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REDLINE VERSION

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 Varembé
CH-1211 Geneva 20
Switzerland

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

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colour inside

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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:~~2007~~2017, *High-voltage switchgear and controlgear – Part 1: Common specifications for alternating current switchgear and controlgear*

IEC 62271-100:~~2008~~2021, *High-voltage switchgear and controlgear – Part 100: Alternating current circuit-breakers*

IEC 62271-102:~~2001~~2018, *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:~~2011~~2017, 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

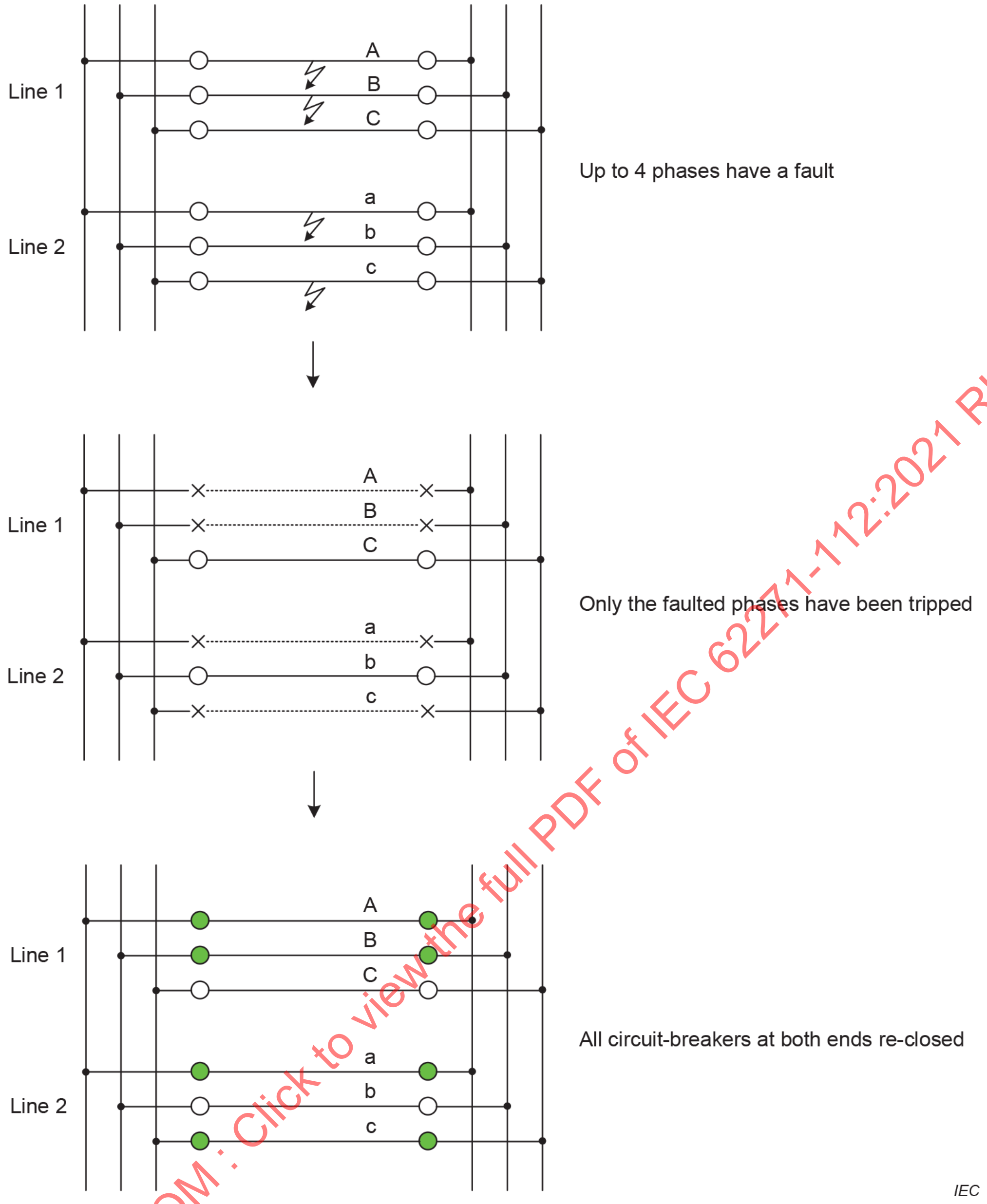
3.1.101
secondary arc
arc that remains at the faulted point after interruption of the short-circuit current fed by the network

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 un-faulted

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.

~~2~~4 Normal and special service conditions

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

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

~~4~~5 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

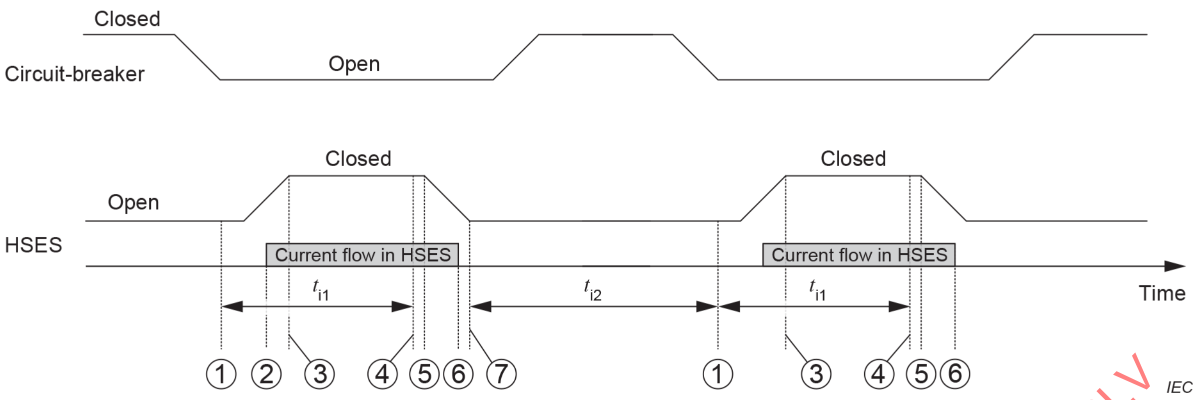
– t_{i1} is a time that is longer than the time required for secondary arc extinction and for dielectric recovery of air insulation at the faulted point. t_{i1} is determined by users considering system stability. The preferred value of t_{i1} is 0,15 s;

– 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~~ $\left(^{+10}_{-0}\ \%\right)$	~~Rated power frequency recovery voltage~~ $\left(^{+10}_{-0}\ \%\right)$	~~First TRV peak~~ $\left(^{+10}_{-0}\ \%\right)$	~~Time to first peak~~ $\left(^{+10}_{-0}\ \%\right)$	~~Rated induced current~~ $\left(^{+10}_{-0}\ \%\right)$	~~Rated induced voltage~~ $\left(^{+10}_{-0}\ \%\right)$
~~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.

5.106.11 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.

~~5~~6.101 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 1 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 62271-1:20072017.

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 IEC62271-1:2007 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.

~~6~~7.102 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 $^{+0}_{-20}$ %).

~~6~~7.103 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.

~~6~~7.105 Tests to prove the induced current making and breaking performance of HSES

~~6~~7.105.1 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 μF;

– 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.

~~6~~7.105.2 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 1~~ 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.

~~6~~7.105.3 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.

~~6~~7.105.4 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.

~~6~~7.105.5 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 62271-102:2001~~ 7.108.9 of IEC 62271-102:2018 is applicable.

~~7~~8 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 $^{+20}_{-0}$ % or $^{+10}_{-10}$ % or $^{+0}_{-20}$ %).

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

~~8~~9 Guide to the selection of HSESs (informative)

For the selection of HSESs described in ~~Table 1~~ 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.

~~9~~10 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.

~~11~~12 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.

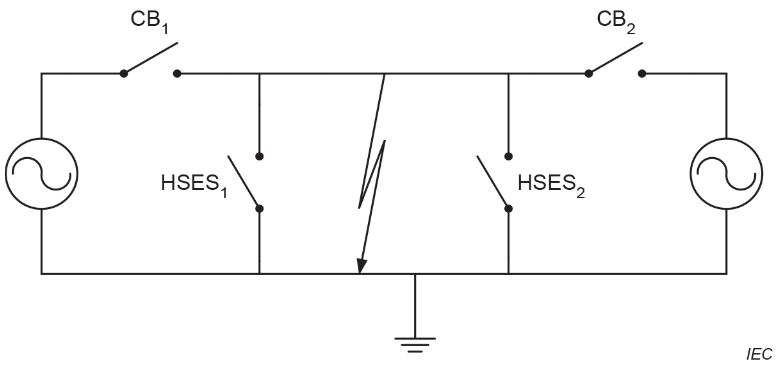
Therefore, the time duration between the duty cycles is specified by the user.

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.

