इंटरनेट मानक

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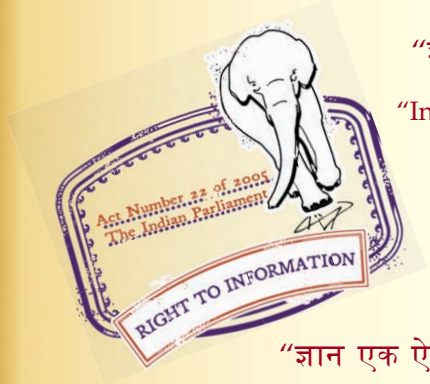
IS/IEC 62271-102 (2003): High-Voltage Switchgear and Controlgear, Part 102: Alternating Current Disconnectors and Earthing Switches [ETD 8: High Voltage Switchgear and Controlgear]



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"ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है"
Bhartṛhari—Nītiśatakam
"Knowledge is such a treasure which cannot be stolen"

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भारतीय मानक

उच्च-वोल्टता के स्विचगियर और नियंत्रणगियर

भाग 102 प्रत्यावर्ती धारा वियोजक भू-सम्पर्कन स्विच

Indian Standard

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR

PART 102 ALTERNATING CURRENT DISCONNECTORS AND EARTHING SWITCHES

ICS 29.130.10

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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Price Group 17

CONTENTS

High-Voltage Switchgear and Controlgear Sectional Committee, ETD 08

NATIONAL FOREWORD

This Indian Standard (Part 102) which is identical with IEC 62271-102 : 2003 'High-voltage switchgear and controlgear — Part 102: Alternating current disconnectors and earthing switches' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the High-Voltage Switchgear and Controlgear Sectional Committee and approval of the Electrotechnical Division Council.

This standard is to be read in conjunction with IEC 60694 : 1996 'Common specifications for high-voltage switchgear and controlgear standards'. In order to simplify the indication of corresponding requirements the same numbering of clauses and subclauses is used as in IEC 60694 : 1996. Amendments to these clauses and subclauses are given under the same numbering, whilst additional subclauses are numbered from 101.

The text of IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker, while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their respective places are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60137 : 1995 Insulating bushings for alternating voltages above 1 000 V	IS 2099 : 1986 Bushings for alternating voltages above 1 000 volts (*second revision*)	Technically Equivalent
IEC 60265-1 : 1998 High-voltage switches — Part 1: Switches for rated voltages above 1 kV and less than 52 kV	IS 9920 (Part 1) : 2002 High-voltage switches: Part 1 Switches for rated voltages above 1 kV and less than 52 kV (*first revision*)	Identical
IEC 60265-2 : 1988 High-voltage switches — Part 2: High-voltage switches for rated voltages of 52 kV and above	IS 9920 (Part 2) : 2001 High-voltage switches: Part 2 High-voltage switches for rated voltages of 52 kV and above (*first revision*)	do
IEC 60298 : 1990 A.C. metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV	IS 3427 : 1997 A.C. metal enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV (*first revision*)	do
IEC 60466 : 1987 A.C. insulation-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 38 kV	IS 14659 : 1999 A.C. insulation-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 38 kV	do

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60517 : 1990 Gas-insulated metal-enclosed switchgear for rated voltages of 72.5 kV and above	IS/IEC 60517 : 1990 Gas-insulated metal-enclosed switchgear for rated voltages of 72.5 kV and above	Identical
IEC 60694 : 1996 Common specifications for high-voltage switchgear and controlgear standards	IS 12729 : 2004 Common specifications for high-voltage switchgear and controlgear standards (*first revision*)	Technically Equivalent
IEC 60865-1 : 1993 Short-circuit currents — Calculation of effects — Part 1: Definitions and calculation methods	IS 13235 : 1991 Calculation of the effects of short-circuit currents	do

The technical committee responsible for the preparation of this standard has reviewed the provisions of the following International Standard referred in this adopted standard and has decided that it is acceptable for use in conjunction with this standard:

International Standard	*Title*
ISO 2768-1 : 1989	General tolerances — Part 1: Tolerances for linear and angular dimensions without individual tolerance indications

Only the English language text has been retained while adopting it in this Indian Standard, and as such the page numbers given here are not the same as in the IEC Standard.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be same as that of the specified value in this standard.

Indian Standard

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR

PART 102 ALTERNATING CURRENT DISCONNECTORS AND EARTHING SWITCHES

1 General

1.1 Scope

This part of IEC 62271 applies to alternating current disconnectors and earthing switches, designed for indoor and outdoor enclosed and open terminal installations for voltages above 1 000 V and for service frequencies up to and including 60 Hz.

It also applies to the operating devices of these disconnectors and earthing switches and their auxiliary equipment.

Additional requirements for disconnectors and earthing switches in enclosed switchgear and controlgear are given in IEC 60298, IEC 60466 and IEC 60517.

NOTE Disconnectors in which the fuse forms an integral part are not covered by this standard.

1.2 Normative references

Subclause 1.2 of IEC 60694 is applicable with the following additions:

IEC 60137:1995, *Insulating bushings for alternating voltages above 1 000 V*

IEC 60265-1:1998, *High-voltage switches – Part 1: Switches for rated voltages above 1 kV and less than 52 kV*

IEC 60265-2:1988, *High-voltage switches – Part 2: High-voltage switches for rated voltages of 52 kV and above*

IEC 60298:1990, *A.C. metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

IEC 60466:1987, *A.C. insulation-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 38 kV*

IEC 60517:1990, *Gas-insulated metal-enclosed switchgear for rated voltages of 72,5 kV and above*

IEC 60694:1996, *Common specifications for high-voltage switchgear and controlgear standards*

IEC 60865-1:1993, *Short-circuit currents – Calculation of effects – Part 1: Definitions and calculation methods*

ISO 2768-1:1989, *General tolerances – Part 1: Tolerances for linear and angular dimensions without individual tolerance indications*

2 Normal and special service conditions

Clause 2 of IEC 60694 is applicable.

3 Definitions

Clause 3 of IEC 60694 is applicable with the following additions:

This clause covers required definitions, most of them by reference to IEC 60050(151), IEC 60050(441) and IEC 60050(604).

3.1 General terms

3.1.101
indoor switchgear and controlgear

[IEV 441-11-04]

3.1.102
outdoor switchgear and controlgear

[IEV 441-11-05]

3.1.103
temperature rise (of a part of a disconnector or earthing switch)
difference between the temperature of the part and the ambient air temperature

3.1.104
user
person or legal entity using the disconnectors or earthing switches

NOTE This may include the purchaser (for example an electricity supplier), but it may also include the contracting company, the staff responsible for installation, the maintenance or operating staff or anybody else temporarily or permanently responsible for the disconnector, earthing switch or substation, or even the operation of the switchgear.

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
disconnector

IEV 441-14-05 is applicable with the following additional notes:

NOTE 1 "Negligible current" implies currents such as the capacitive currents of bushings, busbars, connections, very short lengths of cable, currents of permanently connected grading impedances of circuit-breakers and currents of voltage transformers and dividers. For rated voltages of 420 kV and below, a current not exceeding 0,5 A is a negligible current for the purpose of this definition; for rated voltage above 420 kV and currents exceeding 0,5 A, the manufacturer should be consulted.

"No significant change in voltage" refers to such applications as the by-passing of induction voltage regulators or circuit-breakers.

NOTE 2 For a disconnector having a rated voltage of 52 kV and above, a rated ability of bus-transfer current switching may be assigned.

3.4.101.1
disconnector class M0
disconnector having a mechanical endurance of 1 000 operating cycles, suitable for applications in distribution and transmission systems fulfilling the general requirements of this standard

3.4.101.2
disconnector class M1
disconnector having an extended mechanical endurance of 2 000 operating cycles, mainly for applications where the disconnector is operated in conjunction with a circuit-breaker of an equal class

3.4.101.3
disconnector class M2
disconnector having an extended mechanical endurance of 10 000 operating cycles, mainly for applications where the disconnector is operated in conjunction with a circuit-breaker of an equal class

3.4.102
divided support disconnector
(earthing switch)

[IEV 441-14-06(07)]

NOTE Examples are pantograph and semi-pantograph disconnectors.

3.4.103
centre-break disconnector

[IEV 441-14-08]

3.4.104
double-break disconnector

[IEV 441-14-09]

3.4.105
earthing switch
IEV 441-14-11 is applicable with the following addition:

NOTE An earthing switch having a rated voltage of 52 kV and above may have a rating for switching and carrying induced currents.

Classes E1, E2 and E3 of IEC 60265-1 are based on electrical endurance of switches and switch-disconnectors. These devices may sometimes be operated against a short-circuit as a normal operation duty and the electrical endurance may be the measure of "low maintenance".

3.4.105.1
earthing switch class E0
earthing switch suitable for applications in distribution and transmission systems fulfilling the general requirements of this standard

3.4.105.2
earthing switch class E1
earthing switch class E0 with a short-circuit making capability

NOTE This class of earthing switch is able to withstand two making operations at rated making current.

3.4.105.3
earthing switch class E2
earthing switch of class E1 requiring minimal maintenance, capable of an extended number of short-circuit making operations suitable for applications in systems up to and including 52 kV

NOTE This class of earthing switch proves its reduced maintenance requirements by a number of five making operations at rated making current, but also requires minimal maintenance as lubrication (replenishment of gas and cleaning of external surfaces where applicable).

3.5 Parts of switching devices

3.5.101
pole of a switching device
[IEV 441-15-01]

3.5.102
main circuit (of a switching device)
[IEV 441-15-02]

3.5.103
contact (of a mechanical switching device)
[IEV 441-15-05]

3.5.104
main contact
[IEV 441-15-07]

3.5.105
control contact
[IEV 441-15-09]

3.5.106
"a" contact
make contact
[IEV 441-15-12]

3.5.107
"b" contact
break contact
[IEV 441-15-13]

3.5.108
position signalling device
part of a disconnector or earthing switch which uses auxiliary energy to indicate whether the contacts of the main circuit are in the open or closed position

3.5.109
terminal (as a component)
component provided for the connection of a device to external conductors

[IEV 151-01-03]

3.5.110
contact zone (for divided support disconnectors and earthing switches)
spatial region of positions the fixed contact may take up for correct engagement with the moving contact

3.6 Operation

3.6.101
operation (of a mechanical switching device)
[IEV 441-16-01]

3.6.102
operation cycle (of a mechanical switching device)
[IEV 441-16-02]

3.6.103
closing operation (of a mechanical switching device)
[IEV 441-16-08]

3.6.104
opening operation (of a mechanical switching device)
[IEV 441-16-09]

3.6.105
positively driven operation
[IEV 441-16-12]

3.6.106
dependent manual operation (of a mechanical switching device)

IEV 441-16-13 is applicable with the following addition:

NOTE Dependent manual operation may be performed by a crank or by a swing lever (horizontal or vertical).

3.6.107
dependent power operation (of a mechanical switching device)
[IEV 441-16-14]

3.6.108
stored energy operation (of a mechanical switching device)
[IEV 441-16-15]

3.6.109
independent manual operation (of a mechanical switching device)
[IEV 441-16-16]

3.6.110
closed position (of a mechanical switching device)

IEV 441-16-22 is applicable with the following addition:

NOTE Predetermined continuity means that the contacts are fully engaged to carry the rated normal and the rated short-circuit currents, as applicable.

3.6.111
open position (of a mechanical switching device)
[IEV 441-16-23]

3.6.112
interlocking device
[IEV 441-16-49]

3.7 Characteristic quantities

3.7.101
peak making current (of an earthing switch)
peak value of the first major loop of the current in a pole of the earthing switch during the transient period following the initiation of current during a making operation

NOTE Where, for a three-phase circuit, a single value of (peak) making current is referred to, this is, unless otherwise stated, the highest value in any phase.

3.7.102
peak current
peak value of the first major loop of current during the transient period following initiation

3.7.103
normal current (of a disconnector)
current which the main circuit of the disconnector is capable of carrying continuously under specified conditions of use and behaviour

3.7.104
short-time withstand current

[IEV 441-17-17]

3.7.105
peak withstand current

[IEV 441-17-18]

3.7.106
rated value
quantity value assigned, generally by a manufacturer, for a specified operating condition of a component, device or equipment

[IEV 151-04-03]

3.7.107
insulation level
test voltage, under specified conditions, that the insulation of a device is designed to withstand

[IEV 151-04-14]

3.7.108
one minute power frequency withstand voltage
r.m.s. value of the sinusoidal alternating voltage at power frequency which the insulation of the disconnector or earthing switch withstands under specified test conditions

(see IEC 60060-1)

3.7.109
impulse withstand voltage
peak value of the standard impulse voltage wave which the insulation of the disconnector or earthing switch withstands under specified test conditions

(see IEC 60060-1)

NOTE Depending on the shape of the wave, the term may be qualified as switching impulse withstand voltage or lightning impulse withstand voltage. [IEV 604-03-29, IEV 604-03-30].

3.7.110
external insulation
distances in atmospheric air, and surfaces of solid insulation of disconnectors and earthing switches in contact with the air, which are subject to dielectric stresses and to the effect of atmospheric and other external conditions such as pollution, humidity, vermin, etc.

[IEV 604-03-02, modified]

NOTE External insulation is either weather-protected or non-weather-protected, designed to operate outside or inside closed shelters, respectively

3.7.111
internal insulation
internal solid, liquid or gaseous parts of the insulation of equipment which are protected from the effects of atmospheric and other external conditions

[IEV 604-03-03]

3.7.112
self-restoring insulation
insulation which completely recovers its insulating properties after a disruptive discharge

[IEV 604-03-04]

3.7.113
non-self-restoring insulation
insulation which loses its insulating properties or does not recover them completely after a disruptive discharge

[IEV 604-03-05]

NOTE Definitions 3.7.112 and 3.7.113 apply only when the discharge is caused by the application of a test voltage during a dielectric test. However, discharges occurring in service may cause a self-restoring insulation to lose partially or completely its original insulating properties.

3.7.114
parallel insulation
insulator arrangement with two insulators in parallel where the distance between the two insulators might influence the dielectric strength

NOTE With open terminal disconnectors and earthing switches, parallel insulation is used when a drive insulator is situated next to a support insulator.

3.7.115
disruptive discharge
phenomena associated with the failure of insulation under electric stress, in which the discharge completely bridges the insulation under test, reducing the voltage between the electrodes to zero or nearly to zero

NOTE 1 The term applies to discharges in solid, liquid and gaseous dielectrics and to combinations of these.

NOTE 2 A disruptive discharge through a solid dielectric produces permanent loss of dielectric strength (non-self-restoring insulation); in a liquid or gaseous dielectric the loss may be only temporary (self-restoring insulation).

3.7.116
clearance

[IEV 441-17-31]

3.7.117
clearance between poles

[IEV 441-17-32]

3.7.118
clearance to earth

[IEV 441-17-33]

3.7.119
clearance between open contacts

IEV 441-17-34 is applicable with the following additional note:

NOTE When determining the total clearance, the sum of the distances should be taken into consideration.

3.7.120
isolating distance (of a pole of a mechanical switching device)

[IEV 441-17-35]

3.7.121
mechanical terminal load
external load acting on each terminal

NOTE 1 The external load is the result of the combined mechanical forces to which the disconnector or earthing switch may be subjected. Wind forces acting on the equipment itself are not included as they do not contribute to the external load.

NOTE 2 A disconnector or earthing switch may be subjected to several mechanical forces different in value, direction and point of action.

NOTE 3 The terminal loads as defined here do not usually apply to enclosed switchgear.

3.7.121.1
static mechanical terminal load
static mechanical terminal load at each terminal equivalent to the mechanical force to which this terminal of the disconnector or earthing switch is subjected by the flexible or rigid conductor connected to this terminal

3.7.121.2
dynamic mechanical terminal load
combination of the static mechanical load and the electromagnetic forces under short-circuit conditions

3.7.122
bus-transfer current switching
opening and closing of disconnectors under load when this load is not interrupted, but transferred from one bus to another

3.7.123
induced current switching
breaking or making of an earthing switch of inductive or capacitive currents that are induced in an earthed or unearthed system by a parallel high-voltage system

NOTE When two or more transmission lines are mounted together on line towers or where two or more lines mounted on different towers are located close by, energy will be induced electrostatically and electromagnetically from a live system into a de-energized system resulting in capacitive or inductive currents flowing in this system, depending whether it is earthed at one or at both ends.

4 Ratings

Clause 4 of IEC 60694 is applicable with the following additions to the list of ratings:

k) rated short-circuit making current (for earthing switches only);

l) rated contact zone (for divided support disconnectors only);

m) rated mechanical terminal load;

and for rated voltages 52 kV and above:

n) rated values of the bus-transfer current switching capability of disconnectors;

o) rated values of the induced current switching capability of earthing switches.

4.1 Rated voltage (U_r)

Subclause 4.1 of IEC 60694 is applicable.

4.2 Rated insulation level

Subclause 4.2 of IEC 60694 is applicable with the following addition:

For disconnectors having an isolating distance in parallel to the base of the disconnector and having integral earthing switches, the safety requirements are fulfilled during the temporary approach of the earthing blade to the opposite live parts, if the 1 min power frequency withstand voltage for the smallest gap is not lower than that specified in 6.2.5.

NOTE 1 The temporary reduction of dielectric strength is not a general problem of safety requirements, except during the short period of operation of an earthing switch having a manual operating mechanism only. For this reason, and because no ageing is taken into consideration, the reduced dielectric strength is acceptable. An impulse voltage test is not required because of the very low probability of a lightning or switching impulse during the earthing procedure.

NOTE 2 If national safety regulations specify higher withstand values for earthing switches which have manual operating mechanisms only, this has be agreed upon between user and manufacturer.

NOTE 3 If the minimum temporary clearance is larger than the clearances given in IEC 60071-2, no test is required.

4.3 Rated frequency (f_r)

Subclause 4.3 of IEC 60694 is applicable.

4.4 Rated normal current and temperature rise

Subclause 4.4 of IEC 60694 is applicable. This subclause generally applies only to disconnectors.

NOTE Consideration should be given to the skin effect depending on the shape, construction and material of the main current path of a disconnector operated with 60 Hz, because with rectangular-shaped conductors deviations of more than 5 % compared with 50 Hz have been experienced.

4.5 Rated short-time withstand current (I_k)

Subclause 4.5 of IEC 60694 is applicable with the following addition:

If an earthing switch is combined with a disconnector as a single unit, the rated short-time withstand current of the earthing switch shall, unless otherwise specified, be at least equal to that assigned to the disconnector.

4.6 Rated peak withstand current (I_p)

Subclause 4.6 of IEC 60694 is applicable with the following addition:

If an earthing switch is combined with a disconnector as a single unit, the rated peak withstand current of the earthing switch shall, unless otherwise specified, be at least equal to that assigned to the disconnector.

4.7 Rated duration of short-circuit (t_k)

Subclause 4.7 of IEC 60694 is applicable with the following addition:

If an earthing switch is combined with a disconnector as a single unit, the rated duration of the short-time withstand current of the earthing switch shall, unless otherwise specified, be at least equal to that assigned to the disconnector.

4.8 Rated supply voltage of closing and opening devices and of auxiliary and control circuits (U_a)

Subclause 4.8 of IEC 60694 is applicable.

4.9 Rated supply frequency of closing and opening devices and of auxiliary circuits

Subclause 4.9 of IEC 60694 is applicable.

4.10 Rated pressure of compressed gas supply for insulation and/or operation

Subclause 4.10 of IEC 60694 is applicable.

4.101 Rated short-circuit making current

Earthing switches to which a rated short-circuit making current has been assigned shall be capable of making at any applied voltage, up to and including that corresponding to their rated voltage, any current up to and including their rated short-circuit making current.

If an earthing switch has a rated short-circuit making current, this shall be equal to the rated peak withstand current.

4.102 Rated contact zone

The manufacturer shall state the rated values of contact zone (indicated by x_r, y_r and z_r). The values in tables 1 and 2 are for reference only. The rated values shall be obtained from the manufacturer. This refers also to a tolerable angular displacement of the fixed contact.

For proper function of the disconnector or earthing switch, the user shall ensure that the fixed contact stays within these limits by considering the service conditions when specifying the substation design and the cantilever strength of insulators (see 8.102.3).

Table 1 – Recommended contact zones for "fixed" contacts supported by flexible conductors

Rated voltage (U_r) kV	x mm	y mm	$z1$ mm	$z2$ mm
72,5 – 100	100	300	200	300
123 – 145	100	350	200	300
170	200	400	200	300
245	200	500	250	450
300	200	500	250	450
362	200	500	300	450
420	200	500	300	500
550	200	600	400	500

x = total amplitude of longitudinal movement of the supporting conductor (temperature).

y = total horizontal deflection (perpendicular to supporting conductor) (wind).

z = vertical deflection (temperature and ice).

NOTE $z1$ are values for short-span, $z2$ are values for long-span of the flexible conductors to which the fixed contacts are mounted.

Table 2 – Recommended contact zones for "fixed" contacts supported by rigid conductors

Rated voltage (U_r) kV	x mm	y mm	z mm
72,5 – 100 – 123 – 145	100	100	100
170 – 245 – 300 – 362 – 420	150	150	150
550	175	175	175
800	200	200	200

x = total amplitude of longitudinal movement of the supporting conductor (temperature).

y = total horizontal deflection (perpendicular to supporting conductor) (wind).

z = vertical deflection (ice).

