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TECHNICAL REPORT

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AMENDMENT 1

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 62271-306:2012-12/AMD1:2018-08(en)

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FOREWORD

This amendment has been prepared by subcommittee 17A: Switching devices, of IEC technical committee 17: High-voltage switchgear and controlgear.

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

DTR	Report on voting
17A/1161/DTR	17A/1169/RVDTR

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- withdrawn,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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INTRODUCTION to the Amendment

At the SC 17A meeting held in Delft (NL) in 2013, the decision was made form a new maintenance team (MT 57) with the task to amend/revise IEC 62271-306. The objective was to update the publication to amendment 2 of IEC 62271-100. Together with MT 34 (IEC 62271-1), MT 36 (IEC 62271-100) and MT 28 (IEC 62271-101) the decision was made to move some of the informative annexes to IEC 62271-306.

This amendment includes the following significant technical changes.

- Annex G of IEC 62271-1:2007 has been included;
- Annexes E, G, H, J, L and Q of IEC 62271-1:2007 have been included;
- I.2 of IEC 62271-100:2008 + A1:2012 has been included;
- Informative parts of Annex O of IEC 62271-100:2008 have been included;
- Former Clause 14 has been added to Clause 13;

- Clause 14 now has heading "Synthetic making and breaking tests". This clause contains annexes A, B, C, D and G of IEC 62271-101;
- Clause 9 has been restructured;
- 16.4 (No-load transformer switching) has been rewritten;
- Annex B has been expanded to include information about fully compensated transmission lines and cables;
- Annex D has been rewritten.

1.2 Normative references

Replace the existing references to IEC 62271-100, IEC 62271-101 and IEC 62271-110 by the following new references:

IEC 62271-100:2008, *High-voltage switchgear and controlgear – Part 100: Alternating current circuit-breakers*
Amendment 1:2012
Amendment 2:2017

IEC 62271-101:2012, *High-voltage switchgear and controlgear – Part 101: Synthetic testing*

IEC 62271-110:2012, *High-voltage switchgear and controlgear – Part 110: Inductive load switching*

3.3 Capacitive current switching class C1 and C2

Replace the existing text of this subclause by the following new text:

Two classes are defined:

- Class C1: low probability of restrike;
- Class C2: very low probability of restrike.

IEC 60056 contained a definition of the term "restrike-free circuit-breaker". This definition was removed when the capacitive current switching requirements and test procedures were revised. The revised requirements and test procedures were first published in the first edition of IEC 62271-100 (published in 2001). The reason why the term "restrike-free circuit-breaker" was deleted from the standard was because it did not correspond to a physical reality.

The first edition of IEC 62271-100 introduced the term "restrike probability" during the type tests, corresponding to a certain probability of restrike in service, which depends on several parameters (see 9.4.6). For this reason, the term cannot be quantified in service.

The main differences in restrike performance between class C1 and C2 type tests are the number of tests shots and the allowable number of restrikes. Class C2 tests are performed on a pre-conditioned circuit-breaker. Pre-conditioning is done performing 3 breaking operations at 60 % of the rated short-circuit current. The pre-conditioning was derived based on CIGRE statistics and is considered to create interrupter wear that is broadly representative of long term service conditions.

The choice for the user between class C1 and C2 depends on:

- the service conditions;

- the operating frequency;
- the consequences of a restrike to the circuit-breaker or to the system.

Class C1 is acceptable for medium-voltage circuit-breakers and circuit-breakers applied for infrequent switching of transmission lines and cables.

Class C2 is recommended for capacitor bank circuit-breakers and those used on frequently switched transmission lines and cables.

The above given conditions are essential when choosing the circuit-breaker for a capacitive switching application, the needed performance class and the voltage factor should be known and demonstrated by the relevant type test. It is important to note that the performance class may vary for different capacitive current switching applications. For example, a circuit-breaker used to switch an overhead line may be tested for class C1 whereas the same circuit-breaker is tested in accordance with class C2 for capacitor bank switching.

