

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

AMENDMENT 1  
AMENDEMENT 1

Determination of power losses in high-voltage direct current (HVDC) converter stations with line-commutated converters

Détermination des pertes en puissance dans les postes de conversion en courant continu à haute tension (CCHT) munis de convertisseurs commutés par le réseau

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## FOREWORD

This amendment has been prepared by subcommittee 22F: Power electronics for electrical transmission and distribution systems, of IEC technical committee 22: Power electronic systems and equipment.

The text of this amendment is based on the following documents:

CDV	Report on voting
22F/214/CDV	22F/224/RVC

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

The committee has decided that the contents of this amendment and the base 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

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- withdrawn,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

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**Determination of power losses in high-voltage direct current (HVDC) converter stations.**

*Replace the title of the document as follows:*

**Determination of power losses in high-voltage direct current (HVDC) converter stations with line-commutated converters**

## 2 Normative references

*Delete the following reference:*

IEC 60289:1988, *Reactors*

*Replace the existing references to IEC 60076-1:1993, IEC 60633:1998, IEC 60700-1:1988, IEC 60747-6:1983 and IEC 60871-1:1997 as follows:*

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

IEC 60633, *Terminology for high-voltage direct current (HVDC) transmission*

IEC 60700-1, *Thyristor valves for high voltage direct current (HVDC) power transmission – Part 1: Electrical testing*

IEC 60747-6, *Semiconductor devices – Part 6: Thyristors*

IEC 60871-1, *Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V – Part 1: General*

*Add the following new reference:*

IEC 60076-6, *Power transformers – Part 6: Reactors*

### 3 Definitions and symbols

#### 3.1 Definitions

*Add the following new definition*

##### 3.1.7

##### **station essential auxiliary load**

load whose failure will affect the conversion capability of the HVDC converter station (e.g. valve cooling), as well as load that must remain working in case of complete loss of a.c. power supply (e.g. battery chargers, operating mechanisms)

NOTE Total “operating losses” minus “no load operation losses” may be considered as being quantitatively equivalent to “load losses” as in conventional a.c. substation practice.

#### 3.2 Letter symbols

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*Replace the definitions of letter symbols  $\alpha$ ,  $\mu$ ,  $I_d$ ,  $R$  and  $U_{V0}$  as follows:*

- $\alpha$  (trigger) delay angle, in radians (rad) [IEC 61803:1999/AMD1:2010](https://standards.iteh.ai/catalog/standards/sist/ab167bec-8e0e-47b6-a979-956a0c/iec-61803-1999-amd1-2010)
- $\mu$  overlap angle, in radians (rad) <https://standards.iteh.ai/catalog/standards/sist/ab167bec-8e0e-47b6-a979-956a0c/iec-61803-1999-amd1-2010>
- $I_d$  direct current, in amperes (A)
- $R$  resistance value, in ohms ( $\Omega$ )
- $U_{V0}$  r.m.s. value of the phase-to-phase no-load voltage on the valve side of the converter transformer excluding harmonics, in volts (V)

##### 4.2.1 Outdoor standard reference temperature

*Add, after the first sentence, the following new sentence:*

Corresponding valve hall temperature may be defined by the supplier if necessary.

*Add the following note:*

NOTE If not defined, the wet-bulb temperature is recommended to be 14 °C which corresponds to approximately 50 % RH at 20 °C dry bulb temperature.

#### 4.3 Operating parameters

*Add the following words at the end of the fourth paragraph:*

“... or as decided by the control system for the defined operating condition”.

## 5.1 Thyristor valve losses

Replace, in the first line of the third paragraph, the words “Symbol  $t$  combines ...” with “Symbol  $th$  combines ...”.

