and compact UHV AC substation construction. However, it is necessary to pay attention to the resonant over-voltage during reclosing and to examine the recovery voltage at the time of extinguishing the secondary arc. Compared with 4-legged reactor, the HSES can extinguish the secondary arc in any system condition. It is necessary to consider the coordinated operation of HSES and circuit breaker.

5.3 Insulation coordination

5.3.1 General

The insulation design requires the information of both facility configuration and overvoltage analysis on the transmission system. This realizes the proper insulation coordination for UHV transmission systems. Specific UHV countermeasures to suppress the overvoltages are adopted for the rational design of UHV facilities.

5.3.2 Lightning overvoltage

It is recommended first to analyze the waveform of the lightning surge entering the UHV AC substation under various circuit-conditions with surge arresters. Second, based on the results of overvoltage analysis, it is also recommended to determine the lightning impulse withstand voltage (LIWV) based on IEC 60071-1 from an economical point of view. Especially in UHV transmission systems, direct lightning overvoltage should be considered due to large lightning current and long duration of wave tail.

5.3.3 Slow front overvoltage (SFO)

Earth-fault overvoltage is one of the slow front overvoltages. Since the maximum voltage appears most likely in the middle of the overhead line, there is no effective measure for suppressing the earth-fault overvoltage in the substation. Therefore, earth-fault overvoltage is the lowest target of the SFO insulation level.

Other SFOs are caused by the switching of a circuit breaker. Closing resistors are widely applied for suppressing the closing surge of a circuit breaker. To reduce a SFO further, a measure for suppressing interrupting overvoltage, such as opening resistors, is required. As a new technology, the control switching also emerged. The SFO insulation level should be determined in coordination with the application of the suppressing method of SFO.

5.3.4 Very fast front overvoltage (VFFO)

The very fast front overvoltage, caused by re-strikes and pre-strikes which occur during the switching operation of a disconnector, have a very high frequency. This overvoltage is not expected to be suppressed by surge arresters.

Therefore, the surge level may exceed the level of the lightning surge or fast front overvoltage (FFO).

In particular, in case of gas insulated switchgear (GIS), the surge propagates and reflects repeatedly on the very little attenuating pipe-sheathed busbar. Since the reduced insulation level is adopted for UHV GIS based on the application of surge arrester with low protective level, different countermeasures could be applied to mitigate the effect of very fast front overvoltage (VFFO).

The frequency of the surge on the air insulated conductors decreases because of the low surge propagation speed compared with GIS. It is reported that some examples of VFFO analysis for a Hybrid IS substation indicated lower VFFO compared with GIS.

VFFO is a very fast oscillating surge, which may affect the insulation performance of winding equipment such as transformers and winding type potential transformers. The influence to the secondary system should also be considered.

Therefore, in case of UHV class, the probability for the VFFO to affect the whole system becomes more important.

To reduce the level of VFFO, various measures have been applied. Disconnector with resistor is one example.

5.3.5 AC temporary overvoltage

By studying the withstand capacity of transmission facilities (mainly arresters), overvoltage levels such as overvoltage including frequency increase when load shedding is carried out due to loss of transmission route or AC overvoltage occurs due to the Feranti effect, necessary countermeasures are determined.

6 Transmission line and substation design

6.1 General

UHV is the highest system voltage for the AC transmission systems. It is necessary to consider carefully any related items concerning specification, design, dimension, structure, manufacturing, testing, transportation, on-site assembling, on-site testing, inspection, commissioning, quality, reliability, and so forth. The basic idea of main components for the UHV AC transmission system is described in Subclauses 6.2 to 6.5.

6.2 Transmission line

6.2.1 General

The transmission line is the most important component in a UHV AC transmission system, so it should have enough reliability against weather conditions, geology, topography, and environmental impact.

6.2.2 Basic concept for selecting the UHV AC transmission line

Considering that the construction of a UHV AC transmission line needs a large-scale development, the route of a UHV AC transmission line should be selected based on the comprehensive deliberations on the following items:

a) being straight;

b) complying various regulations;

c) avoiding areas where a transmission line is not suitable, such as:
   – terrain and geology such as landslide, steep terrain, and fault;
   – natural protected areas, habitats of endangered or rare species of animals and plants, and burial sites of cultural material;
   – densely populated areas, passing through steep mountains or crossing large rivers;
   – severe environmental conditions such as heavy pollution, thunderstorm, heavy snow, and strong wind;

d) areas which are under consideration for construction and maintenance.

6.2.3 Conductor design for the transmission line

It is crucial for the UHV AC transmission line to reduce the occurrence of the corona noise generating from the wire caused by its high-voltage. The corona level should be set in consideration of the power transmission capacity, the transmission losses, and the accepted level for the nearby residential area as well as the boundary level. The size and the number of conductors are selected based on the corona level.