4.103 Rated mechanical terminal load

The rated mechanical terminal load shall be stated by the manufacturer.

Disconnectors and earthing switches shall be able to close and open while subjected to their rated static mechanical terminal loads.

The maximum static mechanical terminal load to which the terminal of a disconnector or earthing switch is allowed to be subjected under the most disadvantageous conditions is the rated static mechanical terminal load of this disconnector.

Recommended rated static mechanical terminal loads are given in table 3 and are intended to be used as a guide.

The maximum external dynamic mechanical load to which the terminal of a disconnector or earthing switch is allowed to be subjected is the rated dynamic mechanical load of this disconnector.

Disconnectors and earthing switches shall be able to withstand their rated dynamic mechanical terminal load under short-circuit.

The rating of the disconnector or earthing switch for terminal loads depends not only on the design, but also on the strength of the insulators used.

The required cantilever strength of an insulator shall be calculated taking into consideration the height of the terminal above the top of the insulator as well as additional forces acting on the insulator (see 3.7.122 and 8.102.3).

Table 3 – Recommended static mechanical terminal loads

Rated voltage (U_r) kV	Rated normal current A	Two- and three-column disconnectors		Divided support disconnectors		Vertical Force F_c [a] N
		Straight load F_{a1} and F_{a2}	Cross-load F_{b1} and F_{b2}	Straight load F_{a1} and F_{a2}	Cross-load F_{b1} and F_{b2}	
		In figure 7		In figure 8		
		N	N	N	N	
52 – 72,5	800 – 1 250	400	130	800	200	500
100-123-145	1 250	500	170	800	200	1 000
170	1 250	600	200	1 000	300	
	2 000	800	250	1 250	400	
245	800 – 1 250	800	270	1 250	400	
	2 000	1 000	330	1 600	500	1 250
300 – 362	2 000	1 000	400	1 600	500	
	3 150	1 500	500	1 800	600	1 500
420	2 000	1 600	530	2 000	800	
	4 000	2 000	660	4 000	1 600	
550	2 000	1 600	530	2 000	800	1 500
	4 000	2 000	660	4 000	1 600	
800	2 000	1 600	530	2 000	800	1 500
	4 000	2 000	660	4 000	1 600	

[a] F_c simulates the downward forces caused by the weight of the connecting conductors. With flexible conductors the weight is included in the longitudinal or perpendicular forces.

4.104 Rated values of the bus-transfer current switching capability of disconnectors

The rated values are given together with all other details in annex B.

This subclause is applicable to disconnectors rated 52 kV and above.

4.105 Rated values of the induced current switching capability of earthing switches

The rated values are given together with all other details in annex C.

This subclause is applicable to earthing switches rated 52 kV and above.

4.106 Rated values of mechanical endurance for disconnectors

A disconnector shall be able to perform the following number of operations taking into account the programme of maintenance specified by the manufacturer:

Table 3a – Classification of disconnectors for mechanical endurance

Class	Type of disconnector	Number of operating cycles
M0	Standard disconnector (normal mechanical endurance)	1 000
M1	Disconnector intended for use with a circuit-breaker of equal class (extended mechanical endurance)	2 000
M2	Disconnector intended for use with a circuit-breaker of equal class (extended mechanical endurance)	10 000

4.107 Rated values of electrical endurance for earthing switches

Earthing switches have three classes of electrical endurance:

- earthing switches with no making capability = class E0;
- earthing switches with short-circuit making capability = class E1 (these earthing switches have the making capability of two making operations);
- earthing switches with a short-circuit making capability of five making operations = class E2.

5 Design and construction

5.1 Requirements for liquids in disconnectors and earthing switches

Subclause 5.1 of IEC 60694 is applicable.

5.2 Requirements for gases in disconnectors and earthing switches

Subclause 5.2 of IEC 60694 is applicable.

5.3 Earthing of disconnectors and earthing switches

Subclause 5.3 of IEC 60694 is applicable with the following addition.

Metallic enclosures and operating mechanisms not mounted together with and not electrically connected to the metallic frame of the disconnector or earthing switch, shall be provided with an earthing terminal marked with the protective earth symbol.

5.4 Auxiliary and control equipment

Subclause 5.4 of IEC 60694 is applicable with reference to 5.104 of this standard.

5.5 Dependent power operation

Subclause 5.5 of IEC 60694 is applicable with the following additions.

This requirement applies also to disconnectors and earthing switches with dependent power operation having a rated switching and/or making current.

Disconnectors and earthing switches having a pneumatic or hydraulic operating device shall be capable of closing and opening when the supply pressure is between 85 % and 110 % of the rated value. For operation of releases see 5.8.

5.6 Stored energy operation

Subclause 5.6 of IEC 60694 is applicable.

5.7 Independent manual operation

Subclause 5.7 of IEC 60694 is applicable.

5.8 Operation of releases

Subclause 5.8 of IEC 60694 is applicable.

5.9 Low- and high-pressure interlocking and monitoring devices

Subclause 5.9 of IEC 60694 is applicable.

5.10 Nameplates

Subclause 5.10 of IEC 60694 is applicable with the following additions:

- the nameplates of disconnectors and earthing switches (and their operating devices) shall be marked in accordance with table 4;
- the nameplate shall be visible in the position of normal service and installation.

Table 4 – Nameplate information

	Abbreviation	Unit	Disconnector	Earthing switch [b]	Operating device
Manufacturer			x	x	x
Designation of type			x	x	x
Serial number			x	x	x
Year of manufacture			x	x	x
Rated voltage	U_r	kV	x	x	
Rated lightning impulse withstand voltage	U_p	kV	x	x	
Rated switching impulse withstand voltage for rated voltages 300 kV and above	U_s	kV	x	x	
Rated normal current	I_r	A	x		
Rated short-time withstand current	I_k	kA	x	x	
Rated duration of short-circuit	t_k	s	(x)[a]	(x)[a]	
Rated filling pressure for insulation and/or operation	P_{re}	MPa	x	x	x
Rated supply voltage of auxiliary circuits	U_a	V			x
Rated static mechanical terminal load	F	N	(x)	(x)	
Mechanical endurance class of disconnectors	M_r		(x) [c]		
Electrical endurance class of earthing switches	E_r			(x) [c]	
Mass (including liquid)	m	kg	(x)	(x)	(x)

NOTE 1 The marking of values indicated by x is mandatory.

NOTE 2 The marking of values indicated by (x) is optional.

NOTE 3 The word "rated" does not need to appear on the nameplate.

[a] Mandatory if t different from 1 s.

[b] An earthing switch combined with a disconnector as a single unit does not require a separate nameplate unless it has a short-circuit rating different from the disconnector.

[c] The class marking is mandatory if different from M0 or E0. It may be included into the type designation to avoid additional space requirement.

5.11 Interlocking devices

Subclause 5.11 of IEC 60694 is applicable.

5.12 Position indication

Subclause 5.12 of IEC 60694 is applicable (see also 5.104).

5.13 Degree of protection by enclosures

Subclause 5.13 of IEC 60694 is applicable with the following addition for the cubicles of secondary equipment.

The degree of protection provided by cubicles for outdoor installation shall be a minimum of IP3XDW.

For indoor installations the degree of protection shall be not less than IP2X.

In addition, generally no protection of persons against inadvertent contact with hazardous parts is required after the enclosure has been opened (see clause 11 of IEC 60694).

5.14 Creepage distances

Subclause 5.14 of IEC 60694 is applicable with the following addition:

Although the creepage distance may correspond to 5.14 of IEC 60694, with parallel insulation the distance between the two parallel insulators has to be taken into consideration.

5.15 Gas and vacuum tightness

Subclause 5.15 of IEC 60694 is applicable.

5.16 Liquid tightness

Subclause 5.16 of IEC 60694 is applicable.

5.17 Flammability

Subclause 5.17 of IEC 60694 is applicable.

5.18 Electromagnetic compatibility (EMC)

Subclause 5.18 of IEC 60694 is applicable.

5.101 Special requirements for earthing switches

Flexible copper connections between movable parts of an earthing switch and its frame shall have a cross-section of at least 50 mm².

This minimum value of the cross-sectional area of copper connections is given to ensure mechanical strength and resistance to corrosion.

Where the flexible connection is used to carry the short-circuit current, it shall be designed accordingly. If another material is used, a suitable equivalent of cross-section shall be provided.

5.102 Requirements in respect of the isolating distance of disconnectors

For reasons of safety, disconnectors shall be designed in such a way that no dangerous leakage currents can pass from the terminals of one side to any of the terminals of the other side of the disconnector.

This safety requirement is met when any leakage current is led away to earth by a reliable earth connection or when the insulation involved is effectively protected against pollution in service.

NOTE It is usual that the isolating gap of a disconnector is longer than the phase-to-ground insulating distance since IEC 60694 specifies higher withstand test levels across the isolating distance than for the phase-to-ground insulation.

Where a long creepage distance is required, the phase-to-ground insulation distance should become longer than the isolating gap. For such cases, to maintain low probability of disruptive discharge across the isolating gap, the use of protective devices such as surge arresters or rod gaps may be necessary.

5.103 Mechanical strength

Disconnectors and earthing switches having a rated static mechanical terminal load when installed according to the manufacturer's instructions shall be able to withstand their rated static and dynamic mechanical terminal load without impairing their reliability or current-carrying capacity.

5.104 Operation of disconnectors and earthing switches – Position of the movable contact system and its indicating and signalling devices

5.104.1 Securing of position

Disconnectors and earthing switches, including their operating mechanisms, shall be designed in such a way that they cannot come out of their open or closed position by gravity, wind pressure, vibrations, reasonable shocks or accidental touching of the connecting rods of their operating system.

Disconnectors and earthing switches shall permit temporary mechanical locking in both the open and closed position for safety purposes (for example maintenance).

NOTE This last requirement need not be met in the case of disconnectors or earthing switches that are operated by means of a hook-stick.

5.104.2 Additional requirements for power-operated mechanisms

Power operated mechanisms shall also provide a manual operating facility. Connecting a hand-operating device (for instance a hand crank) to the power-operated mechanism shall ensure safe interruption of the control energy to the power-operated mechanism.

5.104.3 Indication and signalling of position

Indication and signalling of the closed and open position shall not take place unless the movable contacts have reached their closed or open position, respectively, and the first paragraph of 5.104.1 is fulfilled.

NOTE For the definition of "closed" and "open" see 3.6.110 and 3.6.111.

5.104.3.1 Indication of position

It shall be possible to know the operating position of the disconnector or earthing switch. For the open position this requirement is met if one of the following conditions is fulfilled:

- the isolating distance or gap is visible;
- the position of each movable contact ensuring the isolating distance or gap is indicated by a reliable visual position indicating device.

NOTE In some countries the design of the disconnector is such that the isolating distance is visible.

The kinematic chain between the movable contacts and the position indicating device shall be designed with sufficient mechanical strength to meet the requirements of the specified tests (annex A). The position indicating kinematic chain shall be a continuous mechanical connection to ensure a positively driven operation. The position indicating device may be marked directly on a mechanical part of the power kinematic chain by suitable means. The strain-limiting device, if any, shall not be part of the position indicating kinematic chain.

Where all poles of a disconnector or earthing switch are mechanically coupled so as to be operable as a single unit, it is permissible to use a common position indicating device.

5.104.3.2 Electrical position signalling by auxiliary contacts

A common signal for all poles of a disconnector or earthing switch shall be given only if all poles of the disconnector or earthing switch have a position in accordance with 5.104.3.

Where all poles of a disconnector or earthing switch are mechanically coupled so as to be operable as a single unit, it is permissible to use a common position indicating device.

5.105 Maximum force required for manual operation

The values given below also apply to maintenance hand operation of normally motor-operated disconnectors and earthing switches.

NOTE These values include ice-breaking, if applicable.

The operating height above servicing level should be agreed between manufacturer and user.

5.105.1 Operation requiring more than one revolution

The force needed to operate a disconnector or earthing switch requiring more than one revolution (hand crank for example) shall not be higher than 60 N with a possible peak of 120 N during a maximum of 10 % of the total required revolutions.

5.105.2 Operation requiring up to one revolution

The force needed to operate a disconnector or earthing switch requiring up to one revolution (swing lever for example) should not exceed 250 N (refer to 5.6.3 of IEC 60694). A peak value of 450 N is accepted during a rotation of 15° maximum.

5.106 Dimensional tolerances

For the mounting dimensions and the dimensions of high-voltage connections as well as the earthing connections of disconnectors and earthing switches, the tolerances given in ISO 2768-1 shall apply for linear and angular dimensions.

6 Type tests

Clause 6 of IEC 60694 is applicable with the following additions:

6.1 General

Subclause 6.1 of IEC 60694 is applicable.

6.1.1 Grouping of tests

Subclause 6.1.1 of IEC 60694 is applicable with the following additions to the mandatory type tests given in IEC 60694:

Mandatory type tests:

– tests to prove satisfactory operation and mechanical endurance (6.102) (M);

Optional type tests:

– tests to prove the short-circuit making performance of earthing switches (6.101);
– tests to prove satisfactory operation under severe ice conditions (6.103);
– tests to prove satisfactory operation at temperature limits (6.104);
– tests to verify the proper function of position indicating devices (6.105 and annex A);
– tests to prove the bus-transfer current switching capability of disconnectors (6.106 and annex B);
– tests to prove the induced current-switching capability of earthing switches (6.107 and annex C);
– tests to prove the bus-charging current switching ability of disconnectors used in metal enclosed switchgear (6.108 and annex F).

For the mandatory tests, not more than four samples shall be used; for optional tests, additional test samples are accepted.

6.1.2 Information for identification of specimens

Subclause 6.1.2 of IEC 60694 is applicable.

6.1.3 Information to be included in type-test reports

Refer to 6.1.3 of IEC 60694 with the following addition (where applicable):

The following details concerning insulators used during the type tests are of particular importance and shall be given in the relevant test reports:

– rated cantilever strength;
– rated torsional strength of support insulators (and operating insulators, where applicable);
– height and number of elements;
– creepage length and shed-profile.

In the case of dielectric tests, information shall be included regarding the smallest gap at which the indicating or signalling device can signal the position OPEN. The minimum size of the gap and the height above ground used for the test shall be stated (see 6.2.3). Also the distance of the lowest part of insulation to ground shall be given.

In the case of short-circuit tests, the following information shall be included:

- details of the mechanical and electrical connection of the tested switchgear to the other parts of the test circuit including the static terminal load and the dimensions of the conductor;
- information on the mounting arrangements used;
- details of the mounting of the fixed contact to the upper conductor with divided support disconnectors;
- arrangement of the operating mechanism of disconnector or earthing switch having one mechanism for three phases;
- the contact resistance before and after the short-circuit test;
- where access is possible, the contact force before and after tests.

6.2 Dielectric tests

Subclause 6.2 of IEC 60694 is applicable.

6.2.1 Ambient air conditions during tests

Subclause 6.2.1 of IEC 60694 is applicable.

6.2.2 Wet test procedure

Subclause 6.2.2 of IEC 60694 is applicable.

6.2.3 Conditions of disconnectors and earthing switches during dielectric tests

Subclause 6.2.3 of IEC 60694 is applicable with the following addition:

Dielectric tests on disconnectors or earthing switches when in the OPEN position shall be carried out with the minimum isolating distance for the disconnector or gap for the earthing switch at which the indicating or signalling device can signal the position OPEN or the minimum isolating distance compatible with the locking arrangements specified in 5.104, whichever is the smallest.

This requirement does not apply to independent operated indoor disconnectors and earthing switches.

6.2.4 Criteria to pass the test

Subclause 6.2.4 of IEC 60694 is applicable with the following addition.

The disconnector or earthing switch shall be considered to have passed the impulse tests if the following conditions are fulfilled:

a) the number of disruptive discharges shall not exceed two for each series of 15 impulses;

b) no disruptive discharges on non-self-restoring insulation shall occur.

This is verified by at least five impulses without disruptive discharge following that impulse out of the series of 15 impulses, which caused the last disruptive discharge. If this impulse is one of the last five out of the series of 15 impulses, additional impulses shall be applied.

If disruptive discharges occur and, for any reason, evidence cannot be given during testing that the disruptive discharges were on self-restoring insulation, after the completion of the dielectric tests the disconnector or earthing switch shall be dismantled and inspected. If punctures of non-self-restoring insulation are observed, the disconnector or earthing switch shall be considered to have failed the test.

NOTE 1 If the atmospheric correction factor K_t is less than 1,00 but greater than 0,95, it is permissible to follow the criteria stated in 6.2.4 of IEC 60694 if the correction factor is not applied during the tests. Then, if one or two disruptive discharges out of 15 impulses occur in the external insulation, the particular test series showing flashover(s) is repeated with the appropriate correction factor so that no external disruptive discharge occurs.

NOTE 2 For GIS disconnectors or earthing switches tested with test bushings which are not part of the disconnector or earthing switch, flashover across the test bushings should be disregarded and should not be counted.

NOTE 3 The determination of the location of the observed disruptive discharges should be carried out by the laboratory using sufficient detection means, for example, photographs, video recordings, internal inspection, etc.

Where applicable, the requirements of IEC 60298 and IEC 60517 shall be considered.

6.2.5 Application of the test voltage and test conditions

Subclause 6.2.5 of IEC 60694 is applicable with the following addition.

Disconnectors having an isolating distance in parallel to the base of the disconnector and having integrated earthing switches, shall be tested in the most unfavourable position of the earthing blade with the power frequency test voltage given in table 5 (see 4.2).

These tests are not required for disconnectors that can only be operated with both terminals de-energized.

Table 5 – Power frequency 1 min withstand voltages

U_r kV	Test voltage kV	
	Solidly earthed neutral	Unearthed neutral
72,5	84	94
100	116	130
123	142	160
145	167	188
170	196	221
245	283	-
300	346	-
362	418	-
420	484	-
550	635	-
800	924	-

NOTE 1 For an explanatory note see annex D.

NOTE 2 These tests are not required with disconnectors of lower rated voltage.

6.2.6 Tests of disconnectors and earthing switches of a rated voltage $U_r \leq 245$ kV

Subclause 6.2.6 of IEC 60694 is applicable.

6.2.7 Test of disconnectors and earthing switches of rated voltage above 245 kV

Subclause 6.2.7 of IEC 60694 is applicable.

6.2.8 Artificial pollution tests

Subclause 6.2.8 of IEC 60694 is applicable with the following addition.

NOTE Care should be taken when considering the performance of parallel insulation under pollution and rain (additional pollution tests may be necessary).

6.2.9 Partial discharge tests

Subclause 6.2.9 of IEC 60694 is applicable.

6.2.10 Test on auxiliary and control circuits

Subclause 6.2.10 of IEC 60694 is applicable.

6.2.11 Voltage test as condition check

Subclause 6.2.11 of IEC 60694 is applicable.

6.3 Radio interference voltage (riv) test

Subclause 6.3 of IEC 60694 is applicable.

6.4 Measurement of the resistance of circuits

Subclause 6.4 of IEC 60694 is applicable.

6.5 Temperature-rise tests

Subclause 6.5 of IEC 60694 is applicable.

6.6 Short-time withstand current and peak withstand current tests

Subclause 6.6 of IEC 60694 is applicable.

6.6.1 Arrangement of the disconnectors and earthing switches and of the test circuit

Subclause 6.6.1 of IEC 60694 is applicable with the following additions:

6.6.1.101 General test conditions

The disconnector or earthing switch under test shall be installed with its own operating mechanism as far as necessary to make the test representative.

Disconnectors having accessories to accommodate a bus-transfer current switching capability, and earthing switches having accessories to accommodate induced current switching capability, shall be tested with these devices mounted.

Tests shall be carried out employing the least favourable position of the operating mechanism and the main contacts. Consideration should be given to 5.104.3 and, where applicable, to annex A.

Where the design requires an adjustment of the position indicator or the position signalling device, this shall be performed according to the instruction manual. No deviation of these devices is acceptable for dielectric tests and short-circuit tests.

If the design allows tolerances, these shall be declared by the manufacturer prior to the test. The short-time withstand current and peak current withstand tests shall be performed with the signalling device set at the maximum or minimum specified tolerance giving the least favourable status of the main contacts indicated by the signalling device. This requirement does not apply to independent operated indoor disconnectors and earthing switches.

In any case, the same setting of the position signalling device shall be used for the dielectric test and the short-time withstand current and peak withstand current tests.

NOTE The least favourable status of the main contacts is for dielectric tests, the smallest gap at which the "OPEN" signal appears, and for short-circuit tests the first position at which during closing operation the "CLOSED" signal appears.

To make the test results generally applicable, disconnectors and earthing switches shall be tested with the test arrangements specified in figures 3, 4, 5 or 6. Where flexible conductors are used in the test set-up, disconnectors and earthing switches shall be loaded with their rated static mechanical terminal loads.

The test arrangement shall also be representative of the least favourable conditions of electromagnetic forces tending to open the disconnector or earthing switch. The tests on an earthing switch integral to a disconnector shall be made with the same test connections as for the disconnector test.

Disconnectors or earthing switches having one common operating mechanism for three poles shall be tested with the operating mechanism mounted at a distance from the pole under test, which shall not be less than the phase distance.

Earthing switches not forming an integral part of a disconnector shall be tested in an arrangement that fulfils the same requirements as for disconnectors.

