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IEEE C37.60™



**High-voltage switchgear and controlgear –
Part 111: Automatic circuit reclosers and fault interrupters for alternating current
systems up to 38 kV**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 111: Automatic circuit reclosers and fault interrupters for alternating current systems up to 38 kV

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This second edition cancels and replaces the first edition, published in 2005, and constitutes a technical revision. The main changes with respect to the previous edition are as follows:

- a) addition of exclusion of devices with dependent manual operation to 1.1;
- b) harmonization of the amplitude factor k_{af} used for calculating the TRV for cable connected systems consistent with recent harmonization of the circuit-breaker standards between IEEE and IEC;
- c) deletion of requirements for radio influence voltage (RIV) tests;
- d) addition of specifications and ratings to cover the cutout recloser and its special requirements.

The text of this standard is based on the following IEC documents:

FDIS	Report on voting
17A/1010/FDIS	17A/1020/RVD

Full information on the voting for the approval of this standard 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.

A list of all parts of the IEC 62271 series can be found, under the general title *High-voltage switchgear and controlgear*, on the IEC website.

This standard is to be read in conjunction with IEC 62271-1:2007, to which it refers and which is applicable unless otherwise specified in this standard. In order to simplify the indication of corresponding requirements, the same numbering of clauses and subclauses is used as in IEC 62271-1. Amendments to these clauses and subclauses are given under the same references whilst additional subclauses are numbered from 101.

A list of IEEE participants can be found at the following URL:
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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 111: Automatic circuit reclosers and fault interrupters for alternating current systems up to 38 kV

1 Overview

1.1 Scope

This part of IEC 62271 applies to all overhead, pad mounted, dry vault and submersible single or multi-pole alternating current automatic circuit reclosers and fault interrupters for rated maximum voltages above 1 000 V and up to 38 kV.

Devices that require a dependent manual operation are not covered by this standard.

In order to simplify this standard where possible, the term recloser/FI (reclosers/FIs) has been substituted for automatic circuit recloser or fault interrupter or both.

1.2 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.

NOTE 1 In this dual logo standard, normative references are made to both an IEEE and IEC standards. In each case, the specifications in two referenced standards have been judged by the Maintenance Team to be technically equal even though the exact wording may be different. Differences in the wording are considered to be editorial only.²

IEC 60050-151:2001, *International Electrotechnical Vocabulary – Part 151:Electrical and magnetic devices*

NOTE 2 IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse (<http://www.iec.ch/>). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (<http://www.ansi.org>)

IEC 60050-441:1984, *International Electrotechnical Vocabulary – Chapter 441: Switchgear, controlgear and fuses*

IEC 60071-2:1996, *Insulation co-ordination – Part 2: Application guide*

IEC 60255-22-1:2007, *Measuring relays and protection equipment – Part 22-1:Electrical disturbance tests – 1 MHz burst immunity tests*

IEC 60255-22-4:2008, *Measuring relays and protection equipment – Part 22-4:Electrical disturbance tests – Electrical fast transients/burst immunity test*

IEC 60270, *High-voltage test techniques – Partial discharge measurements*

² Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement the standard.

IEC 60815 (all parts), *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions*

IEC 62271-1:2007, *High-voltage switchgear and controlgear – Part 1: Common specifications*

IEC 62271-100:2008, *High-voltage switchgear and controlgear – Part 100: Alternating-current circuit-breakers*

IEEE Std 1-2000™, *IEEE Recommended Practice – General Principles for Temperature Limits in the Rating of Electrical Equipment and for the Evaluation of Electrical Insulation*

NOTE 3 IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (<http://standards.ieee.org/>)

IEEE Std 4™, *IEEE Standard Techniques for High-Voltage Testing*

IEEE Std 693™, *IEEE Recommended Practice for Seismic Design of Substations*

IEEE Std C37.90.1™-2002, *IEEE Standard Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus*

IEEE Std C37.100™-1992, *IEEE Standard Definitions for Power Switchgear*

IEEE Std C57.12.28™, *IEEE Standard for Pad-Mounted Equipment – Enclosure Integrity*

IEEE Std C37.100.1™-2007, *IEEE Standard of Common Requirements for High Voltage Power Switchgear Rated above 1 000 V*

IEEE Std C37.301™, *IEEE Standard for High-Voltage Switchgear (Above 1 000 V) Test Techniques – Partial Discharge Measurements*

2 Normal and special service conditions

Clause 2 of IEC 62271-1:2007 is replaced by the following.

2.101 General

Unless otherwise specified, high-voltage switchgear and controlgear, including the operating devices and the auxiliary equipment which form an integral part of them, are intended to be used in accordance with their rated characteristics and the normal service conditions listed in 2.102.

If the actual service conditions differ from these normal service conditions, high-voltage switchgear and controlgear and associated operating devices and auxiliary equipment shall be designed to comply with any special service conditions required by the user, or appropriate arrangements shall be made (refer to 2.103).

NOTE 1 Appropriate action should also be taken to ensure proper operation under such conditions of other components, such as relays.

NOTE 2 Detailed information concerning classification of environmental conditions is given in IEC 60721-3-3 (indoor) and IEC 60721-3-4 (outdoor).

2.102 Normal service conditions

2.102.1 Indoor switchgear and controlgear

The normal service conditions for indoor switchgear and controlgear are:

- a) the ambient air temperature does not exceed 40 °C. The minimum ambient air temperature is -30 °C for class “minus 30 indoor”;
- b) the influence of solar radiation may be neglected;
- c) the altitude does not exceed 1 000 m above sea level (switchgear ratings are based on sea level);
- d) the ambient air is not significantly polluted and would be classified as having pollution level I “light” according to IEEE Std C37.100.1-2007, Table C.1 or IEC 60071-2:1996, Table 1;
- e) the conditions of humidity are as follows:
 - 1) the average value of the relative humidity, measured over a period of 24 h, does not exceed 95 %;
 - 2) the average value of the relative humidity, over a period of one month, does not exceed 90 %.

For these conditions, condensation may occasionally occur;

NOTE 1 Condensation can be expected where sudden temperature changes occur in periods of high humidity.

NOTE 2 To withstand the effects of high humidity and condensation, such as breakdown of insulation or corrosion of metallic parts, switchgear designed and tested for such conditions should be used.

NOTE 3 Condensation may be prevented by special design of the building or housing, by suitable ventilation and heating of the station or by the use of dehumidifying equipment. Other options include heaters with thermostats/humidistat inside the switchgear. Condensation may also be due to ground level rainwater or for underground applications, from incoming cable raceways connected to switchgear.

- f) vibration due to causes external to the switchgear and controlgear, or earth tremors are insignificant relative to the normal operating duties of the equipment and do not exceed the low performance level defined in IEEE Std 693. The manufacturer will assume that, in the absence of specific requirements from the user, there are none.

NOTE 4 The interpretation of the term “insignificant” is the responsibility of the user or specifier of the equipment. Either the user is not concerned with seismic events, or his or her analysis shows that the risk is “insignificant.”

2.102.2 Outdoor switchgear and controlgear

The normal service conditions for outdoor switchgear and controlgear are:

- a) the ambient air temperature does not exceed 40 °C. The minimum ambient air temperature is -30 °C for class “minus 30 outdoor”;
- Rapid temperature changes should be taken into account;
- b) solar radiation as much as 1 044 W/m² (a clear day at noon) may be expected. See IEEE Std C37.24 [1]³ for details on evaluating the effects of solar radiation;

NOTE 1 Under certain conditions of solar radiation, appropriate measures, e.g., roofing, forced ventilation, etc., may be necessary, or derating may be used in order not to exceed the specified allowable temperature rises. The specific latitude of location should be considered.

- c) the altitude does not exceed 1 000 m above sea level (switchgear ratings are based on sea level);

³ Numbers in square brackets refer to the bibliography.

