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High-voltage switchgear and controlgear –
Part 101: Synthetic testing

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Appareillage à haute tension –
Partie 101: Essais synthétiques

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –**Part 101: Synthetic testing**

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This second edition cancels and replaces the first edition published in 2006 and its Amendment 1 published in 2010. It constitutes a technical revision.

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

- addition of the new rated voltages of 1 100 kV and 1 200 kV;
- revision of Annex F regarding circuit-breakers with opening resistors;
- alignment with the second edition of IEC 62271-100:2008 and its Amendment 1 (2012).

The text of this standard is based on the first edition of IEC 62271-101 and the following documents:

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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.

This publication shall be read in conjunction with IEC 62271-100, published in 2008, to which it refers. The numbering of the subclauses of Clause 6 is the same as in IEC 62271-100. However, not all subclauses of IEC 62271-100 are addressed; merely those where synthetic testing has introduced changes.

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

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 101: Synthetic testing

1 Scope

This part of IEC 62271 mainly applies to a.c. circuit-breakers within the scope of IEC 62271-100. It provides the general rules for testing a.c. circuit-breakers, for making and breaking capacities over the range of test duties described in 6.102 to 6.111 of IEC 62271-100:2008, by synthetic methods.

It has been proven that synthetic testing is an economical and technically correct way to test high-voltage a.c. circuit-breakers according to the requirements of IEC 62271-100 and that it is equivalent to direct testing.

The methods and techniques described are those in general use. The purpose of this standard is to establish criteria for synthetic testing and for the proper evaluation of results. Such criteria will establish the validity of the test method without imposing restraints on innovation of test circuitry.

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.

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62271-100, as well as the following, apply.

3.1

direct test

test in which the applied voltage, the current and the transient and power-frequency recovery voltages are all obtained from a circuit having a single-power source, which may be a power system or special alternators as used in short-circuit testing stations or a combination of both

3.2

synthetic test

test in which all of the current, or a major portion of it, is obtained from one source (current circuit), and in which the applied voltage and/or the recovery voltages (transient and power frequency) are obtained wholly or in part from one or more separate sources (voltage circuits)

3.3

test circuit-breaker

circuit-breaker under test

SEE: 6.102.3 of IEC 62271-100:2008.

3.4**auxiliary circuit-breaker**

circuit-breaker forming part of a synthetic test circuit used to put the test circuit-breaker into the required relation with various circuits

3.5**current circuit**

that part of the synthetic test circuit from which all or the major part of the power-frequency current is obtained

3.6**voltage circuit**

that part of the synthetic test circuit from which all or the major part of the applied voltage and/or recovery voltage is obtained

3.7**prospective current** (of a circuit and with respect to a circuit-breaker)

current that would flow in the circuit if each pole of the test and auxiliary circuit-breakers were replaced by a conductor of negligible impedance

[SOURCE: IEC 60050-441:1984, 441-17-01, modified]

3.8**actual current**

current through the test circuit-breaker (prospective current modified by the arc voltage of the test and auxiliary circuit-breakers)

3.9**distortion current**

calculated current equal to the difference between the prospective current and the actual current

3.10**post-arc current**

current which flows through the arc gap of a circuit-breaker when the current and arc voltage have fallen to zero and the transient recovery voltage has begun to rise

3.11**current-injection method**

synthetic test method in which the voltage circuit is applied to the test circuit-breaker before power-frequency current zero

3.12**initial transient making current****ITMC**

transient current which flows through the circuit-breaker at the moment of voltage breakdown prior to the initiation of current from the current circuit during making

3.13**injected current**

current supplied by the voltage circuit of a current injection circuit when it is connected to the circuit-breaker under test

3.14**voltage-injection method**

synthetic test method in which the voltage circuit is applied to the test circuit-breaker after power frequency current zero

3.15

reference system conditions

conditions of an electrical system having the parameters from which the rated and test values of IEC 62271-100 are derived

3.16

time delay of making device

t_m

time interval, during synthetic making test, between the instant of breakdown of the applied voltage and the initiation of current from the current circuit

3.17

minimum clearing time

sum of the minimum opening time, minimum relay time (0,5 cycle), and the minimum arcing time at current interruption after the minor loop of the first-pole-to-clear, during test duty T100a only, as declared by the manufacturer

NOTE This definition should be used only for the determination of the test parameters during short-circuit breaking tests according to test duty T100a.

[SOURCE: 3.7.159 of IEC 62271-100:2008]

3.18

pre-strike

voltage breakdown between the contacts during a making operation which initiates current flow

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4 Synthetic testing techniques and methods for short-circuit breaking tests

4.1 Basic principles and general requirements for synthetic breaking test methods

4.1.1 General

Any particular synthetic method chosen for testing shall adequately stress the test circuit-breaker. Generally, the adequacy is established when the test method meets the requirements set forth in the following subclauses.

A circuit-breaker has two basic positions: closed and open. In the closed position a circuit-breaker conducts full current with negligible voltage drop across its contacts. In the open position it conducts negligible current but with full voltage across the contacts. This defines the two main stresses, the current stress and the voltage stress, which are separated in time.

If closer attention is paid to the voltage and current stresses during the interrupting process (Figure 1), three main intervals can be recognized:

- High-current interval

The high-current interval is the time from contact separation to the start of the significant change in arc voltage. The high-current interval precedes the interaction and high-voltage intervals.

