SLOVENSKI STANDARD
SIST EN 60427:1998

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Report on synthetic testing of high-voltage alternating current circuit-breakers (IEC 427:1989)

Synthetic testing of high-voltage alternating current circuit-breakers

Synthetische Prüfung von Hochspannungs-Wechselstrom-Leistungsschaltern

Essais synthétiques des disjoncteurs à courant alternatif à haute tension

Ta slovenski standard je istoveten z: EN 60427:1992

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ENGLISH VERSION

Report on synthetic testing of high voltage alternating current circuit-breakers
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Essais synthétiques des disjoncteurs à courant alternatif à haute tension
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Synthetische Prüfung von Hochspannungs-Wechselstrom-Leistungsschaltern
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This European Standard was approved by CENELEC on 1992-06-16. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B-1050 Brussels

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FOREWORD

As a consequence of the IEC-CENELEC Agreement, HD 580 S1:1990 (IEC 427:1989) was submitted to the CENELEC voting procedure for conversion into a European Standard.

The text of the International Standard was approved by CENELEC as EN 60427 on 1992-06-16.

The following dates were fixed:

- latest date of publication of an identical national standard (dop) 1993-09-01
- latest date of withdrawal of conflicting national standards (dow) 1993-09-01

Annexes designated "normative" are part of the body of the standard. In this standard, annex ZA is normative.

For products which have complied with HD 580 S1:1990 before 1993-09-01, as shown by the manufacturer or by a certification body, this previous standard may continue to apply for production until 1998-09-01.

ENDORSEMENT NOTICE

The text of the International Standard IEC 427:1989 was approved by CENELEC as a European Standard without any modification.

ANNEX ZA (normative)

OTHER INTERNATIONAL PUBLICATIONS QUOTED IN THIS STANDARD WITH THE REFERENCES OF THE RELEVANT EUROPEAN PUBLICATIONS

When the international publication has been modified by CENELEC common modifications, indicated by (mod), the relevant EN/HD applies.

IEC Publication	Date	Title	EN/HD	Date
56 (mod)	1987	High-voltage alternating-current circuit-breakers	HD 348 S4	1991

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INTERNATIONAL STANDARD

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Essais synthétiques des disjoncteurs à courant alternatif à haute tension

Synthetic testing of high-voltage alternating current circuit-breakers

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CEI/IEC 427:1989

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SYNTHETIC TESTING OF HIGH-VOLTAGE ALTERNATING CURRENT CIRCUIT-BREAKERS

FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules insofar as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

PREFACE

This standard has been prepared by Sub-Committee 17A: High-voltage Switchgear and Controlgear, of IEC Technical Committee No. 17: Switchgear and Controlgear.

It forms the second edition of IEC Publication 427 and replaces the first edition, which was published in 1973 as a report.

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

Six Months' Rule	Report on Voting
17A(CO)200	17A(CO)206

Full information on the voting for the approval of this standard can be found in the Voting Report indicated in the above table.

In order to simplify the indication of corresponding requirements, the same numbering of clauses is used as in IEC Publication 56. The appendices and their figures are named AA, BB, etc.

According to the new rules for the drafting and presentation of International Standards (IEC/ISO), a comma as the decimal sign is used in the English text.

The following IEC publication is quoted in this standard:

Publication No. 56 (1987): High-voltage alternating-current circuit-breakers.

SYNTHETIC TESTING OF HIGH-VOLTAGE ALTERNATING CURRENT CIRCUIT-BREAKERS

1. Introduction

During the past few decades experience has been gained with synthetic testing techniques and 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 Publication 56.

This is why it was decided to include synthetic testing methods, after a thorough revision of the first edition of IEC Publication 427, as equivalent to the direct test methods.

2. Scope

This standard applies to a.c. circuit-breakers within the scope of IEC Publication 56 (Clause 1). It provides the general rules for testing a.c. circuit-breakers, for making and breaking capacities over the range of test-duties described in Sub-clauses 6.102 to 6.111 of IEC Publication 56, by synthetic methods.

Note. — Circuits for the test duties described in Sub-clause 6.111 have not yet been standardized. However, present methods are given in Appendix GG.

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.

3. Definitions

The definitions of IEC Publication 56 and the following definitions apply:

3.1 *Direct test*

A 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*

A 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*

The circuit-breaker under test (see Sub-clause 6.102.2 of IEC Publication 56).

3.4 *Auxiliary circuit-breaker(s)*

The circuit-breaker(s) 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 test voltage is obtained.

3.7 *Prospective current* (of a circuit and with respect to a circuit-breaker) (IEV 441-17-01 modified)

The 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.

3.8 *Actual current*

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

3.9 *Distortion current*

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

3.10 *Post-arc current*

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

3.11 *Current-injection method*

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

3.12 *Injected current*

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

3.13 *Voltage-injection method*

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

3.14 *Reference system conditions*

The conditions of an electrical system having the parameters from which the rated and test values of IEC Publication 56 are derived.

SECTION ONE – SYNTHETIC TESTING TECHNIQUES AND METHODS

4. Short-circuit breaking tests

4.1 *Basic principles and general requirements for synthetic breaking test methods*

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 sub-clauses.