- d) the ambient air may be polluted by dust, smoke, corrosive gas vapors, or salt. The pollution does not exceed the pollution level II—medium according to IEEE Std C37.100.1-2007, Table C.1 or IEC 60071-2:1996, Table 1;
- e) the ice coating shall be considered in the range from 1 mm up to, but not exceeding, 20 mm;

NOTE 2 Typical ice classes are 1 mm for class 1, 10 mm for class 10, and 20 mm for class 20.

- f) the wind speed does not exceed 34 m/s (122 km/h) (76 mi/h);
- g) the presence of condensation and/or precipitation should be taken into account;

NOTE 3 Characteristics of precipitation are defined in IEC 60721-2-2 [2] and IEEE Std 4.

- h) vibration due to causes external to the switchgear or earth tremors are insignificant relative to the normal operating duties of the equipment and do not exceed the low performance level defined in IEEE Std 693. The manufacturer will assume that, in absence of specific requirements from the user, there are none;

NOTE 4 The interpretation of the term “insignificant” is the responsibility of the user or specifier of the equipment. Either the user is not concerned with seismic events, or his or her analysis shows that the risk is “insignificant.”

- i) for submersible units, the water head does not exceed 3 m above the base of the enclosure during occasional submersion. Exposure to chemical or electrochemical reactions may be encountered in a sub-grade environment. The sub-grade environment may contain chemicals that contribute to mild corrosive reactions.

2.103 Special service conditions

2.103.1 General

When high-voltage switchgear and controlgear is used under conditions different from the normal service condition given in 2.102, the user's requirements should refer to standardized steps as follows.

Special service conditions shall be brought to the attention of those responsible for the manufacture of the equipment to define or prevent loss of performance or service life, if any, from specified values. Applicable standards such as those for altitude correction shall be used when available.

2.103.2 Altitude

The basis of rating for switchgear is standard reference atmosphere, commonly known as sea level conditions. Historically, switchgear has been successfully applied at altitudes up to 1 000 m without the use of an altitude correction factor.

For installations at an altitude higher than 1 000 m, the required insulation withstand level of external insulation at the service location shall be determined by multiplying the rated insulation levels at sea level by the altitude correction factor K_a in accordance with Figure K.1.

In this standard, the rated symmetrical interrupting current (rated short-circuit breaking current), related required capabilities and interrupting times need not be corrected for altitude.

NOTE This standard recognizes the revised IEEE treatment of altitude correction factors for applications above 1 000 m as specified in Figure 1 of IEEE Std C37.100.1-2007. This figure is reproduced in Annex K for reference and is not the same Figure 1 in IEC 62271-1:2007. Additional information about the differences between the IEEE and IEC treatment of altitude correction factors is also given in Annex K.

2.103.3 Pollution

For installation in polluted ambient air, pollution level III (heavy) or IV (very heavy) of IEC 60815 should be specified for outdoor installation.

For indoor installation, reference can be made to IEC/TS 62271-304.

2.103.4 Temperature and humidity

For installation in a location where the ambient temperature can be outside the normal (usual) service condition range stated in 2.102.1 and 2.102.2, the preferred ranges of minimum and maximum temperature to be specified should be selected from one of the following:

- a) -40 °C and +40 °C for cold climates (class “minus 40 outdoor” or class “minus 40 indoor”);
- b) -50 °C and +40 °C for very cold climates (class “minus 50 outdoor”);
- c) -15 °C and +50 °C for hot climates;
- d) -5 °C and +55 °C for very hot climates.

In certain regions with frequent occurrence of warm humid winds, sudden changes of temperature may occur resulting in condensation even indoors.

In tropical indoor conditions, the average value of relative humidity measured during a period of 24 h can be 98 %.

2.103.5 Vibrations, shock, or tilting

Standard switchgear and controlgear is designed for mounting on substantially level structures, free from excessive vibration, shock, or tilting. Where any of these abnormal conditions exists, requirements for the particular application should be specified by the user.

For installations where earthquakes are likely to occur, the severity level according to a relevant standard or specification (e.g. IEC 62271-300 or IEC 62271-207 and IEC 62271-210) should be specified by the user.

2.103.6 Wind speed

In some regions, for example in North America, a value for the wind speed is 40 m/s.

2.103.7 Other special (unusual) service conditions ⁴

When special environmental conditions prevail at the location where switchgear and controlgear is to be put in service, they should be specified by the user by reference to IEC 60721 series. Refer also to Annex M.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-441 IEC 60050-151, IEC 62271-1, IEEE Std C37.100-1992, as well as the following apply.

Additional terms and definitions are classified so as to be aligned with the classification used in IEC 60050-441.

⁴ Topics that are not covered in the common requirements standards are assigned a second level clause number beginning with number 101, e.g. 4.101 of this standard covers Rated minimum tripping current (for series-trip reclosers/FIs). Since this topic is not considered “common” to other relevant equipment switchgear standards, it is not included in the common requirements standard; the topic is unique to this standard.

3.1 General terms

3.1.101

accessible

admitting close approach because not guarded by locked doors, elevation, or other effective means

3.1.102

automatic circuit recloser

self-controlled device for making, carrying, and automatically interrupting and reclosing an alternating-current circuit, with a predetermined sequence of opening and reclosing followed by resetting, hold-closed, or lockout operation. It includes an assembly of control elements required to detect overcurrents and control the recloser operation

Note 1 to entry: Refer to Annex F for background information of an automatic circuit recloser.

3.1.103

cutout mounted recloser

single-phase automatic circuit recloser consisting of an interrupter which mounts in a fuse support or base as defined in IEEE Std C37.40 [3] and IEC 60282-2 [4]

3.1.104

dry vault

ventilated, enclosed area not subject to flooding

[SOURCE: IEEE Std C37.100:1992]

3.1.105

fault interrupter

self-controlled mechanical switching device capable of making, carrying, and automatically interrupting an alternating current. It includes an assembly of control elements to detect overcurrents and control the fault interrupter

Note 1 to entry: Refer to Annex G for background information of a fault interrupter.

[SOURCE: IEEE Std C37.100:1992]

3.1.106

pad-mounted equipment

pad mounted equipment

enclosed equipment, the exterior enclosure of which is at earth potential, positioned on a surface-mounted pad

Note 1 to entry: This definition is similar to that given in NESC (US) National Electrical Safety Code) C2-2012 ⁵ [5].

Note 2 to entry: The term "pad-mounted enclosure" is also defined in 3.9 of IEEE Std C57.12.28-2005 as follows: "An enclosure containing electrical apparatus, typically located outdoors at ground level where the general public has direct contact with the exterior surfaces of the equipment. The general construction of this equipment is such that authorized personnel may obtain direct access to the apparatus inside the equipment compartment(s)."

3.1.107

restrike (of an a.c. mechanical switching device)

resumption of current between the contacts of a mechanical switching device during a breaking operation with an interval of zero current of a quarter cycle of power frequency or longer

⁵ National Electrical Safety Code and NESC are both registered trademarks and service marks of the Institute of Electrical and Electronics Engineers, Inc.

[SOURCE: IEC 60050-441:1984, 441-17-46]

3.1.108

re-ignition

resumption of current between the contacts of a mechanical switching device during a breaking operation with an interval of zero current of less than a quarter cycle of power frequency

[SOURCE: IEC 60050-441:1984, 441-17-45]

3.1.109

series-trip recloser

recloser in which main-circuit current above a specified value, flowing through a solenoid or operating coil, provides the energy necessary to open the main contacts

Note 1 to entry: The IEEE definition for a series-trip recloser is similar to the IEC definition for a self-tripping circuit breaker. Reference: IEC 62271-100:2008, 3.4.118.

