

INTERNATIONAL STANDARD



**High-voltage switchgear and controlgear –
Part 112: Alternating current high-speed earthing switches for secondary arc
extinction on transmission lines**



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IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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INTERNATIONAL
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

**Part 112: Alternating current high-speed earthing switches
for secondary arc extinction on transmission lines**

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 62271-112:2013. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC 62271-112 has been prepared by subcommittee 17A: Switching devices, of IEC technical committee 17: High-voltage switchgear and controlgear. It is an International Standard.

This second edition cancels and replaces the first edition published in 2013. This edition constitutes a technical revision.

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

The document has been updated to the second edition of IEC 62271-1:2017.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
17A/1311/FDIS	17A/1314/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

This International Standard should be read in conjunction with IEC 62271-1:2017, to which it refers and which is applicable, unless otherwise specified. In order to simplify the indication of corresponding requirements, the same numbering of clauses and subclauses is used as in IEC 62271-1:2017. Amendments to these clauses and subclauses are given under the same numbering, whilst additional subclauses, are numbered from 101.

A list of all parts in the IEC 62271 series, published 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 document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 112: Alternating current high-speed earthing switches for secondary arc extinction on transmission lines

~~1~~ General

1 Scope

This part of IEC 62271 applies to AC high-speed earthing switches (hereinafter termed HSES) designed for indoor and outdoor installation and for operation at service frequencies of 50 Hz and 60 Hz on systems having rated voltages of 550 kV and above.

HSESs described in this document are intended to extinguish the secondary arc remaining after clearing faults on transmission lines by the circuit-breakers.

For more detailed information on HSESs, refer to Annex A.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60050-441:1984, *International Electrotechnical Vocabulary (IEV) – Part 441: Switchgear, controlgear and fuses*
IEC 60050-441:1984/AMD1:2000

IEC 62271-1:20072017, *High-voltage switchgear and controlgear – Part 1: Common specifications for alternating current switchgear and controlgear*

IEC 62271-100:20082021, *High-voltage switchgear and controlgear – Part 100: Alternating current circuit-breakers*

IEC 62271-102:20042018, *High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches*

IEC 62271-200:2011, *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

~~IEC 62271-203:2011, High-voltage switchgear and controlgear – Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV~~

3 Terms and definitions

For the purposes of this document, the terms and definitions given in Clause 3 of IEC 62271-1:20142017, as well as the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

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

3.1 General terms and definitions

3.1.101

secondary arc

arc that remains at the faulted point after interruption of the short-circuit current fed by the network

Note 1 to entry: This secondary arc is supplied by electrostatic or electromagnetic induction from the adjacent **healthy** live phases.

3.1.102

single-phase auto-reclosing scheme

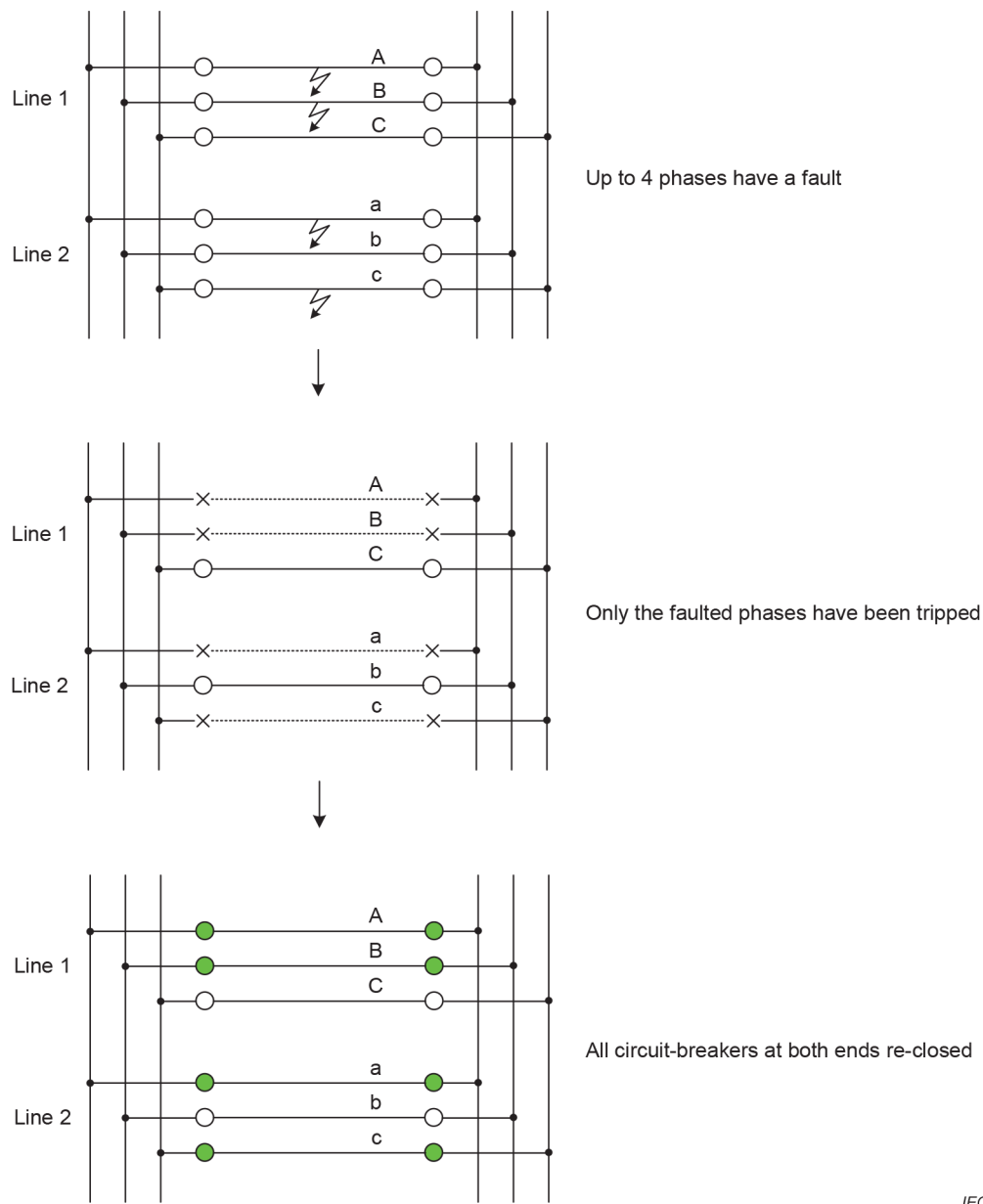
auto-reclosing scheme in which a faulted phase circuit is opened and automatically re-closed independently from the other phases

