INTERNATIONAL STANDARD

IEC 62271-100

2001

AMENDMENT 2
2006-07

Amendment 2

High-voltage switchgear and controlgear –

Part 100:
High-voltage alternating-current circuit-breakers

*This **English-language** version is derived from the original **bilingual** publication by leaving out all French-language pages. Missing page numbers correspond to the French-language pages.*

International Electrotechnical Commission, 3, rue de Varembé, PO Box 131, CH-1211 Geneva 20, Switzerland
Telephone: +41 22 919 02 11 Telefax: +41 22 919 03 00 E-mail: inmail@iec.ch Web: www.iec.ch

Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

PRICE CODE V

For price, see current catalogue

FOREWORD

This amendment has been prepared by subcommittee 17A: High-voltage switchgear and controlgear, of IEC Technical Committee 17: Switchgear and controlgear.

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

FDIS	Report on voting
17A/754/FDIS	17A/761/RVD

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 maintenance result 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- withdrawn,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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CONTENTS

Add, to the list, the following new Annexes L and M:

Annex L (informative) Explanatory notes on the revision of TRVs for circuit-breakers of rated voltages higher than 1 kV and less than 100 kV

Annex M (normative) Requirements for breaking of transformer-limited faults by circuit-breakers with rated voltage higher than 1 kV and less than 100 kV

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3 Definitions

Add, on page 31, the following definitions after 3.1.127:

3.1.128
effectively earthed neutral system
system earthed through a sufficiently low impedance such that for all system conditions the ratio of the zero-sequence reactance to the positive-sequence reactance (X_0/X_1) is positive and less than 3, and the ratio of the zero-sequence resistance to the positive-sequence reactance (R_0/X_1) is positive and less than 1. Normally such systems are solidly earthed (neutral) systems or low impedance earthed (neutral) systems

NOTE For the correct assessment of the earthing conditions not only the physical earthing conditions around the relevant location but the total system is to be considered.

3.1.129
non-effectively earthed neutral system
system other than effectively earthed neutral system, not meeting the conditions given in 3.1.128. Normally such systems are isolated neutral systems, high impedance earthed (neutral) systems or resonant earthed (neutral) systems

NOTE For the correct assessment of the earthing conditions not only the physical earthing conditions around the relevant location but the total system is to be considered.

Add, on page 33, the following definitions after 3.4.118:

3.4.119
cable system
system in which the TRV during breaking of terminal fault at 100 % of short-circuit breaking current does not exceed the two-parameter envelope derived from Table 24 of this standard

NOTE 1 This definition is restricted to systems of rated voltages higher than 1 kV and less than 100 kV.

NOTE 2 Circuit-breakers of indoor substations with cable connection are generally in cable-systems.

NOTE 3 A circuit-breaker in an outdoor substation is considered to be in a cable-system if the total length of cable (or equivalent length when capacitors are also present) connected on the supply side of the circuit-breaker is at least 100 m. However if in an actual case with an equivalent length of cable shorter than 100 m a calculation can show that the actual TRV is covered by the envelope defined from Table 24, then this system is considered as a cable system.

NOTE 4 The capacitance of cable-systems on the supply side of circuit-breakers is provided by cables and/or capacitors and/or insulated bus.

3.4.120
line system
system in which the TRV during breaking of terminal fault at 100 % of short-circuit breaking current is covered by the two-parameter envelope derived from Table 25 of this standard and exceeds the two-parameter envelope derived from Table 24 of this standard

NOTE 1 This definition is restricted to systems of rated voltages equal to or higher than 15 kV and less than 100 kV.

NOTE 2 In line-systems, no cable is connected on the supply side of the circuit-breaker, with the possible exception of a total length of cable less than 100 m between the circuit-breaker and the supply transformer(s).

NOTE 3 Systems with overhead lines directly connected to a busbar (without intervening cable connections) are typical examples of line-systems.