Basic intervals

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 Appendix BB2).

— 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.

4.1.1 *High-current interval*

During this 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 Appendix AA.

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 Appendix AA).

The tolerance on the amplitude and the power frequency of the prospective breaking current, as given in Sub-clauses 6.103.2 and 6.104.3 of IEC Publication 56, shall not be exceeded by the actual current through the test circuit-breaker. Therefore the following conditions shall be met:

— the actual current amplitude during the last loop in the test circuit-breaker shall comply with the requirements for the prospective current stated in Sub-clause 6.104.3 of IEC Publication 56. The amplitude of the final loop of the actual test current in a single phase circuit shall be not less than 90% of the value specified;

— the duration of the final loop of the actual power-frequency test current shall be not less than 90% of the loop duration given by the rated frequency after taking into account, where this is appropriate, the effect of the specified d.c. component;

— when performing synthetic tests on circuit-breakers possessing arc-voltage characteristics which would significantly modify the current in service, the influence of the arc-voltage on the current amplitude and loop duration may be allowed for when considering the tolerances given above.

The detailed procedure for estimating these corrections with examples for establishing the tolerances is given in Appendix AA.

To keep within the tolerances for the test current, it is acceptable to increase the current by increasing the voltage or reducing the reactance of the current circuit, or to apply a current with an increased d.c. component or a reduced power frequency. For this purpose the specified tolerances for d.c. component and power frequency may be exceeded subject to the consent of the manufacturer.

4.1.2 *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 ionised 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 wave forms shall be the same for a synthetic test as under reference system conditions (Sub-clause 3.14), 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 Sub-clause 4.2.1 and for the voltage injection method in Sub-clause 4.2.2.

Note. — 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.

4.1.3 *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 Sub-clauses 4.102, 4.105, 4.106 and 6.104.5 of IEC Publication 56. Suitable methods for determining the prospective TRV in synthetic test circuits can be selected from Appendix GG of IEC Publication 56.

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

Notes 1. — If the test circuit-breaker is fitted with low ohmic parallel resistors, a special procedure may be necessary (see Appendix FF).

2. — If the TRV is obtained from more than one source the overall wave shape should not show any appreciable discontinuity.

In principle, the power-frequency recovery voltage for the basic short-circuit test-duties shall equate with the requirements of Sub-clause 6.104.7 of IEC Publication 56. In synthetic testing the recovery voltage is supplied from the voltage circuit, either directly or in series with the current circuit. This gives a d.c. voltage, or a combined a.c. and d.c. voltage, or an a.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 0,1 s as specified in Sub-clause 6.104.7 of IEC Publication 56. 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 Sub-clause 6.104.7 of IEC Publication 56 which starts with a minimum peak value of $0,95\ h\sqrt{2}\ U/\sqrt{3}$.

h = first pole-to-clear factor (1,3 or 1,5).
U = rated voltage of the circuit-breaker.

— Whether an exponentially decaying d.c., an a.c. or a combined a.c. and d.c. recovery voltage is used, its instantaneous value (for d.c.) or its peak value (or a.c. or combined a.c. and d.c) should in principle be kept as close as possible to $\sqrt{2} \cdot U/\sqrt{3}$ and in any case must not fall below $0,5\ \sqrt{2}\ U/\sqrt{3}$ in less than 0,1 s (see Figure 2).

— If an exponentially decaying d.c. or a combined a.c. and d.c. recovery voltage imposes an inappropriate stress on the circuit-breaker compared to that due to the specified a.c. recovery voltage in reference system conditions, then a more appropriate circuit may be used taking into account Sub-clause 6.104.7 of IEC Publication 56 and also the limits stated above.

4.2 *Synthetic test circuits and related specific requirements for breaking tests*

4.2.1 *Current injection methods*

These methods can be described in terms of general principles as follows (see Appendix BB):

— the current from the voltage source is superimposed on the current in the test circuit-breaker prior to the interaction interval;

— an auxiliary circuit-breaker interrupts the current from the current circuit prior to the interaction interval.

During the interaction interval the test circuit-breaker is exposed to the voltage of the voltage circuit having an impedance which is representative of the reference system conditions. This explains the validity of current injection methods. Several current injection methods are known but only the conditions for parallel current injection are given below since this method is used by the majority of the test laboratories. The following conditions shall be met:

a) TRV wave-shaping circuit

1) The shape and magnitude of the prospective TRV shall comply with the specified values.

2) Ideally the equivalent surge impedance Z_h (see Figure 3) shall be equal to $(du/dt)/(di/dt)$ during the interaction interval. du/dt is the rate of rise of the specified transient recovery voltage and di/dt is the rate of decrease of the specified short-circuit current.

3) The combination of the stray and lumped capacitance C_{dh} in parallel with Z_h gives rise to the delay time $t_d = Z_h\ C_{dh}$.

b) Inductance of the voltage circuit

The value of the inductance of the voltage circuit shall be between 1,0 and 1,5 times the inductance derived from the equivalent power-frequency voltage divided by the prospective current.