6.2.4 Pollution design for insulators

Pollution degree for insulators should be selected based on the distance from the coast. Pollution degree should be based on the actual state of a site.

6.2.5 Air clearance between tower and conductor

The basic concept of insulation design for a transmission line is to withstand switching overvoltage and temporary overvoltage which occur within the power system. The air clearance, which is determined by switching overvoltage, has saturated characteristics to the overvoltage level at the UHV class. Therefore, air clearance of UHV AC transmission is designed shorter by the effective mitigation of switching overvoltage, such as closing (and/or opening) resistor and surge arrester with a low protective level. The clearances to be maintained under swing conditions due to the wind of insulator strings and conductors are designed, considering the probability of simultaneous occurrence of various conditions of overvoltage and wind conditions.

6.2.6 Right of way (ROW)

ROW should be determined by air clearances and regulations.

6.2.7 Height of conductor

The height of the conductor is determined according to the electric field regulation in each country.

6.2.8 Structural tower design, foundation

The compact design for UHV AC transmission towers and foundations is necessary to increase the reliability of the transmission system and to decrease construction cost.

6.3 Substation

6.3.1 Area survey and selection

UHV AC substation is different from the following existing substations:

– increasing required areas and amounts of assembling units;
– increasing difficulty of construction because people are keen on protecting the environment. UHV equipment is larger than lower voltage class. Transportation and on-site assembling affect the environment during construction;
– locating severe condition areas such as the back side of the mountain because the selection of a UHV AC transmission line route depends on the location of power generation plants.

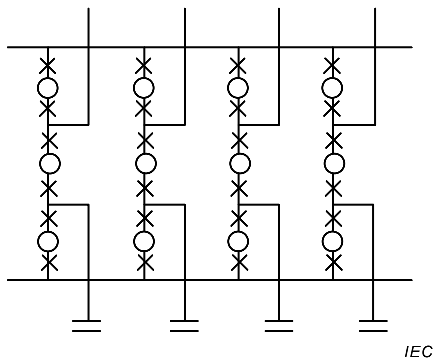
Especially for the UHV AC transmission system, the survey and selection of areas should be carried out based on the following considerations:

a) keeping consistent with the transmission line;
b) securing the transportation routes for heavy equipment;
   – design of the UHV equipment under the transportation restriction; form and weight based on the preliminary transportation condition survey (railways, roads, bridges);
   – appropriate transportation routes selection considering construction cost, construction period, and land acquisition.
c) natural environmental harmony;
   – preservation of the natural environment should be considered during the process of designing to consider construction;
   – the risk management for a natural disaster (collapse, salt contamination, and damage caused by wind and snow).
d) social environmental harmony;
   – satisfying the requirements which the local community and laws and regulations request.

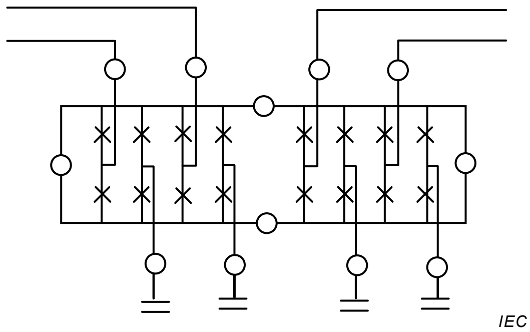
6.3.2 Substation bus scheme

The bus scheme is an important part in a highly reliable UHV AC substation. Therefore, the bus scheme should be determined considering the flexibility of the system operation, outage area during a failure, and maintenance of equipment.

Figure 1 shows two examples of bus schemes.



a) 1·1/2 CB bus



b) Doubler bus 4 Bus-Tie

Figure 1 – Bus scheme

6.3.3 Substation switchgear type

For UHV equipment, there are three types of switchgears: GIS type, Hybrid-IS type, and Air Insulated Switchgear (AIS) type.

a) GIS (Gas Insulated Switchgear)

Switchgear with bays fully made from GIS technology components.

Only external HV connections to overhead or cable lines or to transformers, reactors, and capacitors can have an external insulation.

b) Hybrid -IS (Hybrid Insulated Switchgear)

Switchgear with bays made from a mix of GIS and AIS technology components. This switchgear consists of some bays made of AIS technology components, or made either of GIS technology components only or of a mix of AIS and GIS components.

c) AIS (Air Insulated Switchgear)

Switchgear with bays fully made from AIS technology components.

NOTE A substation, where dead tank types of circuit breakers are installed, is considered as an AIS substation.