Disconnectors and earthing switches integrated in enclosed switchgear shall be tested as part of the switchgear assembly according to IEC 60298, IEC 60466 or IEC 60517.

For divided support disconnectors the vertical position of the contact in the contact zone shall be chosen to represent the most unfavourable condition with respect to the mounting of the fixed contact to flexible conductors or a rigid conductor. In case of doubt the tests shall be performed in the highest and the lowest position of the contact within the rated contact zone.

All tests should preferably be performed three-phase. If a single-phase test is performed, the test should preferably be performed on two adjacent poles. If the test is performed on one pole, the return conductor shall be at phase distance from the tested pole. The return conductor shall be parallel to the main current path of the disconnector or earthing switch and at the same elevation above the base, or the equivalent, for disconnectors and earthing switches with vertical blade. The length of the return conductor shall be as given in figures 3 to 6, as appropriate.

6.6.1.102 Disconnectors and earthing switches with rated voltages below 52kV

The test arrangement given in figure 3 shall be used for disconnectors and earthing switches.

6.6.1.103 Disconnectors and earthing switches with rated voltages of 52 kV and above

The single-phase test arrangement given in figure 4 shall be used for disconnectors with a horizontal isolating distance and the relevant earthing switches; the test arrangement given in figures 5 and 6 shall be used for divided support disconnectors with a vertical isolating gap and the relevant earthing switches.

NOTE Deviations from these test arrangements are only acceptable when based on an agreement between user and manufacturer which might be necessary because of special requirements given by the service conditions.

Three-phase test arrangements shall follow the same general pattern as the single-phase test arrangements of figures 4 to 6.

6.6.2 Test current and duration

Subclause 6.6.2 of IEC 60694 is applicable.

6.6.3 Behaviour of disconnectors and earthing switches during test

Subclause 6.6.3 of IEC 60694 is applicable with the following addition:

a) The rated peak withstand current and the rated short-time withstand current, carried by a disconnector in the closed position during the rated duration of short circuit, shall not cause

   - mechanical damage to any part of the disconnector;
   - separation of the contacts;
   - arcing.

   The behaviour of the contact system during the short-circuit test shall be documented by recording the voltage drop across the main current path of the disconnector.

b) For earthing switches the rated peak and short-time currents shall not cause substantial contact erosion or substantial contact welding.

   Where contact erosion or contact welding is observed following the short-time withstand and peak withstand current test, a second peak withstand current test shall be carried out without any maintenance permitted between the two tests. Sufficient time needs to be allowed between the tests for the contacts to cool down. A no load-operation shall be performed before the second test.

   The earthing switch is considered to have met the requirements if it still provides a sound earth connection after the second test.

   Only light welding of contacts is permitted which means that the earthing switch can be operated under the conditions given in 4.8 up to and including 4.10, and 5.5 and 5.6, with the rated values for power-operated devices and with 120 % of the values given for manually operated devices in 5.105.

6.6.4 Conditions of disconnectors and earthing switches after test

Subclause 6.6.4 of IEC 60694 is applicable with the following addition.

If the resistance of disconnectors with long-length main circuits (≥145 kV) has increased by more than 10 % compared with the resistance before the test, additional measurements at the contacts and movable joints may be necessary. The resistance of any of these parts of the disconnector shall not have increased by more than 20 %.

In the case of enclosed disconnectors and earthing switches, where no complete visual inspection is possible, the following condition checks are applicable:

- for the dielectric strength across the isolating gap and to earth 6.2.11 of IEC 60694 is applicable;
- for the current-carrying capacity, see 4.4.3, point 6 of IEC 60694.

6.7 Verification of the protection

Subclause 6.7 of IEC 60694 is applicable.

6.8 Tightness tests

Subclause 6.8 of IEC 60694 is applicable.

6.9 Electromagnetic compatibility tests (EMC)

Subclause 6.9 of IEC 60694 is applicable.

6.101 Test to prove the short-circuit making performance of earthing switches

6.101.1 General test conditions

Earthing switches of class E1, according to definition 3.4.105.2, having a short-circuit making current capability, shall be subjected to two making operations in a making test series in accordance with the procedure of test duty 5 (class E1) of 6.101.10 of IEC 60265-1 independent of voltage.

Earthing switches of class E2, according to definition 3.4.105.3, for rated voltages less than 52 kV having a rated short-circuit making current capability, shall be subjected to a making test series in accordance with test duty 5 of 6.101.10 (class E3) of IEC 60265-1, except that the number of making operations shall be increased to five.

NOTE For earthing switches with rated voltages of 52 kV and above, IEC 60265-2 applies insofar as it refers to the acceptability of alternative testing methods, e.g. ignition wire.

6.101.2 Behaviour of earthing switches when making short-circuit currents

Earthing switches having a rated short-circuit making current shall, when making the short circuit, comply with the following conditions of behaviour:

During operation, the earthing switch shall neither show signs of excessive distress nor endanger the operator.

In the case of liquid-filled earthing switches, there shall be no outward emission of flame, and the gases produced, together with the liquid carried with the gases, shall be allowed to escape in such a way as not to cause electrical breakdown or endanger the operator.

For other types of earthing switches, flame or metallic particles such as might impair the insulation level of the earthing switch shall not be projected beyond the boundaries specified by the manufacturer and shall not endanger the operator.

6.101.3 Conditions of the earthing switch after the making test

After performing the specified operations, the mechanical parts including parts related to the electrical field control (for example field electrode of a GIS earthing switch) and insulators of the earthing switch shall be practically in the same condition as before. Only the short-circuit making performance may be impaired.

In case of doubt, a condition test according to 6.2.11 of IEC 60694 is applicable.

NOTE Only light welding of contacts is permitted which means that the earthing switch can be operated under the conditions given in 4.8 up to and including 4.10, and 5.5 and 5.6, with the rated values for power operated devices, and with 120 % of the values given for manually operated devices in 5.105.

6.102 Operating and mechanical endurance tests

For three-phase disconnectors operated by one mechanism, where applicable, the terminal load shall be applied to all terminals simultaneously.

6.102.1 General test conditions

The tests shall be made at any convenient ambient air temperature at the place of test. The supply voltage shall be measured at the terminals of the operating devices with full current flowing. Auxiliary equipment forming part of the operating device shall be included.

6.102.2 Contact zone test

This test shall be made in order to prove satisfactory operation of divided support disconnectors (according to figures 1 and 2), in the various positions of the fixed contact within the limits of the rated contact zone according to 4.102. With the device in the open position, the fixed contact shall be placed in the following positions (according to figures 1 and 2), h being the highest position (stated by the manufacturer) of the fixed contact above the mounting plane:

a) at a height of h on the vertical axis of the assembly;

b) at a height of $h - z_r$ on the same axis;

c) at a height equal to h and displaced from the axis horizontally by $+y_r/2$;

d) at a height equal to h and displaced from the axis horizontally by $-y_r/2$.

The subscript, r, indicates the rated value assigned to the disconnector by the manufacturer.

With the device in the open position, the fixed contact shall be placed in the following positions, x_r being the total amplitude of movement of the fixed contact in the x-direction.

e) at a distance equal to $+x_r/2$;

f) at a distance equal to $-x_r/2$.

In each position, the device shall close and open correctly.

6.102.3 Mechanical endurance test

6.102.3.1 Test procedure

The mechanical endurance test shall consist of 1 000 operating cycles with, where applicable, 50 % of the rated static terminal load applied to the three-phase disconnector or earthing switch in direction Fa1 or Fa2 (figures 7 and 8), without voltage on, or current through the main circuit. For disconnectors having two or three insulators and a normally horizontal isolating gap, the 50 % rated static terminal load shall be applied at both sides of the disconnector, but in opposite directions. For disconnectors and earthing switches with one insulator (operating insulators not being taken into consideration) the terminal load shall be applied to only one side of the disconnector or earthing switch.

The closed and open positions shall be attained during each operating cycle.

During the test the specified operation of the control and auxiliary contacts and position indicating devices (if any) shall be verified according to 5.104 and according to 5.4 of IEC 60694.

The tests shall be made on disconnectors and earthing switches equipped with their own operating mechanisms. During the tests lubrication in accordance with the manufacturer's instructions is permitted, but no mechanical adjustment or other maintenance is allowed.

On a disconnector or earthing switch having a power-operated mechanism

- 900 close-open operating cycles shall be made at rated supply voltage and/or rated pressure of compressed gas supply;
- 50 close-open operating cycles at the specified minimum supply voltage and/or minimum pressure of compressed gas supply;
- 50 close-open operating cycles at the specified maximum supply voltage and/or maximum pressure of compressed gas supply.

These operations shall be made at a rate such that the temperatures of the energized electrical components do not exceed the values given in table 3 of IEC 60694.

Prior to commencing the tests, the manufacturer shall state the parameters to be used as comparators before and after the test series, for example:

- operating time;
- maximum energy consumption;
- for disconnectors with manual mechanisms only, registration of the maximum operating forces;
- verification of satisfactory operation of the auxiliary contacts and position indicating devices, if applicable.

For manually operated disconnectors and earthing switches, the handle may, for convenience of testing, be replaced by an external power-operated device. In this case, it is not necessary to vary the supply voltage. As an alternative to direct measurement, as required by 5.105, the force may be calculated from the input power taking into consideration the operating speed.

6.102.3.2 Verification of successful operation

Before and after the mechanical endurance test programme one of the following test series shall be performed without the static terminal load applied:

- five close-open operating cycles at the minimum supply voltage and/or pressure;
- five close-open operating cycles at the maximum supply pressure for operation (only for gas or liquid operated disconnectors or earthing switches);
- five close-open manual operations (only for hand-operated disconnectors and earthing switches).

During these operating cycles the operating characteristics such as operating time and maximum energy consumption shall be recorded or evaluated. With disconnectors having manual mechanisms only, the maximum forces shall be recorded. Satisfactory operation of the auxiliary contacts and position indicating devices (if any) shall be verified.

The variation between the mean values of each parameter, as required in 6.102.3.1, measured before and after the mechanical endurance test, shall be validated by the manufacturer and included into the test report.

After the test, all parts, including contacts, shall be in good condition and shall not show undue wear; see also 4.4.3, point 6, of IEC 60694.

The main circuit resistance shall be measured before and after the mechanical endurance test. The resistance shall not vary by more than 20 % from the value measured before the test.

For gas-insulated disconnectors and earthing switches, a tightness test before and after the mechanical endurance test shall be performed.

Since the influence of ambient temperature has to be considered, the temperature shall be recorded.

6.102.4 Operation during application of the rated static mechanical terminal load

Twenty operating cycles with the rated power supply shall be made with the rated mechanical static terminal load applied at both terminals:

- longitudinal load applied in direction Fa1 or Fa2;
- perpendicular load applied in direction Fb1 or Fb2, both in the same direction;
- Fc simulates the downward forces caused by the weight of the connecting conductors. With flexible conductors, the weight is included in the longitudinal or perpendicular forces.

For only manually operated disconnectors and earthing switches the number of operating cycles may be reduced to 10.

For disconnectors with a horizontal isolating gap, the load shall be applied on both sides at the same time.

The disconnector may be adjusted before the test and after having been loaded with 50 % of the rated longitudinal or transversal mechanical terminal force.

During each operation the disconnector or earthing switch shall close and open correctly.

For verification, before and after the complete sequence of operating cycles, 6.102.3.2 and the appropriate comparators as required in 6.102.3.1 for mechanical endurance tests, are applicable.

6.102.5 Extended mechanical endurance tests

The tests defined in this subclause shall be performed on disconnectors class M1 and M2.

In the case of disconnectors and earthing switches in GIS, the enclosure shall not be opened during the test.

Disconnectors being frequently operated, for example those operating in conjunction with circuit-breakers, require extended mechanical endurance tests which shall be carried out as follows:

a) The extended mechanical endurance tests programme shall consist of a number of close-open operations carried out in accordance with 6.102.1 and 6.102.3.1.

   According to the service requirements, one of the following number of operating cycles shall be performed:

   - 2 000 (for disconnectors class M1);
   - 10 000 (for disconnectors class M2).

   After each series of 1 000 operating cycles, or at maintenance intervals, the operating characteristics shall be recorded or evaluated.

   Between the specified test series, some maintenance such as lubrication and mechanical adjustment is allowed and shall be performed in accordance with the manufacturer's instructions. Change of significant sub-components, such as contacts, is not permitted.

   The programme of maintenance during the tests shall be defined by the manufacturer before the tests and recorded in the test report.

b) Before and after the total test programme mechanical tests shall be performed and the operating characteristics shall be verified as required in 6.102.3.2.

   The following tests shall also be performed:

   - contact zone test (6.102.2), if applicable;
   - verification of operation during application of rated static mechanical terminal loads (6.102.4), if applicable.

c) In addition after the total test programme, checks and tests shall be performed as follows:

   - verification of satisfactory operation with the minimum duration of the operating signal given by the manufacturer;
   - verification of the satisfactory condition of the mechanical travel limit stops;
   - verification of operation of the mechanical effort-limiting devices, if any.

d) After the total test programme, all parts, including contacts, shall be in good condition and shall not show undue wear in accordance with the relevant clauses of IEC 60694; see also 4.4.3, point 6 of IEC 60694.

6.103 Operation under severe ice conditions

According to 2.1.2 e) of IEC 60694, three classes of ice coating are specified:

- class 1 (1 mm ice coating);
- class 10 (10 mm ice coating);
- class 20 (20 mm ice coating).

10 mm and 20 mm ice coatings are considered to be representative of severe ice conditions, as stated in 2.1.2 e) of IEC 60694.

Disconnectors and earthing switches having accessories to accommodate a bus-transfer current switching capability (disconnectors only) and a switching capability of induced currents (earthing switches only) shall be tested with these devices mounted.

6.103.1 Introduction

Formation of ice may produce difficulties in the operation of electric power systems. Under certain atmospheric conditions, a deposit of ice can build up to a thickness that sometimes makes the operation of outdoor switching equipment difficult.

Nature produces ice coatings which may be divided into two general categories:

a) clear ice generally resulting from rain falling through air somewhat below the freezing point of water, and

b) rime ice, characterized by a white appearance, formed for example from atmospheric moisture condensing on cold surfaces.

6.103.2 Applicability

The tests defined in this subclause shall be made only if the manufacturer claims suitability of disconnectors and earthing switches for operation under severe conditions of ice formation. A procedure is described for producing clear ice coatings which compare with those encountered in nature so that reproducible tests can be made. For severe ice conditions, a choice is provided between two classes of ice thickness: 10 mm and 20 mm.

NOTE Disconnector commutating contacts for bus-transfer current switching and accessories fitted to earthing switches to accommodate a switching capability of induced currents may not be able to perform these switching capabilities under the severe ice conditions.

6.103.3 Test arrangement

a) All parts of the disconnector or earthing switch to be tested shall be assembled, together with their operating mechanism, in a room which can be cooled to a temperature of about –10 °C, or outdoors if it is desired to perform the tests in conditions of natural frost. The energizing of heating elements of the control mechanism is permitted during the test. Support and operating insulators and other operating members may be shortened to reduce the height of the assembly to suit the test facilities available, provided the angle of rotation of the parts affected and the bending of thrust linkages remain unchanged.

NOTE In choosing the refrigeration capacity required, the heat content of the water with which the apparatus under test is sprayed should be taken into account.

b) A single-pole of a three-pole apparatus may be tested if each pole has a separate operating mechanism. In the case of a three-pole apparatus having one common operating mechanism for the three poles, the complete three-pole device shall be tested. The only exception is if the testing laboratory cannot accommodate complete standard three-pole apparatus with voltage larger than 72,5 kV; in this case, tests with a single-pole operated by the common mechanism may become necessary. In this situation, exact details of the test procedure and the measured torque shall be reported in order to evaluate the test result concerning the capability of the mechanism to operate the three-pole apparatus. It is up to the user to agree to this type of single-pole testing. However, preference should be given instead to a modification of mounting structures or spacing wherever possible, in order to enable that three-pole tests may be made.

c) The disconnector or earthing switch shall be tested for operation from the open position and the closed position separately.

d) Prior to the test, any trace of oil or grease on parts which do not need to be lubricated in service shall be removed with an appropriate solvent. This is because thin films of oil or grease prevent ice from adhering and greatly change the results of tests.

e) To facilitate measurement of ice thickness, a copper bar or tube 30 mm in diameter and 1 m in length shall be mounted in a horizontal position in a place where it will receive the same general rainfall as the apparatus under test. If the specific thermal capacities per unit surface area of test bar and apparatus under test differ considerably, even identical spraying conditions may produce very different ice coatings. These differences in thickness may be minimized by short periods of spraying alternating with longer periods of cooling.

f) The arrangement shall allow the entire apparatus to be sprayed with artificial rain falling from above at various angles, from the vertical to 45°. The water used in the spray should be cooled to a temperature between 0 °C and 3 °C and should reach the test object in the liquid state.

NOTE As a guide, it has been observed that between 20 l and 80 l per hour per m^2 of area sprayed is required to cause ice to be deposited at a rate of approximately 6 mm/h.

g) After having made the adjustments and prior to the operation under severe ice conditions, the disconnector and the earthing switch shall be subjected to the routine mechanical operating tests of 7.101.

6.103.4 Test procedure

6.103.4.1 Formation of ice deposits

A coating of solid clear ice of the required thickness, 10 mm or 20 mm, shall be produced. A typical test procedure for the formation of ice is described below.

a) With the test disconnector/earthing switch in the open or closed position, lower the air temperature to 2 °C and start the spray of pre-cooled water. Continue this spray for a minimum of 1 h while holding the air temperature between 0,5 °C to 3 °C.

b) Lower the room temperature to within –7 °C and –3 °C while continuing the water spray. The rate of temperature change is not critical and may be whatever is obtainable with available refrigeration apparatus.

c) Hold the room temperature within –7 °C and –3 °C and continue to spray until the specified thickness of ice can be measured on the top surface of the test bar. The amount of water should be controlled to cause ice to build up over the entire disconnector/earthing switch at the rate of approximately 6 mm/h.

d) Discontinue the spray and maintain the room temperature within –7 °C and –3 °C for a period of at least 4 h. This ensures that all parts of the disconnector and the ice coating have assumed a constant temperature. Following this ageing period, the satisfactory operation of the disconnector/earthing switch including its auxiliary equipment, shall be checked.

6.103.4.2 Checking of operation

If the disconnector or earthing switch is manually operated, the test will be considered as satisfactorily completed if the apparatus has been operated to its final closed or open position, and if it does not sustain damage which may later interfere with its mechanical or electrical performance. If the disconnector or earthing switch is electrically, pneumatically or hydraulically operated, the test will be considered as satisfactorily completed if the apparatus has been operated on the first attempt up to its final closed or open position by the operating device supplied at its rated voltage or pressure, and if it does not sustain damage which may later interfere with its mechanical or electrical performance.

The following tests will demonstrate that the disconnector or earthing switch is able to withstand its rated normal current, rated short-time withstand current and rated peak withstand current, as applicable:

- immediately after the closing operation by checking the galvanic contact with a battery and lamp arrangement using a maximum voltage of 100 V;
- with the temperature restored to normal ambient by measuring the resistance of the main current path which shall not show significant change.

6.104 Operation at the temperature limits

These tests apply only to outdoor disconnectors and earthing switches and shall be performed only on special request of the user.

Single poles of three-pole apparatus may be tested if each pole has a separate operating mechanism. In the case of three-pole apparatus having one common operating mechanism for the three poles, the complete three-pole device shall be tested.

Exception: if the testing laboratory cannot accommodate complete standard three-pole apparatus of a voltage higher than 72,5 kV, tests with a single-pole operated by the common mechanism may become necessary. In this case, exact details of the test procedure and the measured torque shall be reported in order to evaluate the test result with reference to the capability of the mechanism to operate the three-pole apparatus. It is up to the user to agree to this type of single-pole testing. However, preference should be given instead to a modification of mounting structures or spacing, wherever possible, in order to enable the three-pole test to be made.

The time required from the beginning of the command "Open" until receipt of the signal "Open position reached" or until the actual open position is reached (whichever is the longer), shall be recorded in the test report.

Similarly, the time to fully close, or signal closed, shall be recorded.

6.104.1 Operation at minimum ambient air temperature

The disconnector or earthing switch shall be placed in a test chamber in the closed position. It shall be complete with its operating mechanism and auxiliary equipment. The temperature shall be lowered and maintained at the minimum ambient temperature appropriate to the class of the disconnector or earthing switch (see 2.1 of IEC 60694) for a period of 12 h. The apparatus shall then satisfactorily complete three operating cycles, at minimum and maximum supply energy. The energizing of heating elements of the control mechanism is permitted during the test.

For gas-insulated disconnectors and earthing switches, a tightness test shall be performed in accordance with 6.8 of IEC 60694 before and after the operation at minimum ambient air temperature.

6.104.2 Operation at maximum ambient air temperature

The disconnector or earthing switch shall be placed in a test chamber in the closed position. It shall be complete with its operating mechanism and auxiliary equipment. The temperature shall be raised and maintained at the maximum ambient temperature of 40 °C (see 2.1 of IEC 60694) for a period of at least 4 h and long enough to reach temperature balance between the whole of the test object and the test chamber. The disconnector or earthing switch shall then satisfactorily complete three operating cycles at minimum and maximum supply energy.

6.105 Tests to verify the proper functioning of the position indicating device

These tests apply when a position indicating device is used as an alternative to the visible isolating distance or gap.