3.1.103

multi-phase auto-reclosing scheme

auto-reclosing scheme applied to double circuit overhead lines in which all faulted phase circuits are opened and re-closed independently provided that at least two different phases remain unfaulted

Note 1 to entry: An example of multi-phase auto-reclosing scheme is indicated in Figure 1.

**Key**

- | | |
|--|-----------------------------|
| 1) Up to 4 phases have a fault | ○ Closed circuit-breaker |
| 2) Only the faulted phases have been tripped | × Open circuit-breaker |
| 3) All circuit-breakers at both ends re-closed | ● Re-closed circuit-breaker |

Figure 1 – Explanation of a multi-phase auto-reclosing scheme

Note 2 to entry: Other than the scheme described in 3.1.102 and 3.1.103, a three-phase auto-reclosing scheme is commonly applied. In this scheme, all three phases of **one circuit** are tripped and re-closed at both ends even if a fault occurred in one phase. So far high-speed earthing switches are rarely applied with this scheme.

3.1.104**successive fault**

additional earth fault that occurs in the adjacent phase circuit(s) during the time interval between a single-phase earth fault and the opening of the high-speed earthing switch(es)

3.2 Assemblies of switchgear and controlgear

No particular definitions.

3.3 Parts of assemblies

No particular definitions.

3.4 Switching devices

3.4.101

high-speed earthing switch

HSES

earthing switch that has the capability to:

- make, carry and interrupt the induced current;
- withstand the recovery voltage caused by electromagnetic and/or by electrostatic couplings prior to circuit re-closure;
- make and carry the rated short-circuit current

Note 1 to entry: The high-speed operation applies normally to both closing and opening.

Note 2 to entry: A high-speed earthing switch is not intended to be used as a maintenance earthing switch.

~~3.4.103.1~~ 102

high-speed earthing switch class M0

high-speed earthing switch having a normal mechanical endurance of 1 000 operation cycles

~~3.4.103.2~~

high-speed earthing switch class M1

high-speed earthing switch having an extended mechanical endurance of 2 000 operation cycles for special requirements

3.5 Parts of switchgear and controlgear

No particular definitions.

3.6 Operational characteristics of switchgear and controlgear

No particular definitions.

3.7 Characteristics quantities

No particular definitions.

~~24~~ Normal and special service conditions

~~Clause 2 of IEC 62271-1:2007 is applicable.~~

Clause 4 of IEC 62271-1:2017 is applicable.

45 Ratings

5.1 General

~~Clause 4 of IEC 62271-1:2007 is applicable with the following additions.~~

Clause 5 of IEC 62271-1:2017 is applicable with the following additions.

NOTE Categories corresponding to the fault modes are explained in Annex B.

4.4 — Rated normal current and temperature rise

~~Subclause 4.4 of IEC 62271-1:2007 is not applicable.~~

5.5 Rated continuous current (I_r)

Subclause 5.5 of IEC 62271-1:2017 is not applicable.

45.101 Rated short-circuit making current (I_{ma})

~~Subclause 4.101 of IEC 62271-102:2001 is applicable.~~

Subclause 5.101 of IEC 62271-102:2018 is applicable.

45.102 Rated operating sequence

The rated characteristics of the HSES are referred to the rated operating sequence.

a) C – t_{i1} – O,

or

b) C – t_{i1} – O – t_{i2} – C – t_{i1} – O

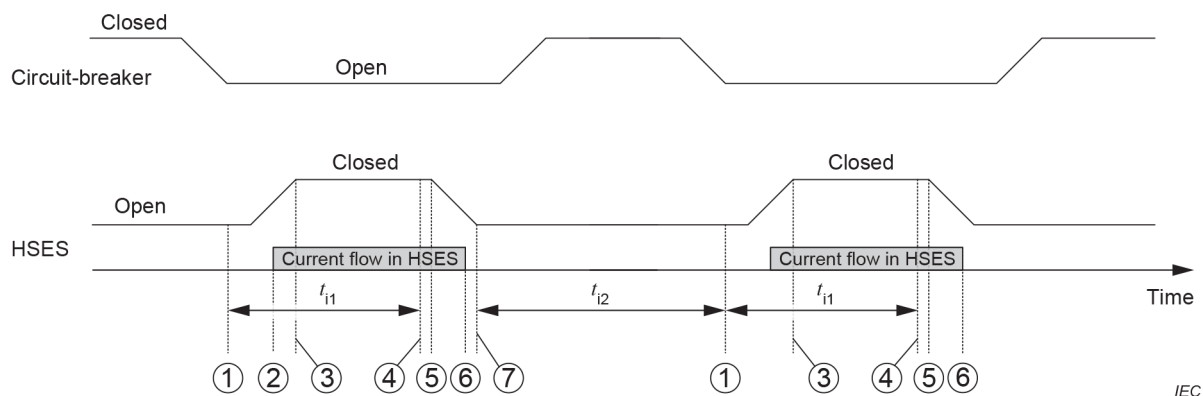
Where

- t_{i1} is a time that is longer than the time required for secondary arc extinction and for dielectric recovery of air insulation at the faulted point. t_{i1} is determined by users considering system stability. The preferred value of t_{i1} is 0,15 s;
- t_{i2} is the intermediate time that is given by the system protection. t_{i2} includes the closing time of the circuit-breakers after the HSESs open, the duration of a new line fault and the break-time of the circuit-breakers. Following this time t_{i2} , the HSES can be reclosed. The preferred value of t_{i2} is 0,5 s.

