IEC 62271-110

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INTERNATIONAL STANDARD

NORME INTERNATIONALE

High-voltage switchgear and controlgear –
Part 110: Inductive load switching

Appareillage à haute tension –
Partie 110: Manœuvre de charges inductives

IEC 62271-110:2012

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

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 110: Inductive load switching

FOREWORD

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International Standard IEC 62271-110 has been prepared by subcommittee 17A: High-voltage switchgear and controlgear, of IEC technical committee 17: Switchgear and controlgear.

This third edition cancels and replaces the second edition published in 2009 and constitutes a technical revision.

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

– former Table 2 has been split into three new tables to conform with IEC 62271-100 and to address actual in-service circuit configurations.
– the criteria for successful testing has been revised to a more explicit statement (see 6.114.11a).
– comments received in response to 17A/959/CDV and 17A/981/RVC have been addressed.

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

FDIS	Report on voting
17A/1016/FDIS	17A/1025/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

This standard is to be read in conjunction with IEC 62271-1:2007, and with IEC 62271-100:2008, to which it refers and which are 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 and IEC 62271-100. Additional subclauses are numbered from 101.

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

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- withdrawn;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

The contents of the corrigendum of October 2012 have been included in this copy.

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 110: Inductive load switching

1 General

1.1 Scope

This part of IEC 62271 is applicable to a.c. circuit-breakers designed for indoor or outdoor installation, for operation at frequencies of 50 Hz and 60 Hz on systems having voltages above 1 000 V and applied for inductive current switching with or without additional short-circuit current breaking duties. The standard is applicable to circuit-breakers in accordance with IEC 62271-100 that are used to switch high-voltage motor currents and shunt reactor currents and also to high-voltage contactors used to switch high-voltage motor currents as covered by IEC 62271-106. For circuit-breakers applied to switch shunt reactor currents at rated voltages according to IEC 62271-1:2007 Tables 2a and 2b, combined voltage tests across the isolating distance are not required (refer to 4.2).

Switching unloaded transformers, i.e. breaking transformer magnetizing current, is not considered in this standard. The reasons for this are as follows:

a) due to the non-linearity of the transformer core, it is not possible to correctly model the switching of transformer magnetizing current using linear components in a test laboratory. Tests conducted using an available transformer, such as a test transformer, will only be valid for the transformer tested and cannot be representative for other transformers;

b) as detailed in IEC 62271-306[1], the characteristics of this duty are usually less severe than any other inductive current switching duty. It should be noted that such a duty may produce severe overvoltages within the transformer winding(s) depending on the circuit-breaker re-ignition behaviour and transformer winding resonance frequencies.

Short-line faults, out-of-phase current making and breaking and capacitive current switching are not applicable to circuit-breakers applied to switch shunt reactors or motors. These duties are therefore not included in this standard.

Subclause 1.1 of IEC 62271-100:2008 is otherwise applicable.

1.2 Normative references

Subclause 1.2 of IEC 62271-100:2008 is applicable with the following addition:

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

2 Normal and special service conditions

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

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1 To be published.

3 Terms and definitions

For the purposes of this document, the definitions of IEC 60050-441 and IEC 62271-1 apply as well as the following specific to inductive load switching.

3.101
inductive current
power-frequency current through a circuit-breaker drawn by an inductive circuit having a power factor 0,5 or less

3.102
small inductive current
inductive current having a steady state value considerably less than the rated short-circuit breaking current

3.103
current chopping
abrupt current interruption in the circuit-breaker at a point-on-wave other than the natural power-frequency current zero of the circuit connected to the circuit-breaker

3.104
virtual current chopping
current chopping originated by transients in (parts of) the circuit

3.105
chopping current
current interruption prior to the natural power-frequency current zero of the circuit connected to the switching device

3.106
chopping level
maximum recorded value of the chopping current due to true current chopping in a specific circuit under rated voltage and normal operating conditions

3.107
load side oscillation
oscillation of the interrupted load side network after current chopping or natural current zero

3.108
suppression peak
first peak of the transient voltage to earth on the load side of the circuit-breaker

3.109
recovery peak
maximum value of the voltage across the circuit-breaker occurring after definite polarity change of the recovery voltage

Note 1 to entry: Suppression peak and recovery peak are not necessarily the absolute maxima in the transient recovery voltage. Previous breakdowns may have appeared at higher voltage values.