3.4.121
circuit-breaker class S1
circuit-breaker intended to be used in a cable system

3.4.122
circuit-breaker class S2
circuit-breaker intended to be used in a line-system, or in a cable-system with direct connection (without cable) to overhead lines

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3.8 Index of definitions

Add the following definitions in the list of index:

C

Cable system 3.4.119

Circuit-breaker class S1 .... 3.4.121

Circuit-breaker class S2 .... 3.4.122

E

Effectively earthed neutral system 3.1.128

L

Line system 3.4.120

N

Non-effectively earthed neutral system 3.1.129

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4 Rating

Replace, on page 65, the existing item p) by the following:

p) characteristics for short-line faults related to the rated short-circuit breaking current, for circuit-breakers designed for direct connection to overhead lines, irrespective of the type of network on the source side, and rated at 15 kV and above and at more than 12,5 kA rated short-circuit breaking current;

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4.102.2 Representation of TRV

Replace, on page 75, the existing items b) and c) by the following:

b) Two-parameter reference line (see Figure 11):

u_c = reference voltage (TRV peak value), in kV;

t_3 = time in µs.

TRV parameters are defined as a function of the rated voltage (U_r), the first-pole-to-clear factor (k_{pp}) and the amplitude factor (k_{af}) as follows:

$$u_c = k_{pp} \times k_{af} \sqrt{(2/3)} \times U_r$$

where k_{af} is equal to

1,4 for terminal fault in the case of cable systems;

1,54 for terminal fault and short-line fault, in the case of line systems;

1,25 for out-of-phase;

t_3 for the supply side circuit for short-line fault = t_3 (terminal fault).

t_3 for out-of-phase = 2 × t_3 (terminal fault).

c) Delay line of TRV (see Figures 10 and 11):

t_d = time delay, in microseconds;

u' = reference voltage, in kilovolts;

t' = time to reach u', in microseconds

The delay line starts on the time axis at the rated time delay and runs parallel to the first section of the reference line of rated TRV and terminates at the voltage u' (time co-ordinate t').

For rated voltages lower than 100 kV:

t_d = 0,15 × t_3, for terminal fault and out-of-phase in the case of cable systems;

t_d = 0,05 × t_3, for terminal fault and short-line-fault in the case of line systems;

t_d = 0,15 × t_3, for out-of-phase in the case of line systems;

$u' = u_c/3$;

t' is derived from t_d and t_3 according to Figure 11, $t' = t_d + t_3/3$.

For rated voltages equal or higher than 100 kV:

t_d = 2 µs for terminal fault and for the supply side circuit for short-line fault;

t_d = 2 µs to 0,1 × t_1 for out-of-phase;

$u' = u_1/2$;

t' is derived from u', u_1/t_1 (RRRV) and t_d according to Figure 10, $t' = t_d + u'$/RRRV.

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4.102.3 Standard values of TRV related to the rated short-circuit breaking current

Replace the first paragraph by the following:

Standard values of TRV for three-pole circuit-breakers of rated voltages less than 100 kV make use of two parameters. Values are given in:

– Table 24, for cable systems;

– Table 25, for line systems.

Replace the fourth paragraph by the following:

The values given in the tables are prospective values. They apply to circuit-breakers for general transmission and distribution in three-phase systems having service frequencies of 50 Hz or 60 Hz and consisting of transformers, overhead lines and cables.

Replace the existing item b) by the following:

b) circuit-breakers directly connected to transformers without appreciable additional capacitance between the circuit-breaker and the transformer which provides approximately 50 % or more of the rated short-circuit breaking-current of the circuit-breaker. However the special case of circuit-breakers of rated voltage less than 100 kV with a connection of low capacitance to a transformer is covered in Annex M.

Replace the existing item c) by the following:

c) circuit-breakers in substations with series reactors (information is given in 8.103.7 and in Clause L.5 for circuit-breakers rated less than 100 kV);

Replace the sixth paragraph by the following:

The transient recovery voltage corresponding to the rated short-circuit breaking current when a terminal fault occurs, is used for testing at short-circuit breaking currents equal to the rated value. However, for testing with short-circuit breaking currents less than 100 % of the rated value, other values of transient recovery voltage are specified (see 6.104.5). Further additional requirements apply to circuit-breakers designed for direct connection to overhead lines, rated at 15 kV and above and having rated short-circuit breaking currents exceeding 12,5 kA, which may be operated in short-line fault conditions (see 4.105).