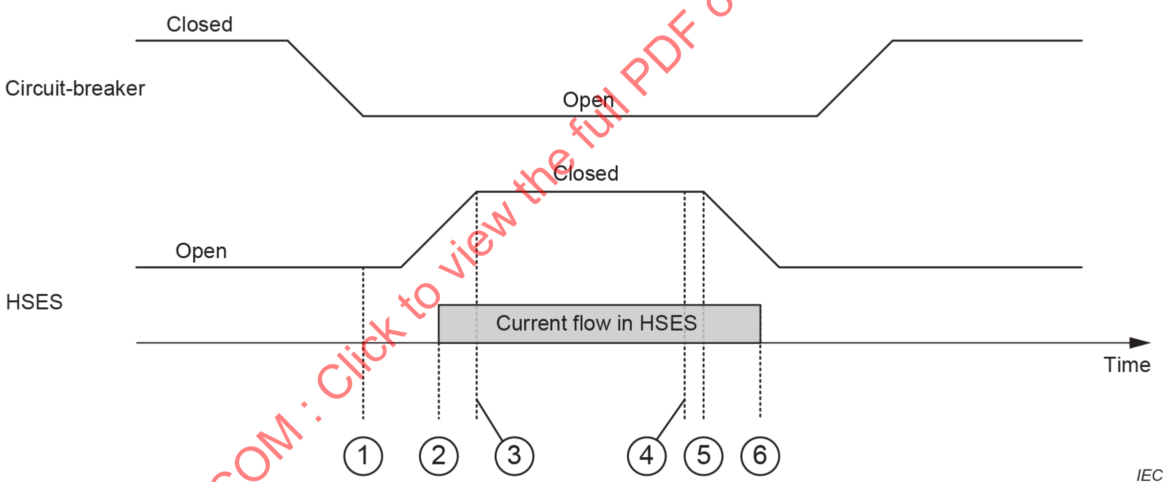


Key

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

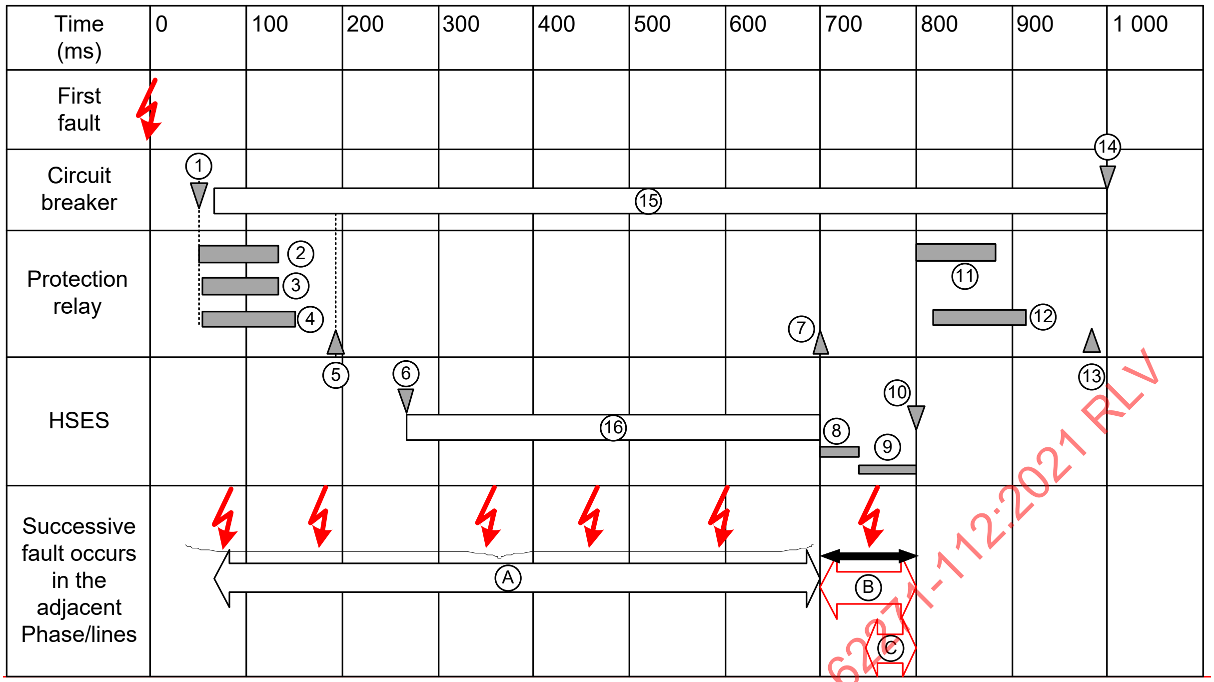
A typical timing chart of the relationship between the transmission line circuit-breakers that interrupt the fault and the HSESs is shown in Figure A.2. This figure shows the first O – C operation of the circuit-breakers and the first C – O operation of the HSESs.



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 CB_1, CB_2 open~~

~~2 Confirmation of CB_1 and CB_2 in open position~~

~~3 Main relay function recovery~~

~~4 Confirmation of re-close condition~~

~~5 $HSES_1$, $HSES_2$ close command~~

~~6 $HSES_1$, $HSES_2$ close~~

~~7 $HSES_1$, $HSES_2$ open command~~

~~8 $HSES_1$, $HSES_2$ opening time~~

~~9 $HSES_1$, $HSES_2$ arcing time~~

~~10 $HSES_1$, $HSES_2$ open~~

~~11 Confirmation of $HSES_1$, $HSES_2$ in open position~~

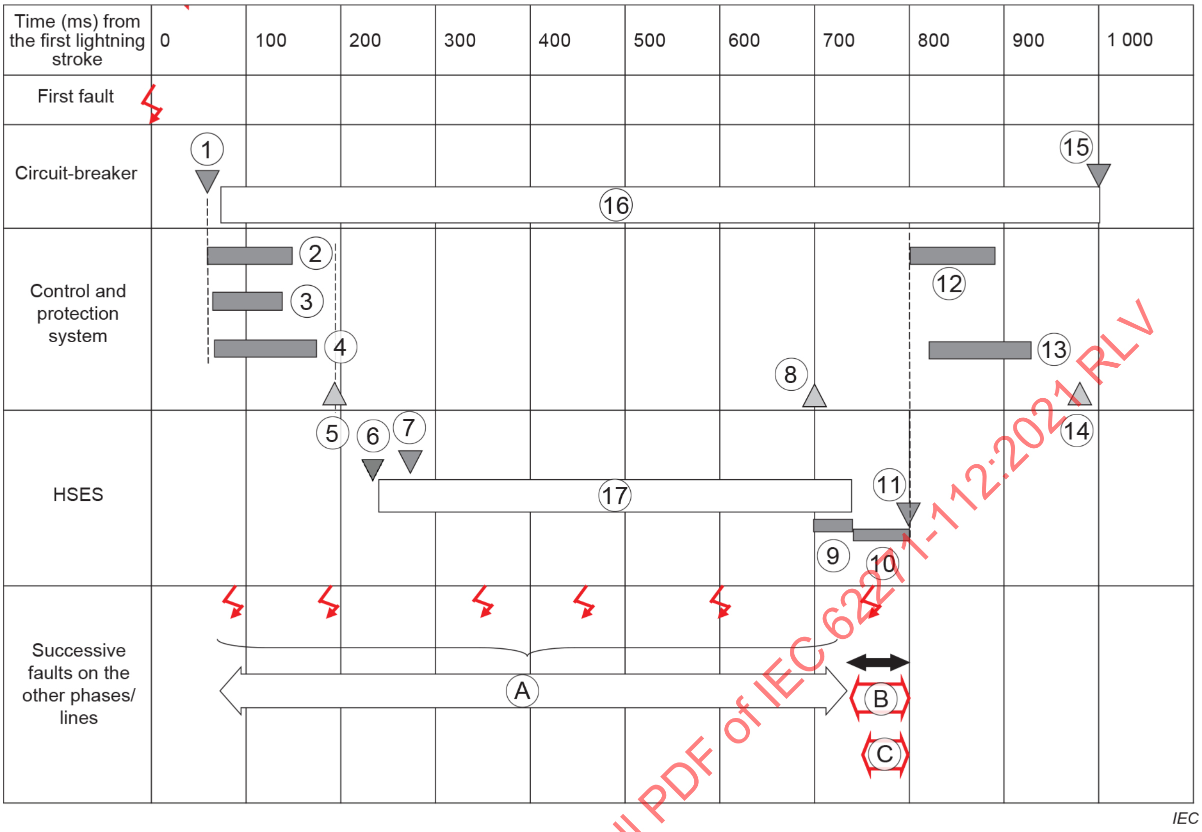
~~12 Confirmation of CB_1, CB_2 re-close condition~~

~~13 CB_1, CB_2 close command~~

~~14 CB_1, CB_2 re-close at 1 s~~

~~15 CB_1, CB_2 remain open~~

~~16 $HSES_1$, $HSES_2$ remain close~~



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 CB_1, CB_2 open

2 Confirmation of CB_1 and CB_2 in open position

3 Main relay function recovery

4 Confirmation of re-close condition

5 $HSES_1$, $HSES_2$ instant of initiation of closing operation

6 Instant of current flow

7 $HSES_1$, $HSES_2$ instant of contact touch

8 $HSES_1$, $HSES_2$ instant of initiation of opening operation

9 $HSES_1$, $HSES_2$ opening time

10 $HSES_1$, $HSES_2$ arcing time

11 $HSES_1$, $HSES_2$ instant of arc extinction

12 Confirmation of $HSES_1$, $HSES_2$ in open position

13 Confirmation of CB_1,CB_2 re-close condition

14 CB_1, CB_2 close command

15 CB_1, CB_2 re-close at 1 s

16 CB_1, CB_2 remain open

17 $HSES_1$, $HSES_2$ remain close

CB_1, CB_2, $HSES_1$ and $HSES_2$ 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	– 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.