6.1.3.1 TRVs for terminal faults

Delete the penultimate paragraph of this subclause.

Add, at the end of the existing 6.3, the following new subclauses, figures and tables.

6.4 General considerations regarding TRV

6.4.1 General

The purpose of 6.4 is to provide a background framework for some of the TRV requirements.

6.4.2 TRV waveshapes

In some cases, particularly in systems with a voltage 100 kV and above, and where the short-circuit currents are relatively large in relation to the maximum short-circuit current at the point under consideration, the transient recovery voltage contains first a period of high rate of rise, followed by a later period of lower rate of rise. This waveshape is generally adequately represented by an envelope consisting of three line segments defined by means of four parameters (see Figure 96).

The TRVs for terminal fault test-duties T100 and T60 represent cases where the major contribution of fault current is over transmission lines from multiple sources. The TRVs consist of the initial component at the fault bus and the additional component due to later arriving multiple reflected waves at the fault bus. The TRVs are overdamped (exponential) owing to the effect of the surge impedances of the lines and represented by four parameters to cover both of the above components. For terminal fault test duties T30 and T10 TRV cases, the fault current is from a single source and damping is determined by the involved circuit elements. The TRVs are underdamped (oscillatory) and thus represented by two parameters.

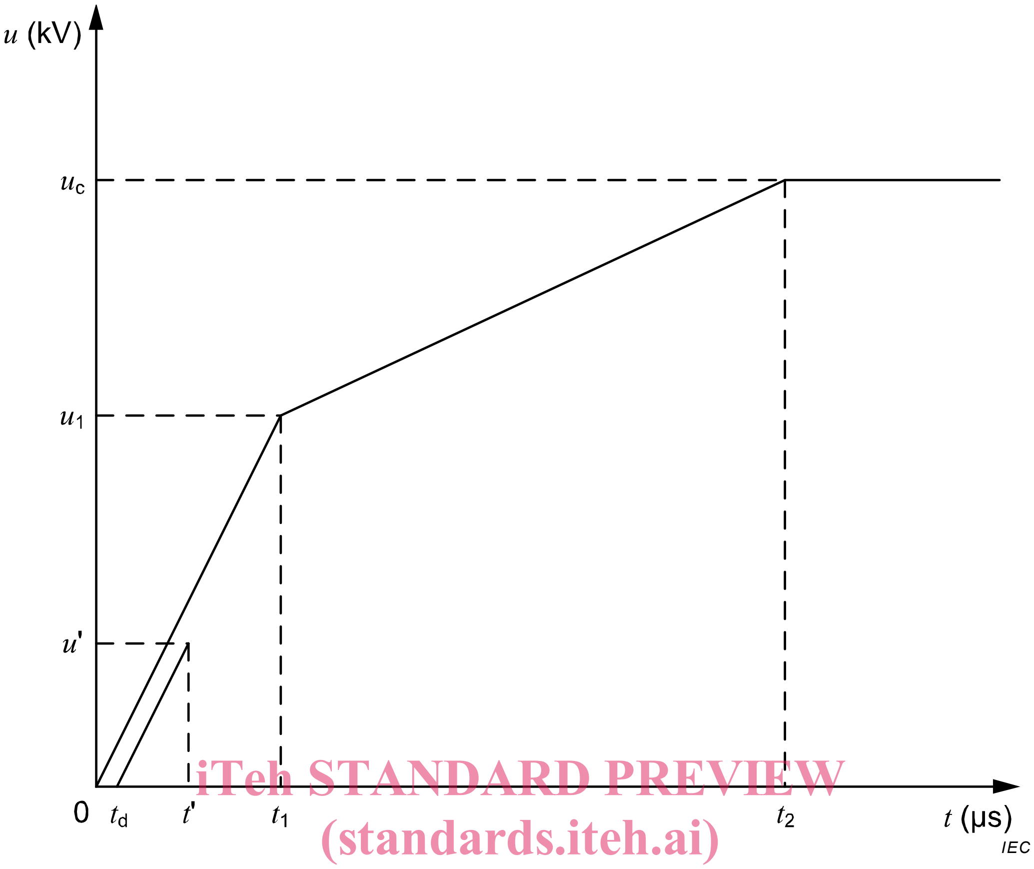

Figure 96 – Representation of a four-parameter TRV and a delay line

In other cases, particularly in systems with a voltage less than 100 kV, or in systems with a voltage greater than 100 kV in conditions where the short-circuit currents are relatively small in relation to the maximum short-circuit currents limited by transformers, the transient recovery voltage approximates to a damped single frequency oscillation. This waveshape is adequately represented by an envelope consisting of two line segments defined by means of two parameters (see Figure 97).

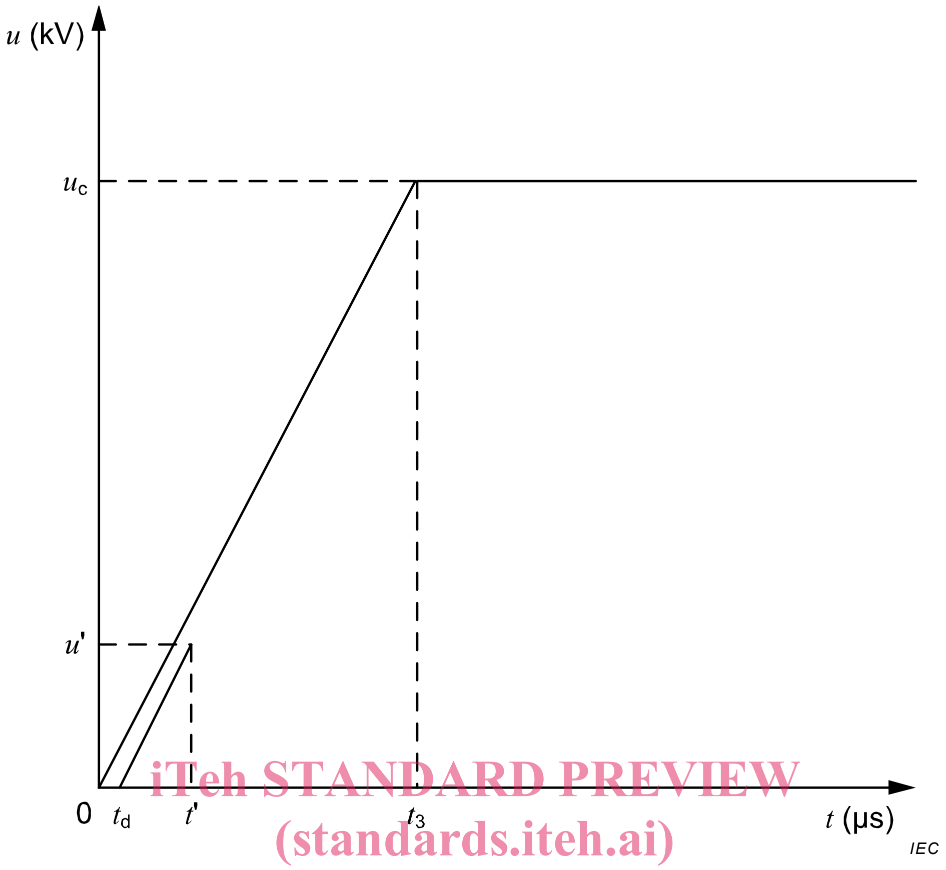

Figure 97 – Representation of a specified TRV by a two-parameter reference line and a delay line

Such a representation in terms of two parameters is a special case of representation in terms of four parameters.

The influence of local capacitance on the source side of the circuit-breaker produces a slower rate of rise of the voltage during the first few microseconds of the TRV. This is taken into account by introducing a time delay.

