IEC/TR 62271-310

Edition 2.0 2008-03

TECHNICAL REPORT

RAPPORT TECHNIQUE

High-voltage switchgear and controlgear – Part 310: Electrical endurance testing for circuit-breakers above a rated voltage of 52 kV

Appareillage à haute tension – Partie 310: Essais d'endurance électrique pour disjoncteurs de tension assignée supérieure à 52 kV

IEC/TR 62271-310:2008

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 310: Electrical endurance testing for circuit-breakers above a rated voltage of 52 kV

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IEC/TR 62271-310, which is a technical report, has been prepared by subcommittee 17A: High-voltage switchgear and controlgear, of IEC technical committee 17: Switchgear and controlgear.

This second edition of IEC/TR 62271-310 cancels and replaces the first edition published in 2004. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

– reduction of number tests in the wear stage;

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– new definition of acceptance test for demonstration of end-of-life thermal interruption capability.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
17A/803/DTR	17A/814/RVC

Full information on the voting for the approval of this technical report 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 IEC 62271 series, under the general title *High-voltage switchgear and controlgear* can be found on the IEC website.

The committee has decided that the contents of this 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;
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INTRODUCTION

Based on experience with existing high-voltage circuit-breakers in service and with system protection and maintenance policies, the majority of circuit-breaker applications are covered by class E1 as defined in 3.4.112 of IEC 62271-100. No additional tests for extended electrical endurance are required.

However, extended electrical endurance (class E2) as defined in 3.4.113 of IEC 62271-100 should be considered for the following reasons:

- Field experience collected so far by CIGRE is limited only for circuit-breaker designs available before 1994 (see for example reference [1], [2], [3][1] and Annex A.3). For this reason, the data collected by CIGRE so far can hardly be extrapolated to new designs. Therefore, for new types of circuit-breakers, extended electrical endurance can only be fully proven by laboratory tests.
- New maintenance practices tend towards “maintenance-free” circuit-breakers. The reduction of maintenance costs is a major issue for most users today.
- Deregulation of the electricity market may increase the electrical stresses applied to the circuit-breakers, within their proven capability. Installation of generation capacity by independent power producers will increase short-circuit levels in certain areas and consequently change stresses on breakers. This may result in higher stresses applied to circuit-breakers compared to past practice when the short-circuit rating of the circuit-breaker was in large excess of the actual fault currents.
- There is a need to standardize a single extended electrical endurance programme to avoid the specification of different programmes from different users.
- Many manufacturers provide information about electrical endurance capabilities of circuit-breakers during the purchasing process. There is a need to standardize the way this information is given to the users.

It must be noted that circuit-breakers having extended electrical endurance capability, are not intended for use in situations in which electrical arcing stress (which is a combination of high probability of fault occurrence and high fault current level) is beyond the 90-percentile of the electrical arcing stress, as summarized by the CIGRE survey [1] and calculations based on this material [3]. In other words, for networks that are prone to a very high electrical arcing stress, a custom made test programme, not covered by this technical report, is needed (see Clause A.7). Similarly, if users consider an interval between major maintenance of the electrical wearing parts of the interrupters of more than 25 years, a custom made test programme has to be considered.

When extended electrical endurance capability is required, this capability is demonstrated by the standardized test programmes outlined below as applicable to overhead line circuit-breakers above a rated voltage of 52 kV.

[1] Figures in square brackets refer to the bibliography.

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 310: Electrical endurance testing for circuit-breakers above a rated voltage of 52 kV

1 Scope

This technical report is applicable to class E2 circuit-breakers above a rated voltage of 52 kV for use on overhead lines.

The test programmes are based on accumulated electrical stresses due to current interruption during a period of 25 years, which was chosen as representative for a maintenance-free interval.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

3 Terms and definitions

For the purposes of this document, the following terms and definition applies.

3.1
circuit-breaker class E2 (circuit-breaker with extended electrical endurance)
circuit-breaker designed so as not to require maintenance of the interrupting parts of the main circuit during its expected operating life

NOTE "Expected operating life" in this definition means a minimum period of use without maintenance of the interrupting parts. Normally the life expectancy of the design is higher.