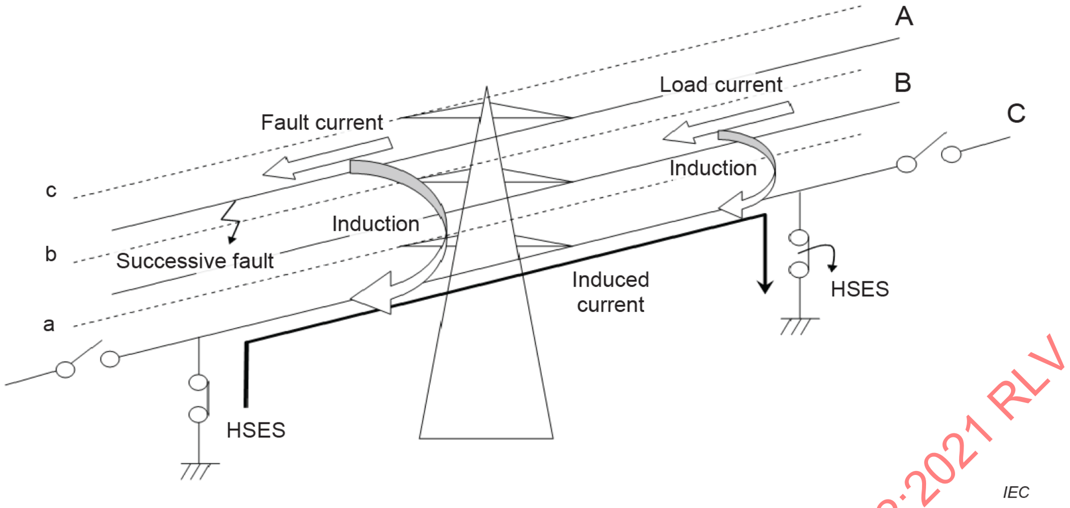
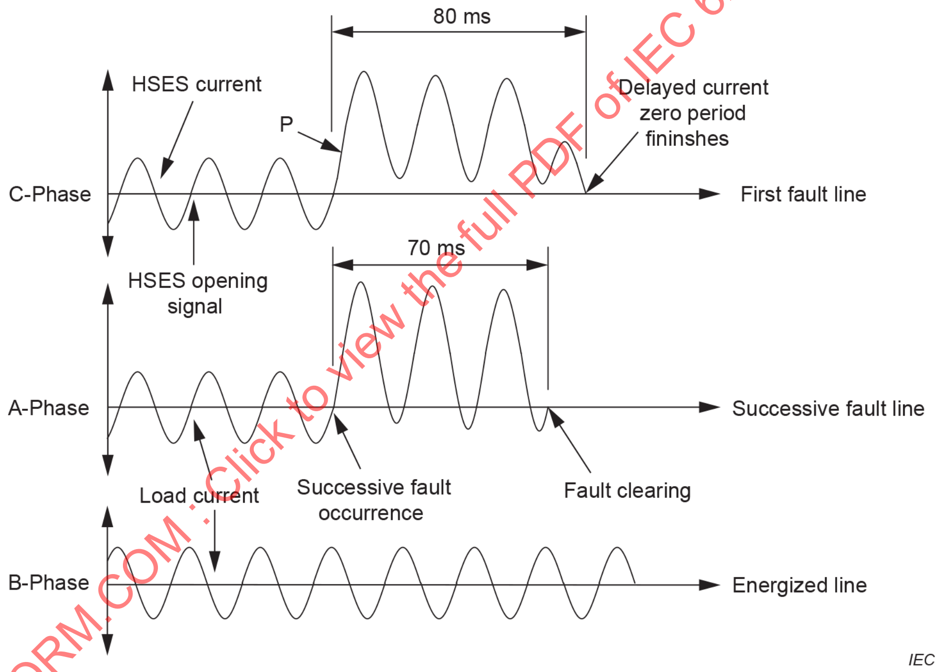


Figure B.1 – System condition to explain successive fault



Key

P is the instant when a successive fault occurs in phase A.

Figure B.2 – Example of waveforms of delayed current zero phenomena

Explanation:

a) an earth fault occurs on phase C;

b) the circuit-breakers at both ends of the line of phase C clear the fault;

c) HSESs in phase C close;

d) before ~~opening of~~ arc extinction in HSESs, a successive fault occurs in phase A;

e) if the timing of the occurrence of the successive fault is near the peak of the current in phase C, delayed current zeros may occur;

f) the circuit-breakers at both ends of line of phase A will clear the fault (maybe after 70 ms);

g) HSESs will clear the induced current (for example 80 ms later).

NOTE The most severe case for HSES will be the case that the second fault follows just before HSES breaks the electromagnetic induced current at the timing of instant P, because arcing time for HSES will be the longest.

B.3.2 Preferred values for single-phase earth fault with delayed current zero phenomena in the presence of a successive fault

Table B.1 – Preferred values for single-phase earth fault with delayed current zero phenomena in the presence of a successive fault

Rated voltage U_r	**Electromagnetic coupling**				**Electrostatic coupling**	
	induced current $(^{+10}_{-0}\ \%)$	**Power-frequency recovery voltage** $(^{+10}_{-0}\ \%)$	**First TRV peak** $(^{+10}_{-0}\ \%)$	**Time to first peak** $(^{+10}_{-0}\ \%)$	**induced current** $(^{+10}_{-0}\ \%)$	**induced voltage** $(^{+10}_{-0}\ \%)$
kV(RMS)	A (RMS)	kV(RMS)	kV (peak)	ms	A (RMS)	kV (RMS)
550	7 800	70	170	0,4	7 800	100
800	7 800	70	170	0,4	7 800	150
1 100 to 1 200	7 800	70	170	0,4	7 800	200

NOTE 1 A typical delayed current zero period is 80 ms, considering relay time, break-time of the circuit-breaker and the time between current zeros.

NOTE 2 This duty is the case considering the interruption occurs after the delayed current zero phenomena have disappeared.

NOTE 3 Actual test may lead to modified current wave shape due to interaction between test circuit and HSES.

This duty corresponds to category 3 in B.2.4.

~~This~~ Delayed current zero period should be specified by the users. During this period current zero should not occur.

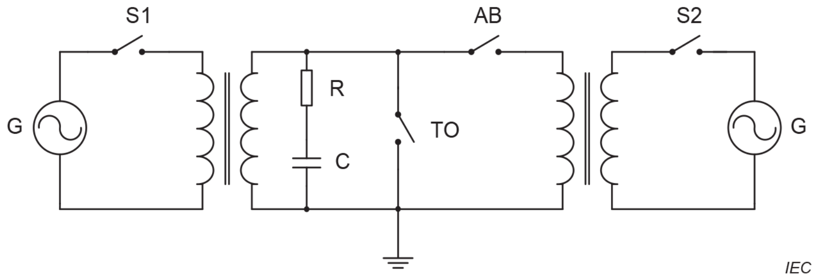
Type tests for HSES indicated in Table B.1 should be included to verify the arcing time of more than 80 ms with the condition specified in Table B.1.

Table B.1 indicates the test condition corresponding to single-phase earth fault with delayed current zero phenomena in the presence of successive single-phase earth fault. A HSES will interrupt the current at current zero. The first prospective current zero crossing should come after 80 ms, whereas the DC time constant of the fault current is 120 ms.

For the test with delayed current zero, the first natural current zero in the inherent condition should not be earlier than 80 ms after initiation of the short-circuit, with a time constant of 120 ms. The HSES will influence the inherent current waveform depending on its capability to force the current through zero. This phenomenon depends on the relative values of arc voltage and applied voltage. Therefore, the test should be performed with the correct applied voltage. If this is not possible due to test limitations, care should be exercised in the interpretation of the test results.

The duty during the delayed current zero phenomena is to confirm that the HSES can withstand such stress during that period. Only after the delayed current zero period finishes, interruption should be conducted.

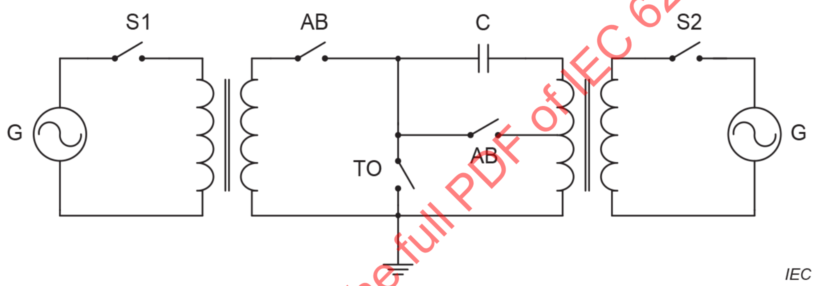
Typical test circuits to realize delayed current zero periods are shown in Figure B.3 and Figure B.4.



Key

G	Generator	R	Resistor
S1	Current making device	C	Capacitor
S2	Current making device	TO	Test object
AB	Auxiliary circuit-breaker		

Figure B.3 – Typical test circuit for electromagnetic coupling test-duty of a HSES with delayed current zero crossings



Key

G	Generator	TO	Test object
S1	Current making device	C	Capacitor
S2	Current making device		
AB	Auxiliary circuit-breaker		

Figure B.4 – Typical test circuit for electrostatic coupling test-duty of HSES with delayed current zero crossings

B.4 Preferred values of currents and voltages for multi-phase re-closing scheme

In case a multi-phase re-closing scheme is applied for the system, as explained in 3.1.103, auto re-closing by circuit-breakers can be conducted for continuing system operation under the condition that at least two lines in different phases remain un-faulted. In other words, re-closing operation can be conducted even under up to 4 phases having earth faults in the system. This duty corresponds to category 4 in B.2.5.

Table B.2 indicates the test condition corresponding to up to four-phase earth faults where a multi-phase auto-reclosing scheme is applied.