3.1.110

shunt-trip recloser

recloser in which the tripping mechanism, by releasing the holding means, permits the main contacts to open, with both the tripping mechanism and the contact opening mechanism deriving operating energy from other than the main circuit

3.1.111

submersible

constructed as to be successfully operable when submerged in water under specified conditions of pressure and time

Note 1 to entry: The IEEE definition for submersible is similar to the IEC 60050-151:2001, 151-16-42.

3.1.112

unit operation (of a recloser)

interrupting operation followed by a closing operation within a specified reclosing interval. The final interruption, after which lockout occurs, is also considered one unit operation

Note 1 to entry: See Figure 1. See also Annex L for a comparison of terms between IEEE and IEC.

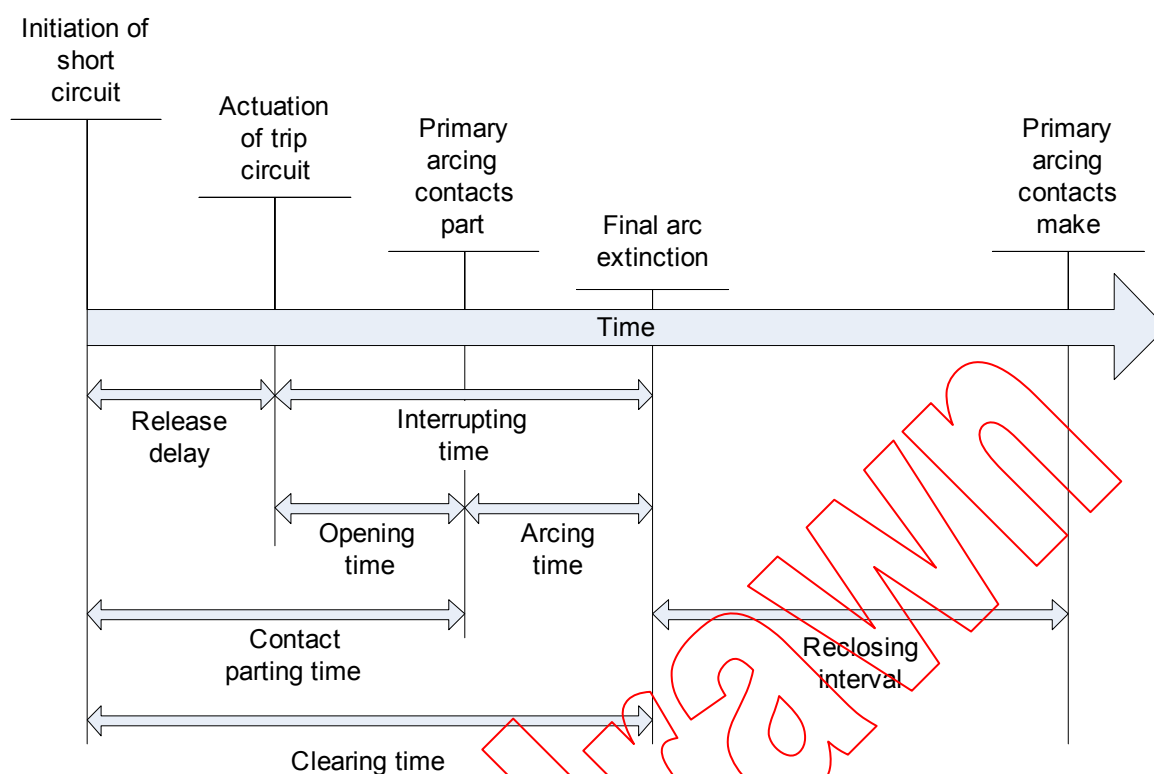


Figure 1 – Unit operation

3.2 Assemblies of switchgear and controlgear

No particular definitions.

3.3 Parts of assemblies

No particular definitions.

3.4 Switching devices

No particular definitions.

3.5 Parts of switchgear and controlgear

No particular definitions.

3.6 Operation

3.6.101

non-reclose

operational setting that blocks the automatic reclose function of a recloser causing it to be on a one-trip-to-lockout sequence

Note 1 to entry: The non-reclose setting causes the recloser to emulate the functionality of a fuse.

Note 2 to entry: The non-reclose setting is not the same as the Hot Line Tag function included in some reclosers.

3.7 Characteristic quantities

3.7.101

cable-charging current

current supplied to an unloaded shielded or belted cable

Note 1 to entry: Current is expressed in A r.m.s.

3.7.102

critical current

value of breaking current, less than rated short-circuit breaking current, at which the arcing time is a maximum and is significantly longer than at the rated short-circuit breaking current

Note 1 to entry: It will be assumed that this is the case if the minimum arcing times in any of the test-duties T20 or T50 is one half-cycle or more longer than the minimum arcing times in the adjacent test-duties.

3.7.103

non-sustained disruptive discharge

NSDD

disruptive discharge associated with current interruption that does not result in the resumption of power frequency current or, in the case of capacitive current interruption, does not result in current in the main load circuit

3.7.104

partial discharge extinction voltage

U_e

applied voltage at which repetitive partial discharges cease to occur in the test object when the voltage applied to the object is gradually decreased from a higher value at which partial discharge pulse quantities are observed

Note 1 to entry: In practice, the extinction voltage U_e is the highest applied voltage at which the magnitude of a chosen partial discharge pulse quantity becomes equal to, or less than, a specified low value.

3.7.105

partial discharge inception voltage

U_i

applied voltage at which repetitive partial discharges are first observed in the test object when the voltage applied to the object is gradually increased from a lower value at which no partial discharges are observed

Note 1 to entry: In practice, the inception voltage U_i is the lowest applied voltage at which the magnitude of a partial discharge pulse quantity becomes equal to or exceeds a specified low value.

3.7.106

prospective transient recovery voltage (of a circuit)

transient recovery voltage following the breaking of the prospective symmetrical current by an ideal switching device

Note 1 to entry: The definition assumes that the switching device or the fuse, for which the prospective transient recovery voltage is sought, is replaced by an ideal switching device, i.e. having instantaneous transition from zero to infinite impedance at the very instant of zero current, i.e. at the "natural" zero. For circuits where the current can follow several different paths, e.g. a polyphase circuit, the definition further assumes that the breaking of the current by the ideal switching device takes place only in the pole considered.

[SOURCE: IEC 60050-441:1984, 441-17-29]

3.7.107

reclosing interval (of an automatic circuit recloser)

open-circuit time between an automatic opening and the succeeding automatic reclosure

Note 1 to entry: The IEEE definition for reclosing interval is similar to the IEC definition 'dead time'. Reference IEC 62271-100:2008, 3.7.140. See Annex L.

3.8 Index of definitions

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4 Ratings

The ratings of the automatic circuit recloser, the cutout mounted recloser and the fault interrupter shall be as specified in Table 1.

**Table 1 – Ratings for automatic circuit recloser, cutout mounted
reclosers and fault interrupters**

Item	Rating description	Reference subclause	Automatic circuit recloser	Cutout mounted recloser	Fault Interrupter
1	Rated maximum voltage (V) or (U_r)	4.1	X	X	X
2	Rated insulation level (U_d), (U_p)	4.2	X	X ^{b,c}	X
3	Rated frequency (f_r)	4.3	X	X	X
4	Rated continuous (normal) current (I_r)	4.4	X	X	X
5	Rated short-time withstand current (I_k)	4.5	X	X	X
6	Rated peak withstand current (I_p)	4.6	X	X	X
7	Rated duration of short circuit (t_k)	4.7	X	X	X
8	Rated supply voltage of closing and opening devices and of auxiliary circuits (U_a)	4.8	X	--	X
9	Rated minimum tripping current (series-trip reclosers only)	4.101	X	X	X
10	Rated symmetrical interrupting current	4.102	X	X	X
11	Rated symmetrical (fault) making current	4.104	X	X	X
12	Rated operating sequence	4.105	X	X	X
13	Rated line-charging and cable-charging current switching	4.106 ^a	X	X ^d	X
14	Rated load (normal) current switching	^a	X	X ^d	X
15	Rated ice breaking capability	6.110	e	e	e
^a Line-charging, cable charging and load current switching are related required capabilities. ^b Rated insulation levels for a cutout mounted recloser are derived in part from the fuse support or base in which it is installed. The fuse support or base shall be considered a part of the cutout mounted recloser for the purpose of design testing. ^c Open position tests for cutout mounted reclosers are given for the device in the “dropped-out” position unless an operating sequence allows the device to rest with an open interrupter gap and a closed isolation gap in which case, both the isolation gap alone and the interrupter gap alone shall be tested for the open position test cases. ^d Switching capability for a cutout mounted recloser may require the use of an auxiliary open and closing device. The auxiliary open and closing device shall be considered a part of the cutout mounted recloser for the purpose of design testing. Consult manufacturer for operating details. ^e Ice rating of 1 mm is assumed unless a higher rating is declared by the manufacturer. See 6.110.					