- Interaction interval

The interaction interval is the time from the start of the significant change in arc voltage prior to current zero to the time when the current including the post-arc current, if any, ceases to flow through the test circuit-breaker (see also Clause B.2).

- High-voltage interval

The high-voltage interval is the time from the moment when the current including the post-arc current, if any, ceases to flow through the test circuit-breaker to the end of the test.

4.1.2 High-current interval

During the high-current interval the test circuit-breaker shall be stressed by the test circuit in such a way that the starting conditions for the interaction interval, within tolerances to be specified, are the same as under reference system conditions.

In synthetic test circuits the ratio of the power-frequency voltage of the current circuit to the arc voltage is low in comparison with tests at reference system conditions due to:

- the voltage of the current circuit being a fraction of the system voltage;
- the fact that the arc voltages of the test circuit-breaker and of the auxiliary circuit-breaker are added.

As a result the duration of the current loop and the peak value of the current will be reduced. This distortion of the current is outlined in Annex A.

Considerations with respect to the arc energy released in the test circuit-breaker lead to a maximum permissible influence in terms of tolerances on two characteristic values of the shape of the current, i.e. current-peak value and current-loop duration (see Annex A).

The tolerance on the amplitude and the power frequency of the prospective breaking current is given in 6.103.2 and 6.104.3 of IEC 62271-100:2008. Therefore, the following conditions concerning the actual current through the test circuit-breaker shall be met:

- for symmetrical testing, the current amplitude and final loop duration shall not be less than 90 % of the required values based on rated current;
- for asymmetrical testing, the current amplitude and final loop duration shall be between 90 % and 110 % of the required values, based on rated current and time constant (see Tables 15 to 22 of IEC 62271-100:2008).

Adjustment measures: <https://standards.iteh.ai/catalog/standards/sist/f71930b3-3508-4585-8784-e3cbbd99b301/iec-62271-101-2012>

The amplitude and duration of the last current loop may be adjusted by several means, such as

- increasing or decreasing of the r.m.s. value of the short-circuit test current,
- changing of the frequency of the test current,
- using pre-tripping or delayed tripping,
- changing the instant of current initiation (initial d.c. component).

4.1.3 Interaction interval

During the interaction interval, the short-circuit current stress changes into high-voltage stress and the circuit-breaker performance can significantly influence the current and voltages in the circuit. As the current decreases to zero, the arc voltage may rise to charge parallel capacitance and distort current passing through the arc. After the current zero the post-arc conductivity may result in additional damping of the transient recovery voltage and thus influence the voltage across the circuit-breaker and the energy supplied to the ionized contact gap. The interaction between the circuit and the circuit-breaker immediately before and after current zero (i.e. during the interaction interval) is of extreme importance to the interrupting process.

During the interaction interval, the current and voltage waveforms shall be the same for a synthetic test as under reference system conditions (see 3.15), taking into account the possible deviations of the current and voltage from the prospective values due to the interaction between the circuit-breaker and the circuit.

The interaction interval presents the critical time for the thermal failure mode of the circuit-breaker. Therefore, it is of extreme importance that the shape and magnitude of the prospective transient recovery voltage (TRV) corresponds to that associated with the prospective current of the relevant test duty.

The above implies strict requirements for the test circuit. The requirements are given for the current injection method in 4.2.1 and for the voltage injection method in 4.2.2.

Depending on the test circuit used, the interaction between circuit and test circuit-breaker may be disturbed by the behaviour of the auxiliary circuit-breaker during the critical interval around current zero.

The arc voltage of the auxiliary circuit-breaker should be less than or equal to the arc voltage of the test circuit-breaker.

If an auxiliary circuit-breaker with a higher arc voltage is used, a higher power-frequency voltage of the current circuit may be necessary.

4.1.4 High-voltage interval

During the high-voltage interval, the gap of the test circuit-breaker is stressed by the recovery voltage.

The prospective TRV shall comply with the requirements of 4.102, 4.105, 4.106 and 6.104.5 of IEC 62271-100:2008.

Suitable methods for determining the prospective TRV in synthetic test circuits can be selected from Annex F of IEC 62271-100:2008.

The impedance of the voltage circuit shall be low enough to give clear evidence of breakdown, if any.

If the test circuit-breaker is fitted with opening resistors, a special procedure may be necessary (see Annex F).

If the TRV is obtained from more than one source the overall waveshape should not show any appreciable discontinuity.

In principle, the power-frequency recovery voltage for the basic short-circuit test duties should preferably be a.c. and shall equate with the requirements of 6.104.7 of IEC 62271-100:2008. In synthetic testing, the recovery voltage is supplied from a voltage circuit, either directly or in series with the current circuit. This gives an a.c. voltage, or a combined a.c. and d.c. voltage, or a d.c. voltage, which in most cases decays due to the limited energy of the voltage source. It may thus not be possible to maintain the recovery voltage for at least 0,3 s as specified in 6.104.7 of IEC 62271-100:2008. Deviations from the specified recovery voltage are acceptable if the following conditions are met:

- The instantaneous value of the recovery voltage during a period equal to 1/8 of a cycle of the rated frequency of the circuit-breaker shall be not less than the equivalent instantaneous value of the power-frequency recovery voltage specified in 6.104.7 of IEC 62271-100:2008 which, for a test with symmetrical current, starts with a minimum peak value of $0,95 \times k_{pp} \times U_r \sqrt{2} / \sqrt{3}$

where

k_{pp} is the first pole-to-clear factor;

U_r is the rated voltage of the circuit-breaker.