GIS and Hybrid-IS types are used more often than AIS type because of the following characteristics of AIS types:

– difficulties of maintenance and inspection because of high placement of charging parts;
– requiring large space for a UHV AC substation, which leads to higher land cost and large environmental impact;
– difficulties of ensuring seismic performance and restraint of vibration during operation in case of porcelain equipment, for example porcelain-type disconnector;
– reducing the gaps of the jointing parts of conductors to avoid the corona;
– difficulties of ensuring performance and long operational life in severe environmental conditions.

Recently, land acquisition of a large space for a UHV AC substation has become more difficult. The importance of size reduction increases. Table 3 shows the pros and cons of three types of switchgear facilities.

Reducing the size of a substation could decrease the total cost of a UHV AC substation, two-type switchgears (GIS and Hybrid-IS) are preferred from the point of view of selecting the site and reducing the land cost. The following matters should be considered:

– residual charge of main circuit effect against GIS spacer;
– induced surge effect to secondary circuit.

Table 3 – Substation switchgears' comparison (GIS, Hybrid-IS, and AIS)

	GIS	**Hybrid-IS**	**AIS**
Reliability	Most devices are sealed in enclosed metal tanks; they are rarely affected by environmental impacts, and anti-earthquake capability is preferable.	By introducing GIS technology, the reliability of Hybrid-IS is improved, but probability of pollution flashover on open air-insulated busbar is higher.	The probability of pollution flashover is the highest.
Maintenance and operation	No maintenance required, but cannot be resumed in a short time after failure.	Lack of operating experience, the working load is higher than GIS.	Operating experience is necessary, but the working load is highest.
Installation	Easiest, and installation time is shortest.	Installation of high frame is inconvenient.	Installation time is long.
Layout	Compact, easy outgoing access.	Easy outgoing access.	Easy outgoing access.
Expansion	Easy expansion, but restricted by manufacturers.	Easy expansion, but needs a lot of space.	Easy expansion, but needs maximum space.
Circumstance	Sealed in enclosed metal tanks, EMI and noise is small, little impact on the environment.	Little impact on the environment.	Strongest impact on the environment.
Construction cost	Highest	High	Lowest
Testing/ commissioning	Higher manufacturer's care in a factory (manufacturing, assembly and testing) and lower efforts on-site (assembly and testing).	Higher manufacturer's care in a factory (manufacturing, assembly and testing) and lower efforts on-site (assembly and testing).	Lower manufacturer's care in a factory (manufacturing, assembly and testing) and higher efforts on-site (assembly and testing).

Table 4 shows the principle technology designs for substations.

Table 4 – The principle technology designs for substations (their components and bays)

Technology design	Insulation	Insulating medium	Enclosure
AIS technology	External insulation	Air	No enclosure or enclosure (porcelain or composite insulators) under high voltage
GIS technology	Internal and external Insulation	SF_6 or SF_6 mixtures	Metal enclosure effectively earthed
Hybrid IS technology	External insulation	SF_6 or SF_6 mixtures and air	Combination of all
NOTE Internal insulation can be air, SF_6, oil, resin or any other kind of insulating media.			

6.3.4 Equipment layout

a) Reduction of the space

Reducing the substation space is very important to acquire the land for a UHV substation easily. Substation layout design should consider the equipment function, maintainability, and reducing the space.

The equipment is basically installed by unit and voltage/current from UHV to lower voltage. Therefore, it is recommended to make the UHV AC substation layout compact when considering the following matters:

– sharing the space for installation and failure response, and minimizing equipment installation space;
– shortening the gas insulated busbar (GIB) of substation;
– reducing the roads in substation as much as possible and utilizing this space for the installation;
– installing the noise source such as transformers at the center as close as possible;
– considering the minimum number of units of the equipment in case of minimizing overall layout;

b) Environmental harmony

To secure the visibility by not damaging the scenery and to coordinate whole substation and neighboring spaces

c) Simplifying the structure

To minimize equipment configuration and simplify the frames

d) Seismic performance

To secure the strength of each piece of equipment and each part against an earthquake stress, and to absorb the displacement among GIS components and the displacement of foundations.

e) Workability

To obtain the workability of installation of UHV equipment in order to keep the high quality of the equipment, UHV equipment is disassembled into separate units for transportation. On site, there is a number of assembling works in a UHV AC substation. Workability is an essential matter to secure the high reliability of on-site equipment assemblies.

f) Construction and maintenance

Construction and maintenance should easily acquire enough working space and maintenance space (including response to failure) for the equipment layout.

g) Failure responding ability

The failure responding procedure should be considered at the design stage in case a failure occurs in the equipment and system. This examination of procedure could be an essential matter in UHV AC substations.