Table B.2 – Preferred values for multi-phase earth faults in a double-circuit system

Rated voltage U_r	Electromagnetic coupling				Electrostatic coupling	
	Induced current ($^{+10}_{-0}$ %)	Power-frequency recovery voltage ($^{+10}_{-0}$ %)	First TRV peak ($^{+10}_{-0}$ %)	Time to first peak ($^{+10}_{-0}$ %)	Induced current ($^{+10}_{-0}$ %)	Induced voltage ($^{+10}_{-0}$ %)
kV(RMS)	A (RMS)	kV(RMS)	kV(peak)	ms	A (RMS)	kV (RMS)
550	1 400	100	250	1,25	150	125
800	1 400	100	250	1,25	210	180
1 100 / 1 200	1 400	100	250	1,25	290	245

B.5 Interrupting condition to cover the cases corresponding to categories 0 and 1

Table B.3 indicates the test conditions corresponding to categories 0 and 1 in B.2.1 and B.2.2.

Table B.3 – Preferred values for covering the cases of categories 0 and 1

Rated voltage U_r	Electromagnetic coupling				Electrostatic coupling	
	Induced current ($^{+10}_{-0}$ %)	Power-frequency recovery voltage ($^{+10}_{-0}$ %)	First TRV peak ($^{+10}_{-0}$ %)	Time to first peak ($^{+10}_{-0}$ %)	Induced current ($^{+10}_{-0}$ %)	Induced voltage ($^{+10}_{-0}$ %)
kV(RMS)	A (RMS)	kV (RMS)	kV(peak)	ms	A (RMS)	kV (RMS)
550	700	80	200	1,0	120	90
800	830	80	200	1,0	170	140
1 100 / 1 200	830	80	200	1,0	230	200

Bibliography

CIGRE SC13 Colloquium 1995-9, *Specification and development of high-speed grounding switch (HSGS) for the use in fault 1 000 kV transmission lines in Japan*

CIGRE SC13-52, Paris 1996, *Development of 1 100 kV GIS – Gas circuit breakers, Disconnectors and High-speed grounding switches*

IEC 62271-112

Edition 2.0 2021-07

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

Appareillage à haute tension –
Partie 112: Sectionneurs de terre rapides à courant alternatif pour l'extinction de l'arc secondaire sur les lignes de transport

IEC 62271-112:2021-07(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

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

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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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.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

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

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 62271-1:2017, *High-voltage switchgear and controlgear – Part 1: Common specifications for alternating current switchgear and controlgear*

IEC 62271-100:2021, *High-voltage switchgear and controlgear – Part 100: Alternating current circuit-breakers*

IEC 62271-102:2018, *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*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in Clause 3 of IEC 62271-1:2017, 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

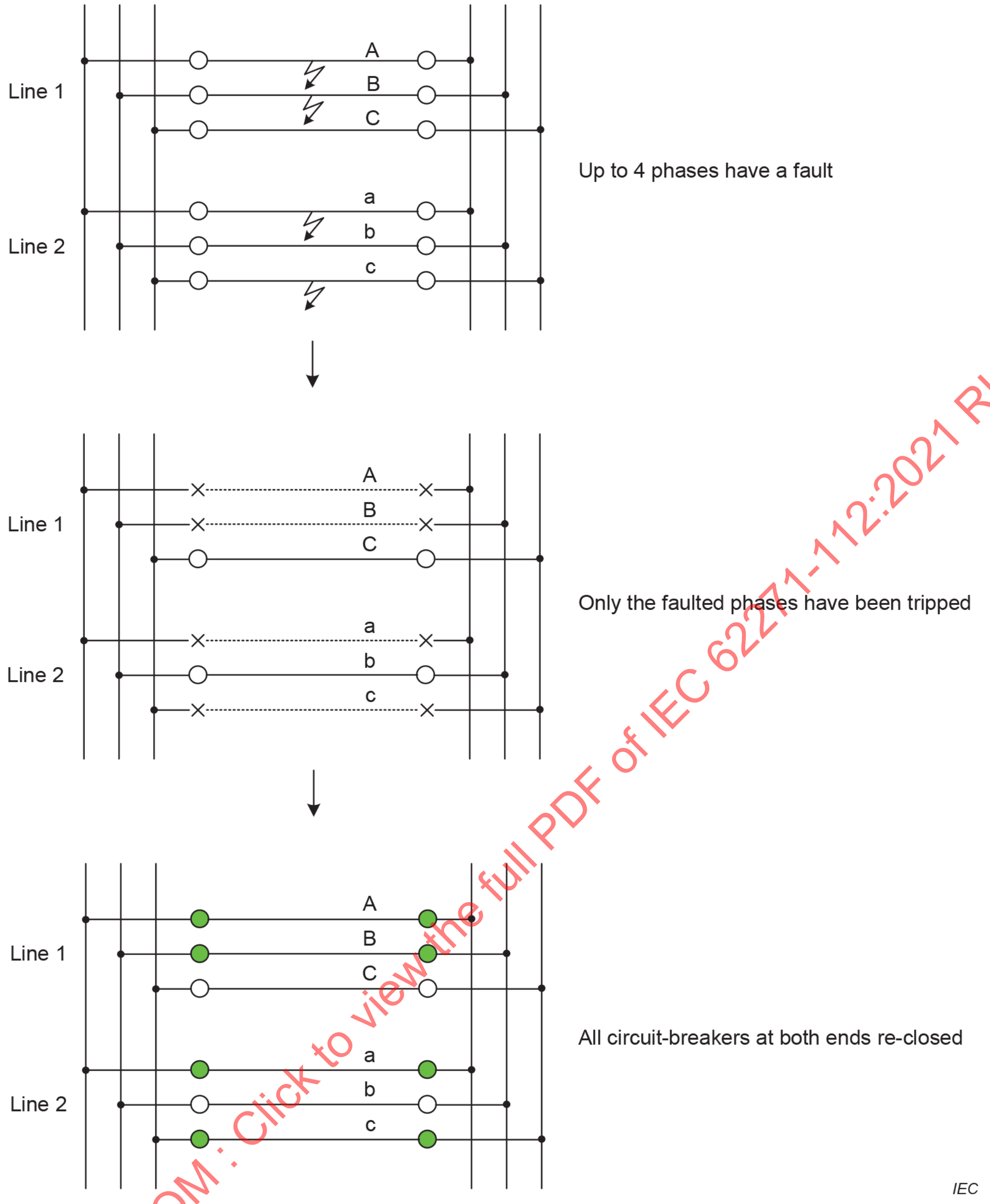
3.1.101
secondary arc
arc that remains at the faulted point after interruption of the short-circuit current fed by the network

Note 1 to entry: This secondary arc is supplied by electrostatic or electromagnetic induction from the adjacent 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 un-faulted

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

2) Only the faulted phases have been tripped

3) All circuit-breakers at both ends re-closed

○ Closed circuit-breaker

× Open circuit-breaker

● 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.

3.4.102
high-speed earthing switch class M0
high-speed earthing switch having a normal mechanical endurance of 1 000 operation cycles

3.4.103
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.

4 Normal and special service conditions

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

5 Ratings

5.1 General

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.

5.5 Rated continuous current (I_r)

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

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

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

5.102 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

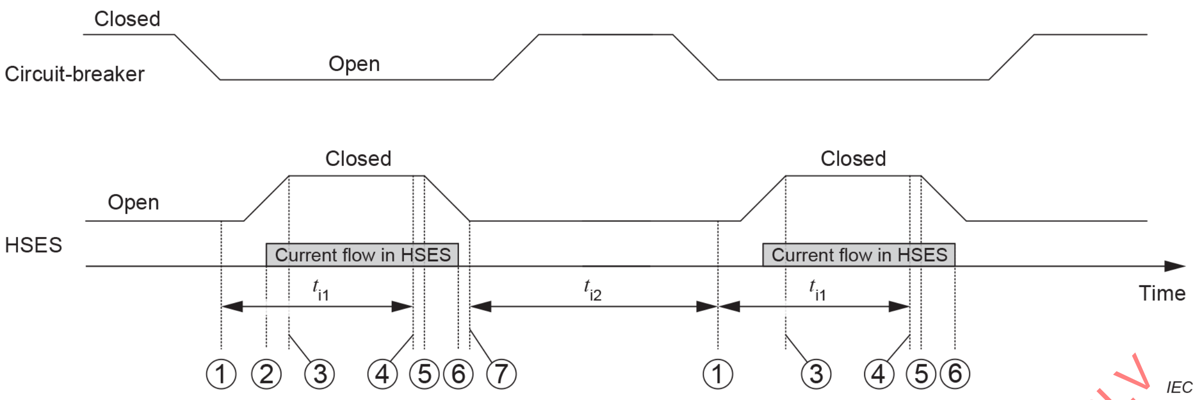
– t_{i1} is a time that is longer than the time required for secondary arc extinction and for dielectric recovery of air insulation at the faulted point. t_{i1} is determined by users considering system stability. The preferred value of t_{i1} is 0,15 s;

– 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 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

6 Design and construction

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

6.5 Dependent power operation

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

6.7 Independent unlatched operation (independent manual or power operation)

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

6.11 Nameplates

The designation of the equipment is specified as HSES.

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

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

6.12 Locking devices

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

6.101 Anti-pumping device

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

6.102 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 2.

The HSES shall have a capability to withstand 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.

7 Type tests

7.1 General

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 62271-1:2017.