In this case the HSES shall be able to operate without intentional time delay.

NOTE t_{i1} and t_{i2} are set by system control scheme and a HSES itself is to be operated according to its own operating time.

Figure 2 shows the time chart for the rated operating sequence of C – t_{i1} – O – t_{i2} – C – t_{i1} – O.



Key

Circuit-breaker	Transmission line circuit-breakers that interrupt the fault	3	Contact touch of HSESs
HSES	High-speed earthing switches	4	Energizing of the opening release of the HSESs
1	Energizing of the closing circuit of the HSESs	5	Contact separation of HSESs
2	Current start in HSESs	6	Arc extinction in HSESs
t_{i1} , t_{i2}	Times defined in 4.5.102	7	Fully open position of HSESs

NOTE 1 A common value for the re-closing time of the circuit-breaker is 1 s to guarantee system stability.

NOTE 2 t_{i1} is normally within the range of 0,15 s to 0,5 s.

NOTE 3 t_{i2} is normally within the range of 0,5 s to 1 s.

NOTE 4 The operating sequence b) is for system stability requirements to cover cases where another fault occurs on the same phase.

NOTE 5 The HSES closing time is normally less than 0,2 s.

Figure 2 – Timing chart of HSES and circuit-breakers

4.103 Standard values for interruption

Standard values for HSES are given in Table 1.

Table 1 – Standardized values of rated induced currents and voltages

Rated voltage U_r	Electromagnetic coupling				Electrostatic coupling	
	Rated induced current (+10 % -0 %)	Rated power frequency recovery voltage (+10 % -0 %)	First TRV peak (+10 % -0 %)	Time to first peak (+10 % -0 %)	Rated induced current (+10 % -0 %)	Rated induced voltage (+10 % -0 %)
kV	A (rms)	kV (rms)	kV	ms	A (rms)	kV (rms)
550	6-800	240	580	0,6	120	115
800	6-800	240	580	0,6	170	170
1-100 to 1-200	6-800	240	580	0,6	230	235

NOTE 1 For Table 1 the rated induced voltages by electrostatic recovery voltage have a 1-cos wave shape.

NOTE 2 For networks with up to two faults (category 0 and 1 as described in B.2) the corresponding values are presented in Table B.3.

~~For networks with delayed current zero crossing occurrence (category 3 as described in B.2), the corresponding values are presented in Table B.1.~~

~~For networks with multi-phase faults (category 4 as described in B.2) the corresponding values are presented in Table B.2.~~

56 Design and construction

~~Clause 5 of IEC 62271-1:2007 is applicable with the following modifications.~~

Clause 6 of IEC 62271-1:2017 is applicable with the following modifications.

56.5 Dependent power operation

~~Subclause 5.5 of IEC 62271-1:2007 is not applicable.~~

Subclause 6.5 of IEC 62271-1:2017 is not applicable.

~~5.7 Independent manual operation power operation (independent unlatched operation)~~

~~Subclause 5.7 of IEC 62271-1:2007 is not applicable.~~

6.7 Independent unlatched operation (independent manual or power operation)

Subclause 6.7 of IEC 62271-1:2017 is not applicable.

~~5.10~~ 6.11 Nameplates

The designation of the equipment is specified as HSES.

Items to be indicated on the nameplate are listed in ~~Table 2~~ Table 1.

~~Table 2 – Items to be listed on nameplate of a HSES~~

Item
Manufacturer
Designation of type
Serial number
Year of manufacture
Rated voltage
Rated lightning impulse withstand voltage
Rated switching impulse withstand voltage
Rated power-frequency withstand voltage
Rated short-time withstand and peak withstand current
Rated duration of short-circuit
Rated filling pressure for insulation and /or operation
Rated supply voltage of auxiliary circuit
Rated frequency
Mechanical endurance class
Mass (including fluid)
Operating sequence

Table 1 – Nameplate information

Item	Abbreviation	Unit
Name of manufacturer		
Type designation		
Serial number		
Year of manufacture		
Rated voltage	U_r	kV
Rated lightning impulse withstand voltage	U_p	kV
Rated switching impulse withstand voltage	U_s	kV
Rated power-frequency withstand voltage	U_d	kV
Rated short-time withstand current	I_k	kA
Rate peak withstand current	I_p	kA
Rated duration of short-circuit	t_k	s
Rated short-circuit making current	I_{ma}	kA
Filling pressure for insulation	P_{re}	MPa
Filling pressure for operation	P_{rm}	MPa
Rated supply voltage(s) of auxiliary and control circuits Specify DC/AC (with rated frequency)	U_a	V
Rated frequency	f_r	Hz
Mechanical endurance class	M_1/M_2	
Electrical endurance class	E_1/E_2	
Type and mass fluid (liquid or gas) for insulation	M_f	kg
Mass (including fluid)	M	kg
Operating sequence	C- t_{r1} -O or C- t_{r1} -O- t_{r2} -C- t_{r1} -O (t_{r1} , t_{r2})	
Minimum and maximum ambient temperature		°C
Category (option) ^a		
^a Category is to refer to Clause B.2		

~~5.11 Interlocking devices~~~~Subclause 5.11 of IEC 62271-1:2007 is not applicable.~~**6.12 Locking devices**

Subclause 6.12 of IEC 62271-1:2017 is not applicable.

56.101 Anti-pumping device

Anti-pumping device shall be provided for pneumatic and hydraulic operating mechanism.

56.102 Special requirements for HSES

A HSES shall be able to earth transmission lines and re-open to achieve their full voltage withstand within the dead time of the auto-reclosing duty cycle of the transmission line circuit-breakers. The dead time is defined by system stability and is normally set around 1 s enabling dielectric recovery of insulation capability at the fault location. Fast operating capability for both making and breaking is required.

The HSES shall have a capability to by-pass secondary arc current on the transmission lines.

The HSES shall have a capability to break induced current by electromagnetic and/or electrostatic coupling on transmission lines with a **transient** recovery voltage specified in ~~Table 4~~ Table 2.