Details of the test requirements are given in annex A.

6.106 Bus-transfer current switching tests

These tests apply only to disconnectors with a rated bus-transfer current switching capability.

Details of the test requirements are given in annex B.

6.107 Induced current switching tests

These tests apply only to earthing switches with a rated induced current switching capability.

Details of the test requirements are given in annex C.

6.108 Bus-charging switching tests

These tests apply only to disconnectors having a rated bus-charging switching capability.

Details of the test requirements are given in annex F.

7 Routine tests

Clause 7 of IEC 60694 is applicable with the following additions:

Addition to the list of routine tests:

f) Mechanical operating tests in accordance with 7.101.

If test reports of routine tests are required by agreement between manufacturer and user, from manufacturers whose system of quality assurance has been certified, reports according to their quality hand book are acceptable.

7.1 Dielectric test on the main circuit

Subclause 7.1 of IEC 60694 is applicable.

If the conditions of paragraph 3 of clause 7, or paragraph 3 of 7.1 of IEC 60694 are not fulfilled, the following applies:

When testing disconnectors the test conditions shall be in accordance with table 6. For an explanation of abbreviations see figure 2 of IEC 60694.

Table 6 – Power frequency voltage tests

Test condition no.	Disconnector position	Voltage applied to	Earth connected to
1[a]	Closed	AaCc	BbF
2[a]	Closed	Bb	AaCcF
3	Open	ABC	abcF
4	Open	Abc	ABCF
5[b]	Open	ABC	Earthing switch

[a] If the insulation between poles is air at atmospheric pressure, test conditions nos. 1 and 2 may be combined, the test voltage being applied between all parts of the main circuit connected together and the base.

[b] Earthing switch in the position resulting in the shortest gap between the tip of the earthing blade and live parts of ABC.

When testing earthing switches, the test voltage shall be applied with the earthing switch in the open position:

- between adjacent insulated terminals with the bases earthed (e.g. A to B with F earthed);
- between all the insulated terminals connected together and the bases earthed (e.g. ABC to F earthed).

7.2 Dielectric test on auxiliary and control circuits

Subclause 7.2 of IEC 60694 is applicable.

7.3 Measurement of the resistance of the main circuit

Subclause 7.3 of IEC 60694 is applicable only to disconnectors.

7.4 Tightness test

Subclause 7.4 of IEC 60694 is applicable.

7.5 Design and visual checks

Subclause 7.5 of IEC 60694 is applicable.

7.101 Mechanical operating tests

Operating tests are made to ensure that the disconnectors or earthing switches show the specified operating behaviour within the specified voltage and supply pressure limits of their operating mechanisms.

During these tests, which are performed without voltage on, or current flowing through the main circuit, it shall be verified that the disconnectors or earthing switches open and close correctly when their operating mechanisms are energized.

The tests shall be performed according to 6.102.3.2. The mentioned test programme shall be performed only once.

During these tests no adjustment shall be made and the operation shall be faultless. The closed and open position shall be reached with the specified indication and signalling during each operating cycle.

After these tests, no parts of the disconnector or earthing switch shall be damaged.

For disconnectors and earthing switches with a rated voltage of 52 kV and above, the mechanical operating routine tests may be performed on sub-assemblies.

Where mechanical routine tests are performed on separate components, they shall be repeated at site on a complete assembled disconnector during the commissioning tests. The same total number of operations as specified in 6.102.3.2 shall be performed.

NOTE The mechanical operating test will not be representative for the operating conditions in the substation when complicated linkages are used between the point of operation and the switchgear and when the bearings are mounted to weak supports.

8 Guide to the selection of disconnectors and earthing switches

8.101 General

For the selection of disconnectors and earthing switches the following conditions and requirements at site should be considered:

- normal current load and overload conditions;
- existing fault conditions;
- static and dynamic terminal loads resulting from the substation design;
- use of rigid or flexible conductors to be connected to the disconnector or earthing switch or to which the separated contact is mounted;
- environmental conditions (climate, pollution, etc.);
- altitude of the substation site;
- required operational performance (mechanical endurance);
- switching requirements (bus-transfer current switching by disconnectors, induced current switching by earthing switches, short-circuit making capacity of earthing switches).

When selecting a disconnector or earthing switch due allowance should be made for the likely future development of the system as a whole so that the disconnector or earthing switch may be suitable not merely for immediate requirements, but also for those of the future.

National requirements enforcing deviation from this standard shall be stated in the tender documents.

8.102 Selection of rated values for normal service conditions

All rated characteristics and classes of a disconnector or earthing switch given in clause 4 shall be considered, as far as applicable, together with the following subclauses.

8.102.1 Selection of rated voltage and rated insulation level

The rated voltage of the disconnector or earthing switch should be chosen so as to be at least equal to the highest voltage of the system at the point where the disconnector or earthing switch is to be installed.

The rated voltage of a disconnector or earthing switch should be selected from the standard values and their related insulation levels given in 4.1 and 4.2 of IEC 60694.

To select the insulation level of disconnectors and earthing switches from tables 1a, 2a, 1b and 2b of IEC 60694, annex D of IEC 60694 should be taken into consideration. Where a disconnector or earthing switch is required for a position necessitating a higher insulation level than given in these tables, this shall be specified in the enquiry (see 9.101).

8.102.2 Selection of rated normal current

The rated normal current of a disconnector should be selected from the standard values given in 4.4.1 of IEC 60694.

It should be noted that disconnectors have no standardized continuous overcurrent capability. When selecting a disconnector, therefore, the rated normal current should be such as to make it suitable for any load current that may occur in service. Where intermittent overcurrents are expected to be frequent and severe, the manufacturer should be consulted.

NOTE It is understood that the rated normal current is the current that a disconnector can carry continuously except in uncommon conditions of use. Such conditions may be met, for example, for generator disconnectors that may be in the closed position for a very long time, at a current near the rated normal current, without being operated, and in a high ambient temperature. In such cases, the manufacturer should be consulted.

8.102.3 Selection of rated contact zone

The rated contact zone should be selected based on the requirements of 4.102.

When selecting the rated contact zone, the user shall verify that the rated contact zone specified by the manufacturer is not exceeded in its specific application for the following additional constraints, if applicable:

- a longitudinal deflection resulting from wind acting on other connected components that are perpendicular to the bus work and from equipment movement;
- a perpendicular deflection resulting from forces from wind on other connected components that are perpendicular to the bus work and from equipment movement;
- a vertical deflection resulting from other vertical loads hung from the bus and from operating loads imposed by the operation of other equipment connected to the bus.

8.102.4 Selection of rated mechanical terminal load

The rated mechanical static and dynamic terminal load should be selected based on the requirements of 4.103 and the definitions of 3.7.121. The most disadvantageous conditions should be considered by the user when specifying the rated terminal loads.

NOTE It is recommended to calculate the required static terminal load on the basis of

- minimum specified ambient air temperature, and
- –10 °C plus ice load plus wind load, or
- –5 °C plus wind load (tropical countries).

To calculate the required static and dynamic terminal loads as well as the required strength of insulators, the forces resulting from the conductors connected to the disconnector or earthing switch, including the forces of wind and ice (if applicable) on these conductors should be considered.

8.102.5 Selection of a bus-transfer current switching capability for disconnectors of 52 kV and above

Although disconnectors are, by definition, only capable of opening and closing a circuit when either negligible current is broken or made or when no significant change in the voltage across the terminals of each of the poles of the disconnector occurs, disconnectors in some applications are used for load transfer from one bus system to another. Even if a bus coupling is closed, the load transfer may be a more or less severe switching operation for the disconnector, depending on the dimensions of the substation and the current to be transferred.

If a bus-transfer current switching capability is required, the values of transfer current and expected recovery voltage shall be selected from those given in annex B and specified in the enquiry (see clause 9).

8.102.6 Selection of an induced current switching capability for earthing switches of 52 kV and above

The definition of an earthing switch does not include a switching capability. A standard earthing switch is capable of opening and closing a connection to earth from an isolated section of a substation or a line when the current to be broken or made is negligible and/or the voltage across the terminal of each of the poles of the earthing switch is so small that only negligible arcing occurs. According to the definition for disconnectors, a current not exceeding 0,5 A is deemed to be a negligible current.

In high-voltage networks tower configurations are sometimes used with more than one system being mounted on the same line tower. In such cases, induced currents have to be switched when earthing or unearthing one of the lines whilst the other line is connected to the system and may be carrying load current. The magnitude of the induced currents to be switched by the earthing switch depends on the capacitive and inductive coupling factors between the lines, and on the voltage, load and length of the parallel system.

If a switching capability is required, it should be selected from the values given in annex C and specified in the enquiry (see clause 9).

8.102.7 Local environmental conditions

For the normal and special service conditions for disconnectors and earthing switches, clause 2 of IEC 60694 applies.

For disconnectors and earthing switches, pollution conditions in certain areas both outdoors and indoors are unfavourable on account of smoke, chemical fumes, salt-laden spray, etc. Where such adverse conditions are known to exist, special consideration should be given to the design and materials used with the disconnector or earthing switch.

For insulators normally exposed to the atmosphere, the required creepage length should be selected according to 5.14 of IEC 60694. The performance of an insulator in polluted atmospheres also depends on the frequency with which artificial washing or other pollution control methods are carried out or natural cleaning occurs.

NOTE A nominal creepage length smaller than given by the product of the rated voltage and the minimum specific creepage length may be used if the porcelain design has been proved by testing to fulfil the requirements of the user.

For open-terminal, indoor installations in coastal areas where salt deposit is a problem, it is recommended, for rated voltages of 52 kV and above, to use equipment with outdoor insulation as this is more readily available than special indoor insulation. The use of GIS installations is also possible.

If a disconnector or earthing switch is to be located where the wind pressure exceeds 700 Pa, this should be stated in the enquiry.

If a disconnector or earthing switch is to be located in a surrounding where an ice-coating with a thickness exceeding 1 mm is expected, this should be stated in the enquiry, taking 6.103 into consideration.

8.102.8 Seismic conditions

Subclause 2.2.4 of IEC 60694 is applicable.

8.102.9 Use at high altitudes

Subclause 2.2.1 of IEC 60694 is applicable.

8.102.10 Selection of rated short-time withstand current and of rated duration of short-circuit

Subclauses 4.5 and 4.7 of IEC 60694 are applicable.

Test arrangements for short-circuit tests given in figures 4, 5 and 6 are minimum requirements. It cannot be excluded that substation designs exist in which the disconnector undergoes higher stresses.

NOTE The relation between current and time is given by the formula I^2t = constant.

8.102.11 Selection of rated peak withstand current and of rated short-circuit making current for earthing switches

The selected disconnector or earthing switch shall have a rated peak withstand current not less than the highest peak value of the fault current occurring in the actual system (by considering the actual value of the time constant of the network).

Subclause 4.6 of IEC 60694 should be considered.

This applies also to the rated short-circuit making current of an earthing switch (where applicable).

9 Information to be given with enquiries, tenders and orders

The following information is specified here as required by IEC 60694. It will be helpful to take into consideration the information given in clause 8.

9.101 Information to be given with enquiries and orders

When enquiring for or ordering a disconnector or an earthing switch, the following particulars should be supplied by the enquirer:

a) Particulars of system, i.e. nominal and highest voltages, frequency, number of phases and details of neutral earthing.

b) Service conditions, including minimum and maximum ambient air temperatures (the latter, if greater than the normal values), altitude if over 1 000 m and any special conditions likely to exist or arise, for example unusual exposure to steam or vapour, moisture, fumes, explosive gases, excessive dust or salt air (see 8.102.7 through 8.102.9).

c) Characteristics of a disconnector or earthing switch. The following information should be given, if applicable:

- number of poles;
- installation: indoor or outdoor;
- rated voltage;
- rated insulation level where a choice exists between different insulation levels corresponding to a given rated voltage or, if other than standard, desired insulation level (see tables 1a, 1b, 2a and 2b of IEC 60694); for disconnectors and earthing switches of rated voltage ≥300 kV, the rated switching impulse withstand voltage;
- rated frequency;
- rated normal current (for disconnectors only);
- rated peak and short-time withstand currents;
- rated short-circuit making current, if any (for earthing switches only); (see 3.4.105)
- if other than standard, specified value of duration of short-circuit;
- rated static and rated dynamic mechanical terminal loading (see 4.103);
- use of rigid or flexible conductors to be connected to the disconnector or earthing switch or to which the separated contact is mounted;
- mounting conditions and HV connections, for example hanging arrangement of the fixed contact of the disconnector and earthing switch; support structure to be supplied with the equipment or not;
- requirements for insulators to be used with the disconnector and earthing switch:
  - class of pollution taken from IEC 60815,
  - profile of the sheds (if applicable); taken from IEC 60815,
  - see item 10);

NOTE Other characteristics of insulators are under the responsibility of the manufacturer of the switchgear.

- required contact zone; if applicable;
- additional requirements where applicable:
  - artificial pollution,
  - operation under severe ice conditions,
  - bus-transfer current switching (disconnectors only),
  - induced current switching (line earthing switches only),
  - extended mechanical endurance class M1 or class M2,
  - short-circuit making capability class E1 or class E2 (earthing switches only);

d) Characteristics of the operating mechanism and associated equipment, in particular:

- method of operation, whether manual or power dependent,
- for independent manual operation: the duration of a time delay,
- the operating height above servicing level,
- for power operation, the type of available supply energy (e.g. compressed air, or electrical d.c. or a.c.) and its ratings (pressure, voltage, frequency),
- number and type of auxiliary contacts,
- degree of protection if higher than that specified in 5.13;

e) Requirements concerning the use of compressed gas and requirements for design and tests of pressure vessels.

f) Any routine tests or additional checks required to be witnessed by the user.

The following checks may be required to be performed in the presence of the user as final tests before shipment, if stated in the order. They may be performed as sample tests on one unit or 1 % of the number of units purchased under one contract:

- thickness of coating (paint, galvanising layer, etc.) for corrosion protection;
- electrical control wire check (if any);
- accessories and documentation (erection and operating instructions, storing and transport instructions);
- operating time (if applicable).

g) Any other information concerning special conditions not included above that might influence the tender or the order.

9.102 Information to be given with tenders

The information given with tenders should cover the requirements specified in 9.101 as applicable, and should state compliance with and deviations from the enquiry details. In addition, full descriptive matter and drawings shall be provided, together with type test certificates or reports, as requested.

9.102.1 Rated values and characteristics

a) number of poles;

b) installation: indoor or outdoor;

c) rated voltage;

d) rated insulation level and especially rated switching impulse withstand voltage, where applicable;

e) rated frequency;

f) rated normal current (for disconnectors only);

g) rated short-time withstand current and peak current;

h) rated short-circuit making current (for earthing switches only);

i) specified type tests, on special request;

j) rated bus-transfer current switching according to annex B;

k) rated induced current switching by earthing switches (class according to annex C);

l) rated mechanical endurance of disconnectors (class M);

m) rated electrical endurance of earthing switches (class E).

9.102.2 Constructional features

a) mass of complete disconnector or earthing switch;

b) minimum clearance in air:

- between poles,
- to earth,
- for isolating distance (for disconnectors only);

c) for divided support disconnectors and earthing switches, the rated contact zone;

d) corrosion protection;

e) for disconnectors having a fixed contact requiring reaction forces when closing and opening the contact, these forces and their direction shall be stated by the manufacturer in the documentation.

9.102.3 Operating mechanism of a disconnector or earthing switch and associated equipment

a) type of operating mechanism;

b) rated supply voltage and/or pressure of operating mechanism;

c) current required at rated supply voltage to operate the disconnector or earthing switch; maximum current and maximum voltage at the terminals of the operating mechanism;

d) quantity of free gas required to operate the disconnector or earthing switch at the rated supply pressure, as applicable;

e) number and type of auxiliary contacts;

f) design of the device or description of means for securing the position;

g) design of indicating and signalling device.

9.102.4 Overall dimensions and other information

The manufacturer shall give the necessary information regarding the overall dimensions of the disconnector or earthing switch in the open and closed positions. The fixing dimensions and mass of the disconnectors and earthing switches should also be given. The dimensions given in drawings of disconnectors and earthing switches are subject to tolerances as standardized by ISO 2768-1 unless otherwise specified.

General information regarding maintenance should also be given (see 10.4).

9.102.5 State of equipment

The manufacturer shall inform the user on the state of assembly in which the disconnector and/or earthing switch is transported and delivered.

10 Rules for transport, storage, installation, operation and maintenance

Clause 10 of IEC 60694 is applicable.

10.1 Conditions during transport, storage and installation

Subclause 10.1 of IEC 60694 is applicable.

10.2 Installation

Subclause 10.2 of IEC 60694 is applicable with the following addition:

Disconnectors and earthing switches shall be packed, as far as is practicable, as one unit.

Packages and crates containing more than one unit or more than one component (insulators, drive rods, operating mechanisms and similar components) should be clearly identified and accompanied by a list of content.

10.3 Operation

Subclause 10.3 of IEC 60694 is applicable.

10.4 Maintenance

Subclause 10.4 of IEC 60694 is applicable with the following addition:

For disconnectors with a bus-transfer current switching capability, the number of operations needs to be taken in account in order to estimate the maintenance intervals.

11 Safety

Clause 11 of IEC 60694 is applicable with the following addition:

NOTE The terms "skilled person" and "instructed person" are defined in IEV 826-09-01 and IEV 826-09-02, respectively. The requirements for "skilled person" and "instructed person" may deviate depending on local safety rules.

11.1 Electrical aspects

Subclause 11.1 of IEC 60694 is applicable.

11.2 Mechanical aspects

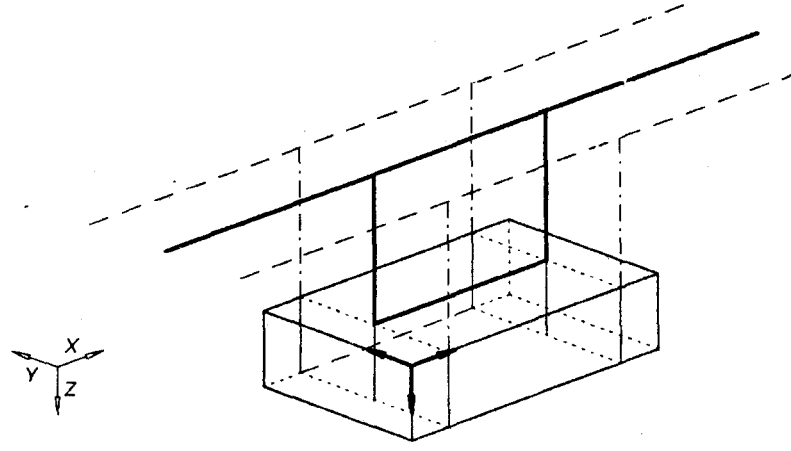
Subclause 11.2 of IEC 60694 is applicable.

11.3 Thermal aspects

Subclause 11.3 of IEC 60694 is applicable with the addition of 5.13.

11.4 Operation aspects

Subclause 11.4 of IEC 60694 is applicable with the addition of 5.104.