### 5.1.4 D.C. voltage-dependent loss per valve

Replace the following equation for  $P_{V4}$ :

$$P_{V4} = \frac{U_{V0}^2}{2\pi R_{DC}} \left\{ \frac{4}{3} + \frac{\sqrt{3}}{4} [\cos(2\alpha) + \cos(2\alpha + 2\mu)] + \frac{6m^2 - 12m - 7}{8} [\sin(2\alpha) - \sin(2\alpha + 2\mu) + 2\mu] \right\}$$

with the following new equation:

$$P_{V4} = \frac{U_{V0}^2}{2\pi R_{DC}} \left\{ \frac{4}{3} \pi + \frac{\sqrt{3}}{4} [\cos(2\alpha) + \cos(2\alpha + 2\mu)] + \frac{6m^2 - 12m - 7}{8} [\sin(2\alpha) - \sin(2\alpha + 2\mu) + 2\mu] \right\}$$

### 5.2.3 Operating losses

Add the following note at the end of the subclause:

NOTE 3 The measured values for  $P_R$ ,  $P_{SE1}$ , and  $P_{WE1}$  are based on the reference temperature as given in IEC 60076-1. Values should be corrected to the operating temperature of the transformer.

### 5.2.4 Auxiliary power losses

Replace the final sentence as follows:.

They shall be measured separately during factory test.

#### 5.3.1 General

Add, at the end of the subclause, the following new paragraph:

For the calculation, it shall be assumed that the a.c. system operates at nominal frequency and the filter components are at their nominal values.

#### 5.3.2 AC filter capacitor losses

Add, at the end of the subclause, the following new paragraph:

Losses in low voltage capacitors (for filters with 2 or more tuning frequencies) are very small and can be neglected.

#### 5.3.3 AC filter reactor losses

Replace, in the third line, the phrase “...corrected to the maximum operating temperature of the winding....” with “...corrected to the operating temperature of the winding....”.

## 5.5 Shunt reactor losses

Replace, in the first paragraph, the reference to “IEC 60289” by “IEC 60076-6”.

## 5.6 DC smoothing reactor losses

Replace, in the third paragraph, the reference to “IEC 60289” by “IEC 60076-6”.

Replace the last sentence of the last paragraph as follows:

They shall be measured separately during the factory test.

### 5.7.3 DC filter reactor losses

Replace in the first paragraph, fourth line, the phrase “...corrected to the maximum operating temperature of the winding...” with “...corrected to the operating temperature of the winding”.

## 5.8 Auxiliaries and station service losses

Add, at the end of the first paragraph, the following new phrase:

“... if losses other than station essential auxiliary loads are required to be considered”.

Replace the second paragraph as follows:

The total station auxiliary losses shall be determined on an averaged basis for no-load operation mode and for the appropriate load level(s) of the station. The losses shall be determined for normal steady-state operating conditions by calculation or direct measurements on the main feeder(s) at each source.

Add, after the second paragraph, the following note:

NOTE Purpose is to determine the average loss during normal operation but not to determine the maximum losses.

Insert, after the third paragraph, the following new paragraph:

If auxiliaries and station service losses are determined by measurement, the following procedures shall be considered.

## 5.9 Radio interference/PLC filter losses

Replace the title as follows:

### 5.9 Series filter losses

Add, at the end of the first paragraph, the following new sentence:

In other applications series filters are used to prevent harmonic interaction between the interconnected a.c. systems or for other purposes.

Replace the second equation for series filters in the d.c. connections as follows:

$$P = I_d^2 \times R + \sum_{n=12}^{n=48} \frac{I_n^2 \times X_n}{Q_n}$$

Replace the first entry of the key for the formula as follows:

$R$  is the d.c. resistance of the reactor, in ohms;

## **Annex A (normative) – Calculation of harmonic currents and voltages**

### **A.3 Harmonic voltages on the d.c. side**

*Replace the formula of the second entry of the key with the following:*

$$F_2 = \frac{(k_3^2 + k_4^2 - 2k_3 \times k_4 \times \cos(2\alpha + \mu))^{1/2}}{\sqrt{2}}$$

## **Annex C (informative) – Bibliography**

*Add the following new references:*

IEC 61378-2:2001, *Convertor transformers – Part 2: Transformers for HVDC applications*

IEC 61378-3:2006, *Convertor transformers – Part 3: Application guide*

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