6.4 Main equipment for the substation and related design

6.4.1 General

UHV is the highest system voltage for the AC transmission systems. Rated voltages of the equipment are also the highest and their rated capacities are also huge. Therefore, it is necessary to consider carefully any related items concerning specification, design, size, dimension, structure, manufacturing, testing, transportation, on-site assembling, on-site testing, inspection, commissioning, quality, reliability, and so forth. The basic idea of main components for the UHV AC transmission system is described in the subclauses below.

6.4.2 Power transformers

One of the key ideas for the substation design is how to formulate the specification which includes important items such as the number of units in the substation, rated voltages, rated capacity by unit, short circuit impedance, tapping range, construction of main tank, terminals, noise level, and so forth, in accordance with the detailed specification, design of the UHV AC transmission system, and its substation.

The following items are also important to consider:

– transportation limitation within all routes from factory to substation and its key constructions for main tank and fittings when considering its dimensions;
– line terminal side connections of primary and secondary sides of transformers such as conventional or direct connections to the switchgear side;
– tertiary terminal connection to make three-phase triangle connection for transformers;
– common neutral terminal connections of auto-transformers in such a way as applying air type bus connection;
– manufacturing capability in the factory.

6.4.3 Switchgear

Another key idea for the substation design is how to formulate the specification which includes important items such as the bus scheme of the substation, total arrangement of switchgear, rated voltage, rated currents by components, based construction, terminals, and so forth in accordance with the detailed specification, and design of the UHV AC transmission system, and its substation.

The following items are also important to consider:

– switchgear layout which considers a simplified and easy on-site construction, operation, maintenance, workability for failure response, and so forth;
– seismic design;
– transportation restriction of all routes from factory to substation;
– construction arrangements in the substation design, if applying GIS, including disconnecting bus arrangements, arrangements of bellows, arrangement of arrestors, gas compartment arrangements, earthing and grounding, and so forth;
– life of gaskets for gas-seal;
– manufacturing capability in the factory;
– design features for easy testability and commissioning.

6.4.4 Air clearance

Air clearance between live parts or between the live part and the earthing part should be considered for insulation coordination in the substation:

– switching surge for air gaps;

– electrical shield on bushing heads.

6.4.5 Seismic performance

Specifications of seismic performance for the equipment depend on the regulation and/or region, country, area, site, condition of basement, and foundation construction. The arrangements in the substation connecting lead line on the bushing and bus side, dynamic transient reaction between equipment, and between foundation and equipment should be also considered.

6.4.6 Tertiary circuit

When a compensator such as reactor and/or capacitor is planned and designed to be installed on the tertiary circuit of the power transformers, the following items should be considered:

– reactive and/or capacitive compensator equipment connection for stability of transmission operating voltage;
– protection procedure for equipment under failure condition with consideration to reduce voltage shock on the tertiary and other circuits.

6.4.7 Substation electrical auxiliary system

Substation electrical auxiliary system supplies electric power to every auxiliary, control and protection equipment and systems in the substation. Then it should be considered how to divide the circuits keeping total reliability for the substation, operation and maintenance at reasonable cost. A back up with high reliability for auxiliary power supply to the cooling equipment of the power transformers should be also considered.

The following items are also important:

– design and arrangements of substation auxiliary equipment and back up scheme;
– DC circuit with high reliability.

6.5 Control and protection and communication

The UHV protection and control systems, including their telecommunication systems, should have high reliability, high operability and high maintainability, and a proper redundancy to prevent a serious influence on UHV AC transmission system operations.

For the design of protection and control systems, and telecommunication systems, it is necessary to consider the following items:

– consistency between substation equipment and protection system;
– minimizing the accident influence with the separation of the system structure by the bus units and/or by the rated voltages;
– harmonizing the layout between the substation equipment and the protection and control apparatus, for high operability and maintainability;
– weather-proof for protection of control panels;
– redundant telecommunication routes for a high reliability;
– anti-vibration and seismic resistant cubicles.

7 Construction

7.1 General

The following special requirements during the construction of transmission lines and substations for the UHV AC transmission systems should be considered:

– large size and heavy weight;

– increasing the number of connecting parts on site;
– multiple bundles of conductors;
– severe environmental conditions of the substation due to the size of large facilities.

It is a crucial matter to establish the construction methods, schedule, and quality control assurance.

7.2 Transmission line

7.2.1 Transportation and preparing work at site

The transportation methods should be selected to meet the increased weight and dimension of materials and erection tools.

7.2.2 Foundation

The construction procedure for tower foundation should be considered to meet the depth and volume of excavation increased by tower weight.

7.2.3 Assembling of tower

Assembling methods should be selected to meet the lifting performance of the crane to handle the increasing package of materials, and increasing working area by a longer arm.