6.4.3 Earthing of the system

The system may be earthed in different ways depending on system voltage and application. The following definitions are used (Clause 3 of IEC 62271-100:2008 and as noted below):

solidly earthed (neutral) system (3.1.106 of IEC 62271-100:2008)
a system whose neutral point(s) is (are) directly earthed

[SOURCE: IEC 60050-601:1985, 601-02-25]

effectively earthed neutral system (3.1.128 of IEC 62271-100:2008)
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 three, and the ratio of the zero-sequence resistance to the positive-sequence reactance (R_0/X_1) is positive and less than one. Normally such systems are solidly earthed (neutral) systems or low impedance earthed (neutral) systems.

Note 1 to entry: 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.

non-effectively earthed neutral system (3.1.129 of IEC 62271-100:2008)
system other than effectively earthed neutral system, not meeting the conditions given in 3.1.128 of IEC 62271-100:2008. Normally such systems are isolated neutral systems, high impedance earthed (neutral) systems or resonant earthed (neutral) systems

Note 1 to entry: 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.

6.4.4 Power frequency recovery voltage and first-pole-to-clear factor

6.4.4.1 General

The first-pole-to-clear factor (k_{pp}) is a function of the earthing arrangements of the system. As defined in 3.7.152 of IEC 62271-100:2008, it is the ratio of the power frequency voltage across the interrupting pole before current interruption in the other poles, to the power frequency voltage occurring across the pole or poles after interruption in all three poles. For non-effectively earthed neutral systems, this ratio is or tends towards 1,5. For rated voltages less than 170 kV, such systems are quite common, particular within Europe and Japan.

For effectively earthed neutral systems, the realistic and practical value is dependent upon the sequence impedances of the actual earth paths from the location of the fault to the various system neutral points (the ratio X_0/X_1). The value used in IEC 62271-100 is taken to be ≤ 3 (see Equation (144)). The X_0/X_1 value is a standard value confirmed by system studies of various networks. Hence, for rating purposes, IEC 62271-100 considers two values for the three-phase short-circuit condition. These are adequate for the many, different, system earthing arrangements:

a) the non-effectively earthed, to cover all unearthed systems and those with some deliberate additional impedance in the neutral system. A standardised value for k_{pp} of 1,5 is used for all such systems;

b) all effectively earthed systems where it is accepted that some impedance exists. For standardization purposes for power systems operating at 800 kV and below the value for k_{pp} used is 1,3. For ultra-high-voltage (UHV) power systems operating above 800 kV, k_{pp} is 1,2 based on an X_0/X_1 ratio of 2.

For single-phase-to-earth faults in solidly or effectively earthed neutral systems, the pole factor k_{pp} is 1,0.

At transmission voltages, there has been an increase in interconnection and transformation, particularly in major urban systems. The high number of transformer neutrals connected effectively to earth causes the value of 1,3 to be questioned. Although this has been considered, the text of IEC 62271-100 does not take these developments into account. It is important for users with such systems to note that as k_{pp} decreases towards unity the value of the second-pole-to-clear factor will fall. In addition, the value of the phase currents will change. The three phases become three independent single-phases each with k_{pp} approaching 1,0. In general the users of such systems are aware of this possibility and of the need to consider the actual system conditions when assessing the suitability of their specified requirements and the test evidence they are offered against these.

For rated voltages higher than 800 kV, systems are characterized by long transmission lines and large transformers that contribute a relatively large part of the total short-circuit current. The first-pole-to-clear factor is function of the X_0/X_1 ratio that is in this case equal to or lower than 2,0, as a consequence k_{pp} is equal to or less than 1,2 and has been standardized to 1,2.

Where the ratio of three-phase to single-phase earth fault current is 1,0, k_{pp} is also 1,0. However, although this is normally assumed to be adequately covered by the use of the three-phase requirements and the associated k_{pp} of 1,2 or 1,3, it is important that evidence is provided to demonstrate the extended arc condition of the single-phase fault. In accordance with IEC 62271-100, a full extinguishing window shall be demonstrated.

It should be noted that in accordance with 6.108 of IEC 62271-100:2008, specific recovery voltage conditions are required to demonstrate the ability of a circuit-breaker to clear double earth faults.

Regarding earthing of the test circuit, reference is made to 6.103.3 of IEC 62271-100:2008.

