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INTERNATIONAL STANDARD

NORME INTERNATIONALE

AMENDMENT 2
AMENDEMENT 2

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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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

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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/374/CDV	22F/393A/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 website 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- withdrawn,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.

CONTENTS

5.9 Series filter losse

Replace the entry as follows (to correct the misprint):

5.9 Series filter losses

3.1.1

auxiliary losses

Replace the existing definition by the following new definition and new note:

electric power required to feed the converter station auxiliary loads

NOTE 1 to entry: The auxiliary losses depend on the number of converter units used and whether the station is in no-load operation or carrying load, in which case the auxiliary losses depend on the load level.

3.1.2

no-load operation losses

Replace the term and its definition as follows:

3.1.2
equipment no-load operation losses
losses produced in an item of equipment with the converter station energised but with the converters blocked and all station service loads and auxiliary equipment connected as required for immediate pick-up of load to specified minimum power

3.1.4

operating losses

Replace the existing term by the following new term:

3.1.4
equipment operating losses

3.1.5

rated load

Replace the existing definition by the following new definition and note:

load related to operation at nominal values of d.c. current, d.c. voltage, a.c. voltage and converter firing angle

Note 1 to entry: The a.c. system shall be assumed to be at nominal frequency and its 3-phase voltages are nominal and balanced. The position of the tap-changer of the converter transformer and the number of a.c. filters and shunt reactive elements connected shall be consistent with operation at rated load, coincident with nominal conditions.

3.1.6

total station losses

Replace the existing term and its definition by the following new term, definition and notes:

3.1.6
total station operating losses
sum of all equipment operating losses (3.1.4) and corresponding auxiliary losses (3.1.1) at a particular load level

Note 1 to entry: It is recognised that some purchasers evaluate “total station no-load operation losses” (definition 3.1.8) and total station load losses individually instead of the evaluating “total station operating losses” (definition 3.1.6).

Note 2 to entry: "Operating losses” minus “no-load operation losses” may be considered as being quantitatively equivalent to “load losses” as in conventional a.c. substation practice.

Note 3 to entry: An illustrative example to derive “load losses”, “equivalent load losses” and corresponding “loss evaluation” is given in Annex D.

3.1.7

station essential auxiliary load

Delete, in the definition added by Amendment 1, the Note.

Insert, between 3.1.5 and 3.1.6 the following new entry 3.1.8:

3.1.8
total station no-load operation losses
sum of all equipment no-load operation losses (3.1.2) and corresponding auxiliary losses (3.1.1)

3.2 Letter symbols

Replace the definition of letter symbol α modified by Amendment 1, as follows:

α (trigger/firing) delay angle, in radians (rad)

4.1 Introduction

Delete, in the third sentence of the second paragraph, the additional blank spaces (misprint).

4.3 Operating parameters

Replace the second paragraph as follows:

The losses of HVDC converter stations are classified into two categories, referred to as operating losses (3.1.4 and 3.1.6) and no-load operation losses (3.1.2 and 3.1.8).

Add, to the last sentence of the subclause, the phrase "(without waiting for tap changer movement) to specified minimum power" *as follows*:

Station service loads and auxiliary equipment (e.g. cooling water pumps) shall be assumed to be connected as required for immediate pick-up of load for the converter station (without waiting for tap changer movement) to specified minimum power.

5.1.7 Turn-off losses per valve

Replace the first sentence of the subclause as follows:

These are additional losses due to reverse current flow in the thyristors at turn-off (see Figure 8).

Renumber the Note as Note 1 and add the following Note 2 at the end of the subclause:

NOTE 2 The most part of the thyristor turn-off losses resulting from this mechanism are dissipated within the thyristor itself, although part of the losses may be dissipated in other components such as the damping resistor and valve reactor.

5.2.2 No-load operation losses

Add, after the paragraph, the following new paragraph:

The transformer tap-changer position shall be as defined in 4.3.

Annex B – Typical station losses

Replace, in the table, the first line starting with "Thyristor valves" as follows:

Item	Typical losses at nominal operating conditions %
Thyristor valves	20 – 40

Replace the sentence under the table as follows:

The total station no-load operation losses range from 10 % to 20 % of the total station operating losses at rated power under nominal operating conditions.

Add, between Annex B and Annex C, the following new Annex D:

Annex D
(informative)

HVDC converter station loss evaluation – An illustration

This annex is included to provide an illustration only to describe the basic concept behind the loss evaluation of HVDC converter stations and is to be considered by readers as a guide only.

