

SOUTH AFRICAN NATIONAL STANDARD

Standard voltages, currents and insulation levels for electricity supply

WARNING

**This document references other
documents normatively.**

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SANS 1019:2021
Edition 3

Table of changes

Change No.	Date	Scope

Foreword

This South African standard was prepared by National Committee SABS/TC 067/SC 05, *Electricity distribution systems and components – Electricity distribution*, in accordance with procedures of the South African Bureau of Standards, in compliance with annex 3 of the WTO/TBT agreement.

This document was approved for publication in December 2021.

This document supersedes SANS 1019:2014 (edition 2.6).

This document is referenced in the Local Government Municipality Systems Act, 2000 (Act No. 32 of 2000).

Reference is made in the preface to the "relevant national legislation". In South Africa this means the Occupational Health and Safety Act, 1993 (Act No. 85 of 1993).

Reference is made in table 1 to the "relevant national legislation". In South Africa this means the Electricity Act, 1987 (Act No. 41 of 1987) and the Regulations promulgated in terms of the Act.

Compliance with this document cannot confer immunity from legal obligations.

Preface

This document is aligned with IEC 60038.

SANS 60071-1 specifies a range of standard insulation levels which have found general acceptance in South Africa. On the basis of experience and applications in the South African electricity supply industry, agreement has been reached regarding IEC insulation levels which shall be accepted for South Africa. The following comments cover the major aspects of the revision of this document:

- a) **Standard voltages.** The ideal of a single international standard voltage in low voltage distribution systems has always been an attractive proposition to ensure rationalization of distribution networks and associated equipment and to assist international trade.
- 1) SANS 780 specifies a standard no-load voltage of 230/400 V and requires the transformer to operate continuously, without deleterious effect, at a primary voltage of 105 % of rated voltage.
 - 2) Therefore, with adequate design, the supply voltage at the consumer terminals under light load conditions would be within the 230 V +6 % limit recommended in IEC 60038. At the other end of the range, under full load conditions with rated voltage on the primary, the supply voltage could drop without it being less than the lower limit of 230 V –10 %, thereby achieving compliance with the international standard voltage of 230/400 V.

Preface (concluded)

b) **Standard insulation levels.** Standard insulation levels for nominal voltages exceeding 1 100 V have now been included in this document. List 2 insulation levels for the medium voltage range (range A) have been taken from SANS 60071-1, table 1 but, because of a high altitude of up to 1 800 m and ground flash densities commonly reaching values of 8 flashes/km²/year or more in large areas of South Africa, it has been considered necessary to introduce list 3 of insulation levels based on the standard values given in SANS 60071-1, table 3.

- 1) List 1 values have not been included in this document.
- 2) The derating effect on voltage withstand values at altitudes greater than 1 000 m affects external insulation only. By the application of the recommendations in SANS 60071-2 and the correct choice of protective levels of surge arresters, it has generally been found possible to adopt the same values for external insulation as for internal insulation.

c) **Test procedures.** Because many test laboratories are situated at a high altitude, it was considered necessary to give guidance on the following:

- 1) testing at altitudes above 1 000 m with reference to insulation levels specified for altitudes up to 1 000 m; and
- 2) testing at altitudes up to 1 000 m in those cases where it has been found necessary to specify a higher insulation level for external insulation than the corresponding level for internal insulation.

Test procedures for the simultaneous testing of internal and external insulation are covered in annex A.

d) **Clearances and creepage distances.** The committee charged with the revision of SANS 1019:1975 did not consider it necessary to include clearances and creepage distances in this revision.

Clearances are covered in the relevant national legislation (see foreword) and creepage distances in SANS 60137.

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Standard voltages, currents and insulation levels for electricity supply

1 Scope

1.1 This standard covers standard voltages and currents for use in a.c. transmission, distribution and reticulation systems (and in equipment for use in such systems) having a nominal frequency of 50 Hz and a nominal voltage exceeding 100 V, based on the standard values given in IEC 60038 and IEC 60059.