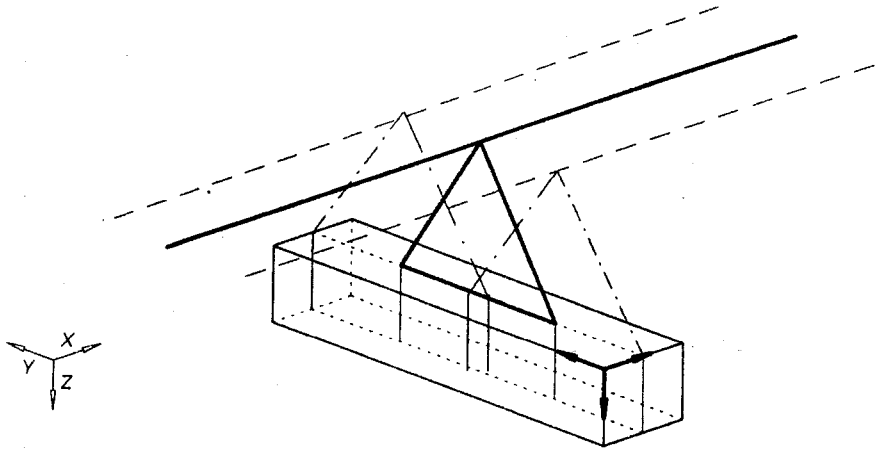
Key

x Longitudinal to support (influence of temperature)

y Perpendicular to support (influence of wind)

z Vertical deflection (temperature and ice)

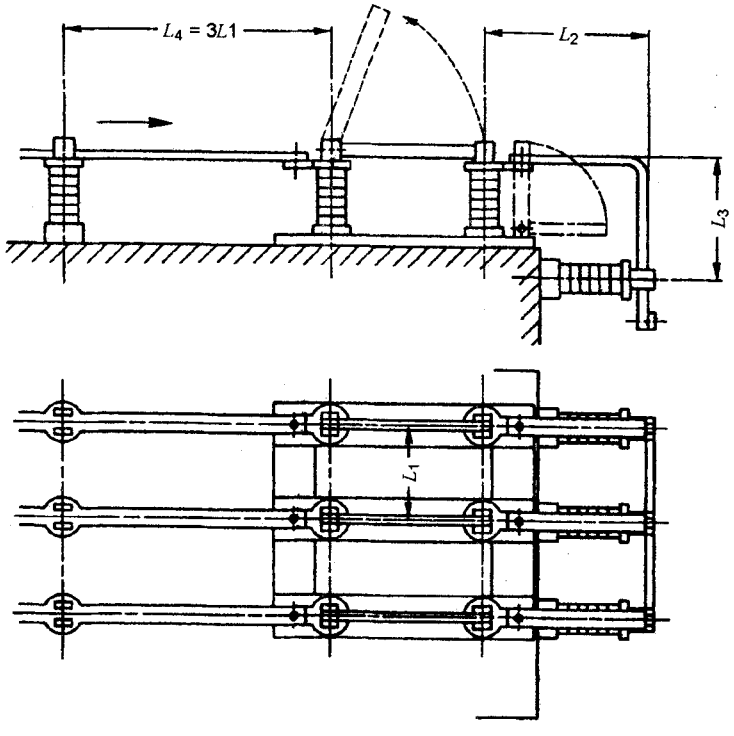
Figure 1 – Fixed contact parallel to support



Key

x	Longitudinal to support (influence of temperature)
y	Perpendicular to support (influence of wind)
z	Vertical deflection (temperature and ice)

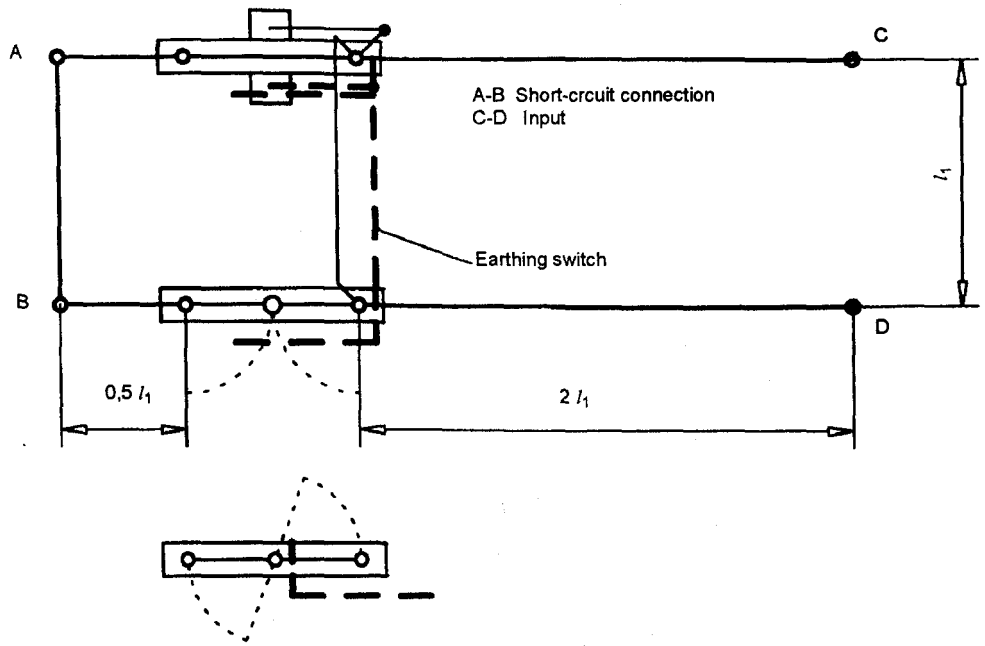
Figure 2 – Fixed contact (as indicated in figure 8) perpendicular to support



NOTE 1 Care should be taken that forces not representative of service conditions are not introduced by the connections to the supply.

NOTE 2 The distances L_2 and L_3 are as small as possible, but not smaller than L_1.

Figure 3 – Three-phase test arrangement for disconnectors and earthing switches with rated voltages below 52 kV



Key

l_1 Minimum centre-to-centre distance between adjacent poles as stated by the manufacturer.

Figure 4 – Single-phase test arrangement for disconnectors with a horizontal isolating distance and for earthing switches with rated voltage of 52 kV and above

Disconnectors intended to be connected in the substation to flexible or rigid conductors shall be tested using flexible conductors and unless otherwise stated with their rated static mechanical terminal load (longitudinal direction F_{a1} in figure 7) in a test set-up with the dimensions given in figure 4. Disconnectors only intended to be connected to rigid conductors may be tested with rigid conductors in a test arrangement with the same dimensions. The dimensions of the conductors used shall be stated in the test report.

All details referring to the test arrangement are mandatory, the details of the disconnector and earthing switch shown are given as an example.

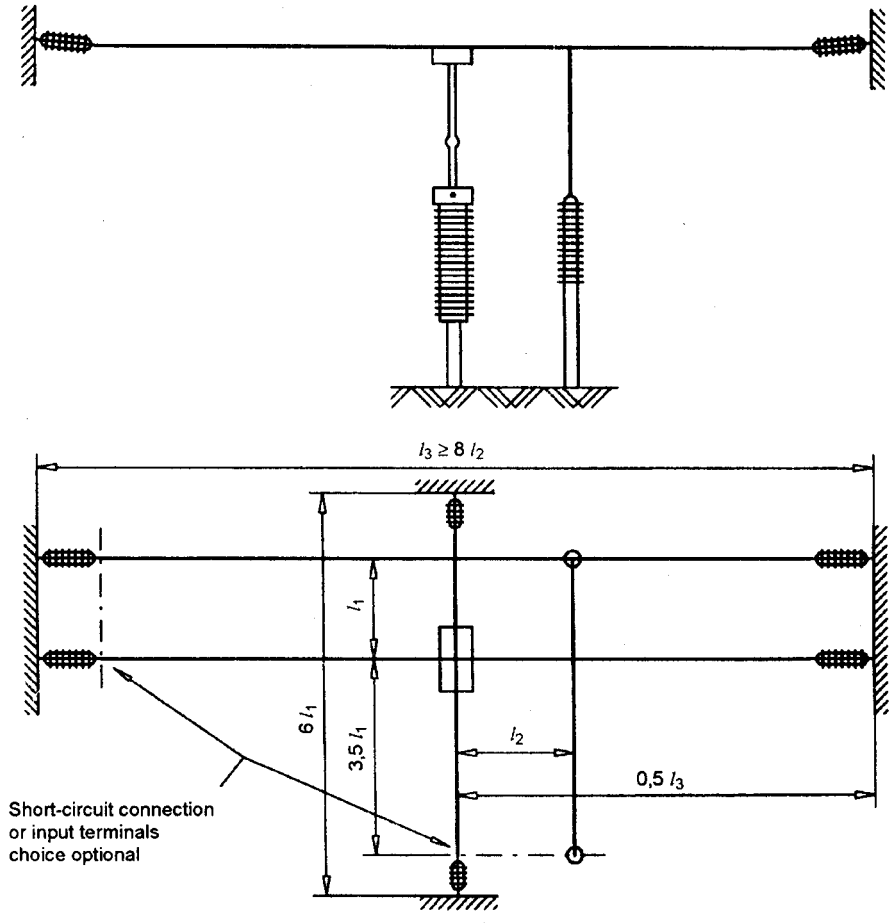
For standardization of tests when they are performed with flexible conductors, and the rated currents of the equipment are larger than 1 250 A normal current and 31,5 kA short-time withstand current for a duration of 1 s, two flexible conductors shall be used having a centre line distance of 70 mm ± 30 mm without spacers. When spacers are required by the user, this shall be agreed upon between manufacturer and user. This and any other deviations that have been agreed upon between manufacturer and user shall be clearly indicated in the test report. Disconnectors and earthing switches with rated voltages of 300 kV and above shall generally be tested with twin conductors. Flexible conductors used shall have a diameter of 32 mm ± 10 %.

Unless the tested disconnector or earthing switch is solidly fixed to the foundation, the spring constant of the support structure shall be taken into consideration (IEC 60865-1).

The test report or certificate shall provide clear details of the mounting arrangements used for the tests or record that the disconnector was solidly fixed to the foundations.

NOTE 1 Care should be taken that forces not representative of service conditions are not introduced by the connections to the supply and that the static terminal loads are not larger than the rated static terminal loads of the switchgear under test. After applying 50 % of the rated static terminal load, the disconnector or earthing switch may be adjusted before the 100 % load is applied.

NOTE 2 In principle, figure 4 is also applicable for testing earthing switches with an appropriate arrangement of the earth conductor.



l_1, l_2 Minimum centre-to-centre distance between adjacent poles, as stated by the manufacturer

Figure 5 – Single-phase test arrangement for divided support disconnectors (earthing switches) with a vertical isolating distance with rated voltages of 52 kV and above to be used with flexible conductors

For standardization of tests when they are performed with flexible conductors, where the rated currents of the equipment are larger than 1 250 A normal current or 31,5 kA short-time withstand current for a duration of 1 s, two flexible conductors shall be used having a centre line distance of 70 mm ± 30 mm without spacers. Other spacer arrangements may be agreed upon between manufacturer and user. Such deviations shall be indicated in the test report. Disconnectors and earthing switches with rated voltages of 300 kV and above shall be tested with twin conductors.

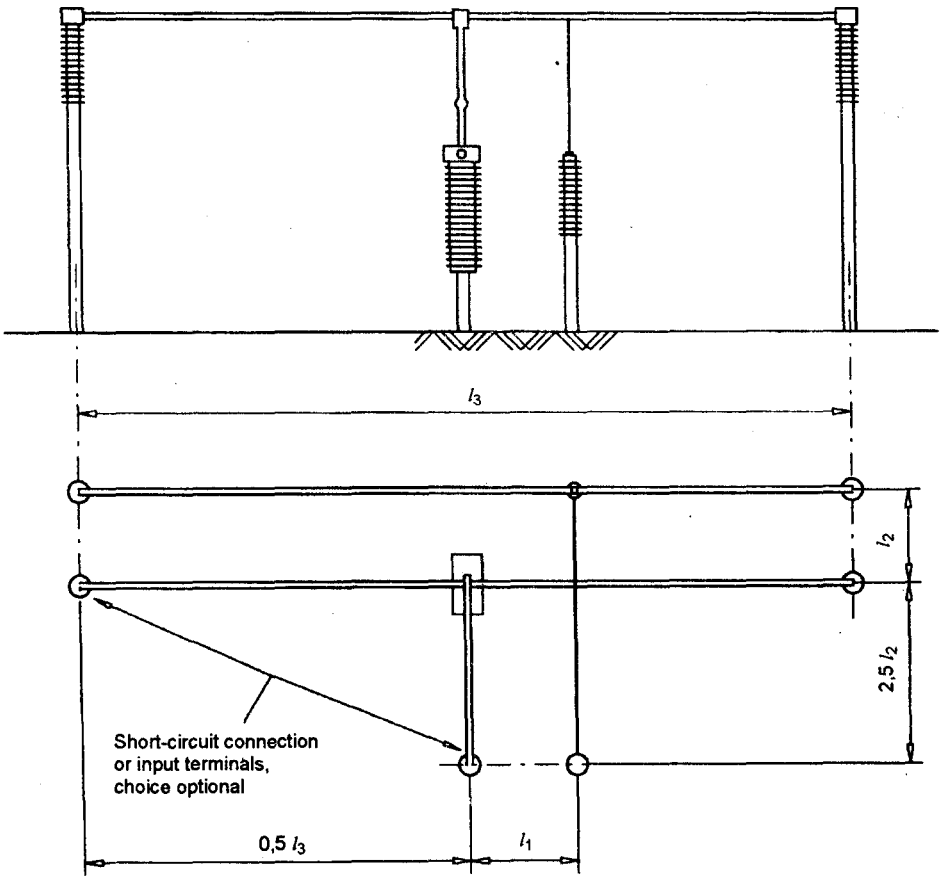
Unless the tested disconnector or earthing switch is solidly fixed to the foundation, the spring constant of the support structure has to be taken into consideration (IEC 60865-1).

The test report or certificate shall provide clear details of the mounting arrangements used for the tests or record that the disconnector was solidly fixed to the foundations.

NOTE 1 Care should be taken that forces not representative of service conditions are not introduced by the connections to the supply and that the static terminal loads are not larger than the rated static mechanical terminal loads of the switchgear under test.

NOTE 2 In principle, figure 5 is also applicable for testing integrated earthing switches with an appropriate arrangement of the earth conductor.

NOTE 3 If, in the test set-up, the short side of the low level conductor cannot be supported, it may be supported by the disconnector. This may result in a higher dynamic mechanical terminal load.



l_1, l_2 Minimum centre-to-centre distance between adjacent poles, as stated by the manufacturer

Key

l_1, l_2 = minimum centre-to-centre distance between adjacent poles, as stated by the manufacturer

$l_3 \geq 4\ l_1$ with $U_r \leq 145$ kV

l_3 = 20 m ± 10 % with $U_r \geq 170$ kV

Figure 6 – Single-phase test arrangement for divided support disconnectors (earthing switches) with a vertical isolating distance with rated voltages of 52 kV and above to be used with rigid conductors

Unless the tested disconnector or earthing switch is solidly fixed to the foundation, the spring constant of the support structure has to be taken into consideration (IEC 60865-1).

The test report or certificate shall provide clear details of the mounting arrangements used for the tests or record that the disconnector was solidly fixed to the foundations.

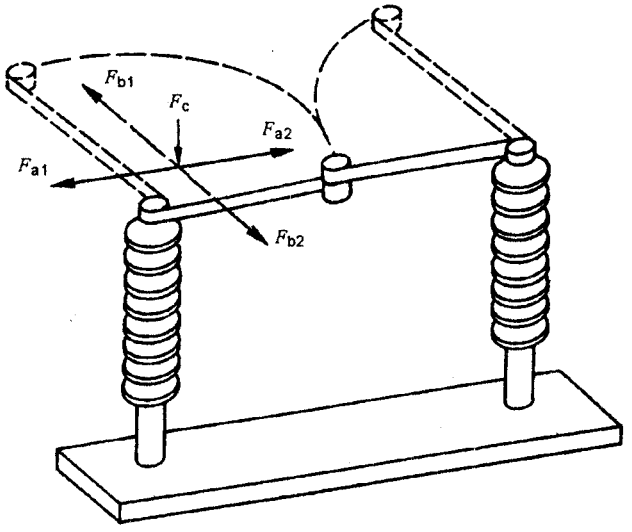
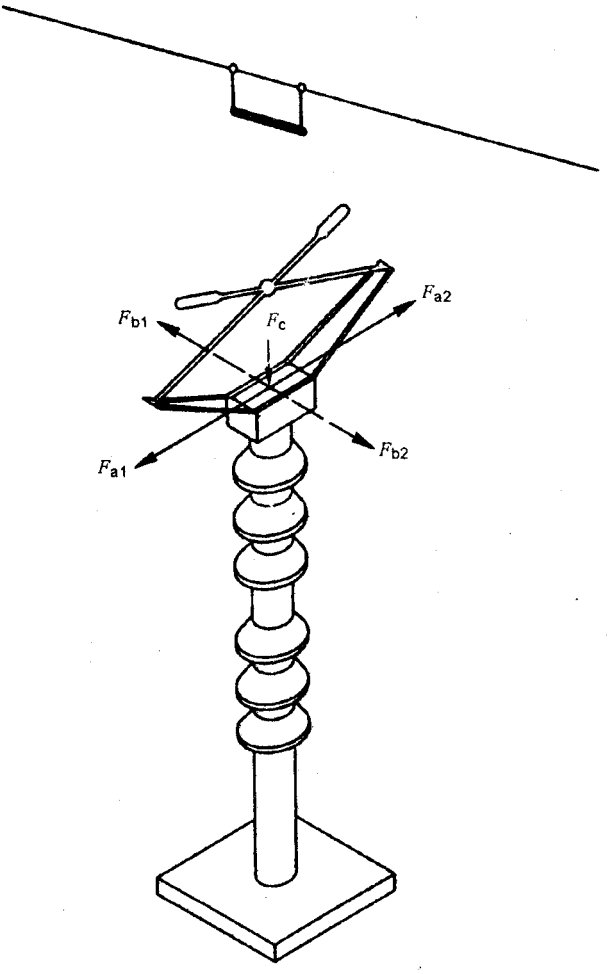


Figure 7 – Example of the application of rated mechanical terminal loads to a two-column disconnector



NOTE Above the pantograph the fixed contact is shown.

Figure 8 – Example of the application of rated mechanical terminal loads to a pantograph disconnector

Annex A
(normative)

Design and testing of position indicating devices

A.1 General

This annex applies to alternating current disconnectors and earthing switches, using a position indicating device as alternative to the visible isolating distance or gap.

NOTE According to 5.104.3, a reliable position indicating device may be used to indicate the position of each movable contact ensuring the isolating distance of a disconnector or the gap of an earthing switch, if the isolating distance or the gap is not visible.

In addition to this standard, IEC 60298, IEC 60265-1, IEC 60265-2, IEC 60466 and IEC 60517 accept as an alternative to a visible isolating distance or gap that the moving contact position is shown by a reliable indicating device.

This annex aims to establish the design requirements and the type tests necessary when the position indicating device is connected to the movable contacts of disconnectors or earthing switches by a mechanical connection.

The following additional design and test requirements have to be fulfilled in order for the indicating device to be considered reliable.

A.2 Normal and special service conditions

Clause 2 of this standard is applicable.

A.3 Definitions

For the purpose of this annex, clause 3 of this standard is applicable with the additions noted below.

A.3.5.111
power kinematic chain
mechanical connecting system from and including the operating mechanism up to and including the moving contacts (figure A.1)

A.3.5.112
position indicating kinematic chain
mechanical connecting system from and including the moving contacts up to and including the indicating device

A.3.5.113
connecting point
most upstream point of the common part of the power and indicating kinematic chains

A.3.5.114
opening point
nearest accessible point upstream of the connecting point where the power kinematic chain may be opened

A.3.5.115
strain limiting device
device that limits to a defined value the torque transmitted to the downstream side of the device irrespective of the torque applied to the upstream side

A.4 Ratings

Clause 4 of this standard is applicable.

A.5 Design and construction

Clause 5 of this standard is applicable with the following addition:

A.5.104.3.1 Reliable position indicating device

The kinematic chain of the position indicating device shall be designed with sufficient mechanical strength such that it meets the requirements of the specified type tests. The position indicating kinematic chain shall be a continuous mechanical connection to ensure positively driven operation. It may be marked directly on a mechanical part of the power kinematic chain by suitable means. The strain limiting device, if any, shall not be part of the position indicating kinematic chain.

A.6 Type tests

Clause 6 of this standard is applicable with the following additions:

A.6.105 Tests to verify the proper function of the position indicating device

Besides the type tests specified in clause 6 of this standard, during which the correct functioning of the indicating device shall be verified, the equipment shall pass one of the tests in A.6.105.1 and the test in A.6.105.2 according to the type of switching device.

The force/torque measured during the tests is the force F_m or the torque T_m respectively, transmitted through the opening point from the upstream part to the downstream part of the power kinematic chain. The force/torque applied by the operating mechanism is measured by attempting an operation while maintaining the power kinematic chain in the position corresponding to the following test positions:

- for disconnectors: the closed position with the moving contact locked;
- for earthing switches: the open position with the moving contact locked.

In the case of a multi-pole switching device, only the moving contact of the pole with the greatest length of the power kinematic chain is locked.

A.6.105.1 Tests on the power kinematic chain

A.6.105.1.1 Disconnectors and earthing switches with dependent power operation without strain limiting device

Electrical, hydraulic and pneumatic operating mechanism

The test shall be carried out according to the following procedure (refer to figure A.1):

- the power kinematic chain is opened at the opening point;
- the operating mechanism is supplied with 110 % of its rated supply voltage or rated supply pressure given in 4.8 and 4.10 of IEC 60694 and the resulting force (F_m) or torque (T_m) is measured at the opening point after an opening or closing command given to the mechanism;
- the force of 1,5 F_m or a torque of 1,5 T_m is applied at the opening point of the power kinematic chain downstream of the opening point, the disconnector or earthing switch being in its relevant test position.

Test results: refer to A.6.105.3.

NOTE The operating mechanism itself may be used to apply 1,5 of the maximum force/torque.

A.6.105.1.2 Disconnectors and earthing switches with dependent manual operation without strain limiting device

The test shall be carried out according to the following procedure:

- the disconnector or earthing switch is put in the test position;
- a force of 750 N is applied halfway along the length of the gripping part of the operating handle of the operating mechanism.

Test results: refer to A.6.105.3.

NOTE In the case of a switching device with both types of mechanisms according to A.6.105.1.1 and A.6.105.1.2, the force/ torque to be applied at the opening point shall be the highest value.

A.6.105.1.3 Disconnectors and earthing switches with independent power/manual operation with strain limiting device

The test shall be carried out according to the following procedure:

- the power kinematic chain is opened at the opening point;
- the force F_m or the torque T_m transmitted by the strain limiting device is measured upstream of the opening point while attempting to operate the switching device either by actuating the power operated mechanism or by hand, until the strain limiting device operates. The operating mechanism is supplied with 110 % of its rated supply voltage or rated supply pressure given in 4.8 and 4.10 of IEC 60694 or, in the case of a manual operating mechanism, a force up to the operation of the strain limiting device with a maximum of 750 N is applied halfway along the length of the gripping part of the operating handle of the operating mechanism;
- a force of 1,5 F_m or a torque of 1,5 T_m is applied at the opening point of the power kinematic chain downstream of the opening point, the disconnector or earthing switch being in its relevant test position..