3.110
voltage escalation
increase in the amplitude of the prospective recovery voltage of the load circuit, produced by the accumulation of energy due to repeated re-ignitions

3.111
re-ignition
resumption of current between the contacts of a mechanical switching device during a breaking operation with an interval of zero current of less than a quarter cycle of power frequency

[SOURCE: IEC 60050-441:1998, 441-17-45]

Note 1 to entry: In the case of inductive load switching the initiation of the re-ignition is a high frequency event, which can be of a single or multiple nature and may in some cases be interrupted without power frequency follow current.

4 Ratings

Clause 4 of IEC 62271-100:2008 is applicable except for the references to short-line faults, out-of-phase making and breaking, capacitive current switching and as noted in specific subclauses below. Circuit-breakers do not normally have inductive load switching ratings. However, circuit-breakers applied for this purpose should meet the requirement of this standard part.

4.2 Rated insulation level

Subclause 4.2 of IEC 62271-1:2007 is applicable with the following addition:

The rated values stated in Tables 1a and 1b and Tables 2a and 2b of IEC 62271-1:2007 are applicable with the exception of columns (6) and (8) in Table 2a and column (7) in Table 2b.

NOTE 1 The reason for this exception is the source-less nature of the shunt reactor load circuit.

NOTE 2 In some cases (high chopping overvoltage levels, or where a neutral reactor is present or in cases of shunt reactors with isolated neutral), it can be necessary to specify an appropriate insulation level which is higher than the rated values stated above.

5 Design and construction

Clause 5 of IEC 62271-100:2008 is applicable.

6 Type tests

6.1 General

Subclause 6.1 of IEC 62271-100:2008 is applicable with the following addition:

Inductive current switching tests performed for a given current rating and type of application may be considered valid for another current rating and same type of application as detailed below:

a) for high-voltage shunt reactor switching at rated voltage 52 kV and above, tests at a particular current rating are to be considered valid for applications up to 150 % of the tested current value;

b) for shunt reactor switching at rated voltage below 52 kV, type testing is required but short circuit test duties T30 and T10 will cover the requirements provided that the TRV values of T30 and T10 are equal to or higher than the reactor switching TRV values.

c) for high-voltage motor switching, type testing for stalled motor currents at 100 A and 300 A is considered to cover stalled motor currents in the range 100 A to 300 A and up to the current associated with the short-circuit current of test duty T10 according to 6.106.1 of IEC 62271-100:2008.

With respect to 6.1a) the purpose of type testing is to also determine reignition-free zones for controlled switching purposes and caution should be exercised when considering applications at higher currents than the tested values.

Annex B of IEC 62271-100:2008 is applicable with respect to tolerances on test quantities.

6.2 Dielectric tests

Subclause 6.2 of IEC 62271-100:2008 is applicable with the following addition:

Refer to 4.2.

6.3 Radio interference voltage (r.i.v.) test

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

6.4 Measurement of the resistance of circuits

Subclause 6.4 of IEC 62271-1:2007 is applicable.

6.5 Temperature-rise tests

Subclause 6.5 of IEC 62271-1:2007 is applicable.

6.6 Short-time withstand current and peak withstand current tests

Subclause 6.6 of IEC 62271-1:2007 is applicable.

6.7 Verification of protection

Subclause 6.7 of IEC 62271-1:2007 is applicable.

6.8 Tightness tests

Subclause 6.8 of IEC 62271-1:2007 is applicable.

6.9 Electromagnetic compatibility tests (EMC)

Subclause 6.9 of IEC 62271-1:2007 is applicable.

6.101 Mechanical and environmental tests

Subclause 6.101 of IEC 62271-100:2008 is applicable.

6.102 Miscellaneous provisions for making and breaking tests

Subclause 6.102 of IEC 62271-100:2008 is applicable with the following addition:

High-voltage motor current and shunt reactor switching tests shall be performed at rated auxiliary and control voltage or, where necessary, at maximum auxiliary and control voltage to facilitate consistent control of the opening and closing operation according to 6.102.3.1 of IEC 62271-100:2008 and at rated functional pressure for interruption and insulation.

For gas circuit-breakers, a shunt reactor switching test shall also be performed at the minimum functional pressure for interruption and insulation. This requirement applies for test duty 4 only (see 6.114.9).

6.103 Test circuits for short-circuit making and breaking tests

Subclause 6.103 of IEC 62271-100:2008 is applicable.

6.104 Short-circuit test quantities

Subclause 6.104 of IEC 62271-100:2008 is applicable.

6.105 Short-circuit test procedure

Subclause 6.105 of IEC 62271-100:2008 is applicable.

6.106 Basic short-circuit test-duties

Subclause 6.106 of IEC 62271-100:2008 is applicable.