4.1 Rated voltage (U_r)

The rated voltage (rated maximum voltage) indicates the upper limit of the highest voltage of the system for which reclosers/FIs are intended to operate.

NOTE For purposes of this standard, the term “rated voltage” (U_r) in IEC is equivalent to the term “rated maximum voltage” (V) in IEEE.

The preferred values of rated voltage of reclosers/FIs are those shown in Columns (2) and (3) of Table 2 and Table 3.

4.2 Rated insulation level

Subclause 4.2 of IEEE Std C37.100.1-2007 or IEC 62271-1:2007 is applicable, with the following modifications:

Table 1a and Table 1b of IEEE Std C37.100.1-2007 and IEC 62271-1:2007 are replaced by Table 2 and Table 3 of this standard.

Table 2 – Preferred voltage ratings and related test requirements applied on overhead line distribution circuits ^a

Line No.	Rated Maximum Voltage, kV		Rated lightning impulse withstand voltage ^b	Rated short-duration power-frequency withstand voltage ^b	
	IEEE Values (See Note 1)	IEC Values (See Note 1)		1 min dry	wet ^c
	kV, r.m.s.	kV, r.m.s.	kV, peak	kV, r.m.s.	kV, r.m.s.
(1)	(2)	(3)	(4)	(5)	(6)
1	--	12	75	28	28
2	15	--	95	36	30
3	15,5	--	110	50	45
4	--	17,5	95	38	38
5	--	24	125	50	50
6	27	--	125	60	50
7	--	36	150	70	70
8	38	--	150	70	60
9	--	36	170	70	70
10	38	--	170	70	60

^a The test values shown in Table 2 are for design tests; refer to 101.1 for field-testing.

^b Performance characteristics specified as test requirements in this standard.

^c Duration of wet test: 60 s for IEC ratings (column (3)) and 10 s for IEEE ratings in column (2); other differences besides time are involved. Refer to IEEE Std 4.

NOTE 1 IEEE values are generally used in most North American countries. IEC values are commonly found outside North America.

NOTE 2 Future designs should standardize the wet test procedure by adopting the IEC test protocol. This test protocol uses the same test voltage and duration as is used for the dry tests in column (5). Refer to IEEE Std 4.

Table 3 – Preferred voltage ratings and related test requirements for reclosers/FIs applied on cable connected distribution circuits ^a

Line No.	Rated Maximum Voltage, kV		Rated lightning impulse withstand voltage	Rated short-duration power-frequency withstand voltage ^b		DC withstand test ^{b,c}
	IEEE Values (See Note 1)	IEC Values (See Note 1)		1 min dry	wet ^d	
	kV, r.m.s.	kV, r.m.s.	kV, peak	kV, r.m.s.	kV, r.m.s.	kV
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	--	12	60	28	28	42
3	15,5	--	95	35	30	53
4	--	17,5	95	38	38	57
5	--	24	95	50	50	78
6	27	--	125	40	36	78
7	--	36	150	70	70	103
8	38	--	150	50	45	103
9	--	36	170	70	70	103
10	38	--	170	70	60	103

^a The test values shown in Table 3 are for design tests; refer to 101.1 for field-testing.

^b These are performance characteristics specified as test requirements in this standard.

^c DC withstand tests are required for pad mounted, dry vault and submersible gear since this type of equipment is interfaced to the power system via separable connectors. The test requirements of separable connectors are specified IEEE Std 386 [7] and these values are reproduced here in column (7). The d.c. withstand test requirement on the recloser/FI demonstrates its capability to withstand either d.c. withstand or Very low frequency (VLF) testing of connected cables.

^d Duration of wet test: 60 s for IEC ratings (column (3)) and 10 s for IEEE ratings in column (2); other differences besides time are involved. Refer to IEEE Std 4. Wet tests are not required for pad-mounted, dry vault and submersible reclosers/FI.

NOTE 1 DC withstand testing of 36/38 kV cables is not a recommended practice. Very low frequency (VLF) testing is used as an alternative to the d.c. withstand test. Reference IEEE Std 400.2 [8].

NOTE 2 Future designs should standardize the wet test procedure by adopting the IEC test protocol. This test protocol uses the same test voltage and duration as is used for the dry tests in column (5). Refer to IEEE Std 4.

NOTE 3 The d.c. withstand test duration was reduced to 5 min in the IEEE Std C37.60:2003 and IEC 62271-111:2005 revisions. In the current revision, the test duration is changed back to 15 min to harmonize with IEC standards.

NOTE 4 IEEE values are generally used in most North American countries. IEC values are commonly found outside North America.

4.3 Rated frequency (f_r)

The rated power-frequency shall be the frequency at which the recloser/FI and its components are designed to operate. The preferred rated power-frequencies are 50 Hz or 60 Hz.

4.4 Rated normal current and temperature rise

4.4.1 Rated normal current (I_r)

NOTE For purposes of this standard, the term "rated normal current" (I_r) in IEC is equivalent to the term "rated continuous current" (I_r) in IEEE.

Subclause 4.4.1 of IEEE Std C37.100.1-2007 or IEC 62271-1:2007 is applicable with the following addition:

The historic values of 600 A and 1 200 A are recognized as preferred values for existing designs.

4.4.2 Temperature rise

Subclause 4.4.2 of IEEE Std C37.100.1-2007 or IEC 62271-1:2007 is applicable with the following additions and modifications:

Table 3 of IEEE Std C37.100.1-2007 and IEC 62271-1:2007 is replaced by Table 4 of this standard.

NOTE Differences between the two tables are identified by NOTE 2 in Table 4.

- a) The temperature rise of any part of switchgear shall not exceed the temperature rise limits specified in Table 4 under the conditions specified in the test clauses.
- b) Reclosers/FIs shall be used under the usual service conditions defined in 2.102.
- c) Current ratings shall be based on the total temperature limits of the materials used. A temperature rise reference is given to permit testing at reduced ambient temperature.
- d) Reclosers/FIs designed for installation in enclosures shall have their ratings based on the ventilation of such enclosures and a 40 °C ambient temperature outside the enclosure.
- e) Outdoor reclosers/FIs and indoor reclosers/FIs without enclosures shall have ratings based on a 40 °C ambient temperature.