7.2.4 Stringing

Reducing high-place work on the transmission line should be considered to handle the conductors.

7.2.5 Quality control

On-site acceptance testing items should be selected considering the on-site work accuracy from the quality aspect of UHV AC transmission line with high reliability.

7.3 Substation

7.3.1 Transportation

A UHV power transformer is very heavy, so a transportation restriction should be considered. In the case of GIS, transportation units by trailers, trucks, or ships should be considered from the factory to the site. Transportation quality assurance by impact recorder or the like should be recommended.

7.3.2 Installation

A UHV transformer needs a long duration of on-site assembling. In addition, the control of the humidity in the work area and the control of the water content of the insulating material are important.

The GIS consists of a number of units to be assembled on site. Therefore, it should be necessary to consider the following methods of work and quality control:

– installation to continue under light rain, fog, or snow in order to keep the schedule because there are a number of on-site connecting GIS units;
– every type of connecting works using less dust and particles temporarily housed at the substation;
– decision of critical values for installation work control including dew point depends on less dust and particles temporarily housed at the substation;

– selection of highly skilled personnel.

8 Commissioning

Figure 2 shows the basic idea of commissioning tests. These commissioning tests confirm the soundness of every piece of equipment because transportation of heavy-weight components depends on each characteristic of UHV equipment, including high-level control for water contents in the insulating materials and connecting points at the substation.

On-site testing facilities should be carefully considered because of increasing exiting power and capacitances of transformers and switchgears.

In the case of testing with the use of a real transmission line, a risk of failure can arise. Testing should be conducted carefully, including dividing the testing area, minimizing the setting time for protecting relays of the equipment, and protecting system in the substation.

The following fundamental operating methods should also be considered:

– energizing timing: energizing step-by-step from power supply side;
– opening timing: opening step-by-step from low voltage side and/or end circuit side.

General method of commissioning on site is shown in Figure 2.

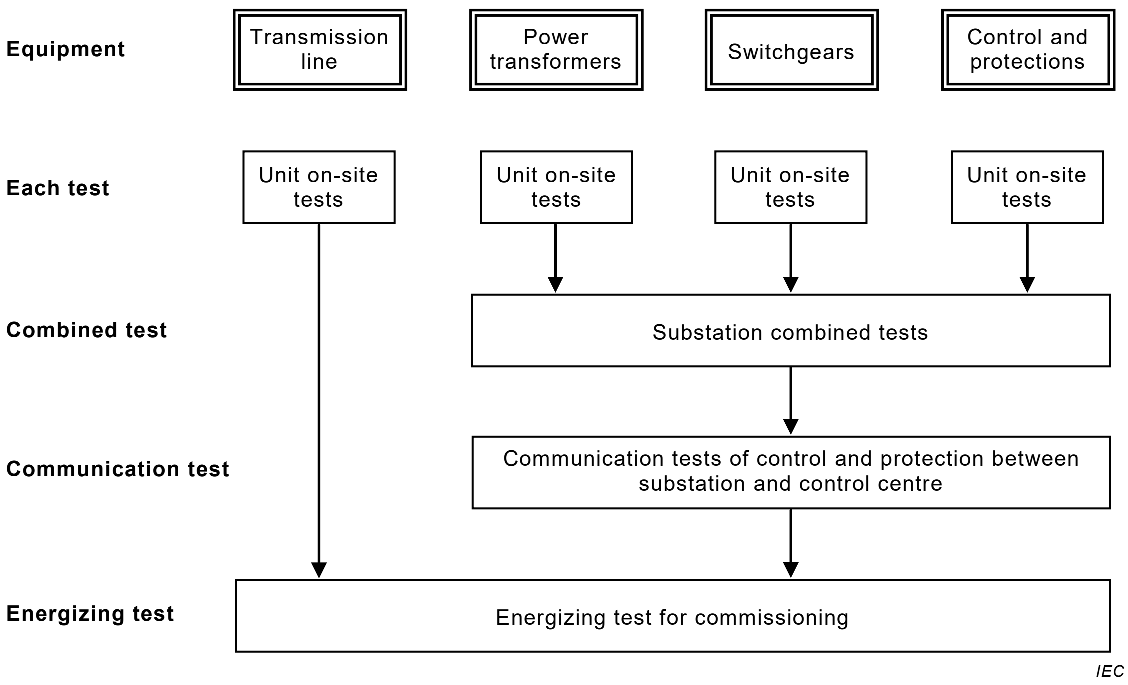


Figure 2 – General method of commissioning on site

9 Operation and maintenance

9.1 Transmission lines

As for UHV AC transmission lines, since the voltage increases, it becomes necessary to take measures to prevent electrostatic induction to the workers.

a) Measures for preventing electrostatic induction to workers

As for work performed on UHV pylons supporting electrical power lines, since a considerable current can be induced in the body of nearby workers, a countermeasure against such current induction is for workers to wear clothing with a conductive property.

b) Live – line maintenance work

Maintenance work under an energizing line is performed on the ground where a predetermined safe distance can be assured. In the case where assuring maintenance work at a safe distance is difficult, maintenance work is performed with the outage of UHV AC transmission lines. However, the work is sometimes carried out on the same potential with live lines under the condition that the power line can't be stopped.