Test results: refer to A.6.105.3.

A.6.105.1.4 Disconnectors and earthing switches with independent power/manual operation being actuated by the release of latching devices without strain limiting device

The test shall be carried out according to the following procedure:

- the power kinematic chain is opened at the opening point;
- the operating energy is stored in the mechanism.

NOTE The energy may be stored in the operating mechanism either by hand or by power.

- the mechanism is given an opening or closing command and the resulting force F_m or torque T_m is measured at the opening point;
- a force of 1,5 F_m or a torque of 1,5 T_m is applied at the opening point of the power kinematic chain downstream of the opening point, the disconnector or earthing switch being in its relevant test position.

Test results: refer to A.6.105.3.

A.6.105.1.5 Disconnectors and earthing switches with independent power/manual operation with or without strain limiting device

The test shall be carried out according to the following procedure:

- the power kinematic chain is opened at the opening point;
- the operating mechanism is supplied with 110 % of its rated supply voltage or rated supply pressure given in 4.8 and 4.10 of IEC 60694 and the force F_m or the torque T_m transmitted is measured at the opening point;

  NOTE 1 Depending on the type of mechanism, the opening or closing command may lead to storing of the operating energy in the mechanism before it is released to the kinematic power chain.

- in the case of a manual operating mechanism, a force up to 750 N shall be applied halfway along the length of the gripping part of the operating handle and the force F_m* or the torque T_m* transmitted is measured at the opening point of the operating mechanism;

  NOTE 2 Depending on the type of mechanism, the manual opening or closing operation may lead to the storing of the operating energy in the mechanism before it is released to the kinematic power chain.

- a force of 1,5 F_m* or a torque of 1,5 T_m*, whichever is the highest when both power and manual operation are provided, is applied at the opening point of the power kinematic chain downstream of the opening point, the disconnector or earthing switch being in its relevant test position.

Test results: refer to A.6.105.3.

A.6.105.2 Test on the position indicating kinematic chain

When the position indicating device is marked directly on a mechanical part of the power kinematic chain no test is required.

If, during service operations, the part of the position indicating kinematic chain between the power kinematic chain and the position indicating device is inside an enclosure providing a minimum degree of protection equivalent to IP2XC of IEC 60529, and which has passed a mechanical impact test according to 6.7.2 of IEC 60694 with an energy of 2 J, no supplementary tests are required but the following remarks shall be considered.

The blows shall be applied to the points of the enclosure that are likely to be the weakest in relation to the protection of the indicating kinematic chain and the indicating device.

In all other cases, a test shall be carried out blocking the position indicating device instead of the moving contact.

Test results: refer to A.6.105.3.

A.6.105.3 Test results

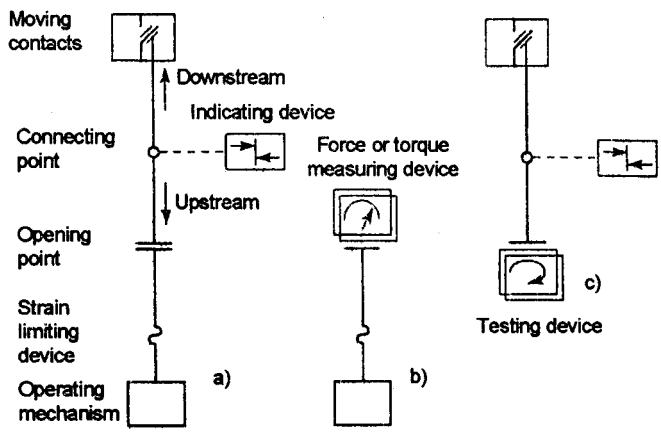
Each test is passed if

- after the test the position indicating device indicates correctly the position of the moving contact,
- there is no permanent distortion on the position indicating kinematic chain. If a distortion or break occurs in the power kinematic chain upstream of the connecting point, it is permitted to replace components in order to complete the required operations. This shall be mentioned in the type test report.

A.7 Routine tests

Clause 7 of this standard is applicable with following addition:

During the mechanical operating tests it shall be verified that the position indicating device indicates correctly the open and closed position of the moving contacts.



Key

_____ power kinematic chain

---------- indicating kinematic chain

(a) Principle of the mechanical connection

(b) Measuring phase (except A.6.105.1.2)

(c) Testing phase (except A.6.105.1.2)

NOTE Upstream is the sense towards the source of energy, downstream is the sense towards the contacts.

Figure A.1 – Position indicating device

Annex B
(normative)

Bus-transfer current switching by disconnectors

B.1 General

This annex applies to alternating current disconnectors, with rated voltages of 52 kV and above, capable of switching bus-transfer currents.

NOTE The switching of bus-transfer currents by disconnectors having rated voltages below 52 kV may also be performed; however, bus-transfer switching current ratings and type tests are not normally required. Tests may be performed upon agreement between the user and manufacturer.

This annex aims to establish switching requirements and specify test methods for disconnectors used to transfer load currents from one bus system to another. For this switching duty, a disconnector having a breaking and making capability is required, depending upon the magnitude of the load transferred, the size of the loop between the location(s) of the bus coupling and the disconnector to be operated.

B.2 Normal and special service conditions

Clause 2 of this standard is applicable.

B.3 Definitions

For the purpose of this annex, clause 3 of this standard is applicable with the additions noted below.

B.3.7.124
bus-transfer current
current which a disconnector is capable of switching when it transfers load from one bus system to another

B.3.7.125
bus-transfer voltage
power frequency voltage across the open disconnector after breaking or before making the bus-transfer current

B.3.7.126
rated bus-transfer current
maximum bus-transfer current that the disconnector is capable of switching at the rated bus-transfer voltage

B.3.7.127
rated bus-transfer voltage
maximum bus-transfer voltage at which the disconnector is capable of switching the rated bus-transfer current

B.4 Ratings

Clause 4 of this standard is applicable with the additions noted below:

Additional ratings for disconnectors used to transfer load currents from one bus system to another, should be selected from the following:

B.4.106.1 Rated -transfer current

The value of the rated bus-transfer current for both air-insulated and gas-insulated disconnectors shall be 80 % of the rated normal current. It will normally not exceed 1 600 A, irrespective of the rated normal current of the disconnector.

NOTE A maximum rated bus-transfer current of 1 600 A was chosen as being typically the highest current which can be switched even though the rated normal current of the disconnector may be substantially greater. It is common practice to select disconnectors based on the short-time current ratings as well as the rated normal current. The maximum continuous current carried by the disconnector, therefore, may be considerably less than the rated normal current. Rated bus-transfer currents greater than 80 % of the rated normal current or greater than 1 600 A may be assigned by the manufacturer.

B.4.106.2 Rated bus-transfer voltage

Rated bus-transfer voltages are given in table B.1. Other rated-bus transfer voltages may be assigned by the manufacturer.

Table B.1 – Rated bus-transfer voltages for disconnectors

<table>
<tr><th>Rated voltage U_r
kV</th><th>Air insulated disconnectors
V r.m.s.</th><th>Gas insulated disconnectors
V r.m.s.</th></tr>
<tr><td>52
72,5
100
123
145
170</td><td>100</td><td>10</td></tr>
<tr><td>245
300
362</td><td>200</td><td rowspan="2">20</td></tr>
<tr><td>420</td><td rowspan="2">300</td></tr>
<tr><td>550
800</td><td>40</td></tr>
</table>

B.5 Design and construction

Clause 5 of this standard is applicable with the following addition:

B.5.10 Nameplates

The rated bus-transfer current shall be marked on the nameplate of a disconnector having a bus-transfer current making and breaking capability.

B.6 Type tests

Clause 6 of this standard is applicable with the following additions:

In addition to those tests specified in clause 6 of this standard, a disconnector having a bus-transfer current making and breaking capability shall be subjected to making and breaking tests under bus-transfer conditions.

NOTE An individual type test does not need to be repeated for change of construction detail if the manufacturer can demonstrate that this change does not influence the result of that individual type test. This means that bus-transfer current switching devices of a given design may also be used with other disconnectors, without repeating the type test, if the manufacturer can show evidence that the bus-transfer current switching device is operated by the other disconnector in the same way as by the disconnector with which the type test has been performed. It has to be considered that the bus-transfer current switching capability only depends on the characteristic values of the test circuit and the operating speed, and not on the dielectric characteristic and current ratings of the disconnector.

B.6.106 Making and breaking tests

B.6.106.1 Arrangement of the disconnector for tests

The disconnector under test shall be completely mounted on its own support or on an equivalent support. Its operating device shall be used in the manner prescribed and in particular, if it is power operated, either electrically or pneumatically, it shall be operated at the minimum supply voltage or minimum air pressure, respectively.

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

For gas-insulated disconnectors, tests shall be performed at the minimum gas density.

Disconnectors having a manual operating device may be operated by remote control using a power operating means such that operating speeds equivalent to those resulting from manual operation are obtained.

NOTE 1 Tests should be conducted to prove that a manually operated disconnector will operate satisfactorily at the minimum operating speed expected, as stated by the manufacturer.

Consideration shall be given to the effects of energization of both terminals of the disconnector. When the physical arrangement of one side of the disconnector differs from that of the other side, the supply side of the test circuit shall be connected to the side which represents the most onerous condition. In case of doubt, 50 % of the breaking and making tests shall be carried out with the supply side of the test circuit connected to one side of the disconnector and 50 % with the supply connected to the other side.

Only single-phase tests on one pole of a three-pole disconnector need be performed provided that the pole is not in a more favourable condition than the complete three-pole disconnector with respect to

- speed of make,
- speed of break,
- influence of adjacent phases.

NOTE 2 Single-pole tests are adequate to demonstrate the making and breaking performance of a disconnector, provided that it can be demonstrated that the arcing time and arc reach are such that there is no possibility of involvement of an adjacent phase. If, on the basis of a single-pole test, it is shown that the arc may reach an adjacent phase, then three-pole tests should be performed using the specific disconnector configuration.

B.6.106.2 Earthing of the test circuit and disconnector

The frame of the disconnector shall be earthed. The test circuit shall be earthed as shown in figure B.1. For gas-insulated disconnectors, it may be necessary to use an alternative test circuit, see B.6.106.6.

B.6.106.3 Test frequency

Disconnectors shall preferably be tested at rated frequency; however, for convenience of testing, tests may be performed at either 50 Hz or 60 Hz and are considered to be equivalent.

B.6.106.4 Test voltage

The test voltage shall be selected so as to yield the required rated bus-transfer voltage ($^{+10}_{-0}$ %) across the open disconnector terminals as given in table B.1.

The test voltage shall be measured immediately after current interruption.

As noted in 6.106.1, only single-pole tests are normally required. If three-pole tests are required, then the test voltage of each phase shall not differ from the average test voltage by more than 10 %.

The power frequency recovery voltage shall be maintained for at least 0,3 s after interruption.

B.6.106.5 Test current

The test current shall be equal to the rated bus-transfer current ($^{+10}_{-0}$ %) as defined in B.3.106.3. The test current shall be measured before operation of the disconnector.

The current to be interrupted shall be symmetrical with negligible decrement. The contacts of the disconnector shall not be separated until transient currents, due to the closing of the circuit, have subsided.

If three-pole tests are performed, the test current is the average of the current in all three poles. The test current for each phase shall not differ from the average test current by more than 10 %.

B.6.106.6 Test circuits

Field tests or laboratory tests may be made. For laboratory tests, the test circuits A and B (see figure B.1) shall have a power factor not exceeding 0,15. Either test circuit may be used at the convenience of the test laboratory.

The characteristic values of the test circuit components, U_{BT} and Z_{BT}, are selected to provide the required test current and the power frequency recovery voltage.

If three-pole tests are required, the three-phase test circuit shall incorporate the same elements in each phase as for the single-phase test circuit in order to yield the appropriate test voltages and currents. The neutral of the supply circuit shall be earthed.

NOTE 1 Other test circuits may be used which will produce the required test currents and voltages, and the proper transient recovery voltage (TRV) parameters.

NOTE 2 For gas-insulated disconnectors, the insulation integrity to earth during switching is normally not in question. In case of doubt, tests may be conducted with the rated phase-to-earth voltage of the disconnector applied to the enclosure. A separate voltage source may be used.

NOTE 3 For field tests, it may not be possible to achieve the required tolerances on the test currents and voltages. These requirements may be waived upon agreement between the manufacturer and the user.

The prospective TRV waveforms should have the form of a triangular wave due to the surge impedance of the connected bus system. For convenience in testing, however, transient recovery voltages having a (1 – cos) form may be used, having a frequency of not less than 10 kHz and a prospective amplitude factor not less than 1,5.

NOTE 4 TRV control components may be added to the test circuit.

NOTE 5 The arc voltage of the disconnector under test will typically be relatively high compared to the test voltage. This will result in a significant damping of the TRV and a phase shift in the current such that the test current will be practically in phase with the test voltage. The TRV parameters (rate-of-rise and peak value), therefore, are not significant and a detailed specification is not required.

B.6.106.7 Test duties

One hundred make-break operating cycles shall be made.

NOTE These 100 operating cycles are not considered adequate to demonstrate electrical life but they do provide an indication of contact erosion.

The opening operation shall follow the closing operation with a time delay between the two operations at least sufficient for any transient currents to subside.

The tests shall be performed without reconditioning of the disconnector during the test programme.

B.6.106.8 Behaviour of the disconnector during tests

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

Outward emission of flame or metallic particles from the disconnector during operation is permitted, if this does not impair its insulation level or prove to be harmful to a local operator or others in the vicinity.

B.6.106.9 Condition of disconnector after tests

The mechanical functions and the insulation of the disconnector shall be essentially in the same condition as before the tests. The disconnector shall be capable of carrying its rated normal current without the temperature rise exceeding the values specified.

Evidence of mechanical wear and erosion due to arcing is acceptable as long as it is consistent with the anticipated operating life of the disconnector. The quality of the material used for arc extinguishing, if any, may be impaired and its amount reduced below the normal level. There may be deposits on the insulators caused by the decomposition of the arc extinguishing medium.

The isolating properties of a disconnector in the open position shall not be reduced below what corresponds to normal wear and ageing, by deterioration of insulating parts.

Visual inspection and no-load operation of the disconnector after tests are usually sufficient for verification of the above requirements. In case of doubt, it may be necessary to perform the appropriate tests for confirmation.

If the isolating properties are doubted, a condition checking test according to 6.2.11 of IEC 60694 should be performed to verify the isolating properties.

B.6.106.10 Type test reports

The results of all type tests shall be recorded in type test reports containing sufficient data to prove compliance with this standard. Sufficient information should be included so that the essential parts of the disconnector tested can be identified.

The test report shall contain the following information:

a) typical oscillographic or similar records of the tests performed (at least one oscillogram for each 10 operations);

b) test circuit;

c) test currents;

d) test voltages;

e) power frequency recovery voltages;

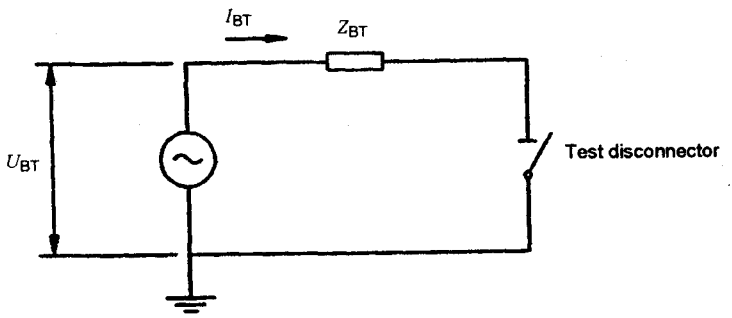
f) prospective transient recovery voltages;

g) arcing times;

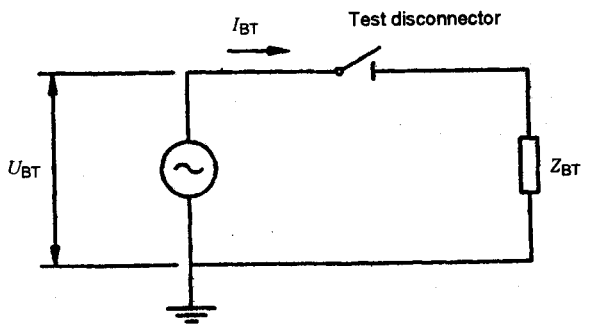
h) number of making and breaking operations;

i) record of the condition of the contacts after test (see B.6.106.9).

General information concerning the supporting structure of the disconnector should be included. The operating time of the disconnector and the type of operating devices employed during the tests should, where applicable, be recorded.



Test circuit A



Test circuit B

Key

I_{BT} = rated bus-transfer current = U_{BT}/Z_{BT}

Figure B.1 – Test circuits for bus-transfer current making and breaking tests

Annex C
(normative)

Induced current switching by earthing switches

C.1 General

This annex applies to alternating current earthing switches, with a rated voltage of 52 kV and above, capable of switching induced currents.

NOTE The making and breaking of induced currents is occasionally required for earthing switches having rated voltages below 52 kV; however, induced current ratings and type tests are not normally required. Tests may be performed upon agreement between the user and manufacturer.

The aim of this annex is to standardize switching requirements for earthing switches used to earth transmission lines. In the case of multiple configurations of overhead transmission lines, current may circulate in de-energized and earthed lines as a result of capacitive and inductive coupling with adjacent energized lines. Earthing switches applied to earth these lines shall therefore be capable of assuring the following service conditions:

- making and breaking of a capacitive current when the earth connection is open at one termination and earthing switching is performed at the other termination;
- making and breaking of an inductive current when the line is earthed at one termination and earthing switching is performed at the other termination;
- carrying continuously the capacitive and inductive currents.

C.2 Normal and special service conditions

Clause 2 of this standard is applicable.

C.3 Definitions

Clause 3 of this standard is applicable with the following additions:

C.3.4.105.4
class A earthing switch
earthing switch designated to be used in circuits having relatively short sections of line or low coupling to adjacent energized circuits

C.3.4.105.5
class B earthing switch
earthing switch designated to be used in circuits having relatively long lines or high coupling to adjacent energized circuits

NOTE Earthing switches having a making capability (class E1 and E2) which belong to class A or B will have a combined class designation, i.e. A+E1, B+E2, etc.

C.3.7.128
electromagnetically induced current
inductive current that an earthing switch is capable of switching when it connects to and disconnects from earth one termination of a de-energized transmission line, with the other termination earthed, and with an energized line carrying current in parallel with, and in proximity to, the earthed line

NOTE 1 The inductive current in a de-energized line earthed at both terminations is dependent upon the current in the energized line and the coupling factor to the energized line, as determined by the circuit configuration on the tower.

NOTE 2 The inductive voltage across an open earthing switch at one termination of a line, when a second line termination is earthed, is dependent upon the current in the energized line, the coupling factor to the energized line, as determined by the circuit configuration on the tower, and the length of that part of the earthed line which is in proximity to an energized line.

C.3.7.129
electrostatically induced current
capacitive current that an earthing switch is capable of switching when it connects to or disconnects from earth one termination of a de-energized transmission line, with the other termination open, and with an energized line in parallel with, and in proximity to, the earthed line

NOTE 1 The capacitive current in a de-energized line earthed at one termination is dependent upon the voltage of the energized line, the coupling factor to the energized line as determined by the circuit configuration on the tower, and the length of the earthed line between the earthed termination and the open termination.

NOTE 2 The capacitive voltage across an open earthing switch at one termination of a line, when the second line termination is open, is dependent upon the voltage of the energized line and the coupling factor to the energized line, as determined by the circuit configuration on the tower.

C.4 Ratings

Clause 4 of this standard is applicable with the following additions:

Earthing switches having rated voltages of 52 kV and above may require induced current and voltage ratings. Depending upon the severity of the switching duty, earthing switches for this application are divided into class A and B (see C.3.102.5.4 and C.3.102.5.5).

C.4.107.1 Rated induced current

Separate ratings for electromagnetically induced and electrostatically induced currents shall be assigned.

The rated induced current is the maximum current that the earthing switch is capable of switching at the rated induced voltage.

The rated induced voltage is the maximum power frequency voltage at which the earthing switch is capable of switching the rated induced current.

Rated induced currents for the two classes of earthing switches are given in table C.1.

The earthing switch shall be capable of carrying the rated induced current (see C.6.5).

Table C.1 – Standardized values of rated induced currents and voltages for earthing switches

Rated voltage U_r kV	Electromagnetic coupling				Electrostatic coupling			
	Rated induced current A (r.m.s.)		Rated induced voltage kV (r.m.s.)		Rated induced current A (r.m.s.)		Rated induced voltage kV (r.m.s.)	
	Class		Class		Class		Class	
	A	B	A	B	A	B	A	B
52	50	80	0,5	2	0,4	2	3	6
72,5	50	80	0,5	2	0,4	2	3	6
100	50	80	0,5	2	0,4	2	3	6
123	50	80	0,5	2	0,4	2	3	6
145	50	80	1	2	0,4	2	3	6
170	50	80	1	2	0,4	3	3	9
245	80	80	1,4	2	1,25	3	5	12
300	80	160	1,4	10	1,25	10	5	15
362	80	160	2	10	1,25	18	5	17
420	80	160	2	10	1,25	18	5	20
550	80	160	2	20	2	25	8	25
800	80	160	2	20	3	25	12	32

NOTE 1 Class A earthing switches: low coupling or relatively short parallel lines. Class B earthing switches: high coupling or relatively long parallel lines.