7.3 Radio interference voltage (RIV) test

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

7.5 Continuous current tests

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

7.101 Tests to prove the short-circuit making performance

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

7.102 Operating and mechanical endurance tests

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 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 $^{+0}_{-20}$ %).

7.103 Operation under severe ice conditions

Subclause 7.103 of 62271-102:2018 is applicable.

7.104 Low- and high-temperature tests

Subclause 7.104 of 62271-102:2018 is applicable.

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

7.105.1 General test conditions

Tests shall be performed in accordance with the standard condition values for HSES specified in 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 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 7.102.4.1 of IEC 62271-100:2021.

Test circuits are those shown in 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 μF;

– surge impedance: 245 Ω;

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 5.109 of IEC 62271-102:2018.

7.105.2 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 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.

7.105.3 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.

7.105.4 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.

7.105.5 Condition after the test

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

Subclause 7.108.9 of IEC 62271-102:2018 is applicable.

8 Routine tests

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

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

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

20 % (for example $^{+20}_{-0}$ % or $^{+10}_{-10}$ % or $^{+0}_{-20}$ %).

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

9 Guide to the selection of HSESs (informative)

For the selection of HSESs described in Table 2 and also in Table B.1 and Table B.2 if necessary, the following conditions and requirements at site 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);
– consideration on successive faults and other special conditions such as delayed current zero phenomena during HSES operations;
– required operational performance (mechanical endurance);
– switching requirements (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.

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

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

11 Transport, storage, installation, operating instructions and maintenance

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

12 Safety

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 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.

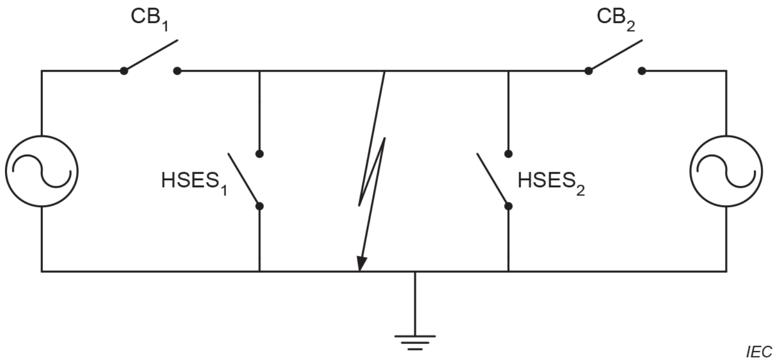
Therefore, the time duration between the duty cycles is specified by the user.

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.

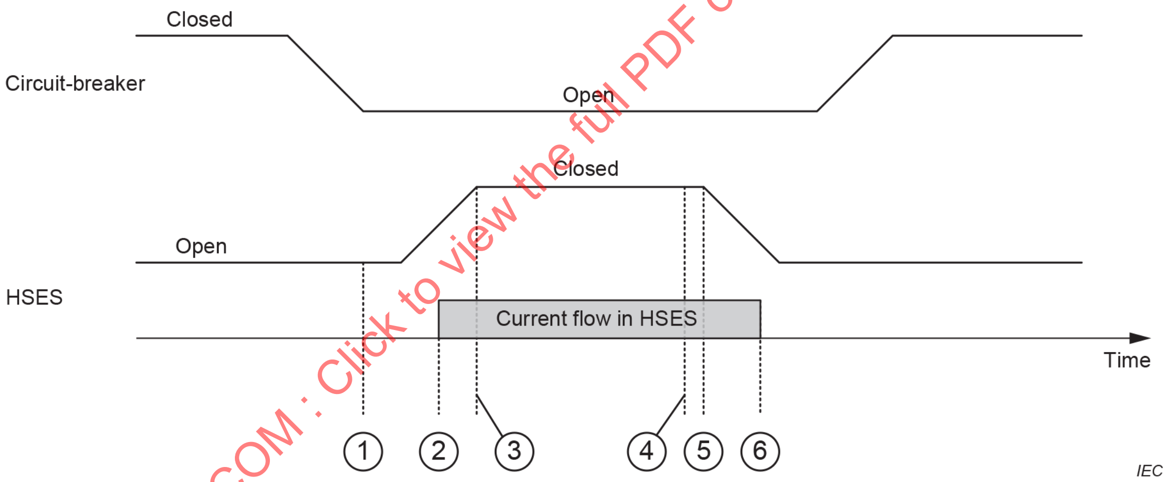


Key

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

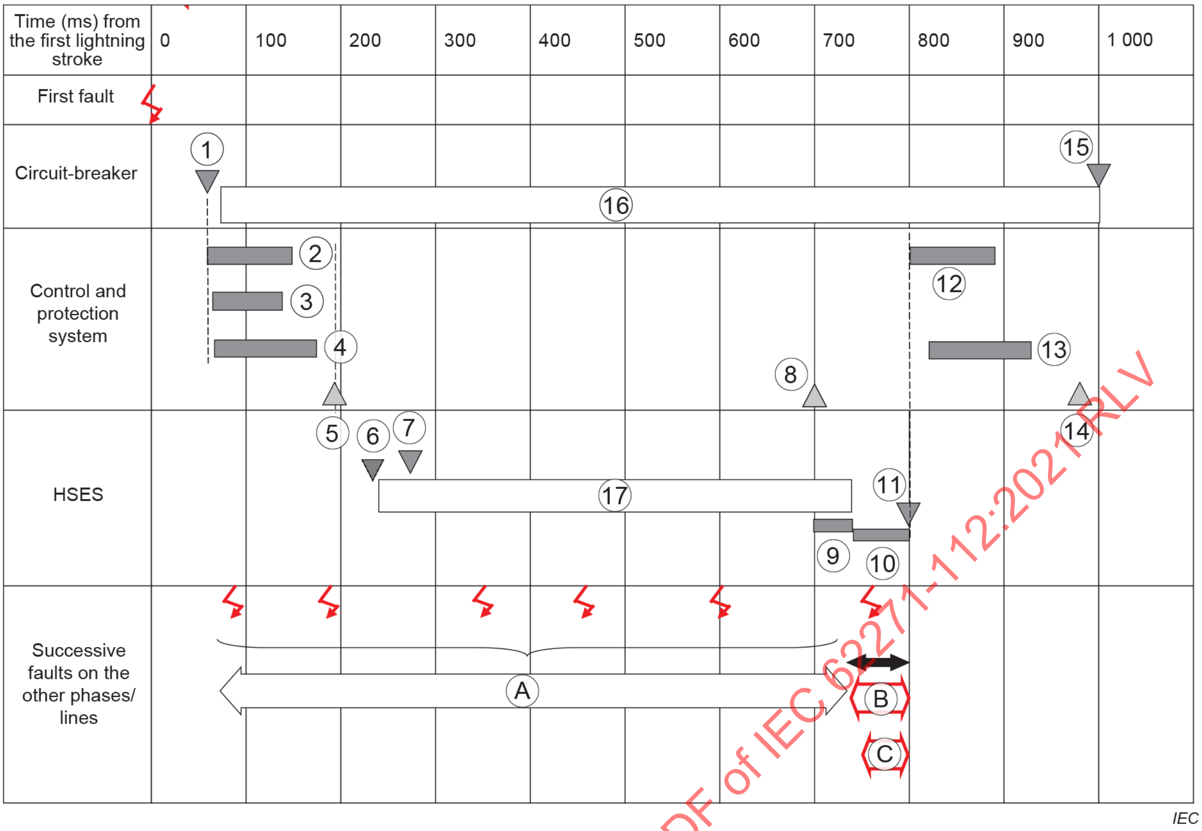
A typical timing chart of the relationship between the transmission line circuit-breakers that interrupt the fault and the HSESs is shown in Figure A.2. This figure shows the first O – C operation of the circuit-breakers and the first C – O operation of the HSESs.



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



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 CB_1, CB_2 open

2 Confirmation of CB_1 and CB_2 in open position

3 Main relay function recovery

4 Confirmation of re-close condition

5 $HSES_1$, $HSES_2$ instant of initiation of closing operation

6 Instant of current flow

7 $HSES_1$, $HSES_2$ instant of contact touch

8 $HSES_1$, $HSES_2$ instant of initiation of opening operation

9 $HSES_1$, $HSES_2$ opening time

10 $HSES_1$, $HSES_2$ arcing time

11 $HSES_1$, $HSES_2$ instant of arc extinction

12 Confirmation of $HSES_1$, $HSES_2$ in open position

13 Confirmation of CB_1,CB_2 re-close condition

14 CB_1, CB_2 close command

15 CB_1, CB_2 re-close at 1 s

16 CB_1, CB_2 remain open

17 $HSES_1$, $HSES_2$ remain close

CB_1, CB_2, $HSES_1$ and $HSES_2$ 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 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	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	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.5 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	– 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 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 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.