9.2 Substations

9.2.1 General

UHV AC substations are sometimes located in rugged geographical regions like mountainous areas, which requires them to accommodate the increasing size of equipment and various new technologies. UHV AC substations should play an important role in the UHV AC transmission systems.

9.2.2 Operation

As for supervisory control of UHV AC substations, computer systems are applied. Furthermore, for integrated management of equipment maintenance, it is desirable to carry out inspections to verify the safety status of facilities and equipment when it is necessary.

a) Operational monitoring

   At control points, status observations made at monitoring items of substation equipment are recorded by computer. Moreover, when monitoring is impossible, workers are temporarily dispatched to the on-site control room to carry out the work described above.

b) Equipment monitoring

   At the control points, it is desirable to monitor the equipment by applying automatic monitoring equipment for automatically processing records, judging abnormalities, processing statistics, collecting data, detecting advanced warnings about malfunctions (e.g. corona discharge, gas-pressure drop, and dissolved gas analysis), and checking operational status of substation equipment and facilities (e.g. temperature and operational frequency/time) via protection relays, monitoring devices, and control equipment.

c) Control

   Substation equipment and facilities are operated remotely from the control points by computer systems. Moreover, when monitoring is impossible as in the rare case of a malfunction of the computer systems, workers are temporarily dispatched to the on-site control room and carry out the work described above.

d) Inspection tour

   Inspection tours are defined as follows:

   – workers are dispatched to on-sites on a time basis when it is required;
   – workers verify the status of the equipment and facilities throughout the whole substation.

It is recommended that monitoring facilities of a substation (equipment and safety status) should be adopted as an automatic system.

9.2.3 Maintenance

To verify and maintain the required functions, necessary maintenance should be carried out in the case that abnormalities are detected by inspection utilizing external diagnostic technology, automatic inspection by protection and control equipment, or by monitoring devices. Figure 3 shows a basic way of considering operation and maintenance of UHV AC substations.

a) Inspection

Although monitoring the status of equipment and facilities by automatic monitoring equipment (including relay checking) is automated, as for devices and equipment that need more detailed verification of functional capability, inspection utilizing external diagnostic technology (Internal diagnosis of GIS by X-ray) is necessary.

b) Repair

In the case that abnormalities are detected by monitoring equipment and facilities, the necessary repair should be carried out by workers dispatched to on-sites from the maintenance base.

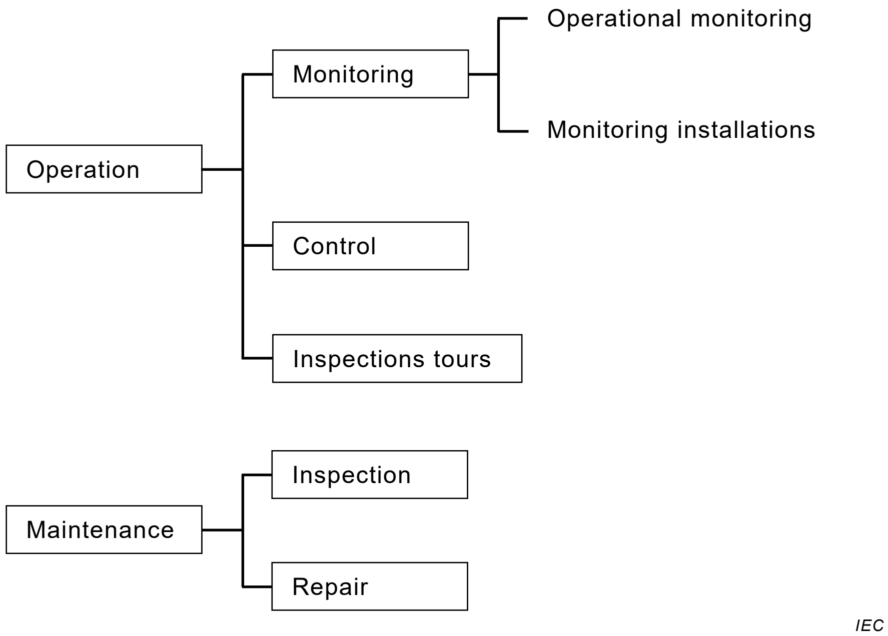


Figure 3 – Basic way of considering operation and maintenance of UHV AC substations

10 Environmental considerations

10.1 Transmission lines

10.1.1 General

The requirements in Subclauses 10.1.2 to 10.1.8 should be considered in UHV AC transmission lines from the viewpoint of the environmental impact due to increases in voltage and scale. In addition, it is necessary to satisfy these requirements in accordance with the environmental regulation of each country.