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4.102.3 Standard values of TRV related to the rated short-circuit breaking current

Replace, on page 79, title and Table 1a by the following tables:

Table 24 – Standard values of transient recovery voltage for class S1 circuit-breakers – Rated voltage higher than 1 kV and less than 100 kV – Representation by two parameters

Rated voltage U_r kV	Type of test	First-pole-to-clear factor k_{pp} p.u.	Amplitude factor k_{af} p.u.	TRV peak value u_c kV	Time t_3 µs	Time delay t_d µs	Voltage u' kV	Time t' µs	RRRV [a] u_c/t_3 kV/µs
3,6	Terminal fault	1,5	1,4	6,2	41	6	2,1	20	0,15
	Out-of-phase	2,5	1,25	9,2	82	12	3,1	40	0,11
4,76 [b]	Terminal fault	1,5	1,4	8,2	44	7	2,7	21	0,19
	Out-of-phase	2,5	1,25	12,1	88	13	4,0	43	0,14
7,2	Terminal fault	1,5	1,4	12,3	51	8	4,1	25	0,24
	Out-of-phase	2,5	1,25	18,4	102	15	6,1	49	0,18
8,25 [b]	Terminal fault	1,5	1,4	14,1	52	8	4,7	25	0,27
	Out-of-phase	2,5	1,25	21,1	104	16	7,0	50	0,20
12	Terminal fault	1,5	1,4	20,6	61	9	6,9	29	0,34
	Out-of-phase	2,5	1,25	30,6	122	18	10,2	59	0,25
15 [b]	Terminal fault	1,5	1,4	25,7	66	10	8,6	32	0,39
	Out-of-phase	2,5	1,25	38,3	132	20	12,8	64	0,29
17,5	Terminal fault	1,5	1,4	30	71	11	10,0	34	0,42
	Out-of-phase	2,5	1,25	44,7	142	21	14,9	69	0,31
24	Terminal fault	1,5	1,4	41,2	87	13	13,7	42	0,47
	Out-of-phase	2,5	1,25	61,2	174	26	20,4	84	0,35
25,8 [b]	Terminal fault	1,5	1,4	44,2	91	14	14,7	44	0,49
	Out-of-phase	2,5	1,25	65,8	182	27	21,9	88	0,36
36	Terminal fault	1,5	1,4	61,7	109	16	20,6	53	0,57
	Out-of-phase	2,5	1,25	91,9	218	33	30,6	105	0,42
38 [b]	Terminal fault	1,5	1,4	65,2	109	16	21,7	53	0,60
	Out-of-phase	2,5	1,25	97,0	218	33	32,3	105	0,45
48,3 [b]	Terminal fault	1,5	1,4	82,8	125	19	27,6	60	0,66
	Out-of-phase	2,5	1,25	123	250	38	41,1	121	0,49
52	Terminal fault	1,5	1,4	89,2	131	20	29,7	63	0,68
	Out-of-phase	2,5	1,25	133	262	39	44,2	127	0,51
72,5	Terminal fault	1,5	1,4	124	165	25	41,4	80	0,75
	Out-of-phase	2,5	1,25	185	330	50	61,7	160	0,56

[a] RRRV = rate of rise of recovery voltage.

[b] Used in North America.

Table 25 – Standard values of transient recovery voltage [c] for class S2 circuit-breakers – Rated voltage equal to or higher than 15 kV and less than 100 kV – Representation by two parameters