6.4.4.2 Equations for the first, second and third-pole-to-clear factors

The equation for the first-pole-to-clear factor is:

$$k_{\mathrm{pp}} = \frac{3X_0}{X_1 + 2X_0} \tag{144}$$

where X_0 is the zero sequence, and X_1 the positive sequence reactance of the system. Table 39 gives the k_{pp} values for various earthing arrangements based on the definitions given in 6.4.1.

Table 39 – First-pole-to-clear factors k_{pp}

Earthing arrangement	X_0/X_1	k_{pp}	System voltage
Solidly earthed	1	1	All
Effectively earthed	2	1,2	> 800 kV
Effectively earthed	3	1,3	≤ 800 kV
Non-effectively earthed	∞	1,5	≤ 170 kV
NOTE Calculation of k_{pp} for the effectively earthed case (X_0/X_1 = 3) gives k_{pp} = 1,286 which is then rounded to 1,3.			

Following interruption of the first pole, the remaining two phases continue to conduct fault current.

In systems with non-effectively earthed neutrals the second and third poles interrupt in series under the phase-to-phase voltage so that for the second and third pole,

$$k_{\mathrm{p}} = \frac{\sqrt{3}}{2},$$

where k_{p} is the pole-to-clear factor of the individual poles.

In systems with effectively earthed neutrals the second pole clears with a pole-to-clear factor of,

$$k_{\mathrm{p}} = \frac{\sqrt{3(X_0^2 + X_0X_1 + X_1^2)}}{X_0 + 2X_1} \tag{145}$$

NOTE In Equations (144) and (145) the resistances are neglected.

Equation (145) can be expressed as a function of the ratio $\alpha = X_0/X_1$:

$$k_{\mathrm{p}} = \frac{\sqrt{3}\sqrt{\alpha^2 + \alpha + 1}}{2 + \alpha}$$

For the third-pole-to-clear in an effectively earthed system k_p = 1. Table 40 gives k_p for each clearing pole as a function of X_0/X_1 as appropriate.

Table 40 – Pole-to-clear factors for each clearing pole

X_0/X_1	**Pole-to-clear factor**		
Ratio	**First**	**Second**	**Third**
1	1,0	1,00	1,0
2	1,2	1,15	1,0
3	1,3	1,26*	1,0
∞	1,5	0,866	0,866

* Equation (145) assumes that system impedances are inductances only.

The respective multiplying factors for the peak value of the TRV (u_c) are given in Table 6 of IEC 62271-100:2008. It is important to note that the amplitude factor is the same for each pole. The multiplying factors are as applied to the power frequency voltages.

6.4.4.3 Standardised values for the second- and third- pole-to-clear factors

As discussed above, IEC 62271-100 has standardised values for the second and third-pole to clear factors for three-phase testing. Subclause 13.3 deals with this topic in relation to demonstration of arcing times for these poles and the appropriate pole factors relevant to each opening pole. It is important to note that on systems where the neutral earthing is solid, both the first-pole-to-clear factor of 1,3 and the values provided above for second pole-to-clear factors are lower. This is likely to be a rare occurrence, generally associated with urban systems where there are numerous effectively earthed transformers in close proximity. Where such differences are significant, the user is generally aware that it may be necessary to specify system-specific requirements and tests (e.g. extinguishing window and single-phase short-circuit current).

Circuit-breakers are rated on the basis of their ability to interrupt a three-phase to earth fault in either an effectively or non-effectively earthed neutral systems. Taking the former case, the three poles clear in sequence:

- The first pole clears with k_{pp} given by Equation (144) leaving a two-phase to earth fault.
- The second pole clears with k_p given by Equation (145) leaving a single-phase to earth fault. For the case of a two-phase to earth, the k_{pp} for the first clearing pole is also given by Equation (145).
- Third pole with k_p = 1 which is also applicable to the single-phase to earth fault case.

Similar logic can be applied to faults in non-effectively earthed neutral systems. A summary of the pole-to-clear factors for the different fault cases is given in Table 41.