The HSES shall have a capability to withstand ~~transient~~ recovery voltage after interruption and rated power frequency voltage to earth ($U_r/\sqrt{3}$) in open position.

The HSES shall be single-pole operated, unless otherwise specified.

67 Type tests

7.1 General

~~Clause 6 of IEC 62271-1:2007 is applicable with the following additions.~~

Clause 7 of IEC 62271-1:2017 is applicable with the following additions.

The dielectric performance shall be verified for phase-to-earth in the open position only in accordance with IEC 62271-1:2007/2017.

~~6.1.1 Grouping of tests~~

~~Subclause 6.1.1 of IEC 62271-1:2007 is not applicable.~~

67.3 Radio interference voltage (RIV) test

~~Subclause 6.3 of 62271-1:2007 is applicable.~~

~~In case of metal enclosed type, 6.3 of CEI 62271-203:2011 is applicable.~~

Subclause 7.3 of IEC 62271-1:2017 is applicable for open position only.

~~6.5 Temperature-rise tests~~

~~Subclause 6.5 of IEC 62271-1:2007 is not applicable.~~

7.5 Continuous current tests

Subclause 7.5 of IEC 62271-1:2017 is not applicable.

67.101 Tests to prove the short-circuit making performance

~~Subclause 6.101 of IEC 62271-102:2001 is applicable.~~

Subclause 7.101 of IEC 62271-102:2018 is applicable.

67.102 Operating and mechanical endurance tests

~~Subclause 6.102 of IEC 62271-102:2001 is applicable.~~

Subclause 7.102 of IEC 62271-102:2018 is applicable with the following modifications.

The rated operating sequence shall be verified during mechanical operation.

The mechanical operating sequence for class M0 shall be one of the following:

- a) A HSES with a specified duty cycle required $C - t_{i1} - O$:
 - 1 000 $C - t_{i1} - O$ operations.
- b) A HSES with a specified duty cycle $C - t_{i1} - O - t_{i2} - C - t_{i1} - O$
 - 500 $C - t_{i1} - O$ operations, plus
 - 250 $C - t_{i1} - O - t_{i2} - C - t_{i1} - O$ operations.

For class M1, the number of operations shall be twice the sequence specified.

Mechanical travel characteristics shall be recorded and acceptance criteria are referred to ~~6.101.1.1 of IEC 62271-100:2008~~ 7.102.4.1 of IEC 62271-100:2021 with the modification of the total tolerance to 20 % (for example $^{+20}_{-0}$ %, $^{+10}_{-10}$ % or $^{+0}_{-20}$ %).

67.103 Operation under severe ice conditions

~~Subclause 6.103 of 62271-102:2001 is applicable.~~

Subclause 7.103 of 62271-102:2018 is applicable.

~~6.104 Operation at the temperature limits~~

~~Subclause 6.104 of 62271-102:2001 is applicable.~~

7.104 Low- and high-temperature tests

Subclause 7.104 of 62271-102:2018 is applicable.

67.105 Tests to prove the induced current making and breaking performance of HSES

67.105.1 General test conditions

Tests shall be performed in accordance with the standard condition values for HSES specified in ~~Table 1~~ Table 2.

Table 2 – Standard values of rated induced currents and voltages

Rated voltage U_r	Electromagnetic coupling				Electrostatic coupling	
	Rated induced current (+10 %) (-0 %)	Rated power-frequency recovery voltage (+10 %) (-0 %)	First TRV peak (+10 %) (-0 %)	Time to first peak (+10 %) (-0 %)	Rated induced current (+10 %) (-0 %)	Rated induced voltage (+10 %) (-0 %)
kV(RMS)	A (RMS)	kV (RMS)	kV(peak)	ms	A (RMS)	kV (RMS)
550	6 800	240	580	0,6	120	115
800	6 800	240	580	0,6	170	170
1 100 / 1 200	6 800	240	580	0,6	230	235

NOTE 1 For Table 2, the rated induced voltages by electrostatic recovery voltage have a “1-cos” wave shape based on the applied power frequency voltage.

NOTE 2 For networks with up to two faults (categories 0 and 1 as described in Clause B.2), the corresponding values are presented in Table B.3.

NOTE 3 For networks with delayed current zero crossing occurrence (category 3 as described in Clause B.2), the corresponding values are presented in Table B.1.

NOTE 4 For networks with multi-phase faults (category 4 as described in Clause B.2), the corresponding values are presented in Table B.2.

NOTE 5 The prospective TRV wave shape for electromagnetic coupling may be of a triangular or “1-cos” form. The time to peak is valid for either wave shape type.

Subclause ~~C.6.105 of IEC 62271-102:2001~~ 7.107 of IEC 62271-102:2018 is applicable with the following additions and modifications.

Number of tests both for electromagnetic and electrostatic coupling:

- 10 times C and O.

Measurement of travel characteristics shall be in accordance with ~~subclause 6.101.1.1 of IEC 62271-100:2008~~ 7.102.4.1 of IEC 62271-100:2021.

Test circuits are those shown in ~~Figures C.1 and C.2 of IEC 62271-102:2001~~ Figure 12 and Figure 13 of IEC 62271-102:2018.

For electrostatic induced current test independent of the rated voltage of the HSES, the test circuit parameters shall be:

- capacitance value $C_1 = 1,56 \mu\text{F}$;
- surge impedance: 245 Ω ;

~~— line length 200 km.~~

NOTE 6 This test condition corresponds to line length 200 km.

The HSES shall preferably be tested at rated frequency; however, for convenience of testing, tests at 50 Hz cover the requirement for 60 Hz and vice versa.

These tests cover the classes of A and B described in ~~Annex C of IEC 62271-102:2001~~ 5.109 of IEC 62271-102:2018.

67.105.2 Induced current switching details

Type tests for HSES having a rated induced current making and breaking capability shall include tests to prove the electromagnetically and/or electrostatically induced current making and breaking capability **under minimum control voltage**.