4 Test procedure

The tests should be carried out on a specimen identical as per 6.1.2 and 6.101.1.1 of IEC 62271-100, to one of those already submitted or to be submitted to type tests.

All tests should be performed as single-phase tests. In combination with type tests, three-phase tests are acceptable.

No intermediate maintenance should be carried out during the extended electrical endurance test programme.

The test programmes as described in 4.2 and 4.3 are divided into a wear stage followed by acceptance tests.

During the wear stage, the circuit-breaker will be stressed with the equivalent number of accumulated breaking operations, but, for convenience of testing, without specified TRV, except when basic short-circuit test duties are used as described in 4.3.

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The acceptance tests should follow the wear stage of the test programmes. The purpose of these acceptance tests is to demonstrate the interrupting capability of the circuit-breaker. It is noted that the worn state of the circuit-breaker is taken into account by not requiring the full interrupting capabilities as specified in IEC 62271-100, but normal service capabilities, in accordance with "near end-of-maintenance-free period conditions" of the circuit-breaker.

The test arrangement should be such that no interference with the circuit-breaker between the tests is necessary. However, if this is not possible and local safety rules require depressurization to enter the test cell, it is allowed to decrease the pressure in the circuit-breaker provided that at least 95 % of the gas is re-used when refilling the circuit-breaker.

There are various possible scenarios for performing a test programme for extended electrical endurance qualification. To limit costs, two alternative possibilities are considered:

- extended electrical endurance qualification obtained separately from type tests;
- extended electrical endurance qualification combined with type tests.

4.1 General explanation to the extended electrical endurance test programme

As a general statement, in defining the extended electrical endurance test programme, consideration has been given to the following:

– The maintenance-free period of 25 years.

NOTE Should any different period be considered, the number of breaking operations in the wear stage per current ratings given above (Table 2 and Table 5) should be multiplied by the ratio of the new period and the assumed 25 year period.

– The basic need is that the test programme should maintain its technical soundness while being simple and affordable.

– Merging of standard type tests and extended electrical endurance type tests into a single test programme. Even if this does not represent the most likely situation to occur in practice, the intent is to define designs with margins high enough to withstand basic expected making and breaking stresses in worn conditions.

– The extended electrical endurance test programme has been defined using modified standard type tests as acceptance tests. The only aim of combining type test with electrical endurance test is cost reduction. It has been agreed that the extended electrical endurance test programme should consist of a no load test, a wear stage (medium arcing times, no TRV) and acceptance tests.

The characteristics and rationale behind each part of the test programme are as follows:

a) No-load test

Before starting any extended electrical endurance qualification on any design, a no-load test as per 6.102.6 of IEC 62271-100 should be performed and results compared with those derived from the reference no-load test to assure design consistency. This test should be performed at the same pressure for interruption and operating mechanism as used in type tests (as required in 6.102.6 of IEC 62271-100) to assure result comparability.

b) Wear stage

This stage will consist of a number of breaking operations with medium arcing time (determined from the arcing times used during standard type tests) and no TRV (except when type tests are part of the wear stage; then IEC 62271-100 conditions will apply).

Pressure for operation and interruption and operating voltages are set at their rated values (except when type tests are part of the wear stage; then IEC 62271-100 conditions will apply). The number of breaking operations at 60 % of the rated short-circuit breaking current is given in Table 2.

Operations at 60 % of the rated short-circuit breaking current are a simplification of the wear expected over the maintenance-free period due to a spread in breaking currents from

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load currents to about 60 % of the rated short-circuit breaking current. Breaking operations at lower short-circuit currents are most likely to occur (see Table A.3).

Operations at 10 % of the rated short-circuit breaking current are considered to be important in order to represent the wear due to low currents. Nine breaking operations at 10 % of the rated short-circuit breaking current, with no TRV, are required together with the breaking operations up to 60 % of the rated short-circuit breaking current in order to complete the wear stage.

No-load tests at rated conditions should be made before the wear stage (to determine the arcing times) and after the wear stage (to determine the arcing times for the acceptance tests).

c) Acceptance tests

These tests consist of the following test duties (the preferred order of testing is as listed below):

1) T10

As per IEC 62271-100, with the following variation: single O operations are performed. Operating voltages and pressures at rated value are chosen to obtain a consistent behaviour of the circuit-breaker during the duty. The minimum arcing time may change due to the worn condition of the circuit-breaker. However, the aim of the test is to show the full arc extinguishing window including the demonstration of the minimum arcing time.