1.2 It also covers standard phase-to-earth insulation levels applicable to equipment (other than rotating electrical machinery) for use in such systems at an altitude not exceeding 1 800 m. The nominal voltages and their associated standard insulation levels are those in use in South Africa, and are based on the values given in SANS 60071-1.

1.3 This standard also covers standard voltages for use in d.c. and a.c. traction systems.

NOTE 1 Test procedures for the simultaneous testing of internal and external insulation are given in annex A.

NOTE 2 Notes on the principles of insulation co-ordination are given in annex B.

NOTE 3 Guidance on the protection of equipment using surge arresters is given in annex C.

NOTE 4 A commonly accepted limit of three-phase supply system balance is given in annex D.

2 Normative references

The following referenced documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies. Information on currently valid national and international standards can be obtained from the South African Bureau of Standards.

IEC 60038, *IEC standard voltages*.

IEC 60059, *IEC standard current ratings*.

SANS 60060-1/IEC 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*.

SANS 60071-1/IEC 60071-1, *Insulation co-ordination – Part 1: Definitions, principles and rules*.

SANS 60071-2/IEC 60071-2, *Insulation co-ordination – Part 2: Application guide*.

3 Definitions

For the purposes of this document, the following definitions apply.

3.1 General definitions

3.1.1

earth fault factor

at a selected location in a three-phase system (generally the point of installation of the equipment) and for a given system configuration, the ratio of the highest r.m.s. phase-to-earth power-frequency voltage on a sound phase during a fault to earth (affecting one or more phases at any point) to the r.m.s. phase-to-earth power-frequency voltage that would be obtained at the selected location without a fault

3.1.2

external insulation

air surrounding the solid insulation of equipment, and the surface(s) of the solid insulation (in contact with the air) that are subject to dielectric stresses and to the effects of atmospheric and other external conditions such as pollution, humidity and vermin

3.1.3

impulse

unidirectional wave of voltage or current which, without appreciable oscillations, rises rapidly to a maximum value and falls, usually less rapidly, to zero with small, if any, loops of opposite polarity

NOTE The parameters which define a voltage or current impulse are polarity, peak value, front time, and time to half value on the tail.

3.1.4

insulation level

combination of the relevant of the following:

- a) the rated short duration power-frequency withstand voltage;
- b) the rated lightning impulse withstand voltage; and
- c) the rated switching impulse withstand voltage

3.1.5

internal insulation

internal solid, liquid or gaseous parts of the insulation of equipment, that are protected from the effects of atmospheric and other external conditions such as pollution, humidity and vermin

3.1.6

phase-to-earth voltage

voltage between phase and earth

3.1.7

phase-to-phase voltage

voltage between phases

3.1.8

point of supply

point at which electricity is supplied to any premises by a supplier

3.2 Definitions concerning system voltage

3.2.1

highest voltage of the system

lowest voltage of the system

highest or lowest value of operating voltage that occurs under normal operating conditions at any time and at any point in the system

NOTE 1 Transient overvoltages due, for example, to switching operations and abnormal temporary variations of voltages, are not taken into account.

NOTE 2 This voltage excludes voltage transients (such as those due to system switching) and temporary voltage variations (such as those due to fault conditions or the sudden disconnection of large loads).

3.2.2

nominal system voltage

suitable approximate value of voltage used to designate or identify a system

3.2.3

nominal system voltage of a three-phase system

U_n

r.m.s. phase-to-phase voltage by which a system is designated and to which certain operating characteristics of the system are related

3.2.4

operating voltage (in a system)

value of the voltage under normal conditions, at a given instant and at a given point of the system

NOTE This value may be expected, estimated or measured.

3.3 Definitions concerning subdivision of nominal voltages

3.3.1

extra high voltage

EHV

set of nominal voltage levels that are used in power systems for bulk transmission of electricity in the range $220 \text{ kV} < U_n \leq 400 \text{ kV}$

3.3.2

high voltage

HV

set of nominal voltage levels that are used in power systems for bulk transmission of electricity in the range $33 \text{ kV} < U_n \leq 220 \text{ kV}$

3.3.3

low voltage

LV

set of nominal voltage levels that are used for the distribution of electricity and whose upper limit is generally accepted to be an a.c. voltage of 1 000 V (or a d.c. voltage of 1 500 V)

NOTE In certain fields of technology, for example, electric motors and mining, voltages up to and including 1 100 V are traditionally regarded as low voltage.