10.1.2 EMF

Aimed at preventing harmful effects on people's health from electromagnetic fields, guidelines are provided by the International Commission on Non-Ionizing Radiation Protection (ICNIRP), and it is necessary to design transmission lines on the basis of those guidelines. Moreover, in the case of independent national standards in different countries, it is necessary to comply with each standard appropriately.

10.1.3 Electrostatic induction

In areas under transmission lines, it is necessary to assure the required height of the lines above the ground in order to prevent the risk of electrostatic induction to people.

10.1.4 Electromagnetic induction

In areas under the transmission lines, it is necessary to eliminate the risk to people from electromagnetic induction even if someone touches metal lines such as communication lines and fences.

10.1.5 Audible noise with corona discharge

Audible noise is an audible sound generated by a corona discharge. Noise level is usually regulated by regional criteria; however, it is difficult to evaluate the loudness of corona noise by an audible noise-level only. The relationship of corona noise with daily sounds is significant, and the noise experience of existing power lines is important. Accordingly, it is necessary to set the acceptable level for people living in the vicinity and select the multi-bundle transmission line that satisfies this level.

Audible noise level with corona discharge for UHV AC transmission lines is generally adopted from 50 dB(A) to 55 dB(A) at the edge of ROW (right of way).

10.1.6 Radio interference with corona discharge

Radio interference is the radio noise caused by corona discharge. As a countermeasure against radio disturbance, a suitable type of conductor bundles should be selected. Moreover, corona noise is propagated through the transmission lines and thus extensively affects radio transmissions, so countermeasures should cover the whole line.

10.1.7 Wind noise

Predominant wind noise is generated when wind blows across transmission lines. It is difficult to evaluate the loudness of wind noise by a noise-level only. In addition, the relationship of wind noise with every-day sounds is significant, so the noise experienced level of existing power lines is important. Accordingly, acceptable levels of its frequency, which is determined by surveys on wind conditions in the areas through which transmission lines pass, and the people living in the vicinity should be considered. Therefore, countermeasures for reducing wind noise shall be taken.

10.1.8 Environmental impact

UHV AC transmission lines should be located as far as possible in the regions separated from populated areas as voltages and sizes increase. It is necessary to study the impact of lines on wild plants and animals, investigate the impact of lines on scenic landscapes, and consider how to harmonize them with the surrounding environment.

10.2 Substations

10.2.1 Earthing design

Under the premise of protecting the entire UHV AC substation, the earthing arrangement should be designed on the basis of compliance with either of two standards: IEEE std.80 or IEC TS 60479-1.

Considering that an earth fault current is large in UHV AC transmission systems, the safety of operators and workers should be assured by the increased touch voltage and step voltage. These voltages should be below a permissible level when an earth fault occurs inside or outside the substation.

10.2.2 Electrostatic-induction design

Regarding the electrostatic induction in UHV AC substations, it is necessary to reduce electrostatic-induction effects at ground level on people in substations on the basis of safety during operation and maintenance work. Accordingly, based on guidelines provided by the

International Commission on Non-Ionizing Radiation Protection (ICNIRP) – named “Guidelines for restricting exposure by time-varying electric, magnetic, and electromagnetic fields” – the permissible electric field is recommended below 100 V/cm at a height of 1,5 m above the ground.

As for the region of the head of the aerial bushings and lower-part shields, it is necessary to configure those components at a ground height that complies with the above-mentioned permissible electric field.

10.2.3 Audible noise mitigation design

The shield ring design for bushing, V-shaped suspension insulator, and so forth is based on suppressing the audible noise level against corona discharge in an appropriate manner.