Withhold

Table 4 – Limits of temperature and temperature rise for various parts and materials of reclosers/Fis (1 of 2)

Nature of the part, of the material and of the dielectric (Refer to points 1, 2 and 3) (Refer to Note 1)		Maximum value	
		Temperature (°C)	Temperature rise at ambient air temperature not exceeding 40 °C (K)
1	Contacts (see point 4)		
	Bare-copper or bare-copper alloy		
	– In air	75	35
	– In SF ₆ (sulfur hexafluoride (see point 5)	105	65
	– In oil	80	40
	Silver-coated or nickel-coated (see point 6)		
	– In air	105	65
	– In SF ₆ (see point 5)	105	65
	– In oil	90	50
	Tin-coated (see point 6)		
	– In air	105 (Note 2)	65 (Note 2)
	– In SF ₆ (see point 5)	105 (Note 2)	65 (Note 2)
	– In oil	90	50
2	Connection, bolted or the equivalent (see point 4)		
	Bare-copper, bare-copper alloy or bar aluminum alloy		
	– In air	90	50
	– In SF ₆ (see point 5)	115	75
	– In oil	100	60
	Silver-coated or nickel-coated (see point 6)		
	– In air	115	75
	– In SF ₆ (see point 5)	115	75
	– In oil	100	60
	Tin-coated		
	– In air	105	65
	– In SF ₆ (see point 5)	105	65
	– In oil	100	60
3	All other contacts or connections made of bare metals or coated with other materials	(See point 7)	(See point 7)
4	Terminals for the connection to external conductors by screws or bolts (see points 8 and 14).	(See point 14)	(See point 14)
	– Bare	90	50
	– Silver, nickel or tin-coated	105	65
	– Other coatings	(See point 7)	(See point 7)
5	Oil for oil switching devices (see points 9 and 10)	80 (Note 2)	40 (Note 2)
6	Metal parts acting as springs	(See point 11)	(See point 11)

Table 4 (2 of 2)

Nature of the part, of the material and of the dielectric (see points and notes below)		Maximum value	
		Temperature (°C)	Temperature rise at ambient air temperature not exceeding 40 °C (K)
7	Materials used as insulation and metal parts in contact with insulation of the following classes (see point 12) – Y – A – E – B – F – Enamel: oil base – synthetic – H – C other insulating material	90 105 120 130 155 100 120 180 (See point 13)	50 65 80 90 115 60 80 140 (See point 13)
8	Any part of metal or of insulating material in contact with oil, except contacts	100	60
9	Accessible parts (See Note 2) – Expected to be touched in normal operation – Which need not be touched in normal operation	50 (Note 2) 70 (Note 2)	
NOTE 1 The points referred to in this table are those of 4.4.3. NOTE 2 Temperature rise in categories noted are not harmonized with IEEE Std C37.100.1-2007 or with IEC 62271-1:2007.			

4.4.3 Particular points of Table 4

The following points are referred to in Table 4 and shall be considered as part of the table:

- Point 1: According to its function, the same part may belong to several categories as listed in Table 4. In this case, the permissible maximum values of temperature and temperature rise to be considered are the lowest among the relevant categories.
- Point 2: For vacuum switching devices, the values of temperature and temperature rise limits are not applicable for parts in vacuum. The remaining parts shall not exceed the values of temperature and temperature rise given in Table 4.
- Point 3: Care shall be taken to ensure that no damage is caused to the surrounding insulating materials.
- Point 4: When engaging parts have different coatings or one part is of bare material, the permissible temperatures and temperature rises shall be the following:
- for contacts, those of the surface material having the lowest value permitted in item 1 of Table 4;
 - for connections, those of the surface material having the lowest value permitted in item 2 of Table 4.

NOTE 1 Point 4 is harmonized with IEEE Std C37.100.1-2007 but not with IEC 62271-1.

Point 5: SF₆ means pure SF₆ or a mixture of SF₆ and other oxygen-free gases.

NOTE 2 Due to the absence of oxygen, a harmonization of the limits of temperature for different contact and connection parts in the case of SF₆ switchgear appears appropriate. In accordance with IEC 60943:1998 [9], which gives guidance for the specification of permissible temperatures, the permissible temperature limits for bare copper and bare copper alloy parts can be equalized to the values for silver-coated or nickel-coated parts in the case of SF₆ atmospheres. In the particular case of tin-coated parts, due to fretting corrosion effects (refer to IEC 60943:1998) an increase of the permissible temperatures is not applicable, even under the oxygen-free conditions of SF₆. Therefore, the initial values for tin-coated parts are kept.

- Point 6: The quality of the coated contacts shall be such that a continuous layer of coating material remains in the contact area.
- a) after making and breaking test (if any),
 - b) after short-time withstand current test,
 - c) after the mechanical endurance test.

According to the relevant specifications for each equipment. Otherwise, the contacts shall be regarded as “bare.”

- Point 7: When materials other than those given in Table 4 are used, their properties shall be considered, notably in order to determine the maximum permissible temperature rises.
- Point 8: The values of temperature and temperature rise are valid even if the conductor connected to the terminals is bare.
- Point 9: At the upper part of the oil.
- Point 10: Special consideration should be given when low flash-point oil is used in regard to vaporization and oxidation.
- Point 11: The temperature shall not reach a value where the elasticity of the material is impaired.
- Point 12: Classes of insulating materials are those given in IEEE Std 1 or IEC 62271-1. Refer also to IEC 60085 [10].
- Point 13: Limited only by the requirement not to cause any damage to surrounding parts.
- Point 14: These values are for connections to bare (uninsulated) cables or bus conductors. For connections to insulated cables, terminals shall not exceed 45 K rise or 85 °C hottest spot total temperature when connected to 90 °C rated cables rated for the full continuous (normal) current of the recloser/FI.

NOTE 3 Point 14 is included in IEEE Std C37.100.1 but not in IEC 62271-1.

4.5 Rated short-time withstand current (I_k)

Subclause 4.5 of IEEE Std C37.100.1-2007 or IEC 62271-1:2007 is applicable with the following additions:

The rated short-time withstand current is the rms value of the current that the switchgear can carry in the closed position during a specified short time under prescribed conditions of use and behaviour.

The standard value of rated short-time withstand current for new design should be selected from the R10 series and shall be equal to the short-circuit rating assigned to switchgear. The historic values of 6 000 A and 12 000 A, are also considered as preferred values.

NOTE The R10 series comprises the numbers 1 – 1,25 – 1,6 – 2 – 2,5 – 3,15 – 4 – 5 – 6,3 – 8 and their products by 10ⁿ.

A recloser/FI is required, by definition, to open and interrupt any current within its symmetrical interrupting current rating with the duration of the current defined by its automatic control. This capability is demonstrated by the standard operating duty test defined in 6.103.4.

4.6 Rated peak withstand current (I_p)

Subclause 4.6 of IEEE Std C37.100.1-2007 or IEC 62271-1:2007 is applicable with the following addition:

The rated peak withstand current is associated with the rated symmetrical interrupting current unless higher values are stated by the manufacturer.

An automatic circuit recloser is required, by definition, to open and interrupt any current within its symmetrical interrupting current rating with peak currents determined by the X/R of the defined test circuits. This capability is demonstrated by the standard operating duty test defined in 6.103.4.

4.7 Rated duration of short-circuit (t_k)

Subclause 4.7 of IEEE Std C37.100.1-2007 or IEC 62271-1:2007 is applicable with the following addition:

The standard rated duration of short-circuit (t_k) is 0,5 s unless otherwise stated by the manufacturer and listed on the nameplate. Optional preferred values are 1 s, 2 s and 3 s.

4.8 Rated supply voltage of closing and opening devices and of auxiliary and control circuits (U_a)

Subclause 4.8 of IEEE Std C37.100.1-2007 or IEC 62271-1:2007 is applicable with the following additions and modifications:

NOTE 1 Subclause 4.8 of IEEE Std C37.100.1-2007 and IEC 62271-1:2007 is not applicable to line-powered or self-powered devices such as series trip or control supplied by integrally mounted current transformers or internal batteries.

The test report shall state which standard, IEEE Std C37.100.1 or IEC 62271-1, was used to establish the rated supply voltage. In this standard, the term “control voltage” has the same meaning as “auxiliary supply voltage”.

NOTE 2 IEEE Std C37.100.1 specifies a minimum and maximum supply voltage in absolute values of voltage whereas IEC 62271-1 specifies the range as a fixed percent of the nominal rated value. The resulting ranges of acceptable operation are similar, but not identical.