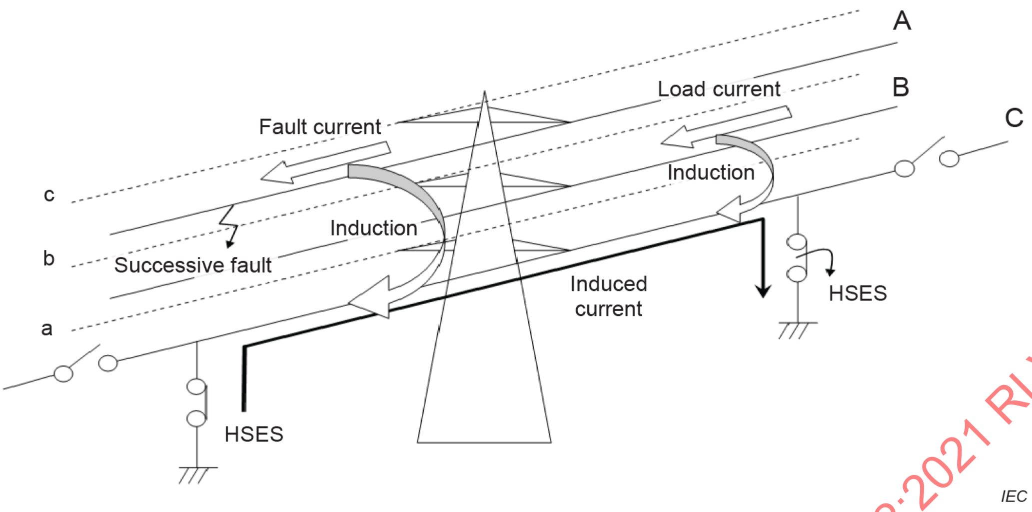
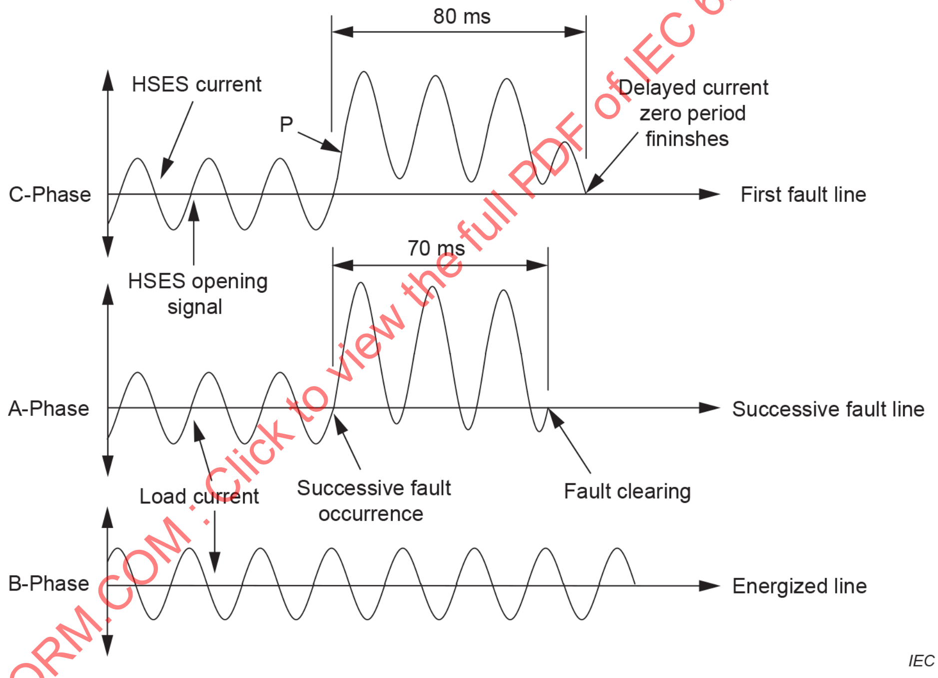


Figure B.1 – System condition to explain successive fault



Key

P is the instant when a successive fault occurs in phase A.

Figure B.2 – Example of waveforms of delayed current zero phenomena

Explanation:

a) an earth fault occurs on phase C;

b) the circuit-breakers at both ends of the line of phase C clear the fault;

c) HSESs in phase C close;

d) before arc extinction in HSESs, a successive fault occurs in phase A;

e) if the timing of the occurrence of the successive fault is near the peak of the current in phase C, delayed current zeros may occur;

f) the circuit-breakers at both ends of line of phase A will clear the fault (maybe after 70 ms);

g) HSESs will clear the induced current (for example 80 ms later).

NOTE The most severe case for HSES will be the case that the second fault follows just before HSES breaks the electromagnetic induced current at the timing of instant P, because arcing time for HSES will be the longest.

B.3.2 Preferred values for single-phase earth fault with delayed current zero phenomena in the presence of a successive fault

Table B.1 – Preferred values for single-phase earth fault with delayed current zero phenomena in the presence of a successive fault

Rated voltage U_r	Electromagnetic coupling				Electrostatic coupling	
	induced current $\left(^{+10}_{-0}\ \%\right)$	Power-frequency recovery voltage $\left(^{+10}_{-0}\ \%\right)$	First TRV peak $\left(^{+10}_{-0}\ \%\right)$	Time to first peak $\left(^{+10}_{-0}\ \%\right)$	induced current $\left(^{+10}_{-0}\ \%\right)$	induced voltage $\left(^{+10}_{-0}\ \%\right)$
kV(RMS)	A (RMS)	kV(RMS)	kV (peak)	ms	A (RMS)	kV (RMS)
550	7 800	70	170	0,4	7 800	100
800	7 800	70	170	0,4	7 800	150
1 100 to 1 200	7 800	70	170	0,4	7 800	200

NOTE 1 A typical delayed current zero period is 80 ms, considering relay time, break-time of the circuit-breaker and the time between current zeros.

NOTE 2 This duty is the case considering the interruption occurs after the delayed current zero phenomena have disappeared.

NOTE 3 Actual test may lead to modified current wave shape due to interaction between test circuit and HSES.

This duty corresponds to category 3 in B.2.4.

Delayed current zero period should be specified by the users. During this period current zero should not occur.

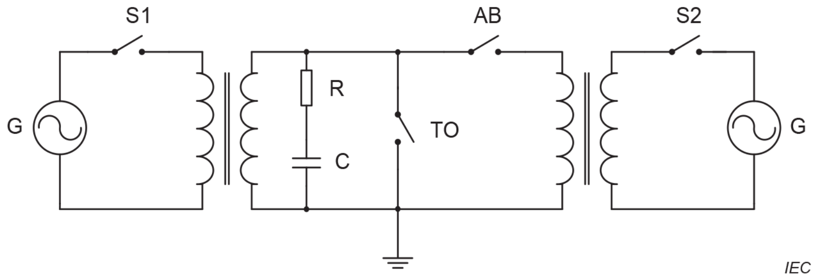
Type tests for HSES indicated in Table B.1 should be included to verify the arcing time of more than 80 ms with the condition specified in Table B.1.

Table B.1 indicates the test condition corresponding to single-phase earth fault with delayed current zero phenomena in the presence of successive single-phase earth fault. A HSES will interrupt the current at current zero. The first prospective current zero crossing should come after 80 ms, whereas the DC time constant of the fault current is 120 ms.

For the test with delayed current zero, the first natural current zero in the inherent condition should not be earlier than 80 ms after initiation of the short-circuit, with a time constant of 120 ms. The HSES will influence the inherent current waveform depending on its capability to force the current through zero. This phenomenon depends on the relative values of arc voltage and applied voltage. Therefore, the test should be performed with the correct applied voltage. If this is not possible due to test limitations, care should be exercised in the interpretation of the test results.

The duty during the delayed current zero phenomena is to confirm that the HSES can withstand such stress during that period. Only after the delayed current zero period finishes, interruption should be conducted.

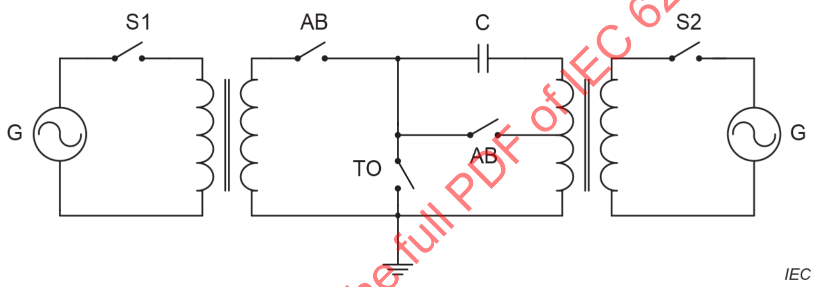
Typical test circuits to realize delayed current zero periods are shown in Figure B.3 and Figure B.4.



Key

G	Generator	R	Resistor
S1	Current making device	C	Capacitor
S2	Current making device	TO	Test object
AB	Auxiliary circuit-breaker		

Figure B.3 – Typical test circuit for electromagnetic coupling test-duty of a HSES with delayed current zero crossings



Key

G	Generator	TO	Test object
S1	Current making device	C	Capacitor
S2	Current making device		
AB	Auxiliary circuit-breaker		

Figure B.4 – Typical test circuit for electrostatic coupling test-duty of HSES with delayed current zero crossings

B.4 Preferred values of currents and voltages for multi-phase re-closing scheme

In case a multi-phase re-closing scheme is applied for the system, as explained in 3.1.103, auto re-closing by circuit-breakers can be conducted for continuing system operation under the condition that at least two lines in different phases remain un-faulted. In other words, re-closing operation can be conducted even under up to 4 phases having earth faults in the system. This duty corresponds to category 4 in B.2.5.

Table B.2 indicates the test condition corresponding to up to four-phase earth faults where a multi-phase auto-reclosing scheme is applied.

