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TECHNICAL SPECIFICATION

Reliability and availability evaluation of HVDC systems –
Part 1: HVDC systems with line commutated converters

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RELIABILITY AND AVAILABILITY EVALUATION OF HVDC SYSTEMS –

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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 62672-1, which is a technical specification, has been prepared by IEC technical committee 115: High voltage direct current (HVDC) transmission for DC voltages above 100 kV.

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

Enquiry draft	Report on voting
115/68/DTS	115/75/RVC

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

Annexes A and B are for information only.

A list of all parts in the IEC 62672 series, published under the general title *Reliability and availability evaluation of HVDC systems*, can be found on the IEC website.

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

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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

RELIABILITY AND AVAILABILITY EVALUATION OF HVDC SYSTEMS –

Part 1: HVDC systems with line commutated converters

1 Scope

This part of IEC 62672 applies to all line-commutated high-voltage direct current (HVDC) transmission systems used for power exchange in utility systems. HVDC stations with voltage sourced converters (VSC) are not covered.

In order to assess the operational performance of HVDC transmission systems, reliability and availability need to be evaluated. For this purpose the HVDC users/owners are encouraged to compile reports on an annual basis based on the recommendations given in this Technical Specification. The purpose of this part of IEC 62672 is to define a standardized reporting protocol so that data collected from different HVDC transmission systems can be compared on an equitable basis. It is recommended that such reports are sent to Cigré SC B4, “HVDC and Power Electronics” (http://b4.cigre.org) who collects such data and publishes a survey of HVDC systems throughout the world on a bi-annual basis.

This part of IEC 62672 covers point-to-point transmission systems, back-to-back interconnections and multi-terminal transmission systems. For point-to-point systems and back-to-back interconnections, i.e. two-terminal systems, statistics are to be reported based on the total transmission capability from the sending end to the receiving end measured at a given point. If, however, the two terminals are operated by different users/owners, or are composed of equipment of different vintage or of equipment from different suppliers, statistics can be reported on an individual station basis if so desired by those responsible for reporting. In such a case, the outage should only be reported under the originating converter station taking care not to report the same event twice. For distributed multi-terminal systems, i.e. systems with more than two terminals, statistics are to be reported separately for each converter station based on its own individual capability.

Multi-terminal systems, incorporating parallel converters but having only two converter stations on the d.c. line, can be considered as either point-to-point systems or as multi-terminal systems for purpose of reporting. Therefore, statistics for this special type of multi-terminal system can be reported based on either total transmission capability or on individual station capability. If the converters at one station use different technology, converter station statistics can be reported separately for each different type of capacity if desired. Multiple bipoles are also to be reported individually. Special mention should be given in the text and in the tabulations to any common events resulting in bipolar outages.

NOTE Usually the agreement between the purchaser and the turnkey suppliers of the HVDC converter station includes specific requirements regarding contractual evaluation. Such specific requirements will govern over this Technical Specification.

2 Normative references

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

IEC 60633:1998, *Terminology for high-voltage direct current (HVDC) transmission*
Amendment 1:2009

3 Terms, definitions and abbreviations

For the purpose of this document, the following terms and definitions apply.

3.1 Outage terms

3.1.1
outage
state in which the HVDC system is unavailable for operation at its rated continuous capacity due to an event directly related to the converter station equipment or d.c. transmission line

Note 1 to entry: Failure of equipment not needed for power transmission shall not be considered as an outage for purposes of this evaluation. AC system related outages will be recorded but not included in HVDC system reliability calculations.

Note 2 to entry: For purposes of this evaluation, outages taken for major reconfiguration or upgrading, such as addition of converters, shall not be reported.

3.1.2
scheduled outage
outage, which is either planned or which can be deferred until a suitable time

Note 1 to entry: Scheduled outages can be planned well in advance, primarily for preventive maintenance purposes such as annual maintenance program. During such planned maintenance outage, it is usual to work on several different equipment or systems concurrently. It is not necessary to allocate such outage time to individual equipment categories. Only the elapsed time should be reported in Table 5 as "PM".

Note 2 to entry: Classified under the scheduled outage category are also outages for work which could be postponed until a suitable time (usually night or weekend) but cannot be postponed until the next planned outage. Equipment category code in Table 5 should be used to identify the affected equipment. This includes discretionary outages based on operating policies, user/owner's preference and maintenance of redundant equipment.

Note 3 to entry: If the scheduled outage is extended due to additional work which would otherwise have necessitated a forced outage, the excess period is to be counted as a forced outage.

3.1.3
forced outage
state in which equipment is unavailable for normal operation but is not in the scheduled outage state

3.1.3.1

trips
sudden interruption in transmission by automatic protective action or manual emergency shutdown

3.1.3.2

other forced outages
other unexpected HVDC equipment problems that force immediate reduction in capacity of HVDC converter stations or system but do not cause or require a trip

Note 1 to entry: Also in this category are outages caused by start-up or de-block delays caused by HVDC equipment.

Note 2 to entry: In some cases the opportunity exists during forced outages to perform some of the repairs or maintenance that would otherwise be performed during the next scheduled outage. See 6.3, rule (f).

3.2 Capacity terms

3.2.1
rated capacity
P_m
maximum capacity (MW), excluding the added capacity available through means of redundant equipment, for which continuous operation under designed conditions is possible

Note 1 to entry: For two-terminal systems reporting jointly, the rated capacity is referred to a particular point in the system, usually at one or the other converter station. For multi-terminal systems or two-terminal systems reporting separately, the rated capacity refers to the rating of the individual converter station.

Note 2 to entry: When the maximum continuous capacity varies according to seasonal conditions, the highest value can be used as the capacity for the purpose of reports prepared according to this Specification for reason of simplicity. However this excludes over-load capability such as available during low – ambient temperature.