6.107 Critical current tests

Subclause 6.107 of IEC 62271-100:2008 is applicable.

6.108 Single-phase and double-earth fault tests

Subclause 6.108 of IEC 62271-100:2008 is applicable.

Subclauses 6.109 to 6.112 of IEC 62271-100:2008 are not applicable to this part of IEC 62271 series.

6.113 High-voltage motor current switching tests

6.113.1 Applicability

This subclause is applicable to three-phase alternating current circuit-breakers having rated voltages above 1 kV and up to 17,5 kV, which are used for switching high-voltage motors. Tests may be carried out at 50 Hz with a relative tolerance of ±10 % or 60 Hz with a relative tolerance of ±10 %, both frequencies being considered equivalent.

Motor switching tests are applicable to all three-pole circuit-breakers having rated voltages equal to or less than 17,5 kV, which may be used for the switching of three-phase asynchronous squirrel-cage or slip-ring motors. The circuit-breaker may be of a higher rated voltage than the motor when connected to the motor through a stepdown transformer. However, the more usual application is a direct cable connection between circuit-breaker and motor. When tests are required, they shall be made in accordance with 6.113.2 to 6.113.9.

When overvoltage limitation devices are mandatory for the tested equipment, the voltage limiting devices may be included in the test circuit provided that the devices are an intrinsic part of the equipment under test.

No limits to the overvoltages are given as the overvoltages are only relevant to the specific application. Overvoltages between phases may be as significant as phase-to-earth overvoltages.

6.113.2 General

The switching tests can be either field tests or laboratory tests. As regards overvoltages, the switching of the current of a starting or stalled motor is usually the more severe operation.

Due to the non-linear behaviour of the motor iron core, it is not possible to exactly model the switching of motor current using linear components in a test station. Tests using linear

components to simulate the motors can be considered to be more conservative than switching actual motors.

For laboratory tests a standardized circuit simulating the stalled condition of a motor is specified (refer to Figure 1). The parameters of this test circuit have been chosen to represent a relatively severe case with respect to overvoltages and will cover the majority of service applications.

The laboratory tests are performed to prove the ability of a circuit-breaker to switch motors and to establish its behaviour with respect to switching overvoltages, re-ignitions and current chopping. These characteristics may serve as a basis for estimates of the circuit-breaker performance in other motor circuits. Tests performed with the test currents defined in 6.113.3 and 6.113.4 demonstrate the capability of the switching device to switch high-voltage motors up to its rated interrupting current.

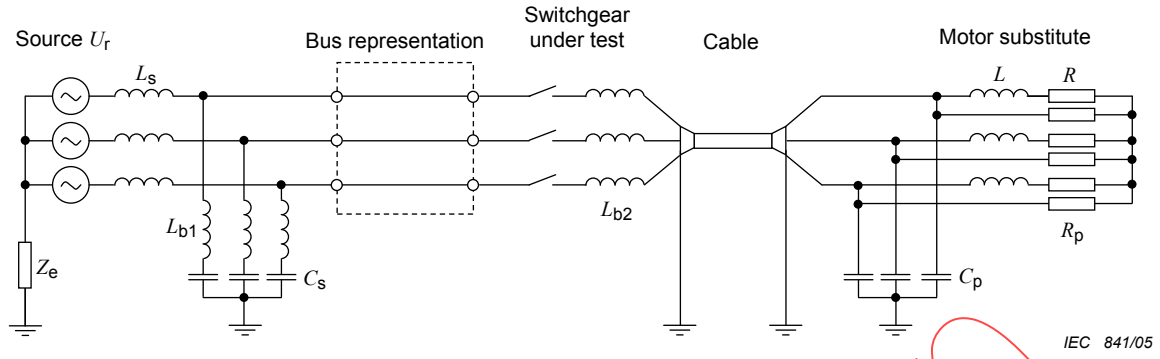
For field tests, actual circuits are used with a supply system on the source side and a cable and motor on the load side. There may be a transformer between the circuit-breaker and motor. However, the results of such field tests are only valid for circuit-breakers working in circuits similar to those during the tests.

The apparatus under test includes the circuit-breaker with overvoltage protection devices if they are normally fitted.

NOTE 1 Overvoltages can be produced when switching running motors. This condition is not represented by the substitute circuit and is generally considered to be less severe than the stalled motor case.

NOTE 2 The starting period switching of a slip-ring motor is generally less severe due to the effect of the starting resistor.

NOTE 3 The rated voltage of the circuit-breaker can exceed that of the motor.