Rated voltage U_r kV	Type of test	First-pole-to-clear factor k_{pp} p.u.	Amplitude factor k_{af} p.u.	TRV peak value u_c kV	Time t_3 μs	Time delay t_d μs	Voltage u' kV	Time t' μs	RRRV [a] u_c/t_3 kV/μs
15 [b]	Terminal fault	1,5	1,54	28,3	31	2	9,4	12	0,91
	Short-line fault	1	1,54	18,9	31	2	6,3	12	0,61
	Out-of-phase	2,5	1,25	38,3	62	9	12,8	30	0,62
17,5	Terminal fault	1,5	1,54	33,0	34	2	11,0	13	0,97
	Short-line fault	1	1,54	22,0	34	2	7,3	13	0,65
	Out-of-phase	2,5	1,25	45	68	10	14,9	33	0,65
24	Terminal fault	1,5	1,54	45,3	43	2	15,1	16	1,05
	Short-line fault	1	1,54	30,2	43	2	10,1	16	0,70
	Out-of-phase	2,5	1,25	61	86	13	20,4	42	0,71
25,8 [b]	Terminal fault	1,5	1,54	48,7	45	2	16,2	17	1,08
	Short-line fault	1	1,54	32,4	45	2	10,8	17	0,72
	Out-of-phase	2,5	1,25	66	90	14	21,9	44	0,73
36	Terminal fault	1,5	1,54	67,9	57	3	22,6	22	1,19
	Short-line fault	1	1,54	45,3	57	3	15,1	22	0,79
	Out-of-phase	2,5	1,25	92	114	17	30,6	55	0,81
38 [b]	Terminal fault	1,5	1,54	71,7	59	3	23,9	23	1,21
	Short-line fault	1	1,54	47,8	59	3	15,9	23	0,81
	Out-of-phase	2,5	1,25	97	118	18	32,3	57	0,82
48,3 [b]	Terminal fault	1,5	1,54	91,1	70	4	30,4	27	1,30
	Short-line fault	1	1,54	60,7	70	4	20,2	27	0,87
	Out-of-phase	2,5	1,25	123	140	21	41,1	68	0,88
52	Terminal fault	1,5	1,54	98,1	74	4	32,7	28	1,33
	Short-line fault	1	1,54	65,4	74	4	21,8	28	0,88
	Out-of-phase	2,5	1,25	133	148	22	44,2	72	0,90
72,5	Terminal fault	1,5	1,54	137	93	5	45,6	36	1,47
	Short-line fault	1	1,54	91,2	93	5	30,4	36	0,98
	Out-of-phase	2,5	1,25	185	186	28	61,7	90	0,99

[a] RRRV = rate of rise of recovery voltage.

[b] Used in North America.

[c] For short-line faults: transient recovery voltage and time quantities are those of the supply circuit. Short-line fault is only applicable for circuit-breakers designed for direct connection to overhead lines.

Replace, on page 85 and Amendment 1, the heading of Table 2 by the following:

Table 2 – Standard multipliers for transient recovery voltage values for second and third clearing poles for rated voltages above 1 kV

Replace, on page 85, NOTE 1 by the following:

NOTE 1 Values for rated voltages less than 100 kV are under consideration.

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4.105 Characteristics for short-line faults

Replace the existing text of 4.105 by the following:

Characteristics for short-line faults are required for class S2 circuit-breakers designed for direct connection to overhead lines (without intervening cable connections) and having a rated voltage of 15 kV and above and a rated short-circuit breaking current exceeding 12,5 kA. These characteristics relate to the breaking of a single-phase earth fault in a system with earthed neutral, where the first-pole-to-clear factor is equal to 1,0.

NOTE In this standard, a single-phase test at phase-to-earth voltage covers all types of short-line fault (see Annex L, Clause L.3).

The short-line fault circuit is composed of a supply circuit on the source side of the circuit-breaker and a short-line on its load side (see Figure 15), with the following characteristics:

a) supply circuit characteristics:

- voltage equal to the phase-to-earth voltage $U_r/\sqrt{3}$ corresponding to the rated voltage U_r of the circuit-breaker;
- short-circuit current, in case of terminal fault, equal to the rated short-circuit breaking current of the circuit-breaker;
- prospective transient recovery voltage, in case of short-line fault, given by the standard values in
  - Table 25, for circuit-breakers in line systems with rated voltages less than 100 kV ;
  - Tables 1b and 1c, for circuit-breakers with rated voltages from 100 kV up to and including 170 kV;
  - Table 1d, for circuit-breakers with rated voltages 245 kV and above.
- ITRV characteristics for circuit-breakers of 100 kV and above derived from Table 3.

b) line characteristics:

- standard values of the RRRV factor, based on a surge impedance Z of 450 Ω, the peak factor k and the line side time delay t_{dL} are given in Table 4. For determination of the line side time delay and the rate-of-rise of the line side voltage, see Figure 16;
- the method for calculation of transient recovery voltages from the characteristics is given in Annex A.