NOTE 2 In some situations (very long sections of the earthed line in proximity to an energized line; very high loading on the energized line; energized line having a service voltage higher than the earthed line, etc.), the induced current and voltage may be higher than the given values. For these situations, the rated values should be subject to agreement between manufacturer and user.

NOTE 3 The rated induced voltages correspond to line-to-earth values for both single-phase and three-phase tests (see C.6.105.6).

C.4.107.2 Rated induced voltage

Separate ratings for electromagnetically and electrostatically induced voltages shall be assigned.

Rated induced voltages for the two classes of earthing switches are given in table C.1.

C.5 Design and construction

Clause 5 of this standard is applicable with the following addition:

C.5.10 Nameplates

The class designation shall be marked on the nameplate of an earthing switch having an induced current making and breaking capability.

C.6 Type tests

Clause 6 of this standard is applicable with the following additions:

Type tests for earthing switches having a rated induced current making and breaking capability shall include:

- tests to prove the electromagnetically induced current making and breaking capability;
- tests to prove the electrostatically induced current making and breaking capability.

C.6.5 Temperature-rise tests

Tests will not normally be required since the rated short-time current of the earthing switch may be used to verify that the temperature rises for typical induced current ratings are insignificant. In case of doubt, temperature-rise tests should be performed upon agreement between the manufacturer and the user.

Subclause 6.5 of IEC 60694 is applicable, if tests are required.

C.6.105 Making and breaking tests

C.6.105.1 Arrangement of the earthing switch for tests

The earthing switch under test shall be completely mounted on its own support or on an equivalent support. Its operating device shall be operated in the manner prescribed and, in particular, if it is electrically or pneumatically operated, it shall be operated either at the minimum supply voltage or at the minimum air pressure, respectively.

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

For gas-insulated earthing switches, tests shall be performed at the minimum gas density.

Earthing switches having a manual operating device may be operated by remote control utilizing a power operating means such that operating speeds equivalent to those resulting from manual operation are obtained.

NOTE 1 Tests should be conducted to prove that a manually operated earthing switch will operate satisfactorily at the minimum operating speed expected, as stated by the manufacturer.

Only single-phase tests on one pole of a three-pole earthing switch need to be performed provided that it is not in a more favourable condition than the complete three-pole earthing switch with respect to

- speed of make,
- speed of break,
- influence of adjacent poles or proximity of energized phases.

NOTE 2 Single-pole tests are adequate to demonstrate the making and breaking performance of an earthing switch provided that it can be demonstrated that the arcing time and arc-reach are such that there is no possibility that involvement of an adjacent energized phase may occur. If, on the basis of a single-pole test, it is determined that the arc may reach an adjacent energized phase, then three-pole tests should be performed using the specific earthing switch configuration.

C.6.105.2 Earthing of test circuit and earthing switch

The test circuit shall be earthed through the terminal of the earthing switch which is normally connected to earth.

C.6.105.3 Test frequency

Earthing switches shall preferably be tested at rated frequency; however, for convenience of testing, tests may be performed at either 50 Hz or 60 Hz and are considered to be equivalent.

C.6.105.4 Test voltage

The test voltages shall be selected such as to yield the appropriate power frequency voltage ($^{+10}_{-0}$ %) across the earthing switch terminals, as shown in table C.2, before making and after breaking. For electromagnetically induced current switching, the test voltage shall be measured immediately after current interruption. For electrostatically induced current switching, the test voltage shall be measured immediately prior to making of the earthing switch.

As noted in C.6.105.1, only single-pole tests are normally required. If three-pole tests are required, then the test voltage of each phase shall not be different from the average test voltage by more than 10 %.

The power frequency test voltage shall be maintained for at least 0,3 s after interruption.

C.6.105.5 Test currents

The test currents shall be equal to the rated induced currents ($^{+10}_{-0}$ %) as shown in table C.1.

The current to be interrupted shall be symmetrical with negligible decrement. The contacts of the earthing switch shall not be separated until transient currents due to closing of the circuit have subsided.

If three-pole making and breaking tests are performed, the test current shall be measured as the average of the current in all three poles. The test current for each phase shall not be different from the average test current by more than 10 %.

Before contact separation, the waveform of the test current for capacitive current breaking tests shall be, as nearly as possible, sinusoidal. This condition is considered to be complied with if the ratio of the r.m.s. value of the total current to the r.m.s. value of the fundamental component does not exceed 1,2. The test current shall not go through zero more than once per half cycle of power frequency before contact separation.

C.6.105.6 Test circuits

Field tests or laboratory tests may be made. For laboratory tests, the transmission lines may be replaced by lumped elements consisting of capacitors, inductors and resistors.

If three-pole tests are required, the three-phase test circuit shall incorporate the same elements in each phase as for the single-phase test circuit in order to yield the appropriate test voltages and currents. The neutral of the supply circuit shall be earthed.

NOTE 1 Test circuits other than those specified may be used as long as they produce the required test currents and voltages and the proper transient recovery voltage parameters.

NOTE 2 For field tests, it may not be possible to achieve the required tolerances on the test currents and voltages. These requirements may be waived upon agreement between the manufacturer and user. It should be noted that if voltage transformers are connected to the earthed voltage line being switched, ferro-resonance may occur during switching depending upon the characteristics of the transformer and the length of the earthed line.

C.6.105.6.1 Test circuit for electromagnetically induced current making and breaking tests

The single-phase test circuit (figure C.1) consists of a supply circuit yielding the appropriate test voltage and test current such that the circuit power factor does not exceed 0,15. The components R and C are selected to yield the appropriate transient recovery voltage parameters. The damping resistance R may be connected in series or in parallel with the capacitance C.

The values of supply voltage (U_L) and inductance (L) may be calculated from the values given in table C.1, so as to produce the proper values of test current and power frequency recovery voltage.

The prospective transient recovery voltage waveforms should have the form of a triangular wave due to the surge impedance of the connected transmission lines. For convenience in testing, however, transient recovery voltages having a (1-cos) form may be used. Values of R and C may be selected to yield the proper transient recovery voltage parameters specified in table C.2.

Table C.2 – Standardized values of recovery voltages for electromagnetically induced current breaking tests

	Class A			Class B		
Rated voltage U_r kV	Power frequency recovery voltage ($^{+10}_{0}$ %) kV r.m.s.	TRV peak ($^{+10}_{0}$ %) kV	Time to peak ($^{0}_{-10}$ %) µs	Power frequency recovery voltage ($^{+10}_{0}$ %) kV r.m.s.	TRV peak ($^{+10}_{0}$ %) kV	Time to peak ($^{0}_{-10}$ %) µs
52	0,5	1,1	100	2	4,5	300
72,5	0,5	1,1	100	2	4,5	300
100	0,5	1,1	100	2	4,5	300
123	0,5	1,1	100	2	4,5	300
145	1	2,3	200	2	4,5	300
170	1	2,3	200	2	4,5	300
245	1,4	3,2	200	2	4,5	330
300	1,4	3,2	200	10	23	850
362	2	4,5	325	10	23	1 000
420	2	4,5	325	10	23	1 000
550	2	4,5	325	20	45	2 000
800	2	4,5	325	20	45	2 000

NOTE 1 Recovery voltages are valid for single-phase or three-phase tests.

NOTE 2 The prospective TRV waveform may be of a triangular or (1-cos) form (see C.6.105.6.1). The time to peak is valid for either waveform type.

C.6.105.6.2 Test circuits for electrostatically induced current making and breaking test

The test circuits 1 or 2 in figure C.2, can be selected as suitable for the test laboratory, since, as long as the equations within the circuit parameters are satisfied, they are equivalent.

The power factor of the test circuit shall not exceed 0,15. The values of supply voltage (U_C), inductance L and capacitance C_2 for test circuit 1 may be calculated from the given values of C_1 in table C.3 and the rated current and voltage values in table C.1, by using the equations noted in figure. C.2. This will result in the appropriate values of test current and voltage as well as the proper inrush current frequency and test circuit surge impedance. Values for test circuit 2 may be calculated from the values derived for test circuit 1.

A resistance (R), not exceeding 10 % of the capacitive impedance [$\omega(C_1 + C_2) \approx \omega C_1$'], as seen from the disconnector, may be inserted in the circuits as shown in figure C.2. The value chosen, however, should not be greater than the surge impedance of the transmission line considered, nor lead to an aperiodic damping of the inrush current when closing the earthing switch.

Table C.3 – Test circuit capacitances (C_1 values) for electrostatically induced current making and breaking tests

Rated voltage kV	Test circuit capacitance	
	Class A ± 10 % μF	Class B ± 10 % μF
52	0,07	0,27
72,5	0,07	0,27
100	0,07	0,27
123	0,07	0,27
145	0,13	0,27
170	0,13	0,27
245	0,15	0,27
300	0,15	0,80
362	0,29	1,18
420	0,29	1,18
550	0,35	1,47
800	0,35	1,47

NOTE Values of C_1 may be calculated from the expression:

$$C_1 = (6D) / (\pi Z_0)$$

where

D is the line length, in km;

Z_0 is the line surge impedance, in Ω.

Surge impedance assumed:

- 52 kV to 170 kV: 425 Ω;
- 245 kV to 300 kV: 380 Ω;
- 362 kV to 800 kV: 325 Ω.

C.6.105.7 Test duties

Ten make-break operating cycles shall be made for each of the electrostatically and electromagnetically induced current making and breaking tests.

NOTE Ten operating cycles are not considered adequate to demonstrate electrical life, but will provide an indication of contact erosion.

The opening operation shall follow the closing operation with sufficient time delay between the two operations for any transient currents to subside.

The tests shall be performed without reconditioning of the earthing switch during the test programme.

C.6.105.8 Behaviour of earthing switch during tests

The earthing switch shall perform successfully without undue mechanical or electrical distress.

Outward emission of flame 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.

C.6.105.9 Condition of earthing switch after tests

The mechanical functions and the insulation of the earthing switch shall be essentially in the same condition as before the test. The earthing switch shall be capable of carrying its rated peak withstand current and its rated short-time withstand current.

Evidence of mechanical wear and erosion due to arcing is acceptable as long as it is consistent with the anticipated operating life and maintenance regime of the earthing switch. The quality of material used for arc extinguishing, if any, may be impaired and its amount reduced below the normal level. There may be deposits on the insulators caused by the decomposition of the arc extinguishing medium.

Visual inspection and no-load operation of the earthing switch after tests are usually sufficient for verification of the above requirements. In case of doubt, it may be necessary to perform the appropriate tests for confirmation.

If the isolating properties across the open earthing switch are doubted, a condition checking test according to 6.2.11 of IEC 60694 shall be performed to verify the isolating properties.

C.6.105.10 Type test reports

The results of all type tests shall be recorded in type test reports containing sufficient data to prove compliance with this standard. Sufficient information should be included so that the essential parts of the earthing switch tested can be identified.

The test report shall contain the following information:

a) typical oscillographic or similar records;

b) test circuits;

c) test currents;

d) test voltages;

e) power frequency recovery voltages;

f) prospective transient recovery voltages;

g) arcing times;

h) number of making and breaking operations;

i) condition of earthing switch after test.

General information concerning the supporting structure of the earthing switch should be included. The operating time of the earthing switch and the type of operating devices employed during the tests should, where applicable, be recorded.

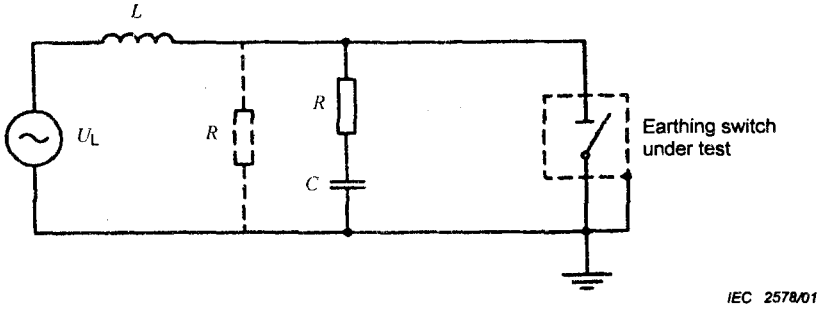
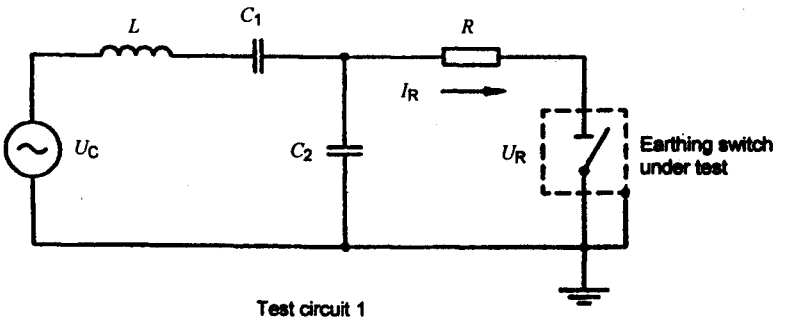
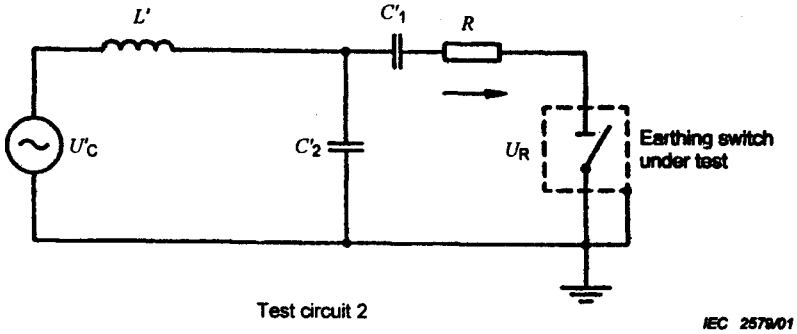


Figure C.1 – Test circuit for electromagnetically induced current making and breaking tests



Test circuit 1



Test circuit 2

IEC 2579/01

$$L = Z_0^2 \times C_1 \qquad L' = L \times \left[\frac{C_1}{C_1 + C_2}\right]^2$$

$$u_C = \frac{i_R}{\omega C_1} \qquad u_C' = \left[\frac{C_1}{C_1 + C_2}\right] \times u_C, \text{ or } u_C' = u_R$$

$$C_2 = C_1 \times \left[\frac{u_C}{u_R} - 1\right] \qquad C_1' = C_1 + C_2 \qquad C_2' = C_2\left(1 + \frac{C_2}{C_1}\right)$$

where

Z_0 is the surge impedance of the line:

- 425 Ω for rated voltages of 52 kV up to and including 170 kV;
- 380 Ω for rated voltages of 245 kV up to and including 300 kV;
- 325 Ω for rated voltages of 362 kV up to and including 800 kV.

Key

i_R is the rated induced current from table C.1

u_R is the rated induced voltage from table C.1

C_1 is the test circuit impedance given in table C.3

Figure C.2 – Test circuits for electrostatically induced current making and breaking tests

Annex D
(informative)

Test voltage for the most disadvantageous dielectric position of an earthing switch during operation (temporary approach)

For standardization of dielectric strength during the temporary approach, the following facts need to be taken into consideration:

- for rated voltages up to and including 170 kV, two types of systems exist; one with a solidly earthed neutral and the other with a resonance earthed neutral using a Peterson coil;
- for rated voltages of 245 kV and above, the solid earthing of the neutral is the standard;
- for rated voltages of 300 kV and above, the proportion of the power frequency withstand voltage to the system voltage is reduced compared with the proportion of the test voltage to the system voltage below 300 kV. (In the higher range switching impulse tests are standardized).

Therefore, for the lower voltage range, it is reasonable to standardize two different test voltages for the temporary approach (one for solidly earthed systems and one for resonance earthed systems) and to standardize one test voltage only for system voltages of 245 kV and above.

Because of the relatively low power frequency withstand voltage for systems of 300 kV and above, the disconnectors and earthing switches of 245 kV have a singular position. On the one hand, they belong to the range with solidly earthed systems; on the other hand, they belong to the test voltage range below 300 kV. This makes it necessary, therefore, to consider whether to relate the required dielectric strength to the standardized power frequency withstand voltage (line-to-earth) or to the rated voltage.

A fixed relation to the line-to-earth withstand voltage would give too high a value for the lower rated voltages and too low a value for the higher rated voltages.

Since the safety distances in substations are not related to the dielectric test voltages but to the rated voltage, the dielectric strength for the temporary approach should also be related to the rated voltage and the earthing condition of the network. Also the fact should be considered that the test voltages might be changed once in a while, and this should not result in a change of the test voltage for the temporary approach distance.

For standardization, the following values are therefore suggested:

a) for rated voltages up to and including 170 kV:
   - $2 \times U_r/\sqrt{3}$ for solidly earthed neutral systems,
   - $1{,}3 \times U_r$ for unearthed neutral systems;

b) for rated voltages of 245 kV up to and including 800 kV which are generally solidly earthed:
   - $2 \times U_r/\sqrt{3}$

The suggested test voltages for the earthing switch blade in the most disadvantageous position are given in table 5 after taking into consideration the above-mentioned details.

Annex E
(normative)

Special requirements for disconnectors and earthing switches used in gas-insulated and/or metal-enclosed switchgear

E.1 General

E.1.1 Overview

This annex applies specifically to alternating current disconnectors and earthing switches used in gas-insulated and in metal-enclosed switchgear designed for voltages above 1 000 V and for service frequencies up to and including 60 Hz.

Only those parts of the components implementing the specific function of disconnection or earthing are considered. Should disconnectors and earthing switches be integrated into a compartment or a cubicle, IEC 60517 or IEC 60298 will apply, depending on the voltage level.

E.1.2 Normative references

Subclause 1.2 of this standard is applicable.

E.2 Normal and special service conditions

Clause 2 of this standard is applicable.

E.3 Definitions

Clause 3 of this standard is applicable with the following additions:

E.3.5.116
bushing
component carrying one or more conductors through an enclosure and insulating it therefrom including the means of attachment (3.109 of IEC 60517)

E.3.7.129
design temperature (of the enclosure)
highest temperature which can be reached by the enclosure under service conditions

(3.114 of IEC 60517)

E.3.7.130
design pressure (of the enclosure)
pressure used to determine the thickness of the enclosure

(3.115 of IEC 60517)

E.3.7.131
rated filling pressure for insulation (or density)
pressure in Pascal (Pa) for insulation and/or for switching, referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, to which the assembly is filled before being put into service, or automatically replenished

(3.6.4.1 of IEC 60694)

E.3.7.132
minimum functional pressure for insulation (or density)
pressure (Pa) for insulation and/or for switching, referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which and above which rated characteristics of switchgear and controlgear are maintained and at which a replenishment becomes necessary

(3.6.4.5 of IEC 60694)

E.4 Ratings

Clause 4 of this standard is applicable with the following additions made to the list of ratings:

p) rated bus-charging current switching capability, when applicable (see annex F).

E.4.2 Rated insulation level

Subclause 4.2 of IEC 60694 is applicable.

E.4.10 Rated filling pressure (or density) for insulation

Subclause 4.10 of IEC 60694 is applicable.

E.5 Design and construction

Clause 5 of this standard is applicable with the following additions:

E.5.3 Earthing of disconnectors and earthing switches

Subclause 5.3 of IEC 60694 and 5.3 of IEC 60517 or IEC 60298 are applicable.

If, for testing purposes, an external connection through the earthing switch exists that requires disconnecting of the earth point, it shall be able to withstand the rated short-circuit current. The relevant insulation level (d.c. and a.c.) of this external connection – when removed – shall be stated by the manufacturer. Where required, the dielectric losses (mW) of the external grounding connection insulation system shall be given.

E.5.10 Nameplates

Subclause 5.10 of this standard is applicable with the following additions:

The following data shall be provided:

- rated pressure for operation;
- minimum gas density (or pressure);
- design pressure for enclosure.

E.5.105 Internal fault

Refer to 5.101.4 of IEC 60298 or 5.102 of IEC 60517, where applicable.

E.5.106 Enclosures

Refer to 5.102.1, 5.102.2 and 5.102.5 of IEC 60298 or subclauses 5.103.1 and 5.103.2 of IEC 60517, where applicable, and to 5.15 of IEC 60694.

E.5.107 Pressure relief

Refer to 5.104 of IEC 60298 or 5.105 of IEC 60517, where applicable.

E.6 Type tests

Clause 6 of this standard is applicable with the following additions:

E.6.1 General

Disconnectors and earthing switches forming part of the main circuit of gas-insulated or metal-enclosed switchgear and controlgear shall be tested to verify their rated characteristics according to this annex, under the proper conditions of installation and use, i.e. they shall be tested as normally installed in the gas-insulated or metal-enclosed switchgear and controlgear with all associated components, the arrangement of which may influence the performance, such as connections, supports, provisions for venting etc.

NOTE In determining which associated components are likely to influence the performance, special attention should be given to the mechanical forces due to the short-circuit current, venting of arc products, the possibility of disruptive discharges, etc. It is recognized that, in some cases, such influences may be quite negligible.

E.6.1.1 Grouping of tests

Subclause 6.1.1 of this standard is applicable with the following additions:

NOTE (O) = optional.

- test to prove the bus-charging current switching by disconnectors (E.6.108) (O);
- pressure withstand test for enclosures (E.6.109) (O);
- test under conditions of arcing due to an internal fault (E.6.110) (O).