The test currents shall be within a tolerance of ($+10\%$ / -0%) of the rated induced currents as shown in ~~Table 4~~ Table 2.

For convenience of testing, the control voltage of the HSES can be either the rated or maximum of the auxiliary supply voltage if the control voltage does not affect the making and breaking capability of HSES. This condition is considered to be satisfied if the travel characteristics of that condition are within a range of ($+5\%$ / -5%) of those obtained with a minimum control voltage.

Induced current making and breaking tests shall be conducted without maintenance.

67.105.3 Arrangement of the HSES before the test

The HSES under test shall be completely mounted on its own support or on a mechanically equivalent test support. Its operating device shall be operated in the manner prescribed and, in particular, if it is electrically, hydraulically or pneumatically operated, it shall be operated either at the minimum supply voltage or at the minimum functional pressure for operation, respectively.

Before commencing making and breaking tests, no-load operations shall be made and details of the operating characteristics of the HSES, such as travel characteristics, closing time and opening time, shall be recorded.

If applicable, tests shall be performed at the minimum functional pressure for interruption and insulation.

67.105.4 Behaviour of the HSES during the test

The HSES shall perform successfully without undue mechanical or electrical distress.

During tests, the HSES shall not

- show signs of distress;
- show harmful interaction with adjacent laboratory equipment;
- exhibit behaviour which could endanger an operator.

Outward emission of gases, flames or metallic particles from the switch during operation is permitted, if this does not impair the insulation level of the earthing switch or prove to be harmful to an operator or other person in the vicinity, **or prove to be harmful to an operator or other person in the vicinity**.

Should doubt exist after an operation, the testing is to be continued or repeated with indicators as specified in IEC 62271-200:2011 mounted in the most onerous position likely for personnel to stand during the operation of the HSES.

67.105.5 Condition after the test

Comparison of mechanical characteristics before and after the test shall be done according to ~~subclause 6.102~~ 7.102.3.2 of IEC 62271-102:2018.

Subclause ~~C.6.105.9 of IEC 62271-102:2004~~ 7.108.9 of IEC 62271-102:2018 is applicable.

78 Routine tests

~~Clause 7 of IEC 62271-1:2007 is applicable with the following additions.~~

Clause 8 of IEC 62271-1:2017 is applicable with the following additions.

For mechanical operating test, refer to ~~subclause 7.101 of IEC 62271-100:2008~~ 8.101 of IEC 62271-100:2021.

Mechanical travel characteristics shall be recorded and acceptance criteria are referred to ~~subclause 6.101.1.1 of IEC 62271-100:2008~~ 7.102.4.1 of IEC 62271-100:2021 with the modification of the tolerance to

20 % (for example $+20\%$ or $+10\%$ or $+0\%$).

Timing test of close and open with rated and minimum conditions of auxiliary supply shall be verified.

89 Guide to the selection of HSEs (informative)

For the selection of HSEs described in ~~Table 4~~ Table 2 and also in Table B.1 and Table B.2 if necessary, the following conditions and requirements at site ~~shall~~ should be considered:

- existing fault conditions;
- number of circuits;
- auto-reclosing scheme (single or multi auto-reclosing scheme);
- required operating sequence (the operating sequence is linked to circuit-breaker operating sequence);
- ~~– the operating sequence is linked to circuit-breaker operating sequence;~~
- consideration on successive faults and other special conditions such as delayed current zero phenomena during HSES operations;
- required operational performance (mechanical endurance);
- switching requirements (~~fault making capability~~ making and short-circuit breaking capability);
- class M1 is mainly for applications where the HSES is operated in special requirement where frequent lightning strokes occur.

910 Information to be given with enquiries, tenders and orders (informative)

~~Clause 9 of IEC 62271-1:2007 is applicable.~~

Clause 10 of IEC 62271-1:2017 is applicable.

~~10 Rules for Transport, storage, installation, operation and maintenance~~

~~Clause 10 of IEC 62271-1:2007 is applicable.~~

11 Transport, storage, installation, operating instructions and maintenance

Clause 11 of IEC 62271-1:2017 is applicable.

1112 Safety

~~Clause 11 of IEC 62271-1:2007 is applicable.~~

Clause 12 of IEC 62271-1:2017 is applicable.

Annex A (informative)

Background information on the use of HSESs

A.1 General

Single-phase or multi-phase auto-reclosing schemes are generally applied for high-voltage transmission systems to enhance system reliability. When on an overhead line a fault involving earth occurs, circuit-breakers located at both ends of the line open to clear the fault. In case of high-voltage overhead lines (especially for system voltages equal to or higher than 550 kV), where the conductors are located in the vicinity of each other and transmission systems are single phase operated, a lower current ~~may~~ can remain at the fault point after interruption of the short-circuit current. This current is called secondary arc current and is caused by the electrostatic or electromagnetic coupling with the other adjacent live conductors, and this secondary arc current is difficult to self-extinguish in a short time. From a system stability point of view it is preferable to apply auto-reclosing scheme with a reclosing time in the order of 1 s maximum. To achieve auto-reclosing in due time some means are necessary to extinguish the secondary arc before re-closing circuit-breakers.

Especially for short distance lines without shunt reactors or for double circuit systems with multi-phase auto-reclosing scheme, where 4 legged reactors are not suitable, one of the useful and important means is to apply a special earthing switch for the purpose of secondary arc extinction. This earthing switch is generally designed for high-speed operation to ensure that the required switching performance is met and is called high-speed earthing switch (acronym HSES).

The secondary arc extinction performance will be influenced by the recovery voltage and secondary arc current at the fault location, both of which will be influenced by the following:

- tower configuration, e.g. single or double circuit lines (i.e. several circuits mounted on one tower), distance between phases and circuits, height of lines above ground level, etc.;
- transposition of the transmission lines (untransposed or transposed);
- occurrence of successive earth faults on the other line.