Table 41 – Pole-to-clear factors for other types of faults in non-effectively earthed neutral systems

Type of fault	First-pole-to-clear	Second-pole-to-clear	Third-pole-to-clear
Phase-to-earth	1	-	-
Two-phase not involving earth	Simultaneous clearing of both poles: $k_\mathrm{p} = \dfrac{\sqrt{3}}{2}$	Simultaneous clearing of both poles: $k_\mathrm{p} = \dfrac{\sqrt{3}}{2}$	-
Two-phase-to-earth	$k_\mathrm{p} = \dfrac{\sqrt{3}\sqrt{\alpha^2 + \alpha + 1}}{2 + \alpha}$	1	-
Three-phase not involving earth	1,5	Simultaneous clearing of both poles: $k_\mathrm{p} = \dfrac{\sqrt{3}}{2}$	Simultaneous clearing of both poles: $k_\mathrm{p} = \dfrac{\sqrt{3}}{2}$

6.4.5 TRV characteristics

6.4.5.1 Terminal fault TRVs for rated voltages higher than 1 kV and less than 100 kV

6.4.5.1.1 General

Following the decision taken at the SC17A meeting in Beijing (CN) in October, 2002, IEC SC 17A/WG35 has prepared a proposal for the revision of TRVs for circuit-breakers rated above 1 kV and less than 100 kV.

This proposal used the input coming from former Working groups of CIGRE Study Committee A3 (Switching Equipment) that have studied the necessity to adapt the TRV requirements for circuit-breakers rated less than 100 kV. In 1983, a CIGRE SC A3 Task Force reported on Transient Recovery Voltages in Medium Voltage Networks. The results of the study have been published in Electra 88. Another CIGRE working group, WG 13.05, studied the TRVs generated by clearing transformer fed faults and transformer secondary faults. The results have been presented in Electra 102 (1985). In 1992, together with CIRED, CIGRE SC A3 created working group CC-03 to investigate again the definition of TRVs for medium voltage switchgear. The outcome of these investigations has been published in CIGRE Technical Brochure 134 (1998) and is in line with earlier studies.

The first edition of IEC 62271-100 (IEC 62271-100:2001) was amended in 2006 (Amendment 2) to include the new TRV values. The modifications can be summarized as follows:

a) In order to cover applications in all types of networks (distribution, industrial and sub-transmission) for rated voltages higher than 1 kV and less than 100 kV, and for standardization purposes, two types of systems and two classes of circuit-breakers are defined:

   – cable systems:

     cable-systems are defined in 3.1.132 of IEC 62271-100:2008;

   – line systems:

     line systems are defined in 3.1.133 of IEC 62271-100:2008;

   – Circuit-breaker class S1: circuit-breaker to be used in a cable system;

   – Circuit-breaker class S2: circuit-breaker to be used in a line system.

b) A particular test duty T30 is specified for the special case of circuit-breakers intended to be connected to a transformer with a connection of small capacitance (cable length less than 20 m), in order to verify their capability to interrupt transformer-limited faults. This is covered in Annex M of IEC 62271-100:2008.

In the general case where the capacitance of the connection is high enough, the normal test duty T30 demonstrates the capability to interrupt transformer-limited faults.

6.4.5.1.2 Terminal fault TRV for circuit-breakers in line systems

6.4.5.1.2.1 General

In North America, line systems are prevalent at 72,5 kV and below. Therefore, the TRV ratings as listed in Table 2 of ANSI C37.06-2000 were the basis to define the new Table 25 of IEC 62271-100:2008. The values for t_3 are 0,88 times the T_2 values specified in ANSI.

NOTE 1 The factor 0,88 is derived from a pure "1-cos"-waveshape multiplied with ½ amplitude factor. The standard TRV wave-shape "1-cos" in ANSI C37-06-2000 for rated voltages less than 100 kV did not coincide with the precise mathematical equation for parallel or series damped circuits, for which another ratio t_3/T_2 is applicable.