Key

U_r	rated voltage	
Z_e	earthing impedance	impedance high enough to limit the phase-to earth fault current to less than the test current (can be infinite)
L_s	source side inductance	$\omega L_s \leq 0{,}1\ \omega L$, but prospective short-circuit current ≤ the rated short-circuit current of the tested circuit-breaker
C_s	supply side capacitance	0,03 µF to 0,05 µF for supply circuit A 1,5 µF to 2 µF for supply circuit B
L_{b1}	inductance of capacitors and connections	≤ 2 µH
Bus representation		5 m to 7 m in length spaced appropriate to the rated voltage
L_{b2}	inductance of connections	≤ 5 µH
Cable		100 m ± 10 m, screened, Z_0 = 30 Ω to 50 Ω
L	motor substitute inductance	load circuit 1: 100 A ± 10 A load circuit 2: 300 A ± 30 A
R	motor substitute resistance	$\cos\theta \leq 0{,}2$
C_p	motor substitute parallel capacitance	frequency 10 kHz to 15 kHz
R_p	motor substitute parallel resistance	amplitude factor 1,6 to 1,8

Figure 1 – Motor switching test circuit and summary of parameters

6.113.3 Characteristics of the supply circuits

6.113.3.1 General

A three-phase supply circuit shall be used. The tests shall be performed using two different supply circuits A and B as specified in 6.113.3.2 and 6.113.3.3, respectively. Supply circuit A represents the case of a motor connected directly to a transformer. Supply circuit B represents the case where parallel cables are applied on the supply side.

6.113.3.2 Supply circuit A

The three-phase supply may be earthed through a high ohmic impedance so that the supply voltage is defined with respect to earth. The impedance value shall be high enough to limit a prospective line-to-earth fault current to a value below the test current.

The source inductance L_s shall not be lower than that corresponding to the rated short-circuit breaking current of the tested circuit-breaker. Its impedance shall also be not higher than 0,1 times the impedance of the inductance in the load circuit (see 6.113.4).

The supply side capacitance C_s is represented by three capacitors connected in earthed star. Their value, including the natural capacitance of the circuit shall be 0,04 μF ± 0,01 μF. The inductance L_{b1} of the capacitors and connections shall not exceed 2 μH.

The busbar inductance is represented by three bars forming a busbar each 6 m ± 1 m in length and spaced at a distance appropriate to the rated voltage.

6.113.3.3 Supply circuit B

As supply circuit A with the value of the supply side capacitance increased to 1,75 μF ± 0,25 μF.

6.113.4 Characteristics of the load circuit

6.113.4.1 General

A three-phase load circuit shall be used. The motor substitute circuit is connected to the circuit-breaker under test by 100 m ± 10 m of screened cable. It is recommended that the cable be connected directly to the terminals of the motor or substitute circuit.

The inductance of any intermediate connection should not exceed 3 μH. The shield of the cable shall be earthed at both ends as shown in Figure 1. The tests shall be performed using two different motor substitute circuits as specified in 6.113.4.2 and 6.113.4.3. The inductance L_{b2} of the connections between the circuit-breaker and cable shall not exceed 5 μH.

6.113.4.2 Motor substitute circuit 1

Series-connected resistance and inductance shall be arranged to obtain a current of 100 A ± 10 A at a power factor less than 0,2 lagging. The star point shall not be connected to earth. Resistance R_p shall be connected in parallel with each phase impedance and capacitance C_p between each phase and earth so that the motor substitute circuit has a natural frequency of 12,5 kHz ± 2,5 kHz and an amplitude factor of 1,7 ± 0,1 measured in each phase with the other two phases connected to earth. The prospective transient recovery voltages values shall be determined in accordance with Annex F of IEC 62271-100:2008. A transformer may be introduced at the load end of the cable. This shall be considered as part of the motor substitute circuit.

6.113.4.3 Motor substitute circuit 2

As motor substitute circuit 1, but with the series resistance and inductance reduced to obtain a current of 300 A ± 30 A at a power factor less than 0,2 lagging. The prospective transient recovery voltage shall be as specified for motor substitute circuit 1.

6.113.5 Test voltage

a) The average value of the applied voltages shall be not less than the rated voltage U_r divided by $\sqrt{3}$ and shall not exceed this value by more than 10 % without the consent of the manufacturer.

   The differences between the average value and the applied voltages of each pole shall not exceed 5 %.

   The rated voltage U_r is that of the circuit-breaker when using the substitute circuit, but is that of the motor when an actual motor is used.

b) The power frequency recovery voltage of the test circuit may be stated as a percentage of the power frequency recovery voltage specified below. It shall not be less than 95 % of the