4.9 Rated supply frequency of closing and opening devices and of auxiliary circuits

Subclause 4.9 of IEEE Std C37.100.1-2007 or IEC 62271-1:2007 is applicable.

4.10 Rated pressure of compressed gas supply for controlled pressure systems

For devices that use a compressed gas supply, the rated pressure of compressed gas supply for insulation and/or operation shall be stated by the manufacturer.

4.11 Rated filling levels for insulation and/or operation

The pressure in Pa or PSI (or density) or liquid mass shall be assigned by the manufacturer referred to atmospheric air conditions of 20 °C at which the gas-filled or liquid-filled switchgear is filled before being put into service.

4.101 Rated minimum tripping current ($I_{>min}$)

The minimum tripping current shall be stated by the manufacturer with a tolerance not to exceed the greater of $\pm 10\%$ or ± 3 A.

NOTE 1 The minimum tripping current for shunt-trip reclosers/FIs is variable and is independent of the rated continuous (normal) current. Information on specific reclosers/FIs should be obtained from the manufacturer.

NOTE 2 The term rated minimum tripping current (I_{min}) is similar to the term G_t in IEC 60255-151 [11].

4.102 Rated symmetrical interrupting current (short-circuit breaking current)

The rated symmetrical interrupting current is highest value of the symmetrical component of the short circuit current that the recloser/FI shall be capable of breaking under the conditions of use and behavior prescribed in this standard. Such a current is found in a circuit having a power-frequency recovery voltage corresponding to the rated voltage of the recloser/FI and having a transient recovery voltage equal to the value specified in 4.103.

NOTE 1 The term rated symmetrical interrupting current as used in this standard is equivalent to the term rated short-circuit current as used in IEEE Std C37.04 and short-circuit breaking current as used in IEC 62271-100.

The preferred rated symmetrical interrupting currents of reclosers/FIs shall be selected from the R10 series specified in IEC 60059 [12]. See Annex I for ratings for hydraulically controlled series-trip reclosers and oil interrupting reclosers.

NOTE 2 The R10 series comprises the numbers 1 – 1,25 – 1,6 – 2 – 2,5 – 3,15 – 4 – 5 – 6,3 – 8 and their products by 10^n .

The rated symmetrical interrupting current shall be based on the capability of the recloser/FI to interrupt the corresponding asymmetrical current in circuits having X/R values as given in Columns (5), (7), and (9) of Table 12 and with a power-frequency recovery voltage equal to the rated maximum voltage and with transient recovery voltages as defined in Tables 6, Table 7, Table 8, Table 9, Table 10 and Table 11.

4.103 Transient recovery voltage related to rated symmetrical interrupting current

4.103.1 General

The transient recovery voltage (TRV) related to the rated short-circuit breaking current is the reference voltage that constitutes the limit of the inherent transient recovery voltage of circuits that the recloser/FI shall be capable of withstanding under fault conditions.

NOTE 1 The terms “inherent transient recovery voltage” and “prospective inherent transient recovery voltage” are often used interchangeably. See 3.7.106.

The values given in Table 6, Table 7, Table 8, Table 9, Table 10 and Table 11 are prospective transient recovery voltage values for the test circuits. They apply to reclosers/FI for general distribution in three-phase systems having service frequencies of 50 Hz or 60 Hz and consisting of transformers, overhead lines and short lengths of cable or in cable connected circuits as outlined in Table 5.

In the applications where more severe TRV conditions exist, additional test requirements may be required. A particular case is where the recloser is directly connected to a transformer where a fault on the secondary side provides approximately 50 % or more of the rated symmetrical interrupting current of the recloser and without appreciable additional capacitance between the recloser and the transformer or fault. See Annex F and Annex G for additional information on the definition and application of reclosers and fault interrupters.

NOTE 2 For additional information on transformer-influenced TRV, refer to IEEE Std C37.06.1 [13] or IEC 62271-100.

4.103.2 Representation of TRV waves

The waveform of transient recovery voltages varies according to the arrangement of actual circuits. In systems where reclosers are applied with a rated voltage up to 38 kV, the transient recovery voltage approximates to a damped single frequency oscillation. This waveform is

adequately represented by an envelope consisting of two line segments defined by means of two parameters, a voltage parameter and a time parameter. This envelope is the straight-line boundary of a TRV with the 1-cosine wave shape produced by typical distribution circuits. Methods of drawing TRV envelopes are given in Annex C.

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.

4.103.3 Representation of TRV

The following parameters are used for the representation of TRV:

- a) Two-parameter reference line (see Figure 2):

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

t_3 is the time to reach u_c , in ms.

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:

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

where k_{af} is equal to 1,54 for terminal faults on overhead line and 1,4 for terminal faults on cable connected systems.

- $k_{pp} = 1,0$ for solidly earthed (grounded) systems,
- $k_{pp} = 1,3$ for effectively earthed (grounded) systems and
- $k_{pp} = 1,5$ for unearthed (ungrounded) systems.

the rate of rise of recovery voltage $u_c/t_3 = \text{RRRV}$, is specified as a function of the system voltage based on measurements from typical systems.

t_3 is derived from u_c and the specified value of the RRRV as $t_3 = u_c/\text{RRRV}$.

- b) Delay line of TRV (see Figure 2).

t_d is the time delay, in ms;

u' = reference voltage, in kV;

t' = time to reach u' , in ms.

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

$t_d = 0,15 \times t_3$, $u' = u_c/3$ and

t' is derived from u' , u_c/t_3 and t_d according to Figure 2, $t' = t_d + u'/\text{RRRV}$.

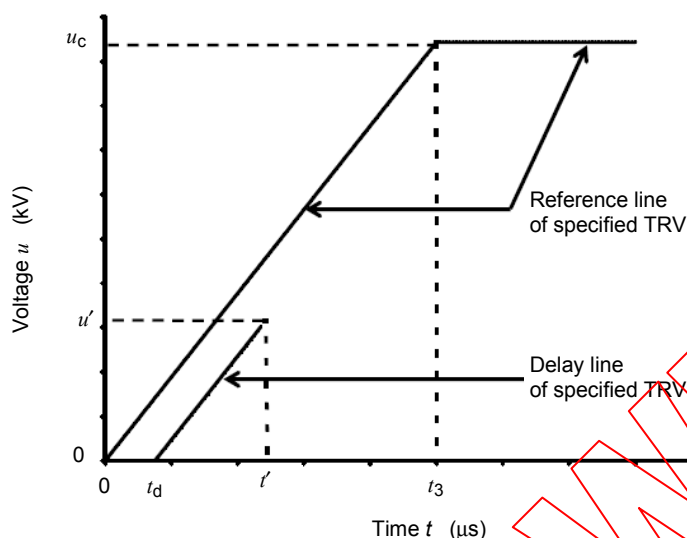


Figure 2 – Representation of the specified TRV as a two-parameter line and a delay line

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

4.103.4.1 General

The standard values of TRV for reclosers/FIs make use of the two parameters described in 4.103.2. Preferred values are given in Table 6, Table 7, Table 8, Table 9, Table 10 and Table 11 for the TRV peak values u_c , the TRV rate of rise of recovery voltage RRRV and the derived time to reach the TRV peak $t_3 = u_c/\text{RRRV}$. These parameters may be used for purposes of specification of TRV.

In Table 6, Table 7, Table 8, Table 9, Table 10 and Table 11, the terms T100, T50 and T20 are defined as the short-circuit test levels of 90 % to 100 %, 45 % to 55 %, and 15 % to 20 % of the rated symmetrical interrupting current respectively.

The transient recovery voltage corresponding to the rated symmetrical interrupting current when a terminal fault occurs, is used for testing at short-circuit breaking currents equal to the rated value. However, for testing at short-circuit breaking currents less than 100 % of the rated value, the TRV reaches a higher peak value and has a faster RRRV. The other values of transient recovery voltage at short-circuit breaking currents less than 100 % of the rated value are also specified in Table 6, Table 7, Table 8, Table 9, Table 10 and Table 11.