NOTE 2 TRV parameters are defined in the standard for rated voltages of 15 kV to 72,5 kV, for rated voltages less than 15 kV the TRV parameters can be derived using k_{pp} = 1,5, the values of amplitude factor, time t_3 and time delay given in 6.4.1.2.2.2, 6.4.1.2.2.3 and 6.4.1.2.2.4.

6.4.5.1.2.2 Amplitude factor

For T100, T60, T30 and T10 the following values were taken from ANSI C37.06-2000:

- 1,54 for T100;
- 1,65 for T60;
- 1,74 for T30;
- 1,8 for T10.

6.4.5.1.2.3 Time t_3

The rate-of-rise of recovery voltage (RRRV) is calculated using Equation (146),

$$\text{RRRV} = 0{,}4\,U_\text{r}^{0{,}305} \qquad (146)$$

Time t_3 for terminal fault is equal to $4{,}65 \times U_\text{r}^{0{,}7}$, with t_3 in µs and U_r in kV. Equation (146) was derived from the values given in Table 2 of ANSI C37.06-2000 for rated voltages 15,5 kV, 25,8 kV, 48,3 kV and 72,5 kV. The same equation is used for other rated voltages.

6.4.5.1.2.4 Time delay

The time delay in Table 25 of IEC 62271-100:2008 is derived using the following equation, t_d = 0,05 × t_3, as in the first edition of IEC 62271-100:2001 for rated voltages 48,3 kV – 52 kV and 72,5 kV. The equation has been extended to the lower rated voltages as no change in the initial part of the TRV wave-shape is expected (the initial part is exponential, even with the short line lengths that can be met in distribution and sub-transmission systems). This requirement is not judged excessive, as in the worst case (U_r = 15 kV), the time delay value of 2 µs is as specified for circuit-breakers with rated voltages higher than 72,5 kV.

It recognizes the fact that this time delay can be critical during short-line fault testing and test duty T100 with ITRV and has therefore to be taken into account. However, as shown in Tables 13 and 14 of the first edition of IEC 62271-100 published in 2001, such verification can be made when performing short-line fault tests. Therefore, as it is already the case for rated voltages higher than 38 kV, it is allowed to have a longer time delay during testing of T100, up to 0,15 × t_3, provided that short-line fault tests are performed. This possibility is indicated in Table 25 of IEC 62271-100:2008.

6.4.5.1.3 Terminal fault TRV for circuit-breakers in cable systems

6.4.5.1.3.1 Amplitude factor

For T60, the value of 1,5 in the first edition of IEC 62271-100:2001 is kept, due to the positive experience obtained.

For T30 and T10, the amplitude factor has been raised from 1,5 to respectively 1,6 and 1,7, as the contribution to TRV comes mainly from the voltage variation across transformer(s), which has low damping; this combined with source voltage results in a TRV with a relatively high amplitude factor.

For T100, the value of 1,4 in the first edition of IEC 62271-100 published in 2001 is retained owing to the positive experience with past editions of this standard.

6.4.5.1.3.2 Time delay

The time delay t_d is as given in the first edition of IEC 62271-100 published in 2001 for rated voltages less than 52 kV, $t_d = 0{,}15 \times t_3$. The equation is generalized to all cable systems (rated voltage less than 100 kV).

6.4.5.1.4 Terminal fault TRV for rated voltages equal to or higher than 100 kV

6.4.5.1.4.1 Amplitude factor

The values of the amplitude factors are given in IEC 62271-100. These values were adopted into IEC 62271-100 as a result of system studies and generally remain acceptable.

6.4.5.1.4.2 Rate-of-rise of recovery voltage and time delay

The values for the rate-of-rise-of-recovery-voltage (RRRV) for the first-pole-to-clear, and the associated time delay values, were derived from system studies, supported by system tests performed in and before the mid-1970s. The values adopted (2 kV/μs etc.) have been shown by this work to be adequate for all developed systems, and are generally acceptable for others. IEC 62271-100 gives multipliers for the RRRV for the second and third poles-to-clear. These values were derived by calculation.