3.3.4

medium voltage

MV

set of nominal voltages that lie above low voltage and below high voltage in the range $1 \text{ kV} < U_n \leq 33 \text{ kV}$

3.3.5

ultra-high voltage

UHV

set of nominal voltage levels that are used in power systems for bulk transmission of electricity in the range $U_n > 400$ kV

3.4 Definitions concerning voltage of equipment

3.4.1

highest voltage for equipment

U_m

highest r.m.s. phase-to-phase voltage for which the equipment is designed in respect of both its insulation and other characteristics that relate to this voltage in the relevant equipment specifications

NOTE This voltage is the maximum value of the highest voltage of the system for which the equipment may be used.

3.4.2

rated voltage for equipment

highest r.m.s. phase-to-phase voltage for which the equipment is designed

4 Limits of voltage variations

4.1 Nominal system voltages lower than 500 V

The voltage at the point of supply shall not deviate from the standard voltage (230/400 V) by more than 10 %.

4.2 Nominal system voltages of 500 V and higher

In the absence of any agreement to the contrary, the voltage at the point of supply shall not deviate from the standard or declared voltage by more than 5 % for any period longer than 10 consecutive minutes.

5 Standard voltages not exceeding 1 100 V

The standard r.m.s. voltage shall be one of the appropriate values given in table 1.

Table 1 — Standard voltages not exceeding 1 100 V

1	2
Nominal voltage, r.m.s.	
V	
Three-phase four-wire systems^a	Three-phase three-wire systems
230/400 ^b	525 950 1 100
<p>^a In the voltage designation of three-phase four-wire systems, the lower value is the voltage measured</p> <p>1) between a phase conductor and the neutral conductor, for use in single-phase two-wire circuits, and</p> <p>2) the higher value is the voltage measured between phase conductors.</p> <p>^b In accordance with IEC 60038 and the relevant national legislation (see foreword).</p>	

6 Standard voltages exceeding 1 100 V and associated insulation levels

6.1 Insulation levels¹⁾

6.1.1 An insulation level U_{IL} shall be assigned to the insulation of equipment for each of the following types of test voltage, as relevant:

- a) lightning impulse voltage;
- b) switching impulse voltage;
- c) short duration power-frequency voltage, each value being chosen from table 3, 4 or 5, appropriate to the highest voltage of the system or highest voltage for equipment U_m assigned to the equipment (see 6.4 to 6.6 (inclusive)); and
- d) insulation levels, where applicable to external insulation, shall be with reference to standard atmospheric conditions in accordance with table 2.

Table 2 — Standard atmospheric conditions

1	2
Standard atmospheric conditions	Values
Temperature	20 °C
Barometric pressure	101,3 kPa
Absolute humidity	11 g/m ³

NOTE 1 While the electric strength of internal insulation is independent of atmospheric conditions, the electric strength of external insulation in air decreases with decreasing air density and increasing ambient temperature.

NOTE 2 For general guidance: the lightning impulse strength of external insulation decreases by 1,25 % for every 100 m of altitude above sea level.

1) See annex B for guidance on the principles of insulation co-ordination.

6.1.2 In those cases where, owing to either low barometric pressures at higher altitudes or exceptional service conditions, it is necessary to assign an external insulation level U_{ILext} that is higher than the corresponding value of U_{IL} assigned in terms of 6.1.1, insulation levels U_{ILext} shall be assigned for the appropriate types of test voltage. Each value shall be chosen from table 3, 4 or 5, as applicable or, in the case of an intermediate value not given in this standard, the appropriate value given in SANS 60071-1 shall be used.

NOTE 1 By judicious selection of protective devices and their location with respect to equipment to be protected, it is generally possible to adopt the same insulation level U_{IL} for internal insulation and external insulation for equipment suitable for use at altitudes up to 1 800 m, i.e. $U_{ILext} = U_{IL}$. This enables manufacturers and users to adopt internationally accepted designs for use in South Africa.