One of the purposes of HVDC converter station loss determination is to evaluate expected life time cost of associated electrical losses reasonably well; not the maximum losses at any time. This is also a mechanism to arrive at an optimum compromise between initial capital investment cost and life time operating cost associated with electrical losses. Actions which take very little time (like few seconds when moving a tap changer) are basically irrelevant in this aspect of evaluating losses as this is to cover a very long period (like 25 years). Similarly, events which last for a short duration should be disregarded for purpose of loss evaluation (e.g. maximum ambient temperature, instead of use of yearly average ambient temperature to be considered). Further, considering operating loss at full load only may not represent the losses corresponding to actual load curve of most of HVDC systems. Hence a realistic method is recommended to be considered by adopting suitable weighting factors to a few sets of load as per expected loading patterns of the particular HVDC transmission link over a long period.

Cost of losses is associated between average price per hour of electricity, the interest rate applicable and design life of the HVDC project. The following formula is an example:

$$L = CE \times T \left\{ \frac{1-(1+R)^{-L}}{R} \right\}$$

where

CE is the cost of 1 kWh of electric energy at the present value ($);

T is the number of hours in a year that the HVDC equipment is expected to be in operation (hours);

R is the interest rate applicable to the investment in HVDC project (% / 100);

L is the life expectancy of the HVDC project (years).

Cost of losses may vary for example from 1 000 $/kW to 5 000 $/kW depending upon country, utility, project or other considerations. Different loss evaluation rates ($/kW) are also used many times for no-load/standby losses and load/operating losses depending upon the evaluation (e.g. cost of lost opportunity of transmitting equivalent energy) perceived by the owner/utility. This means that the owner/utility profits from this evaluation in addition to the cost of lost energy. It may be noted that in case a higher rate of loss evaluation rate is specified, it will lead to a higher initial capital investment cost which may not be optimum considering project utilisation.

The loss evaluation (also called loss capitalisation) figures should be adapted to the application of particular project considering necessary weighting factors depending upon the utilisation of the scheme/project and its expected cost of losses to the owner/utility. For a HVDC transmission scheme, the average time can be divided into:

- energised and in standby (no-load);
- transmitting on average different powers for different time;
- not energised.

In some case it is necessary to keep the system energised in standby mode even when not transmitting power, so that power can be transmitted without any delay and thus a concept of no-load and load loss is considered for loss evaluation (see Cases C and D below).

In some other cases it is not necessary to keep the system energised in standby mode when not transmitting power, in such a case, the concept of operating loss is to be considered for loss evaluation (see Case A, Case B and Case C below).

Some typical scenarios are considered below:

Case A A 3 000 MW HVDC project is expected to be transmitting basically 100 % rated power 100% of time.

Case B A 3 000 MW HVDC project is expected to be transmitting basically 100 % rated power for 9 months while not in operation for 3 months at all in a year.

Case C A 3 000 MW HVDC project is expected to be transmitting basically 100 % rated power for 9 months on average while in remaining 3 months it has to be kept in standby mode so that power transmission can be started immediately whenever required.

Case D A 3 000 MW HVDC project is expected to be basically energised all the time and transmitting following powers for following periods

0 % (0 MW) power but in standby – 10 % of time

10 % (300 MW) power – 10 % of time

50 % (1 500 MW) power – 60 % of time

100 % (3 000 MW) power – 20 % of time

It may be noted that above is just to illustrate method of loss evaluation while the number of loading points to be selected will vary as per specific project requirement.

Loss evaluation under various cases

A typical loss evaluation rate of 3 000 $/kW for total station no-load operation losses and 2 000 $/kW for total station operating losses is considered in below examples.

Case A:

In such a case, concept of operating loss is recommended to be adopted. If total station operating losses of whole station loss at rated power (3 000 MW) load are "d" kW, then loss evaluation would be $d \times 2\,000$ $.

Case B:

In such a case, concept of operating loss is recommended to be adopted. If total station operating losses of whole station loss at rated power (3 000 MW) load are "d" kW, then loss evaluation would be $d \times 2\,000 \times (9/12)$ $.

Case C:

In such a case, concepts of standby and operating loss are recommended to be adopted. If total station operating losses of whole station loss at rated power (3 000 MW) load are "d" kW and total station no-load operation losses are "a" kW, then loss evaluation would be $d \times 2\,000 \times (9/12) + a \times 3\,000\ (3/12)$ $.

Case D:

In such a case, concepts of no-load and load losses is recommended to be adopted. It is assumed that standby losses (which are considered the same as total station no-load operation losses) is "*a*" kW, whereas total station operating losses 10 %, 50 % and 100 % load are "*b*" kW, "*c*" kW and "*d*" kW respectively. It may be noted that losses "a" are calculated at different conditions, for example at a tap position which may be different, than conditions for which losses "*b*", "*c*" and "*d*" are calculated.

Loss in such case would be evaluated according to conditions shown in Table D.1:

Table D.1 — Conditions for calculation of losses in Case D

	Total station operating losses	**Time factor**
10 % load	*b*	0,10
50 % load	*c*	0,60
100 % load	*d*	0,20

Loss evaluation would be $a \times 3\,000 + (b \times 0{,}10 + c \times 0{,}60 + d \times 0{,}20) \times 2\,000$ $.