6.4.5.1.5 Basis for the current TRV values of test-duty T10

Test-duty T10 is detailed in IEC 62271-100 and represents the following cases:

– a transformer limited fault condition with the circuit-breaker under consideration clearing a fault on the remote side of the transformer.

  In such circumstances, the fault current is limited by the impedance of the transformer to a value, chosen for standardization purposes, of approximately 10 %. The value of 10 % is historic, having been established from system studies and modelling using the typical impedance values of transformers of standardised ratings.

  For this duty, the fault-current is limited by the value of the impedance of the transformer. The TRV is also dominated by the transformer characteristics which give it a (1-cos) wave-shape form. The values given in IEC 62271-100 for amplitude factor, time coordinates and delay line have been established from system studies and modelling during the 1960s and before. The present values are accepted as being adequate for the vast majority of systems;

– a long line fault for circuit-breakers having a rated voltage of 245 kV and above

  For rated voltages below 245 kV, $k_{pp} = 1{,}5$ in view of the fact that the contribution of transformers to the short-circuit current is relatively larger at smaller values of the short-circuit current. Additionally, a comparatively large number of transformers having an unearthed neutral are in service in earthed neutral systems. As the damping of the TRV oscillation on a high-voltage transformer is less than in a network, an amplitude factor of

1,7 has been standardised except for line systems, with a voltage reduction across the transformer of 10 % for voltages of 100 kV and above.

Thus, the TRV peak u_c for test-duty T10 is $u_c = k_{pp} \times k_{af} \times U_r \sqrt{2/3}$ with the following parameters:

a) for rated voltages below 100 kV:
   1) for circuit-breakers in cable systems
      k_{pp} = 1,5 and k_{af} = 1,7.
   2) for circuit-breakers in line systems
      k_{pp} = 1,5 and k_{af} = 1,8.

b) for rated voltages of 100 kV up to and including 170 kV:
   k_{pp} = 1,5 and k_{af} = 0,9 × 1,7 = 1,53.

c) for rated voltages of 245 kV up to and including 800 kV:
   k_{pp} = 1,3 and k_{af} = 1,76.

d) for rated voltages above 800 kV:
   k_{pp} = 1,2 and k_{af} =1,76.

6.4.6 Short-line fault TRV

6.4.6.1 General

Short-line fault (SLF) is a mandatory duty for circuit-breakers with rated voltages 15 kV and above that are directly connected to overhead lines. As specified already in IEC 62271-100:2001 for circuit-breakers rated 48,3 kV and above, the rated short-circuit current shall be higher than 12,5 kA (i.e. $I_{sc} \geq 16$ kA).

As it is considered that there are only few line systems below 15 kV, no short-line fault breaking capability is required for rated voltages below 15 kV. In the rare cases where a circuit-breaker with a voltage rating below 15 kV is directly connected to an overhead line, no short-line fault requirement is necessary as the line contribution to the TRV would be too low to produce a significant stress.

NOTE For class S2 circuit-breakers, short-line fault test-duty L90 is not required as it would lead to an unrealistic short length of faulted line.

The short-line fault test specified is regarded as covering three-phase short-line faults as well as two-phase and single-phase faults for the following reasons:

– the representative surge impedance, seen from the terminals of the clearing pole, is such that for all cases the RRRV for all three poles to clear is covered by the specified characteristics listed in Table 8 of IEC 62271-100:2008;
– the single-phase short-line fault test, with an interrupting window of (180°−dα), covers the requirement for the multi-phase fault cases for effectively-earthed and non-effectively earthed systems;
– the withstand of the peak value of TRV during three-phase fault interruption is demonstrated by terminal fault test duty T100.

6.4.6.2 Rated voltage less than 100 kV

6.4.6.2.1 General

In IEC 62271-100:2001, short-line fault requirements have been specified for circuit-breakers with a rated voltage of 52 kV and 72,5 kV, in the range of rated voltages considered in this edition, and directly connected to overhead-lines.