10.2.4 Disaster-prevention design

a) Fire-prevention measures for transformers

   As fire-prevention measures for transformers, it is recommended to install fire-spreading-prevention equipment and water-screen-flooding equipment as well as oil fences to prevent the outflow of oil from the premises to the outside to avoid a fire disaster.

b) Tank rupture-prevention measures for transformers

   In UHV transformers, pressure rise during internal failure of the transformer is very severe. It is important to assure the appropriate tank strength to prevent the tank rupture as well as designing of dimensions and locating pressure relief devices.

c) Fire-spreading-prevention measures

   To prevent fires spreading from surrounding areas (woodlands, etc.) to substation facilities, the disaster-prevention design (such as installation of fire hydrants) should take into account cooperation in fire extinguishing when disasters occur.

d) Snow-damage-prevention measures

   In the case where substations are located in an area of heavy snowfall, countermeasures against the freezing, snow accretion, and snow melting should be implemented.

e) Insulation liquid and gaseous containment measures

   In the case of a liquid and gaseous leakage, proper countermeasures to prevent spreading of hazardous substances in the environment should be taken.

Bibliography

IEC 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60060-2, *High-voltage test techniques – Part 2: Measuring systems*

IEC 60060-3, *High-voltage test techniques – Part 3: Definitions and requirements for on-site testing*

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

IEC 60076-1, *Power transformers – Part 1: General*

IEC 60076-3, *Power transformers – Part 3: Insulation levels, dielectric tests and external clearances in air*

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

IEC TR 62063, *High-voltage switchgear and controlgear – The use of electronic and associated technologies in auxiliary equipment of switchgear and controlgear*

IEC 62271-1, *High-voltage switchgear and controlgear – Part 1: Common specifications*

IEC 62271-3, *High-voltage switchgear and controlgear – Part 3: Digital interfaces based on IEC 61850*

IEC 62271-4, *High-voltage switchgear and controlgear – Part 4: Handling procedures for sulphur hexafluoride (SF_6) and its mixtures*

IEC/IEEE 62271-37-082, *High-voltage switchgear and controlgear – Part 37-082: Standard practice for the measurement of sound pressure levels on alternating current circuit-breakers*

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

IEC 62271-101, *High-voltage switchgear and controlgear – Part 101: Synthetic testing*

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

IEC 62271-104, *High-voltage switchgear and controlgear – Part 104: Alternating current switches for rated voltages higher than 52 kV*

IEC 62271-106, *High-voltage switchgear and controlgear – Part 106: Alternating current contactors, contactor-based controllers and motor-starters*

IEC 62271-108, *High-voltage switchgear and controlgear – Part 108: High-voltage alternating current disconnecting circuit-breakers for rated voltages of 72,5 kV and above*

IEC 62271-109, *High-voltage switchgear and controlgear – Part 109: Alternating-current series capacitor by-pass switches*

IEC 62271-112, *High-voltage switchgear and controlgear – Part 112: Alternating current high-speed earthing switches for secondary arc extinction on transmission lines*

IEC 62271-203, *High-voltage switchgear and controlgear – Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV*

IEC 62271-204, *High-voltage switchgear and controlgear – Part 204: Rigid gas-insulated transmission lines for rated voltage above 52 kV*

IEC 62271-205, *High-voltage switchgear and controlgear – Part 205: Compact switchgear assemblies for rated voltages above 52 kV*

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 62271-208, *High-voltage switchgear and controlgear – Part 208: Methods to quantify the steady state, power-frequency electromagnetic fields generated by HV switchgear assemblies and HV/LV prefabricated substations*

IEC 62271-209, *High-voltage switchgear and controlgear – Part 209: Cable connections for gas-insulated metal-enclosed switchgear for rated voltages above 52 kV – Fluid-filled and extruded insulation cables – Fluid-filled and dry-type cable-terminations*

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

IEC TR 62271-301, *High-voltage switchgear and controlgear – Part 301: Dimensional standardisation of high-voltage terminals*

IEC TR 62271-302, *High-voltage switchgear and controlgear – Part 302: Alternating current circuit-breakers with intentionally non-simultaneous pole operation*

IEC TR 62271-305, *High-voltage switchgear and controlgear – Part 305: Capacitive current switching capability of air-insulated disconnectors for rated voltages above 52 kV*

IEC TR 62271-306, *High-voltage switchgear and controlgear – Part 306: Guide to IEC 62271-100, IEC 62271-1 and other IEC standards related to alternating current circuit-breakers*

IEC TR 62271-310, *High-voltage switchgear and controlgear – Part 310: Electrical endurance testing for circuit-breakers above a rated voltage of 52 kV*

IEEE 80, *IEEE Guide for Safety in AC Substation Grounding*

IEEE 693, *IEEE Recommended Practice for Seismic Design for Substations*

IEEE 1860, *IEEE Guide for Voltage Regulation and Reactive Power Compensation at 1000 kV AC and Above*

IEEE 1861, *IEEE Guide for On-Site Acceptance Tests of Electrical Equipment and System Commissioning of 1000 kV AC and Above*

IEEE 1862, *IEEE Recommended Practice for Overvoltage and Insulation Coordination of Transmission Systems at 1000 kV AC and Above*

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