The rationale behind these T10 tests is based on the fact that openings at low currents are the most likely duty in service. For this reason, it is important to check that the circuit-breaker will, after a reasonable portion of its expected life, represented by the wear stage, be able to successfully clear this duty over the entire arcing window.

2) L_{75} with 60 % of rated short-circuit breaking current

This test consists of L_{75} tests with a test-current of 60 % of the rated short-circuit current as per 4.102.1 of IEC 62271-100 (regarding TRV parameters of the supply side) and 4.105, with the following variation:

– The supply side current in case of a terminal fault is equal to 75 % of the rated short-circuit breaking current (addition of a L_{75} line side circuit will then yield 60 % current). Only due to test laboratory limitations reduction of supply circuit voltage is allowed as an alternative to obtain 60 % of the rated short circuit current.

– Single O operations should be performed.

– Operating voltages and pressures at rated value are chosen.

– The line side time delay of TRV is 0,2 µs or 0,5 µs depending on rated voltage as stated in 4.105 of IEC 62271-100.

The minimum arcing time may change due to the worn condition of the circuit-breaker. However, the aim of the test is to show the full arc extinguishing window including the demonstration of the minimum arcing time.

The rationale behind the selection of this duty is demonstration of short-line fault interruption capability in practical cases where less (75 %) than 100 % rated short-circuit breaking current is available at the breaker terminal.

This test is chosen instead of the standard L_{90}, L_{75} short-line fault tests because the probability to deal with short-line faults with current as high as 90 % or 75 % of the rated short-circuit breaking current is considered very low.

3) Capacitive current switching

Depending on the restrike performance class assigned to the circuit-breaker (C1 or C2 in accordance with IEC 62271-100) a different test duty is performed. The duty consists of either 24 O operations for class C1or 48 O operations for class C2.

Opening operations are performed “round the clock” by moving the setting of the opening signal by 15°.

The capacitive voltage factors (k_c in 6.111.7 of IEC 62271-100) will be reduced, with respect to those used for standard type tests, to 80 % with the exception of circuit

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breakers rated for voltage factors equal to 1,2 where relaxation to 80 % would lead to a test voltage lower than system voltage. Table 1 correlates the capacitive voltage factors to be used for capacitive current switching tests for electrical endurance with capacitive voltage factors used for standard type tests.

Table 1 – Correlation between capacitive voltage factors used for standard capacitive type tests and capacitive voltage factors to be used for extended electrical endurance capacitive current acceptance tests

Capacitive voltage factor k_c used for standard capacitive current type tests	1,2	1,4	1,7
Capacitive voltage factor k_c used during extended electrical endurance capacitive current acceptance tests	1,12	1,12	1,36

Acceptance criteria will be in agreement with 6.111.11.1 b) of IEC 62271-100, i.e. no restrike over 24 O operations, or, in case of 1 restrike, completion of the duty and repetition with no further restrikes (class C1) and either no restrike over 48 O operations or, in case of 1 restrike, completion of the duty and repetition with no further restrikes (class C2).

The rationale behind this requirement is that the capacitive current switching duty is the most common duty for the circuit-breaker, and therefore a check as to its ability to successfully switch capacitive currents near the end of its expected maintenance-free period is needed.

Users need and require that a circuit-breaker, even after a certain period of service, and after having accumulated a certain amount of short-circuits, should be capable of providing reasonable behaviour in terms of statistical restrike performance.

The capacitive current-switching testing protocol, as a stand-alone type test, requires a high number of breaking operations, and included in the test procedure is a number of tests performed at minimum arcing time. This results in an acceleration factor so that a statistical assessment of restrike performance in service based on laboratory tests can be obtained.

The capacitive current-switching duty required by the acceptance tests in the extended electrical endurance test programme is chosen to verify that a reasonable restrike probability performance remains in circuit-breakers approaching their end-of-maintenance-free period based on short-circuit wear.