Replace, on page 91, the existing Table 4, by the following new table:

Table 4 – Standard values of line characteristics for short-line faults

Rated voltage U_r kV	Number of conductors per phase	Surge impedance Z Ω	Peak factor k	RRRV factor 50 Hz s^* (kV/μs)/kA	 60 Hz	Time delay t_{dL} μs
$15 \le U_r \le 38$	1	450	1,6	0,200	0,240	0,1
$48,3 \le U_r \le 170$	1 to 4	450	1,6	0,200	0,240	0,2
$U_r \ge 245$	1 to 4	450	1,6	0,200	0,240	0,5
NOTE These values cover the short-line faults dealt with in this standard. For very short lines ($t_L < 5t_{dL}$) not all requirements as given in the table can be met. The procedures for approaching very short lines will be given in the application guide to this standard (currently prepared by CIGRE WG A3-11).						
* For the RRRV factor s, see Annex A.						

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4.106 Rated out-of-phase making and breaking current

Replace the existing item b) by the following:

b) the transient recovery voltage shall be in accordance with:

- Table 24, for circuit-breakers in cable systems with rated voltages less than 100 kV;
- Table 25, for circuit-breakers in line systems with rated voltages less than 100 kV;
- Tables 1b and 1c, for circuit-breakers with rated voltages from 100 kV up to and including 170 kV;
- Table 1d, for circuit-breakers with rated voltages 245 kV and above.

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Table 6 – Nameplate information

Replace, on page 113, the row on classification with the following:

	Abbreviation	Unit	Circuit-breaker	Operating device	Condition: Marking only required if
Classification			y		If different from E1, C1, M1, S1 for rated voltages less than 100 kV If different from E1, C1, M1 for rated voltages 100 kV and above

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Table 7 – Type tests

Replace "short-line fault tests *" *by the following:*

Short-line fault tests * # ($U_r \geq$ 15 kV and I_{sc} > 12,5 kA, in case of direct connection to overhead lines in systems with earthed neutral)

Page 203 and Amendment 1

6.104.5.1 General

Replace, on page 205, the fifth paragraph and item a) by the following:

TRV parameters are defined as follows as a function of the rated voltage (U_r), the first-pole-to-clear factor (k_{pp}) and the amplitude factor (k_{af}). The actual values of k_{pp} and k_{af} are stated in Tables 24, 25, 1b, 1c, 26, 27, 14a and 14b. The first-pole-to-clear factor k_{pp} is 1,3 as listed in Table 14a for all circuit-breakers rated 100 kV and above where systems are usually effectively earthed. For non-effectively earthed systems from 100 kV to 170 kV, k_{pp} = 1,5 as listed in Table 14b.

a) *For rated voltages less than 100 kV*

A representation by two parameters of the prospective TRV is used for all test-duties.

– In Table 26, for circuit-breakers in cable systems.

TRV peak value $u_c = k_{pp} \times k_{af} \sqrt{(2/3)} \times U_r$ where k_{af} is equal to 1,4 for test-duty T100, 1,5 for test-duty T60, 1,6 for test duty T30 and 1,7 for test duty T10, 1,25 for out-of-phase breaking.

Time t_3 for test-duty T100 is taken from Table 24. Time t_3 for test-duties T60, T30 and T10 is obtained by multiplying the time t_3 for test-duty T100 by 0,44 (for T60), 0,22 (for T30) and 0,22 (for T10).

– In Table 27, for circuit-breakers in line systems.

TRV peak value $u_c = k_{pp} \times k_{af} \sqrt{(2/3)} \times U_r$ where k_{af} is equal to 1,54 for test-duty T100 and the supply side circuit for short-line fault, 1,65 for test-duty T60, 1,74 for test duty T30 and 1,8 for test duty T10, 1,25 for out-of-phase breaking.

Time t_3 for test-duty T100 is taken from Table 25. Time t_3 for test-duties T60, T30 and T10 is obtained by multiplying the time t_3 for test-duty T100 by 0,67 (for T60), 0,40 (for T30) and 0,40 (for T10).

– Time delay t_d for test-duty T100 is 0,15 × t_3 for cable systems, 0,05 × t_3 for line systems, 0,05 × t_3 for the supply side circuit for short-line fault.

– Time delay t_d is 0,15 × t_3 for test-duties T60, T30 and T10 and for out-of-phase breaking.

– Voltage $u' = u_c/3$.

– Time t' is derived from u', t_3 and t_d according to Figure 11, $t' = t_d + t_3/3$.