3.2.2
outage capacity
P_o
capacity reduction (MW) which the outage would have caused if the system were operating at its rated capacity (P_m) at the time of the outage

Note 1 to entry: The outage capacity is referred to the same point in the system used for defining P_m.

3.2.3
outage derating factor
ODF
ratio of outage capacity to rated capacity

$$ODF = P_o / P_m$$

3.3 Outage duration terms

3.3.1
actual outage duration
AOD
time elapsed in decimal hours between the start and the end of an outage

Note 1 to entry: The start of an outage is typically the first switching action related to the outage. The end of an outage is typically the last switching action related to return of the equipment to operational readiness.

Note 2 to entry: In some contractual evaluations between Purchaser and Supplier, AOD can be subjected to correction to adjust for long waiting times, administrative delays, non-availability of tools and tackles, non-availability of spare parts or other needed resources including trained man power, delay in permits etc.

3.3.2
equivalent outage duration
EOD
actual outage duration (AOD) in decimal hours, multiplied by the outage derating factor (ODF), so as to take account of partial loss of capacity

$$EOD = AOD \times ODF$$

Note 1 to entry: Each equivalent outage duration (EOD) may be classified according to the type of outage involved: equivalent forced outage duration (EFOD) and equivalent scheduled outage duration (ESOD).

3.4 Time categories

3.4.1
period hours
PH
number of calendar hours in the reporting period

Note 1 to entry: In a full calendar year the period hours are 8760, or 8784 in leap years.

Note 2 to entry: If the equipment is commissioned part way through a year, the period hours will be proportionately less.

3.4.2
actual outage hours
AOH
sum of actual outage durations within the reporting period

$$AOH = \Sigma\ AOD$$

Note 1 to entry: The actual outage hour (AOH) may be classified according to the type of outage involved: actual forced outage hours (AFOH) and, actual scheduled outage hours (ASOH).

$$AFOH = \Sigma\ AFOD$$
$$ASOH = \Sigma\ ASOD$$

3.4.3
equivalent outage hours
EOH
sum of equivalent outage durations within the reporting period

$$EOH = \Sigma\ EOD$$

Note 1 to entry: The equivalent outage hours (EOH) may be classified according to the type of outage involved: equivalent forced outage hours (EFOH) and equivalent scheduled outage hours (ESOH).

$$EFOH = \Sigma\ EFOD$$

$$ESOH = \Sigma\ ESOD$$

3.5 Availability and utilization terms

3.5.1
energy unavailability
EU
measure of the energy which could not have been transmitted due to outages

Note 1 to entry: The energy unavailability is calculated based on the same point in the system used for defining Pm.

Note 2 to entry: The energy unavailability (EU) may be classified according to the type of outage involved: forced energy unavailability (FEU) and scheduled energy unavailability (SEU).

$$EU = (EOH / PH) \times 100 \quad (\%)$$

$$FEU = (EFOH / PH) \times 100 \quad (\%)$$

$$SEU = (ESOH / PH) \times 100 \quad (\%)$$

Note 3 to entry: SEU covers both scheduled energy unavailability due to planned outage (SEUP) as well scheduled energy unavailability due to deferred outage (SEUD).

3.5.2
energy availability
EA
measure of the energy which could have been transmitted except for limitations of capacity due to outages

Note 1 to entry: The energy availability is calculated based on the same point in the system used for defining P_m.

$$EA = 100 – EU\ (\%)$$

3.5.3
energy utilization
U
factor giving a measure of the energy actually transmitted over the system.

Note 1 to entry: The energy utilization is calculated based on the same point in the system used for defining P_m.

$$U = \frac{E_{total}}{P_m \cdot P_h} U = \frac{E_{total}}{P_m \cdot P_h} \times 100\ \%$$

Where

E_{total} is the total energy transmitted (MWh);

P_m is the rated capacity (MW);

P_h is the period hours (h).

Note 2 to entry: The total energy transmitted is the sum of energy exported and energy imported (expressed in MWh), both referred to the point at which P_m is defined.

3.6 Commutation failure performance terms

3.6.1
recordable a.c. system fault
a.c. system fault which causes one or more of the inverter a.c. bus phase voltages, referred to the terminals of the harmonic filter, to drop immediately following the fault initiation below 90 % of the voltage prior to the fault

Note 1 to entry: AC system faults at, or near, the rectifier are not relevant in this context and are not required to be included in this reporting. An exception to this rule is a special case where the network topology dictates that an a.c. fault near the rectifier also produces a simultaneous recordable fault at the inverter or where specific converter configuration (e.g. no smoothing reactor) is susceptible to a commutation failure in rectifier operation.

3.6.2
commutation failure start
CFS(A)
initiation or onset of commutation failure(s) in any valve group immediately following the occurrence of an a.c. system fault, regardless of whether or not the a.c. fault is "recordable" as defined in 3.6.1

Note 1 to entry: Commutation failures as a result of control problems or switching events are not to be included.

3.6.3
commutation failure start
CFS(B)
initiation or onset of commutation failure(s) in any valve group as a result of control problems, switching events or other causes, but excluding those initiated by a.c. system faults under 3.6.2 above.

3.7 Abbreviations and symbols

For the purpose of this document, the following abbreviations apply.

AC (a.c.)	alternating current
AFOH	actual forced outage hours
AOD	actual outage duration
AOH	actual outage hours
ASOH	actual scheduled outage hours
CFS	commutation failure start
CT	current transformer
DC (d.c.)	direct current
DMR	dedicated metallic return (conductor)
EA	energy availability
EFOD	equivalent forced outage duration
EFOH	equivalent forced outage hours
EOD	equivalent outage duration
EOH	equivalent outage hours