Table 5 – Listing of tables describing TRV values under different rating conditions

Table	1 or 3 poles	Application	Type of device	Interrupting current
Table 6	3	Overhead line Connected circuits	Recloser	> 4 000 A
Table 7	1		Recloser	> 4 000 A
Table 8	3	Cable connected circuits	Recloser	> 4 000 A
Table 9	1		Recloser	> 4 000 A
Table 10	3	Overhead line and Cable connected circuits	Reclosers	≤ 4 000 A
		Cable connected circuits	Fault interrupters	All ratings
Table 11	1	Overhead line and Cable connected circuits	Reclosers	≤ 4 000 A
		Cable connected circuits	Fault interrupters	All ratings

4.103.4.2 First-pole-to-clear factor (k_{pp})

The TRV values are a function of the first-pole-to-clear factor k_{pp} . The first-pole-to-clear factor is a function of the distribution system earthing (grounding) and the characteristics of the switchgear itself.

- a) Unearthed (ungrounded) systems – The preferred (and historic) basis of rating reclosers/FIs is for a three-phase unearthed (ungrounded) fault using a k_{pp} of 1,5. For three pole reclosers/FIs where the interrupter contacts part simultaneously, the TRV values in the tables are for the first pole to clear a three-phase unearthed (ungrounded) fault. The first-pole-to-clear factor of 1,5 is used making the voltage experienced by the first-pole-to-clear equal to 1,5 times line to neutral voltage.

For single pole reclosers/FI that are operated together in a three-phase installation, but where the interrupter contacts do not part simultaneously, the TRV values in the tables are still for the first phase to clear a three-phase unearthed (ungrounded) fault. A first-phase-to-clear factor of 1,732 is used since the voltage experienced by the first-pole-to-clear is equal to 1,732 times line to neutral voltage, which is the full phase-to-phase voltage. This accounts for the fact that with a large separation in the times at which the interrupters open, the worst case is that one interrupter sees the full phase-to-phase voltage. Examples of this condition are three independent single-phase reclosers operating in a cluster on a three-phase distribution feeder or a set of three single-phase reclosers operating from a common control (typically referred to as a triple-single recloser).

NOTE 1 The terms “ground” and “grounding” in IEEE are equivalent to the IEC terms “earth” and “earthing”.

- b) Solidly earthed (grounded) systems – For solidly earthed (grounded) distribution systems, the first-pole-to-clear factor of is 1,0 making the voltage experienced by the first-pole-to-clear equal to 1,0 times line-to-neutral voltage.

For actual single-phase operation with a single pole recloser/FI on a single-phase circuit, the circuit is typically connected from phase to neutral and the neutral is solidly earthed (grounded).

Although reclosers may be applied on solidly earthed (grounded) systems, the basis of rating and test requirements are for unearthed (ungrounded) systems using a first-phase-to-clear factor of 1,5 or 1,732 as explained in a) above.

- c) Effectively earthed (grounded) neutral systems – Some systems, including four-wire distribution circuits as frequently used in North America, are generally found to be effectively earthed (grounded) where a k_{pp} of 1,3 would be appropriate.

Reclosers/FIs that are tested for the unearthed (ungrounded) condition are considered suitable for the effectively earthed (grounded) systems and additional testing is not required by this standard.

NOTE 2 Three-phase testing with an effectively earthed (grounded) circuit may require special consideration by a test laboratory. Any consideration of such tests should be by agreement among the manufacturer, user and the test laboratory.

4.103.4.3 Rate of rise of recovery voltage (RRRV)

For reclosers where the rated short-circuit breaking current is $> 4\,000$ A r.m.s. and the recloser is applied in circuits connected by overhead lines, the TRV values, including the RRRV are essentially the same as those specified in the power circuit breaker standards. TRV values for these applications are covered in Table 6 and Table 7.

For reclosers where the rated short-circuit breaking current is $> 4\,000$ A r.m.s., but the recloser is applied in circuits connected by cables, the TRV values have RRRV values that are approximately 50 % of those for overhead line applications. The added capacitance of the cables slows down the TRV. TRV values for these applications are covered in Table 8 and Table 9.

For reclosers where the rated short-circuit breaking current is $\leq 4\,000$ A r.m.s., and where the recloser is applied in circuits connected by either overhead lines or cables, the TRV values have RRRV values that are 25 % of those for line applications where the rated short-circuit breaking current is $> 4\,000$ A r.m.s., and the recloser is applied in circuits connected by overhead lines. TRV values for these applications are covered in Table 10 and Table 11.

For fault interrupters of all interrupting ratings, the TRV values in Table 10 and Table 11 shall apply based on a cable-connected circuit.

NOTE 1 In Table 6, Table 7, Table 8 and Table 9, the TRV values are essentially the same as those specified in the power circuit breaker standards IEEE Std C37.04b [14], IEEE Std C37.06 [15] and IEC 62271-100.

NOTE 2 The RRRV values for applications where the rated short-circuit breaking current is $\leq 4\,000$ A r.m.s. are derived from the fuse standard C37.41-2000. [16]

Table 6 – Standard values of prospective transient recovery voltage representation by two parameters for three-phase reclosers with rated symmetrical interrupting currents > 4 000 A in overhead line connected circuits

Rated voltage	Test duty	First-pole-to-clear factor	Amplitude factor	TRV peak value	Time	Time delay	Voltage	Time	Rate of rise
U_r		k_{pp}	k_{af}	u_c	t_3	t_d	u'	t'	u_c/t_3
(kV)				(kV)	(μs)	(μs)	(kV)	(μs)	(kV/μs)
12	T100	1,5	1,54	22,6	29	4	7,5	14	0,77
12	T50	1,5	1,68	24,7	17	3	8,2	8	1,45
12	T20	1,5	1,77	26,0	12	2	8,7	6	2,21
15,5	T100	1,5	1,54	29,2	32	5	9,7	15	0,92
15,5	T50	1,5	1,68	31,9	18	3	10,6	9	1,73
15,5	T20	1,5	1,77	33,6	13	2	11,2	6	2,64
17,5	T100	1,5	1,54	33,0	34	5	11,0	16	0,97
17,5	T50	1,5	1,68	36,0	20	3	12,0	10	1,82
17,5	T20	1,5	1,77	38,0	14	2	12,7	7	2,78
24	T100	1,5	1,54	45,3	43	6	15,1	21	1,05
24	T50	1,5	1,68	49,3	25	4	16,4	12	1,97
24	T20	1,5	1,77	52,1	17	3	17,4	8	3,01
27	T100	1,5	1,54	59,9	47	7	17,0	23	1,08
27	T50	1,5	1,68	55,5	27	4	18,5	13	2,03
27	T20	1,5	1,77	58,6	19	3	19,5	9	3,10
36	T100	1,5	1,54	67,9	57	9	22,6	28	1,19
36	T50	1,5	1,68	74,0	33	5	24,7	16	2,24
36	T20	1,5	1,77	78,1	23	3	26,0	11	3,42
38	T100	1,5	1,54	71,7	59	9	23,9	29	1,21
38	T50	1,5	1,68	78,1	34	5	26,0	17	2,27
38	T20	1,5	1,77	82,4	24	4	27,5	11	3,47
Specified values in the table					Calculated values in the table				
U_r	=	Rated voltage			u_c	=	TRV peak value		
k_{pp}	=	First-pole-to-clear factor			u_c	=	$k_{pp} \times k_{af} \times U_r \sqrt{2/3}$		
k_{pp}	=	1,5			u_c	=	$0,816\ 5 \times k_{pp} \times k_{af} \times U_r$		
k_{af}	=	Amplitude factor			t_3	=	Time to u_c		
k_{af} (T100)	=	Specified	=	1,54	t_3	=	u_c / RRRV		
k_{af} (T50)	=	k_{af} (T100) $\times$ 1,09	=	1,68	t_d	=	Time delay for the delay line		
k_{af} (T20)	=	k_{af} (T100) $\times$ 1,15	=	1,77	t_d	=	$0,15 \times t_3$		
RRRV	=	Rate of rise of recovery voltage			u'	=	Voltage point for the delay line		
RRRV (T100)	=	Specified			u'	=	$u_c/3$		
RRRV (T50)	=	RRRV (T100) $\times$ 1,88			t'	=	Time to u'		
RRRV (T20)	=	RRRV (T100) $\times$ 2,87			t'	=	$t_d + u' / \text{RRRV}$		
NOTE The TRV values are calculated for unearthed systems and they cover earthed systems as well. See 4.103.4.2.									