NOTE 2 No values of insulation level other than those given in this standard or in SANS 60071-1 should be used.

6.2 Dielectric tests

6.2.1 General

External insulation shall be tested at the assigned insulation level corrected to standard atmospheric conditions in accordance with SANS 60060-1.

6.2.2 Lightning impulse voltage withstand test

The lightning impulse voltage withstand test shall be conducted in accordance with SANS 60060-1, with the equipment dry for both indoor and outdoor equipment.

6.2.3 Switching impulse voltage withstand test

The switching impulse voltage withstand test shall be conducted in accordance with SANS 60060-1, with the equipment dry for indoor equipment, and with the equipment wet and dry for outdoor equipment. The test that gives the lower disruptive discharge voltage shall be the appropriate test.

6.2.4 Short duration power-frequency voltage withstand test

The short duration dry power-frequency voltage withstand test shall be conducted as a routine test and the short duration wet power-frequency voltage withstand test as a type test.

NOTE 1 See annex A with regard to the simultaneous testing of internal and external insulation.

NOTE 2 Where statistical evaluation is required for determining flash-over or withstand voltages of insulation, SANS 60060-1 or other suitable procedure can be used (see annex B).

6.3 Ranges of highest voltage for equipment

For the purpose of insulation co-ordination, the standard values of the highest voltage for equipment shall be divided into the following three ranges:

- a) Range A: $1 \text{ kV} < U_m < 52 \text{ kV}$;
- b) Range B: $52 \text{ kV} \leq U_m < 300 \text{ kV}$; and
- c) Range C: $300 \text{ kV} \leq U_m$.

6.4 Standard voltages and insulation levels in range A

NOTE See annex B for long duration power-frequency tests to determine aging of internal insulation or performance of external insulation under polluted conditions.

6.4.1 General

The standard highest voltage for equipment U_m and nominal system voltage of a three-phase system U_n shall be of the appropriate combination of values given in columns 1 and 2 of table 3.

6.4.2 Impulse and power-frequency tests

6.4.2.1 The performance under power-frequency operating voltages, temporary overvoltages and switching overvoltages shall be checked by a short duration power-frequency test at the appropriate test voltage given in either column 5 or 6 of table 3, as relevant.

6.4.2.2 The performance under lightning overvoltages shall be checked by a lightning impulse voltage test at the appropriate test voltage given in either column 3 or 4 of table 3, as relevant.

NOTE 1 The choice between lists 2 and 3 should be made by considering the degree of exposure to lightning and switching overvoltages, the type of system neutral earthing and the characteristics of overvoltage protective devices.

NOTE 2 List 1, as given in SANS 60071-1, is not recommended for use in South Africa.

Table 3 — Standard voltages and insulation levels for range A

1	2	3	4	5	6
Highest voltage for equipment U_m , r.m.s. kV	Nominal system voltage U_n , r.m.s. kV	Rated lightning impulse withstand voltage, peak kV		Rated short duration power-frequency withstand voltage, r.m.s. kV	
		List 2	List 3	List 2	List 3
2,4 ^a 3,6 7,2	2,2 3,3 6,6	40 40 60	40 45 75	10 10 20	12 16 22
12 24 36	11 22 33	75 125 170	95 150 200	28 50 70	28 50 70

^a Not a preferred value for use in South Africa. This value is not listed in SANS 60071-1.

6.4.3 List 2 insulation levels

These insulation levels apply in general to equipment in non-exposed installations (such as those connected to cable networks), and the lightning impulse voltage test, if required, shall be a full-wave impulse test only.

NOTE Under special conditions, the relevant equipment specification may require other test voltages for power-frequency or impulse tests in accordance with SANS 60071-1 or may specify that no lightning impulse voltage withstand test is required.

6.4.4 List 3 insulation levels

These insulation levels apply in general to equipment in exposed installations and, in certain cases, the lightning impulse voltage test shall include chopped waves.

NOTE List 3 contains values that are accepted in South Africa and that are not listed in SANS 60071-1.

6.5 Standard voltages and insulation levels in range B

NOTE See C.1.4 for long duration power-frequency tests to determine aging of internal insulation or performance of external insulation under polluted conditions.