E.6.2.9 Partial discharge tests

Subclause 6.2.9 of IEC 60694 is applicable.

No partial discharge tests are required to be performed on the complete disconnector or earthing switch unless they are specified in 6.1.9 of both IEC 60298 and IEC 60517 (GIS). However, in the case of disconnectors or earthing switches using components for which a relevant IEC publication exists, including partial discharge measurements (for example bushings for alternating voltages above 1 000 V: IEC 60137), evidence shall be produced by the manufacturer showing that those components have passed the partial discharge tests as required by the relevant IEC publication. For partial discharge measurement see IEC 60270.

NOTE 1 The measurement of partial discharge test is a suitable means of detecting certain defects in the equipment under test and is a useful complement to the dielectric tests. Experience shows that partial discharges may lead in particular arrangements to a degradation in the dielectric strength of the equipment, especially of solid insulation.

NOTE 2 Other methods, for example UHF or acoustic methods, for measuring or detecting the partial discharge other than the one considered in IEC 60270, can be employed by agreement.

E.6.6.1.101 General test conditions for short-circuit tests

Subclauses 6.6.1 of IEC 60694 and 6.6.1.101 of this standard are applicable.

E.6.102.3 Mechanical endurance test

Disconnectors and earthing switches fitted with interlocks shall be submitted to five operating cycles (unless otherwise required in the relevant standard) in order to check the operation of the associated interlocks. Before each operation the interlocks shall be set in the position intended to prevent the operation of the switching device. During these tests only normal operating forces shall be employed and no adjustment shall be made to the switching devices or interlocks.

The tests are considered satisfactory if the switching devices and the interlocks are in proper working order and if the forces required to operate the switching devices are practically the same before and after the tests.

The interlocks are considered satisfactory if the switching device cannot be operated.

E.6.104 Operation at temperature limits

To verify the satisfactory operation at the temperature limits, a tightness test according to 6.8 of IEC 60694 shall be performed.

E.6.108 Test to prove the bus-charging current switching by disconnectors

The details of the test requirements are given in annex F.

E.6.109 Pressure withstand test for enclosures

Subclause 6.104 of IEC 60298 or IEC 60517 is applicable.

E.6.110 Test under conditions of arcing due to an internal fault

Subclause 6.108 of IEC 60298 or 6.106 of IEC 60517 is applicable.

E.7 Routine tests

Clause 7 is applicable with the following additions.

E.7.1 Dielectric test on the main circuit

Add the following:

NOTE In the case of sealed components the dielectric test is performed at the rated filling pressure.

E.7.101 Mechanical operating tests

Subclause 7.101 of this standard is applicable with the following addition:

Disconnectors and earthing switches with interlocks shall be submitted to five operating cycles in order to check the operation of the associated interlocks. Before each operation, one attempt shall be made to operate each switching device as specified in 6.102.3.2 and E.6.102.3, respectively.

During these tests, which are performed without voltage on or current flowing in the main circuit, it shall be verified in particular that the switching device opens and closes correctly within the specified limits of the supply voltage and pressure of the operating device.

E.7.102 Partial discharge measurement

Subclause 7.101 of IEC 60298 or IEC 60517 are applicable.

NOTE 1 The measurement of partial discharges may be used to detect possible loose material and manufacturing defects.

NOTE 2 Other methods, for example UHF or acoustic methods, for measuring or detecting the partial discharge other than the one considered in IEC 60270 can be employed by agreement.

E.7.103 Pressure withstand test for enclosures

Subclause 7.103 of IEC 60298 or 7.102 of IEC 60517 are applicable.

E.8 Guide to the selection of disconnectors and earthing switches

Clause 8 of this standard is applicable.

E.9 Information to be given with enquiries, tenders and orders

Clause 9 of this standard, of IEC 60298 or of IEC 60517 is applicable with the addition of the following information:

E.9.102.2 rated values and characteristics:

n) bus-charging current capability

E.10 Rules for transport, storage, installation, operation and maintenance

Clause 10 of IEC 60298 or of IEC 60517 is applicable, with the addition of the following sentence in 10.3 of those standards:

For maintenance purposes the disconnector in gas insulated switchgear shall be considered to have its full isolating properties only if the SF_6 pressure is not lower than its minimum functional pressure (density).

Annex F
(normative)

Gas-insulated metal-enclosed switchgear for rated voltages 72,5 kV and above – Requirements for switching of bus-charging currents by disconnectors

F.1 General

It has been found that, particularly at 420 kV and higher system voltage levels, disruptive discharges to earth might occur when switching small capacitive currents with gas-insulated metal-enclosed switchgear disconnectors, such as energizing or de-energizing unloaded sections of busbar duct or parallel capacitors of circuit-breakers. Worldwide investigation has clarified the reasons for this over recent years and given insight into the complexity of very fast transient overvoltage phenomena that occur as an inherent part of capacitive switching with disconnectors in gas-insulated metal-enclosed switchgear. It was concluded that correct design of the disconnector is essential to avoid disruptive discharges to earth.

F.1.1 Overview

This annex applies to alternating current gas-insulated metal-enclosed disconnectors for rated voltages of 72,5 kV and above.

This annex provides test requirements for gas-insulated metal-enclosed disconnectors used to switch small capacitive currents (no load currents) such as occur when sections of busbars or grading capacitors are energized or de-energized.

NOTE Simultaneous switching of several disconnectors in the same circuit is not advisable and thus not considered in this standard.

F.2 Normal and special service conditions

Clause 2 of this standard is applicable.

F.3 Definitions

For the purpose of this annex, the following definitions apply.

F.3.7.133
bus-charging current
current expressed as steady-state r.m.s. value which a disconnector is capable to switch when energizing or de-energizing parts of a busbar system or similar capacitive loads

F.3.7.134
transient voltage to earth (TVE)
voltage to earth which appears at the first prestrike during a closing operation

F.6 Type tests

Tests for disconnectors of rated voltages below 300 kV are generally not necessary and are subject to agreement between manufacturer and user.

NOTE For rated voltages below 300 kV, the ratios between the specified lightning impulse withstand levels (LIWL) and rated voltages are sufficiently high in most cases for tests not to be necessary.

F.6.1 Test duties for making and breaking of bus-charging currents

Three test duties are defined:

- *Test duty 1:* switching of a very short section of busbar duct;
- *Test duty 2:* switching of parallel capacitors for circuit-breakers under 180° out-of-phase condition;
- *Test duty 3:* current-switching capability test.

NOTE 1 Test duty 1 is a normal type test and is mandatory.

NOTE 2 Test duty 2 is a special type test to be carried out according to this specification by agreement between manufacturer and user, but it is not necessary if the circuit-breaker is not equipped with parallel capacitors.

NOTE 3 Test duty 3 is a special type test to be carried out according to this specification by agreement between manufacturer and user. It serves only to indicate the current interruption capability of the disconnector when de-energizing long busbars or other energized parts, for example short length of cables, etc.

Typical current values are given in table F.2.

F.6.2 Arrangement of the disconnector for tests

The operating device of the disconnector under test shall be operated in the manner specified by the manufacturer and, in particular, if it is power operated, it shall be operated at the specified minimum supply voltage and/or minimum pressure.

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

Tests shall be performed at the minimum gas density for normal operation of the disconnector under test. Associated compartments shall be at their minimum gas density as well.

In most cases the physical arrangement of the disconnector involves asymmetries (for example asymmetrical shields, or moving contact/fixed contact differences, etc.). For these cases, the arrangement of the disconnector shall be such as to perform the test under the most onerous conditions. For test duty 1, the most onerous arrangement is considered to be that which results in maximum pre-striking distance for the closing operation. For test duty 2 and test duty 3, the physical arrangement of the disconnector is considered to be of minor importance.

NOTE It is common practice that the same design of disconnector is installed in both horizontal and vertical positions. In this case, variations of the contact speed are possible. However, deviations of up to 15 % from the specified speed are considered to be acceptable for these tests.

Only single-pole tests on one pole of a three-pole operated disconnector need to be performed, provided that this does not mean a change of operating speed of more than ±15 %.

For disconnectors having three poles in one enclosure, three-phase tests are desirable. However, single-phase tests, as specified, can be accepted to demonstrate the making and breaking performance. The two remaining poles not involved in the switching process should be grounded at both terminals.

F.6.3 Test frequency

Disconnectors are preferably tested at rated power frequency. For convenience of testing, however, tests may be performed at either 50 Hz or 60 Hz and are considered to be equivalent.

F.6.4 Test voltages for making and breaking tests

During making and breaking tests the power frequency voltage shall be maintained for at least 0,3 s before and after the switching operation. In the case of a d.c. pre-charge voltage at the load side (test duty 1), the d.c. voltage shall be applied according to the specified level for about 1 min before the close operation. The load side shall not be grounded between the open and close operations. The test circuit should not contain elements that cause a decay of the trapped charge.

With reference to figures F.1, F.3 and F.4, the test voltages at source side and load side of the test arrangement shall be applied as given in table F.1.

The test voltages in table F.1 are valid for the open disconnector. In the case of test duty 3, the test voltage can be considerably higher when the disconnector is in the closed position. This is caused by resonance phenomena, especially if the impedance of the supplying transformer is high, which is normal for transformers used for dielectric a.c. voltage tests.

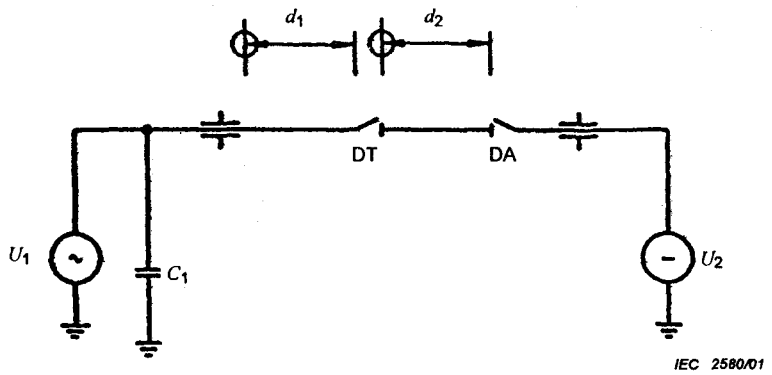
NOTE The above-mentioned voltage increase will enhance the test conditions. It should not be more than 10 %.

Table F.1 – Test voltages for making and breaking tests

Test duty	Test voltage	
	Source side $U1$	Load side $U2$
1	$1{,}1 \times U_r/\sqrt{3}$	Pre-charge with negative d.c. voltage $-1{,}1 \times U_r \times \sqrt{2}/\sqrt{3}$
2	$1{,}1 \times U_r/\sqrt{3}$	AC voltage in phase opposition $1{,}1 \times U_r/\sqrt{3}$ 3
3	$U_r/\sqrt{3}$	–

NOTE 1 U_r is the rated voltage.

NOTE 2 The factor 1,1 has been chosen to take into account statistical effects which are inherent in this kind of switching phenomena, and to restrict the number of test operations to those specified in table F.3. As test duty 3 should only indicate the switching capability of the disconnector, this enhancement of the test voltage is not necessary.



Key

DT Disconnector under test
DA Auxiliary disconnector

Figure F.1 – Test circuit for test duty 1

F.6.5 Test circuits for making and breaking tests

F.6.5.1 Switching of a very short section of busbar, test duty 1

Figure F.1 shows the test circuit for test duty 1. The load side shall be represented by a section of busbar, d_2 3 m to 5 m in length. The connection to the supply side shall be realised by another section of busbar, d_1 in length. In order to obtain representative very fast transient (VFT) conditions, the ratio d_2/d_1, shall be in the range of 0,36 to 0,52. The source-side circuit shall have an added lumped capacitance, C_1. The value of C_1 shall be chosen so that the peak value of the voltage to earth at the disconnector terminals is met as defined in F.6.5.1.1.

Before starting a closing operation, the load side shall be charged by d.c. voltage according to table 1, and the d.c. voltage source disconnected by the auxiliary disconnector, DA.

NOTE Busbar lengths d_1 and d_2 are understood to be taken as the following distances:

d_1: open contact of the disconnector under test (DT) to the bushing connection;

d_2: open contact of the disconnector under test (DT) to the open contact of the auxiliary disconnector (DA).

F.6.5.1.1 Transient voltage values

The voltage transients at the disconnector location during a close operation are used to characterize the behaviour of the test circuit and to ensure consistent overvoltage characteristics under test conditions. Two distinct aspects of transient voltages are of importance: these are the very fast transient (VFT) phenomena and the fast transient (FT) phenomena. The VFT phenomena are determined by the circuit arrangement as described in F.6.5.1. The circuit response for the fast transient phenomena shall be verified at least once for the test arrangement by direct measurement (see F.6.10) under the following conditions:

- source-side test voltage: $U_r/\sqrt{3}$;
- load-side voltage: 0 (no pre-charge).

For these conditions, the peak value of the transient voltage to earth U_{TVE} at the first prestrike during a close operation shall be not less than 1,4 × U_r $\sqrt{2}/\sqrt{3}$ (for practical purposes a variation of 5 % is considered acceptable) and the time to peak shall be less than 500 ns, (figure F.2).

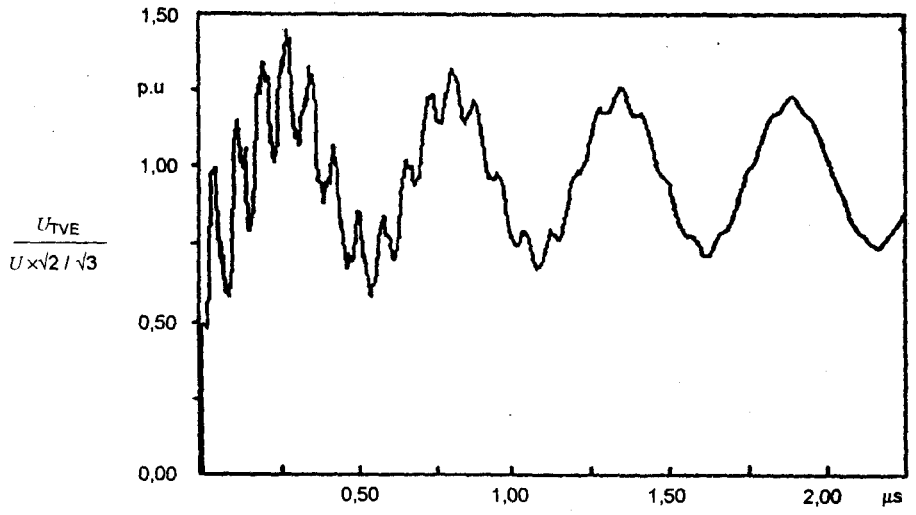


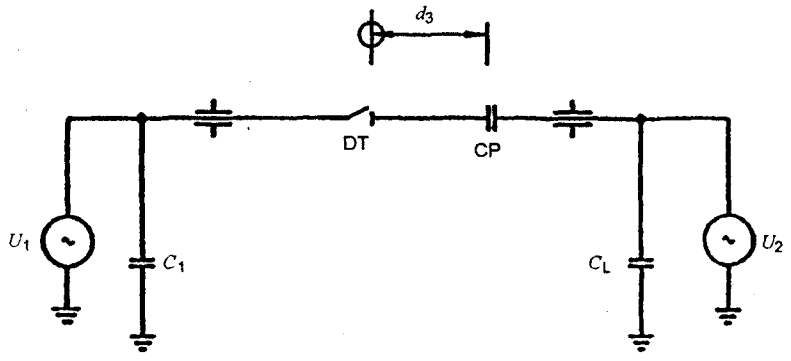
Figure F.2 – Typical voltage waveform (including VFT and FT components)

F.6.5.2 Out-of-phase switching, test duty 2

Figure F.3 shows the test circuit for out-of-phase switching. The parallel capacitance CP of a circuit-breaker may be represented by the actual circuit-breaker or by an adequate capacitance of equal or higher value than the capacitance used in service.

The shortest possible connection d_3 between capacitor (circuit-breaker) and disconnector shall be established. The lengths of the other test circuit parts are not specified, but preferably they should be realised as short as possible using standard components.

The lumped capacitance C_L (figure F.3) shall be of a value not less than 400 pF. The ratio C_1/C_L shall be in the range of 4 to 6.



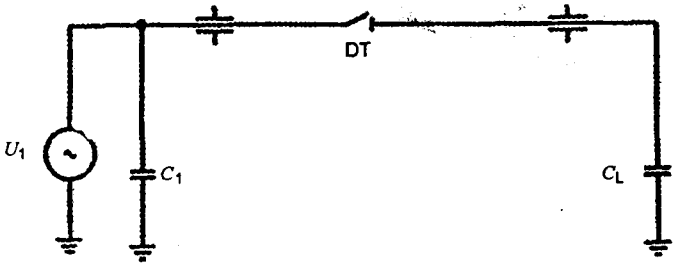
Key

DT Disconnector under test
CP Circuit-breaker parallel capacitor or equivalent capacitor

Figure F.3 – Test circuit for test duty 2

F.6.5.3 Current switching capability test, test duty 3

The test circuit shown in figure F.4 applies. For this type of switching, the specific lengths of the busbar sections are of no significance. On the load side a lumped capacitance C_L should be added in order to achieve the specified bus-charging current as given in table F.2 with a tolerance of ±10 %.



Key

DT Disconnector under test

NOTE 1 In order to reduce resonance effects which can be caused due to a high source impedance, connection of a lumped capacitance C_1 of any value is acceptable to the source side.

NOTE 2 Further testing conditions which affect the transient recovery conditions are subject to agreement between manufacturer and user.

Figure F.4 – Test circuit for test duty 3

Table F.2 – Specified bus-charging currents

Rated voltage U_r kV r.m.s.	72,5	100	123	145	170	245	300	362	420	550	800
Bus-charging current A r.m.s.	0,1	0,1	0,1	0,1	0,1	0,25	0,25	0,5	0,5	0,5	0,8
NOTE The values are normally not exceeded in practice. They apply to 50 Hz as well as to 60 Hz. In case of higher values in practice, other test values should be considered by agreement between manufacturer and user.											

F.6.6 Performance of making and breaking tests

During each test duty, the test series shall be performed without reconditioning the disconnector. The specified number of tests is given in table F.3.

Table F.3 – Specified number of tests

Test duty	**Number of make and break operations**	
	Standard disconnector	**Fast-acting disconnector** [a]
1	50 [b]	200 [a, c]
2	50	200
3	50	50

[a] Disconnectors having a contact speed in the range of 1 m/s or higher at the moment of contact separation.

[b] If the most onerous disconnector arrangement cannot be determined clearly (with reference to F.6.2), test duty 1 shall be repeated with reversed disconnector terminals.

[c] Reduction of the number of tests down to 50 is acceptable if the test voltage is enhanced (to cover statistical effects) to the following values:

– source side: $U_r \times 1{,}2/\sqrt{3}$;

– load side: (d.c. pre-charge): – $U_r \times 1{,}2\ \sqrt{2}/\sqrt{3}$.

F.6.7 Behaviour of the disconnector during making and breaking tests

The disconnector shall perform successfully without mechanical or electrical distress.

Disruptive discharges from phase to earth or, in case of three poles in one enclosure, from phase to phase are not permitted.

NOTE It is essential that disruptive discharges to earth or between phases can be detected properly by adequate measuring or detecting equipment.

F.6.8 Condition after test

The mechanical functions of the disconnector shall be essentially in the same condition as before the test. Evidence of erosion due to arcing and decomposition deposits on insulator surfaces are acceptable, provided the insulating properties of the disconnector are not impaired in the open and closed positions.

After test duty 1 and test duty 2, no specific action is necessary for verification of this requirement.

NOTE Concerning test duty 3, appropriate verification procedures are under consideration.

F.6.9 Type test reports

The results of all type tests shall be recorded in type test reports containing sufficient data to prove compliance with this standard. Sufficient information should be included so that the essential parts of the disconnector tested can be identified.

Additionally the test report shall contain the following information:

a) representative oscillographic record of one make and one break operation;

b) test circuit(s);

c) steady-state test current (only for test duty 3);

d) test voltage(s);

e) transient voltage characteristics;

f) representative record of contact movement;

g) gas pressure during the tests;

h) number of make and break switching operations;

i) condition after test;

j) type of fault detection system;

k) supply voltage or pressure of mechanism operated.

F.6.10 Requirements for measurements

In general, specialized measurements are required during test duty 1 and test duty 2:

- measurements of the transient voltage to earth U_{TVE};
- measurements are required in the case of test duty 1 to ensure that the load side voltage (U_2) meets the specified requirement up to the initiation of the closing operation.

Requirements for the measurements:

- TVE verification shall be carried out at least once for each test circuit used. Configurational changes such as different connecting lead length, equipment orientation, etc., are considered as changes to the test circuit and will require additional measurements;
- TVE measurements shall be made within 1 m of the arcing contacts of the disconnector. If this is not possible, TVE verification may be done by computer calculation, provided that other measurements (within the test section but outside the 1 m zone) are performed at least once to check the validity of the calculation technique;
- care shall be taken that possible stray power frequency interference is taken into account;
- TVE measurement shall be made with sufficient bandwidth to record properly the VFT component.

NOTE VFT measurement is under consideration.

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Telephones: 2323 0131, 2323 3375, 2323 9402 *Website*: www.bis.org.in

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