Table B.2 – Preferred values for multi-phase earth faults in a double-circuit system

Rated voltage U_r	Electromagnetic coupling				Electrostatic coupling	
	Induced current ($^{+10}_{-0}$ %)	Power-frequency recovery voltage ($^{+10}_{-0}$ %)	First TRV peak ($^{+10}_{-0}$ %)	Time to first peak ($^{+10}_{-0}$ %)	Induced current ($^{+10}_{-0}$ %)	Induced voltage ($^{+10}_{-0}$ %)
kV(RMS)	A (RMS)	kV(RMS)	kV(peak)	ms	A (RMS)	kV (RMS)
550	1 400	100	250	1,25	150	125
800	1 400	100	250	1,25	210	180
1 100 / 1 200	1 400	100	250	1,25	290	245

B.5 Interrupting condition to cover the cases corresponding to categories 0 and 1

Table B.3 indicates the test conditions corresponding to categories 0 and 1 in B.2.1 and B.2.2.

Table B.3 – Preferred values for covering the cases of categories 0 and 1

Rated voltage U_r	Electromagnetic coupling				Electrostatic coupling	
	Induced current ($^{+10}_{-0}$ %)	Power-frequency recovery voltage ($^{+10}_{-0}$ %)	First TRV peak ($^{+10}_{-0}$ %)	Time to first peak ($^{+10}_{-0}$ %)	Induced current ($^{+10}_{-0}$ %)	Induced voltage ($^{+10}_{-0}$ %)
kV(RMS)	A (RMS)	kV (RMS)	kV(peak)	ms	A (RMS)	kV (RMS)
550	700	80	200	1,0	120	90
800	830	80	200	1,0	170	140
1 100 / 1 200	830	80	200	1,0	230	200

Bibliography

CIGRE SC13 Colloquium 1995-9, *Specification and development of high-speed grounding switch (HSGS) for the use in fault 1 000 kV transmission lines in Japan*

CIGRE SC13-52, Paris 1996, *Development of 1 100 kV GIS – Gas circuit breakers, Disconnectors and High-speed grounding switches*

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SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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APPAREILLAGE À HAUTE TENSION –

Partie 112: Sectionneurs de terre rapides à courant alternatif pour l'extinction de l'arc secondaire sur les lignes de transport

AVANT-PROPOS

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L'IEC 62271-112 a été établie par le sous-comité 17A: Appareils de connexion, du comité d'études 17 de l'IEC: Appareillage haute tension. Il s'agit d'une Norme internationale.

Cette deuxième édition annule et remplace la première édition parue en 2013. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

Le document a été mis à jour par rapport à la deuxième édition de l'IEC 62271-1:2017.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
17A/1311/FDIS	17A/1314/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/standardsdev/publications.

Il convient que la présente Norme internationale soit lue conjointement avec l'IEC 62271-1:2017, à laquelle elle fait référence et qui est applicable, sauf indication contraire. Pour faciliter le repérage des exigences correspondantes, la numérotation utilisée pour les articles et les paragraphes est identique à celle de l'IEC 62271-1:2017. Les modifications de ces articles et de ces paragraphes ont des références identiques; les paragraphes supplémentaires qui n'ont pas d'équivalents sont numérotés à partir de 101.

Une liste de toutes les parties de la série IEC 62271, publiées sous le titre général *Appareillage à haute tension*, peut être consultée sur le site web de l'IEC.

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APPAREILLAGE À HAUTE TENSION –

Partie 112: Sectionneurs de terre rapides à courant alternatif pour l'extinction de l'arc secondaire sur les lignes de transport

1 Domaine d'application

La présente partie de l'IEC 62271 s'applique aux sectionneurs de terre rapides à courant alternatif (nommés ci-après HSES) conçus pour les installations intérieures et extérieures et pour fonctionner à des fréquences de 50 Hz et 60 Hz sur des réseaux de tensions assignées supérieures ou égales à 550 kV.

Les HSES décrits dans le présent document sont destinés à supprimer l'arc secondaire demeurant après l'élimination des défauts sur les lignes de transport par les disjoncteurs.

Pour de plus amples informations sur les HSES, voir l'Annexe A.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60050-441:1984, *Vocabulaire électrotechnique international – Chapitre 441: Appareillage et fusibles*
IEC 60050-441:1984/AMD1:2000

IEC 62271-1:2017, *Appareillage à haute tension – Partie 1: Spécifications communes pour appareillage à courant alternatif*

IEC 62271-100:2021, *Appareillage à haute tension – Partie 100: Disjoncteurs à courant alternatif à haute tension*

IEC 62271-102:2018, *Appareillage à haute tension – Partie 102: Sectionneurs et sectionneurs de terre à courant alternatif*

IEC 62271-200:2011, *Appareillage à haute tension – Partie 200: Appareillage sous enveloppe métallique pour courant alternatif de tensions assignées supérieures à 1 kV et inférieures ou égales à 52 kV*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions donnés dans l'Article 3 de l'IEC 62271-1:2017, ainsi que les suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

Des termes et définitions supplémentaires sont classifiés afin d'être alignés sur la classification utilisée dans l'IEC 60050-441.

3.1 Termes généraux et définitions

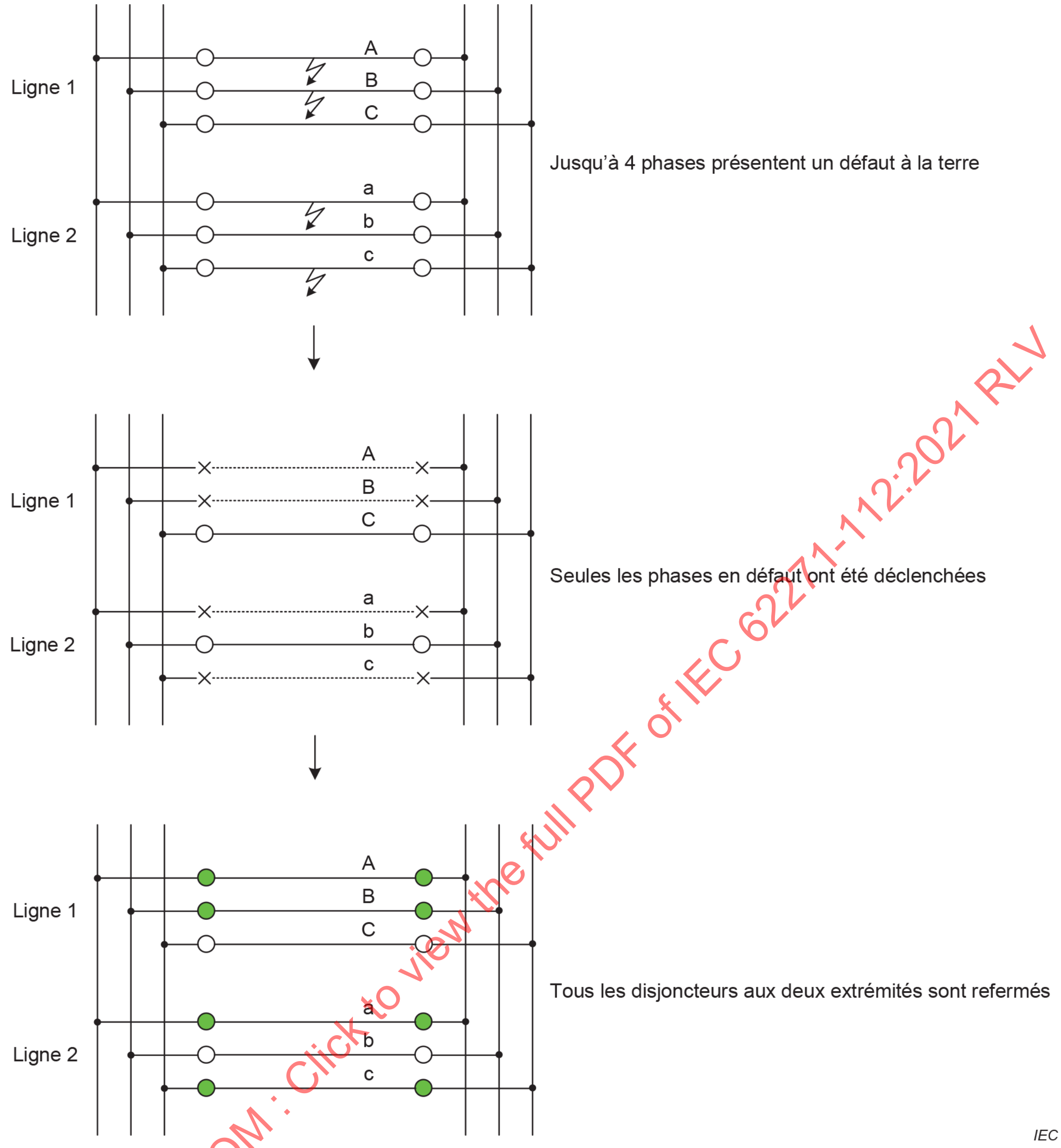
3.1.101
arc secondaire
arc demeurant au point de défaut après la coupure du courant de court-circuit et alimenté par le réseau

Note 1 à l'article: Cet arc secondaire est alimenté par les phases sous tension par induction électrostatique ou électromagnétique.

3.1.102
stratégie de refermeture automatique monophasée
stratégie de refermeture automatique selon laquelle une phase en défaut d'un circuit est déclenchée et refermée indépendamment des autres phases

3.1.103
stratégie de refermeture automatique à plusieurs phases
stratégie de refermeture automatique appliquée aux lignes aériennes à double circuit dans laquelle toutes les phases en défaut sont déclenchées et refermées indépendamment à condition qu'au moins deux phases de circuit différentes restent sans défaut

Note 1 à l'article: Un exemple de stratégie de refermeture automatique à plusieurs phases est montré par la Figure 1.