Table 7 – Standard values of prospective transient recovery voltage representation by two parameters for single-phase reclosers with symmetrical interrupting currents > 4 000 A in overhead line connected circuit

Rated voltage	Test duty	First-pole-to-clear factor	Amplitude factor	TRV peak value	Time	Time delay	Voltage	Time	Rate of rise
U_r		k_{pp}	k_{af}	u_c	t_3	t_d	u'	t'	u_c/t_3
(kV)				(kV)	(μs)	(μs)	(kV)	(μs)	(kV/μs)
12	T100	1,732	1,54	26,1	34	5	8,7	16	0,77
12	T50	1,732	1,68	28,5	20	3	9,5	10	1,45
12	T20	1,732	1,77	30,1	14	2	10,0	7	2,21
15,5	T100	1,732	1,54	33,8	37	6	11,3	18	0,92
15,5	T50	1,732	1,68	36,8	21	3	12,3	10	1,73
15,5	T20	1,732	1,77	38,8	15	2	12,9	7	2,64
17,5	T100	1,732	1,54	38,1	39	6	12,7	19	0,97
17,5	T50	1,732	1,68	41,5	23	3	13,8	11	1,82
17,5	T20	1,732	1,77	43,8	16	2	14,6	8	2,78
24	T100	1,732	1,54	52,3	50	7	17,4	24	1,05
24	T50	1,732	1,68	57,0	29	4	19,0	14	1,97
24	T20	1,732	1,77	60,1	20	3	20,0	10	3,01
27	T100	1,732	1,54	58,8	54	8	19,6	26	1,08
27	T50	1,732	1,68	64,1	32	5	21,4	15	2,03
27	T20	1,732	1,77	67,6	22	3	22,5	11	3,10
36	T100	1,732	1,54	78,4	66	10	26,1	32	1,19
36	T50	1,732	1,68	85,5	38	6	28,5	18	2,24
36	T20	1,732	1,77	90,2	26	4	30,1	13	3,42
38	T100	1,732	1,54	82,8	68	10	27,6	33	1,21
38	T50	1,732	1,68	90,2	40	6	30,1	19	2,27
38	T20	1,732	1,77	95,2	27	4	31,7	13	3,47
Specified values in the table					Calculated values in the table				
U_r	=	Rated voltage			u_c	=	TRV peak value		
k_{pp}	=	First-pole-to-clear factor			u_c	=	$k_{pp} \times k_{af} \times U_r \sqrt{2/3}$		
k_{pp}	=	1,732			u_c	=	$0,816 \ 5 \times k_{pp} \times k_{af} \times U_r$		
k_{af}	=	Amplitude factor			t_3	=	Time to u_c		
k_{af} (T100)	=	Specified	=	1,54	t_3	=	u_c / RRRV		
k_{af} (T50)	=	k_{af} (T100) $\times$ 1,09	=	1,68	t_d	=	Time delay for the delay line		
k_{af} (T20)	=	k_{af} (T100) $\times$ 1,15	=	1,77	t_d	=	$0,15 \times t_3$		
RRRV	=	Rate of rise of recovery voltage			u'	=	Voltage point for the delay line		
RRRV (T100)	=	Specified			u'	=	$u_c / 3$		
RRRV (T50)	=	RRRV (T100) $\times$ 1,88			t'	=	Time to u'		
RRRV (T20)	=	RRRV (T100) $\times$ 2,87			t'	=	$t_d + u' / \text{RRRV}$		
NOTE The TRV values are calculated for unearthed systems and they cover earthed systems as well. See 4.103.4.2.									

Table 8 – Standard values of prospective transient recovery voltage representation by two parameters for three-phase reclosers with symmetrical interrupting currents > 4 000 A in cable connected systems

Rated voltage	Test duty	First-pole-to-clear factor	Amplitude factor	TRV peak value	Time	Time delay	Voltage	Time	Rate of rise
U_r		k_{pp}	k_{af}	u_c	t_3	t_d	u'	t'	u_c/t_3
(kV)				(kV)	(μs)	(μs)	(kV)	(μs)	(kV/μs)
12	T100	1,5	1,40	20,6	61	9	6,9	29	0,34
12	T50	1,5	1,53	22,5	20	3	7,5	10	1,14
12	T20	1,5	1,61	23,7	13	2	7,9	6	1,81
15,5	T100	1,5	1,40	26,6	68	10	8,9	33	0,39
15,5	T50	1,5	1,53	29,0	22	3	9,7	11	1,30
15,5	T20	1,5	1,61	30,6	15	2	10,2	7	2,07
17,5	T100	1,5	1,40	30,0	71	11	10,0	35	0,42
17,5	T50	1,5	1,53	32,8	23	4	10,9	11	1,40
17,5	T20	1,5	1,61	34,5	15	2	11,5	7	2,23
24	T100	1,5	1,40	41,2	88	13	13,7	42	0,47
24	T50	1,5	1,53	45,0	29	4	15,0	14	1,57
24	T20	1,5	1,61	47,3	19	3	15,8	9	2,50
27	T100	1,5	1,40	46,3	94	14	15,4	46	0,49
27	T50	1,5	1,53	50,6	31	5	16,9	15	1,64
27	T20	1,5	1,61	53,2	20	3	17,7	10	2,61
36	T100	1,5	1,40	61,7	109	16	20,6	52	0,57
36	T50	1,5	1,53	67,5	35	5	22,5	17	1,90
36	T20	1,5	1,61	71,0	23	4	23,7	11	3,03
38	T100	1,5	1,40	65,2	109	16	21,7	52	0,60
38	T50	1,5	1,53	71,2	36	5	23,7	17	2,00
38	T20	1,5	1,61	74,9	23	4	25,0	11	3,19
Specified values in the table					Calculated values in the table				
U_r	=	Rated voltage			u_c	=	TRV peak value		
k_{pp}	=	First-pole-to-clear factor			u_c	=	$k_{pp} \times k_{af} \times U_r \sqrt{2/3}$		
k_{pp}	=	1,5			u_c	=	$0,816\ 5 \times k_{pp} \times k_{af} \times U_r$		
k_{af}	=	Amplitude factor			t_3	=	Time to u_c		
k_{af} (T100)	=	Specified	=	1,4	t_3	=	u_c / RRRV		
k_{af} (T50)	=	k_{af} (T100) $\times$ 1,09	=	1,53	t_d	=	Time delay for the delay line		
k_{af} (T20)	=	k_{af} (T100) $\times$ 1,15	=	1,61	t_d	=	$0,15 \times t_3$		
RRRV	=	Rate of rise of recovery voltage			u'	=	Voltage point for the delay line		
RRRV (T100)	=	Specified			u'	=	$u_c/3$		
RRRV (T50)	=	RRRV (T100) $\times$ 3,34			t'	=	Time to u'		
RRRV (T20)	=	RRRV (T100) $\times$ 5,32			t'	=	$t_d + u' / \text{RRRV}$		
NOTE The TRV values are calculated for unearthed systems and they cover earthed systems as well. See 4.103.4.2.									