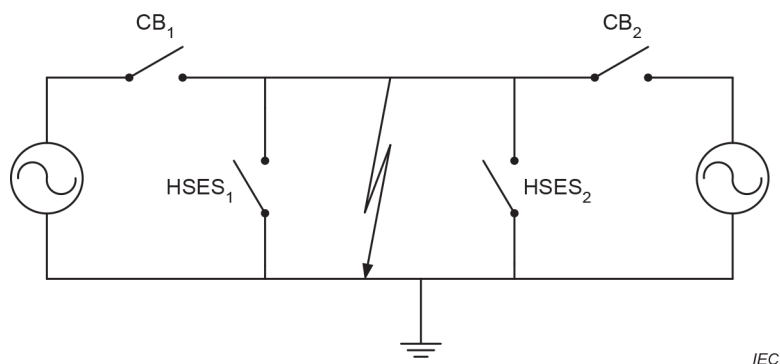
Therefore, the time duration between the duty cycles is specified by the user.

NOTE This HSES is distinguished from a fast acting earthing switch. Refer to Table A.1.

The operating sequence of a HSES is determined by the time to maintain system stability, high-speed auto reclosing sequence of the circuit-breaker, dielectric recovery characteristics of fault point on the transmission line and time coordination with protection relays including the time for confirming the condition of circuit-breaker and HSES, e.g. open/close condition.

A.2 Typical operating sequence

Figure A.1 shows a single line diagram of a power system. A fault has occurred on one phase of the transmission line. The circuit-breakers at the both ends of the line open in order to interrupt the fault current. 0,2 s after completion of the interruption by the circuit-breaker, the HSESs will close and remain in the closed position for several hundred milliseconds. In this period secondary arc current shall be extinguished and the insulation re-established. Opening of the HSESs takes typically 0,1 s after initiation of opening signal to the HSESs. The preceding interrupting HSES will interrupt electromagnetic induced current and the later interrupting HSES will interrupt electrostatic induced current. The circuit-breaker will re-close after completion of the opening operation of the HSESs.

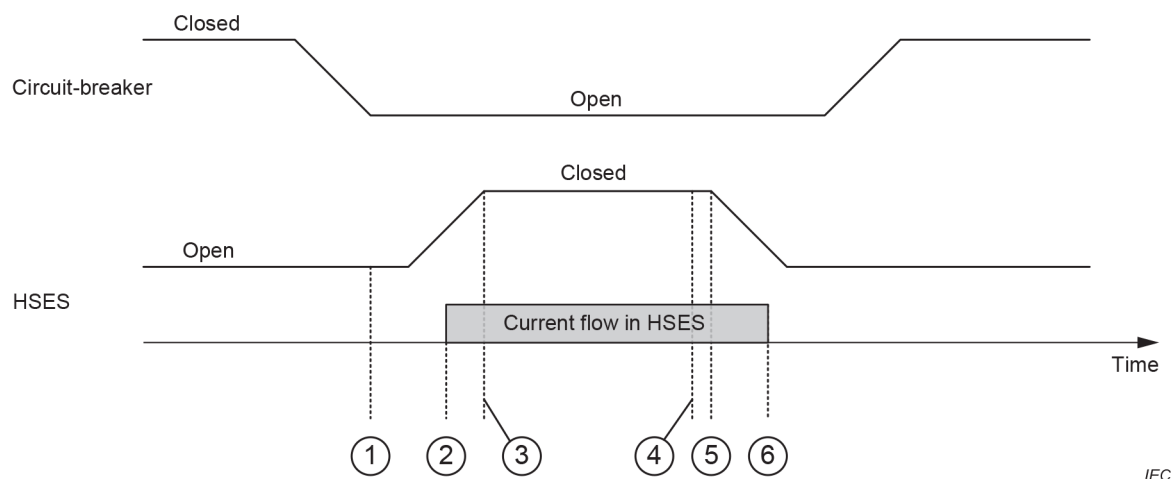


Key

CB_1, CB_2	Transmission line circuit-breakers
$HSES_1, HSES_2$	High-speed earthing switches

Figure A.1 – Single-line diagram of a power system

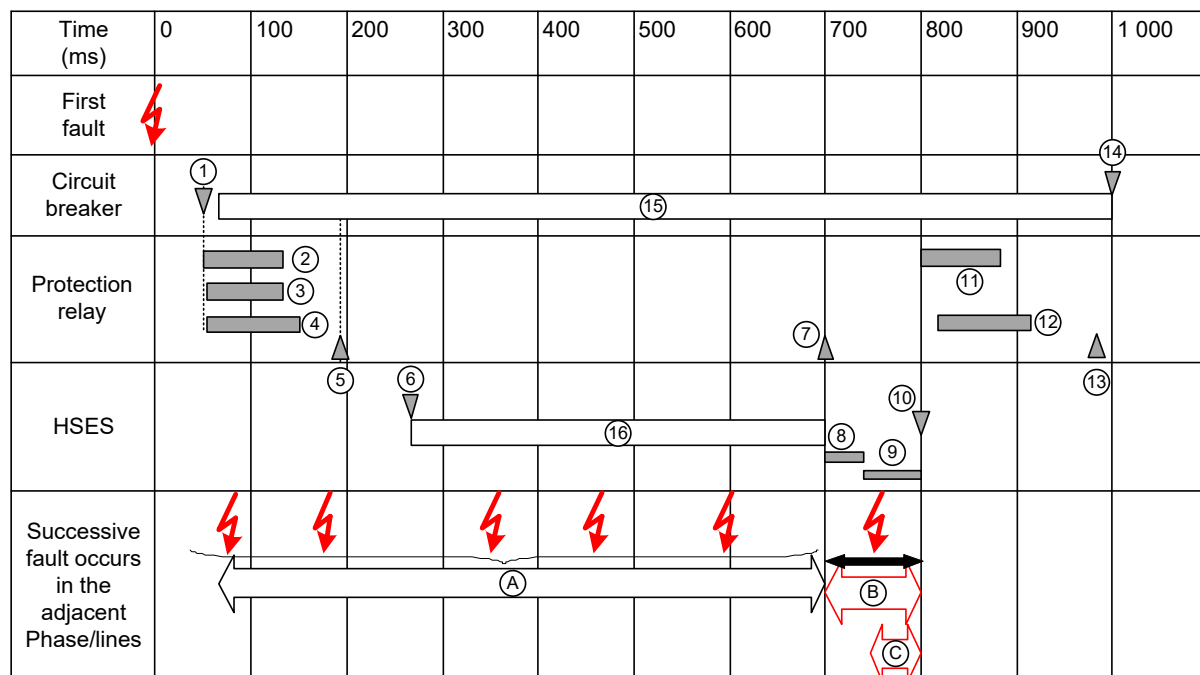
A typical timing chart of the relationship between the transmission line circuit-breakers that interrupt the fault and the HSESs is shown in Figure A.2. This figure shows the first O – C operation of the circuit-breakers and the first C – O operation of the HSESs.