Légende

1)	Jusqu'à 4 phases présentent un défaut à la terre	○	Disjoncteur fermé
2)	Seules les phases en défaut ont été déclenchées	×	Disjoncteur ouvert
3)	Tous les disjoncteurs aux deux extrémités sont refermés	●	Disjoncteur refermé

Figure 1 – Explication d'une stratégie de refermeture automatique à plusieurs phases

Note 2 à l'article: Une stratégie autre que celle décrite en 3.1.102 et 3.1.103 est communément appliquée: une stratégie de refermeture automatique triphasée. Selon cette stratégie, les trois phases sont déclenchées et refermées aux deux extrémités même si un défaut ne survient que sur une phase. Pour le moment, les sectionneurs de terre rapides sont rarement appliqués avec cette stratégie.

3.1.104
défaut successif
défaut à la terre supplémentaire survenant dans un (des) circuit(s) de phase(s) adjacent(s) durant l'intervalle de temps entre un défaut monophasé à la terre et l'ouverture du (des) sectionneur(s) de terre rapide(s)

3.2 Ensembles d'appareillages

Pas de définition particulière.

3.3 Parties d'ensembles

Pas de définition particulière.

3.4 Appareils de connexion

3.4.101
sectionneur de terre rapide
HSES
sectionneur de terre capable:

– d'établir, conduire et couper le courant induit;
– de supporter la tension de rétablissement générée par les couplages électromagnétique et/ou électrostatique avant la refermeture du circuit;
– d'établir et supporter le courant de court-circuit assigné

Note 1 à l'article: En général, le fonctionnement rapide s'applique à la fois pour la fermeture et pour l'ouverture.

Note 2 à l'article: Un sectionneur de terre rapide n'est pas prévu pour être utilisé comme sectionneur de mise à la terre lors d'une maintenance.

Note 3 à l'article: L'abréviation "HSES" est dérivée du terme anglais développé correspondant "high-speed earthing switch".

3.4.102
sectionneur de terre rapide de classe M0
sectionneur de terre rapide doté d'une endurance mécanique de 1 000 cycles de manœuvres

3.4.103
sectionneur de terre rapide de classe M1
sectionneur de terre rapide doté d'une endurance mécanique étendue de 2 000 cycles de manœuvres pour exigences spéciales

3.5 Parties d'appareillage

Pas de définition particulière.

3.6 Caractéristiques de fonctionnement de l'appareillage

Pas de définition particulière.

3.7 Grandeurs caractéristiques

Pas de définition particulière.

4 Conditions normales et spéciales de service

L'Article 4 de l'IEC 62271-1:2017 s'applique.

5 Caractéristiques assignées

5.1 Généralités

L'Article 5 de l'IEC 62271-1:2017 s'applique avec les ajouts suivants.

NOTE Les catégories correspondant aux modes de défaut sont expliquées à l'Annexe B.

5.5 Courant permanent assigné (I_r)

Le paragraphe 5.5 de l'IEC 62271-1:2017 ne s'applique pas.

5.101 Pouvoir de fermeture assigné en court-circuit (I_{ma})

Le paragraphe 5.101 de l'IEC 62271-102:2018 s'applique.

5.102 Séquence de manœuvres assignée

Les caractéristiques assignées du HSES sont rattachées à la séquence de manœuvres assignée.

a) C – t_{i1} – O,

ou

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

où

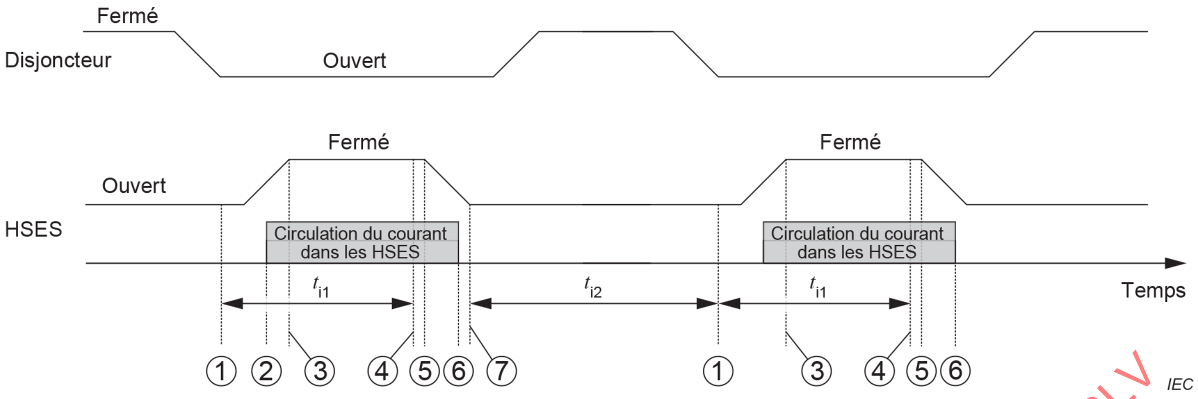
– t_{i1} est une durée supérieure à la durée exigée pour l'extinction de l'arc secondaire et pour le recouvrement diélectrique de l'isolation dans l'air au point en défaut. t_{i1} est déterminé par les utilisateurs en prenant en compte la stabilité du réseau. La valeur préférentielle de t_{i1} est 0,15 s;

– t_{i2} est la durée intermédiaire donnée par la protection du réseau. t_{i2} comprend la durée de fermeture des disjoncteurs après l'ouverture des HSES, la durée d'un nouveau défaut sur la ligne et la durée de coupure des disjoncteurs. Une fois la durée t_{i2} écoulée, les HSES peuvent alors être refermés. La valeur préférentielle de t_{i2} est 0,5 s.

Dans ce cas, le HSES doit être capable de fonctionner sans retard intentionnel.

NOTE t_{i1} et t_{i2} sont établies par une stratégie de système de commande et un HSES doit fonctionner selon son propre temps de fonctionnement.

La Figure 2 présente le chronogramme de la séquence de manœuvres assignée de C – t_{i1} – O – t_{i2} – C – t_{i1} – O.



Légende

Disjoncteur	Disjoncteurs de la ligne de transport qui interrompent le défaut	3	Entrée en contact des HSES
HSES	Sectionneurs de terre rapides	4	Mise sous tension du déclencheur de l'ouverture des HSES
1	Mise sous tension du circuit de fermeture des HSES	5	Séparation des contacts des HSES
2	Début de la circulation du courant dans les HSES	6	Extinction de l'arc dans les HSES
t_{i1}, t_{i2}	Durées définies en 5.102	7	Position d'ouverture complète des HSES

NOTE 1 La valeur commune de la durée de refermeture est 1 s afin de garantir la stabilité du réseau.

NOTE 2 t_{i1} est normalement situé dans la plage de 0,15 s à 0,5 s.

NOTE 3 t_{i2} est normalement situé dans la plage de 0,5 s à 1 s.

NOTE 4 La séquence de manœuvres b) permet la stabilité de réseau dans le cas où un nouveau défaut apparaît sur la même phase.

NOTE 5 La durée de fermeture des HSES est généralement inférieure à 0,2 s.

Figure 2 – Chronogramme des HSES et des disjoncteurs

6 Conception et construction

L'Article 6 de l'IEC 62271-1:2017 s'applique avec les modifications suivantes.

6.5 Manœuvre dépendante à source d'énergie extérieure

Le paragraphe 6.5 de l'IEC 62271-1:2017 ne s'applique pas.

6.7 Manœuvre indépendante sans accrochage mécanique (manœuvre indépendante manuelle ou manœuvre indépendante à source d'énergie extérieure)

Le paragraphe 6.7 de l'IEC 62271-1:2017 ne s'applique pas.

6.11 Plaques signalétiques

La désignation de l'équipement est spécifiée comme étant HSES.

Les éléments devant être indiqués sur la plaque signalétique sont énumérés dans le Tableau 1.

Tableau 1 – Informations sur la plaque signalétique

Élément	Abréviation	Unité
Nom du fabricant		
Désignation du type		
Numéro de série Année de fabrication		
Tension assignée	U_r	kV
Tension assignée de tenue aux chocs de foudre	U_p	kV
Tension assignée de tenue aux chocs de manœuvre	U_s	kV
Tension assignée de tenue à fréquence industrielle	U_d	kV
Courant de courte durée admissible assigné	I_k	kA
Valeur de crête du courant admissible assignée	I_p	kA
Durée de court-circuit assignée	t_k	s
Pouvoir de fermeture assigné en court-circuit	I_{ma}	kA
Pression de remplissage pour l'isolement	P_{re}	MPa
Pression de remplissage pour la manœuvre	P_{rm}	MPa
Tension(s) d'alimentation assignée(s) des circuits auxiliaires et de commande Spécifier courant continu/courant alternatif (avec fréquence assignée)	U_a	V
Fréquence assignée	f_r	Hz
Classe d'endurance mécanique	M_1/M_2	
Classe d'endurance électrique	E_1/E_2	
Type et masse du fluide (liquide ou gaz) pour l'isolement	M_f	kg
Masse (liquide compris)	M	kg
Séquence de manœuvres	C-t_{r1}-O ou C-t_{r1}-O-t_{r2}-C-t_{r1}-O (t_{r1}, t_{r2})	
Température minimale et maximale de l'air ambiant		°C
Catégorie (facultative)[a]		

[a] La catégorie permet de faire référence à l'Article B.2

6.12 Dispositifs de verrouillage

Le paragraphe 6.12 de l'IEC 62271-1:2017 ne s'applique pas.

6.101 Dispositif d'antipompage

Le dispositif d'antipompage doit être fourni pour un mécanisme d'entraînement pneumatique et hydraulique.