Statistical evaluation has shown that the reduced capacitive voltage factor, in combination with the absence of tests at minimum arcing time, has made this acceptance test procedure approximately 25 % as severe as the standard capacitive current switching type test with relation to the restrike probability.

Considering the relatively short length of overhead lines based on the collected data, the test current will correspond to test duty 1 (10 % to 40 % of the rated capacitive switching current of the concerned circuit-breaker).

Capacitive current switching tests are performed with rated pressure for operation, insulation and interruption.

No-load tests at rated conditions should be made after the acceptance tests (for information only).

4) Condition check

A voltage test as condition check, in agreement with 6.2.11 of IEC 62271-100 but with rated pressure for operation, insulation and interruption, should be performed as the final acceptance test. This test is intended to provide confidence that the circuit-breaker, at the completion of the extended electrical endurance test programme, is still able to provide sufficient voltage withstand between contacts without requiring

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inspections that might be of a subjective nature. No visual inspection is required after the condition check.

4.2 Extended electrical endurance qualification obtained separately from type tests

Tables 2 and 3 summarize the kind of tests, acceptance criteria and test conditions to be used for the extended electrical endurance qualification obtained separately from type tests.

For convenience of testing, the order shown in Table 2 and Table 3 of the T10, T60 breaking operations in the wear and acceptance stage can be changed.

Table 2 – Test sequence and criteria for extended electrical endurance tests obtained separately from type tests

Rated short circuit breaking current	≤ 20 kA	25 kA	31,5 kA	40 kA	50 kA	63 kA	80 kA
Type of test							
No-load test	As per IEC 62271-100, 6.102.6 (see 4.1.a)						
Wear tests							
No-load test	As per IEC 62271-100, 6.102.6, except with operating voltages and pressure for interruption at rated conditions (see 4.1.b)						
T60 breaking operations (number of O)	18	15	12	10	8	7	5
T10 breaking operations (number of O)	9						
No-load test	As per IEC 62271-100, 6.102.6, except with operating voltages and pressure for interruption at rated conditions (see 4.1.b)						
Acceptance tests							
T10	As per IEC 62271-100, with the following variation: single O operations are performed						
L75 with 60 % of rated short-circuit current	As per IEC 62271-100, with the following variations: - single O operations are performed - reduction of test current to 60% of rated short-circuit breaking current by increased impedance of the supply circuit.						
LC1	- For circuit-breakers rated class C1: 0 restrikes over 24 O or 1 restrike over 48 O - For circuit-breakers rated class C2: 0 restrikes over 48 O or 1 restrike over 96 O						
No-load test	As per IEC 62271-100, 6.102.6, except with operating voltages and pressure for interruption at rated conditions (see 4.1.c)						
Condition check	According to 6.2.11 of IEC 62271-100 except with operating voltages and pressure for interruption at rated conditions (see 4.1.c)						
NOTE The number of T60 breaking operations in the wear stage is based on the assumption that 3 breaking operations with 60 % of the rated short-circuit current are performed in the acceptance stage. When the number of interruptions performed in the acceptance stage is anticipated to be higher than 3 (i.e. when synthetic tests are performed), This means that when more than 3 tests are expected in the acceptance stage (for example 4 in synthetic tests), the number of tests in the wear stage should be reduced accordingly. All the extra tests during the acceptance stage should be made with TRV.							

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The test conditions are given in Table 3. The tests should be performed using rated values of pressure for operating and interrupting and auxiliary voltages.

Table 3 – Test conditions for extended electrical endurance tests obtained separately from type tests