Key

Circuit-breaker	Transmission line circuit-breakers that interrupt the fault	3	Contact touch of HSESs
HSES	High-speed earthing switches	4	Energizing of the opening release of the HSESs
1	Energizing of the closing circuit of the HSESs	5	Contact separation of HSESs
2	Current start in HSESs	6	Arc extinction in HSESs

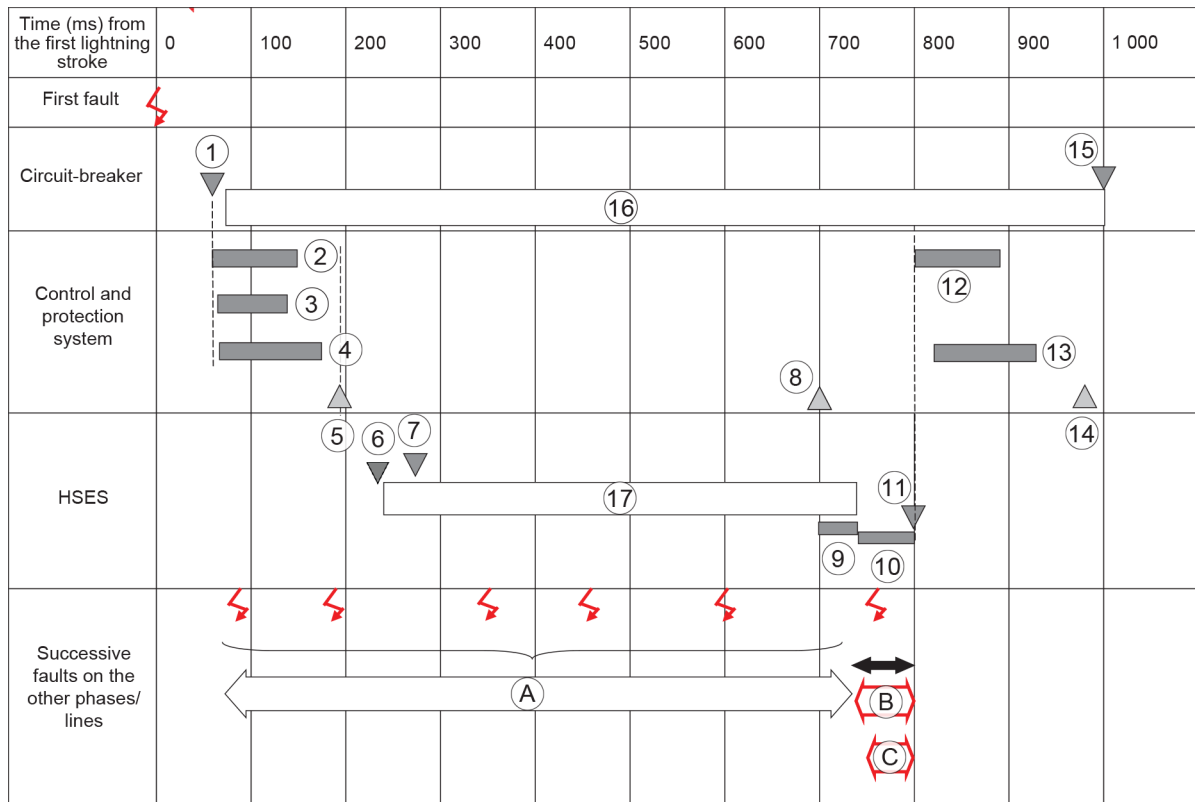
Figure A.2 – Timing chart of the HSESs in relation to the transmission line circuit-breakers



IEC 1899/13

Key

- A There may be successive faults. However these successive faults do not affect on the HSESs interruption since the successive faults on the other phases/ lines will have been cleared by CBs prior to the HSESs opening.
- B Successive fault may affect on HSESs interruption. Common value of break time is up to 100 ms.
- C Arcing time may be longer in case delayed current zero phenomena occurs.
- 1 CB₁, CB₂ open
- 2 Confirmation of CB₁ and CB₂ in open position
- 3 Main relay function recovery
- 4 Confirmation of re-close condition
- 5 HSES₁, HSES₂ close command
- 6 HSES₁, HSES₂ close
- 7 HSES₁, HSES₂ open command
- 8 HSES₁, HSES₂ opening time
- 9 HSES₁, HSES₂ arcing time
- 10 HSES₁, HSES₂ open
- 11 Confirmation of HSES₁, HSES₂ in open position
- 12 Confirmation of CB₁, CB₂ re-close condition
- 13 CB₁, CB₂ close command
- 14 CB₁, CB₂ re-close at 1 s
- 15 CB₁, CB₂ remain open
- 16 HSES₁, HSES₂ remain close



IEC

Key

- A There may be successive faults. However, these successive faults do not affect the HSESs interruption since the successive faults on the other phases/ lines will have been cleared by CBs prior to the HSESs opening.
- B Successive fault may affect HSESs interruption. Common value of break-time is up to 100 ms.
- C Arcing time may be longer in case delayed current zero phenomena occurs.
- 1 CB₁, CB₂ open
- 2 Confirmation of CB₁ and CB₂ in open position
- 3 Main relay function recovery
- 4 Confirmation of re-close condition
- 5 HSES₁, HSES₂ instant of initiation of closing operation
- 6 Instant of current flow
- 7 HSES₁, HSES₂ instant of contact touch
- 8 HSES₁, HSES₂ instant of initiation of opening operation
- 9 HSES₁, HSES₂ opening time
- 10 HSES₁, HSES₂ arcing time
- 11 HSES₁, HSES₂ instant of arc extinction
- 12 Confirmation of HSES₁, HSES₂ in open position
- 13 Confirmation of CB₁, CB₂ re-close condition
- 14 CB₁, CB₂ close command
- 15 CB₁, CB₂ re-close at 1 s
- 16 CB₁, CB₂ remain open
- 17 HSES₁, HSES₂ remain close

CB₁, CB₂, HSES₁ and HSES₂ are explained in Figure A.1.