Type of test	Operations	Test voltage/test current	Operating voltage and pressure for interruption and operation	Arcing time
Wear tests				
No load test	As per IEC 62271-100, 6.102.6		Minimum	
No load test	As per IEC 62271-100, 6.102.6, but with rated pressure for operation, insulation and interruption		Rated	
T60	Only opening operations	According to T60 type test as per 6.106.3 of IEC 62271-100 without TRV	Rated	Medium arcing time according to T60 type test
T10	Only opening operations	According to T10 type test as per 6.106.1 of IEC 62271-100 without TRV	Rated	Medium arcing time according to T10 type test
No load test	As per IEC 62271-100, 6.102.6, but with rated pressure for operation, insulation and interruption		Rated	
Acceptance tests				
T10	Only opening operations	According to T10 type test as per 6.106.1 of IEC 62271-100	Rated	See NOTE 1
L75 with 60 % of rated short-circuit current	Only opening operations	As per 6.109.4 of IEC 62271-100. Reduction of test current to 60 % of rated short-circuit breaking current by increased impedance of the supply circuit (see NOTE 4)	Rated	See NOTE 1
LC1		According to 6.111 of IEC 62271-100. The test voltage is the highest value between 80 % of test voltage specified for type tests and the value corresponding to a voltage factor of 1,12 (see Table 1)	Rated	Around the clock every 15° (electrical degrees)
No load test	As per IEC 62271-100, 6.102.6, but with rated pressure for operation, insulation and interruption		Rated	
Condition check	As per 6.2.11 of IEC 62271-100, but with rated pressure for operation, insulation and interruption		Rated	

NOTE 1 For acceptance tests T10 and L_{75} with 60 % current the arcing times may vary from those shown during type tests due to different pressures for operation and interruption, or due to the worn condition of the circuit-breaker. However the full extinguishing window should be shown including the demonstration of the minimum arcing time.

NOTE 2 For the wear tests T10 and T60, 50 Hz tests cover 60 Hz requirements, provided that the tests have been performed with a medium arcing time belonging to 50 Hz. For acceptance test LC1, 60 Hz tests cover 50 Hz requirements.

NOTE 3 Unit testing according to 6.102.4.2 of IEC 62271-100 is permissible.

NOTE 4 In synthetic testing, this condition is most easily met by designing the circuit for the L_{75} test duty, and then inserting an additional reactance equal to the artificial line reactance into the synthetic supply circuit.

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4.3 Extended electrical endurance qualification combined with type tests

When extended electrical endurance qualification combined with type tests is desired, it is recognized that dictating too stringent constraints may impair the economic viability of such a combination.

In order to allow maximum freedom within this combined programme during the wear tests, the number of breaking operations at T60 with medium arcing time can be replaced by other test duties. Limited to the purpose of this qualification, Equation (1) provides the equivalence between breaking operations carried out at medium arcing time, with current values as used during type tests, and breaking operations at T60 at medium arcing time.

Table 4 – Equivalent number of breaking operations

One single breaking operation at medium arcing time and current value as in	Equivalent number of breaking operation at 60 % of rated short-circuit breaking current (T60)
T10	0,01
OP2	0,15
T30	0,25
T60	1
NOTE During the performance of type tests, some additional breaking operations may occur for no particular reason. In such a case, an evaluation of the equivalence in terms of wear should be made, taking into consideration the actual arcing time (it is assumed that the wear is proportional to the arcing time for the same current).	

$$0{,}01N_{10} + 0{,}15N_{OP2} + 0{,}25N_{30} + N_{60} = M_{90} \quad (1)$$

with

N_{10} the number of breaking operations with 10 % rated short-circuit breaking current;

N_{OP2} the number of breaking operations at test-duty OP2;

N_{30} the number of breaking operations with 30 % rated short-circuit breaking current;

N_{60} the number of breaking operations with 60 % rated short-circuit breaking current;

M_{90} the number (of T60 tests in the combined test programme) as defined in Table 5 aimed to cover 90 % of cumulative electrical stresses in 25 years.

Table 5 – Defined number M_{90} of number of T60 tests combined with type testing

Rated short-circuit breaking current	≤ 20 kA	25 kA	31,5 kA	40 kA	50 kA	63 kA	80 kA
M_{90}	18	15	12	10	8	7	5

Apart from the equivalence criterion expressed in Equation (1), the following requirements should be fulfilled:

– The combined test program should include at least 3 breaking operations at 60 % current, even when in the type-test part of the combined programme a sufficient wear is obtained.

– The combined test program should include at least 9 breaking operations at 10 % current, even when in the type-test part of the combined programme a sufficient wear is obtained.

– Current values of the breaking operations considered in Equation (1) should be at maximum 60 % of the rated short-circuit breaking current.

The acceptance stage should be in accordance with Tables 2 and 3.

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