Figure A.3 – Typical timing chart showing the time between fault initiation and a successful re-close of the transmission line circuit-breakers

Figure A.3 shows typical values of an operating sequence assuming the time interval from the initiation of a fault to the completion of reclosing of the circuit-breakers at both ends of 1 s.

The time duration between the duty cycles is specified by the user.

There are several necessary conditions which need to be fulfilled for successful application of HSES:

- the HSESs need automatic sequential control for each phase such as fault detection – circuit-breakers open – HSESs close – HSESs open – circuit-breakers close;
- the HSESs need a high reliable control system since a mal-operation will lead to an earth fault;
- the HSESs ~~should~~ shall be able to interrupt the induced current and to withstand a TRV caused by electromagnetic and/or electrostatic coupling effects;
- the fault is cleared by the circuit-breakers at both ends of lines.

A.3 Additional information about HSESs

A HSES is commonly used to short-circuit, commutate and clear the induced fault current. A detailed description is provided here.

The following main differences exist between the different earthing switches.

Table A.1 indicates a typical example of earthing switches design in systems having rated voltages of 500 kV and above.

Table A.1 – Comparison of earthing switches

Requirement	Earthing switch class E0	Earthing switch with short-circuit current making capability class E1 (and E2)	High speed earthing switch for secondary arc extinction (HSES)
Closing	Low speed, hand or motor operated	Fast (high-speed) closing operation	Fast (high-speed) closing operation, controlled
Opening	Low speed, hand or motor operated	Low speed, may be hand operated	Fast opening, controlled
Short-circuit current carrying capability	Yes	Yes	Yes
Making capability	None	Yes	Yes
Interrupting capability	None If specified	If specified	Shall be able to interrupt induced current and to withstand the associated TRV
Operating cycle	None	Close	Close- open
Electrical endurance	Withstand capability against full short-circuit current	2 closings against full short-circuit current	E1: 2 closings against full short-circuit current E2: 5 closings against full short-circuit current

A.4 Summary

The HSES needs to be operated in a well defined operating cycle. It needs a clearing capability for the defined induced currents together with a defined TRV withstand capability.

While an earthing switch as well as a fast acting earthing switch require the capability to withstand the full short circuit current, the function of a HSES is to short-circuit and thereafter to clear the induced current and to withstand the related TRV.

A.45 Comparison between the use of four-legged reactor and HSES

Table A.2 shows comparison of a four-legged reactor and HSES.

Table A.2 – Comparison of a four-legged reactor and HSES

	Four-legged reactor	HSES
Secondary arc extinction	<ul style="list-style-type: none"> – Effective especially for single-phase faults that hold the majority of the faults – Difficult to choose a reactance value of reactors that effectively reduce the secondary arc current for all fault modes for double circuit system 	Quick extinction for all fault modes
Flexibility to the network modification	In case a substation is constructed in the middle of a line, it might be required to substitute an existing reactor	No effect on the existing substation equipment
Control and Protection	Special control is not required for secondary arc extinction	Automatic sequential control such as “fault detection → CBs open → HSESs close → HSESs open → CBs close” is necessary in each phase, and it can be easily realized
Economy	A four-legged reactor is appropriate for transmission lines which require shunt reactors for voltage control, while HSES would be economical for the lines without shunt reactors	
Concern	Detailed analysis is necessary so as not to cause resonance between the shunt reactor inductance and line capacitance not only for a power frequency of 50/60 Hz but also in the high frequency band	Highly reliable control system is required since a malfunction leads to a ground fault

Annex B (informative)

Induced current and voltage conditions for other cases

B.1 General

This annex describes categories corresponding to the fault modes and the situations which are not covered by ~~Table 1~~ Table 2, corresponds to categories 0,1,3 and 4 introduced in this annex.

Category 2 is selected as principal duty and listed in the main text, because this duty covers most of the fault cases and will not be so very rare as the duties of categories 3 and 4.

B.2 Categories of fault conditions

B.2.1 Category 0

This is the basic category. One single-line earth fault occurs within the transmission circuits. Category 0 is covered by Table B.3.

B.2.2 Category 1

Up to one single-phase earth fault occurs within each circuit in a double-circuit system. Category 1 is covered by Table B.3.

B.2.3 Category 2

This is the case where a successive single-phase earth fault occurs on another phase during the opening operation of the HSESs at the phase where the first single-phase earth fault occurs. The successive fault may occur in the same circuit or in the adjacent circuit located in the vicinity of the circuit with a faulted line. Category 2 is covered by ~~Table 1~~ Table 2.

B.2.4 Category 3

This is the case where a single-phase to earth fault occurs with delayed current zero crossings in the presence of a successive single-phase earth fault. This duty is indicated in Table B.1.

During the delayed current zero period, the HSESs should withstand the stress caused by the arc that is generated between the contacts of the HSESs.

B.2.5 Category 4

This covers multi-phase faults within two or more phase circuits which are located in the vicinity of each other.

At least two lines in different phases remain without fault condition. This duty is indicated in Table B.2.

B.3 Delayed current zero phenomena

B.3.1 Explanation of an occurrence of delayed current zero phenomena

Delayed current zero phenomena will occur when a fault occurs on an adjacent phase at the time the current of the phase is around its peak. An example of system condition and waveforms are shown in Figure B.1 and Figure B.2, respectively.