6.5.1 General

6.5.5.1 The standard highest voltage for equipment U_m and nominal system voltage of a three-phase system U_n shall be the appropriate combination of values given in columns 1 and 2 of table 4.

6.5.5.2 Where more than one insulation level is given in columns 5 and 6 of table 4, the higher level is appropriate for equipment located in a system where the earth fault factor is greater than 1,4 (see 3.1).

Table 4 — Standard voltages and insulation levels for range B^a

1	2	3	4	5	6
Highest voltage for equipment U_m , r.m.s. kV	Nominal system voltage U_n , r.m.s. kV	Base for p.u. ^b values, $U_m \cdot \frac{\sqrt{2}}{\sqrt{3}}$ kV	Rated lightning impulse withstand voltage, peak		Rated short duration power-frequency withstand voltage, r.m.s. kV
			p.u. ^b	kV	
52 ^c 72,5	44 66	42,5 59	5,88 5,93	250 350	95 140
100	88	82	4,63 5,49	380 450	150 185
145	132	118	4,66 5,50	550 650	230 275
245	220	200	4,25 4,75	850 950	360 395

a Insulation levels for highest voltage for equipment $U_m < 100$ kV are based on an earth fault factor equal to $\sqrt{3}$ and for $U_m \geq 100$ kV, on an earth fault factor equal to $0,8\sqrt{3}$.

b p.u. is the per unit value of $U_m \cdot \frac{\sqrt{2}}{\sqrt{3}}$ kV.

c Where creepage distances are based on millimetres per kilovolt of highest voltage for equipment, the value of 48 kV should be used.

6.5.2 Impulse and power-frequency tests

6.5.2.1 The performance under power-frequency operating voltages, temporary overvoltages and switching overvoltages shall be checked by a short duration power-frequency test at the appropriate test voltage given in column 6 of table 4.

6.5.2.2 The performance under lightning overvoltages shall be checked by a lightning impulse voltage test at the appropriate voltage given in column 5 of table 4. In certain cases, the lightning impulse voltage test shall include chopped waves.

NOTE Under special conditions the relevant equipment specification may require test voltages in accordance with SANS 60071-1 that differ from those given in table 4.

6.6 Standard voltages and insulation levels in range C

NOTE See annex B for long duration power-frequency tests to determine aging of internal insulation or performance of external insulation under polluted conditions.

6.6.1 General

The rated voltage for equipment standard, highest voltage for equipment U_m and nominal system voltage of a three-phase system U_n shall be the appropriate combination of values given in columns 1 and 2 of table 5.

Table 5 — Standard voltages and insulation levels for range C

1	2	3	4		5	6	7	8
Highest voltage for equipment U_m , r.m.s. kV	Nominal system voltage U_n , r.m.s. kV	Base for p.u. ^a values, $U_m \frac{\sqrt{2}}{\sqrt{3}}$ kV	Rated switching impulse withstand voltage, peak		Ratio between rated lightning and switching impulse withstand voltages	Rated lightning impulse withstand voltage, peak kV	Rated short duration power-frequency withstand voltage, r.m.s. kV	
			p.u. ^a	kV				
300	275	245	3,47	850	1,24	1 050	460	
362	330	296	3,21	950	1,37	1 300	570	
420	400	343	3,06	1 050	1,36	1 425	630	
^a p.u. = per unit value of $U_m \cdot \frac{\sqrt{2}}{\sqrt{3}}$, kV.								

6.6.2 Impulse and power-frequency tests

6.6.2.1 The performance under power-frequency operating voltages shall be checked by either a short duration power-frequency test at the appropriate test voltage given in column 8 of table 5, or a long duration power-frequency test in accordance with the requirements of the relevant equipment specification (or both).

NOTE 1 The values given in column 8 of table 5 for short duration power-frequency tests are based on those which have been commonly used in South Africa to take account of the effects of switching overvoltages and temporary overvoltages at power-frequency.

NOTE 2 See also the note to B.4.2.5.

6.6.2.2 The performance under switching overvoltages shall be checked by a switching impulse voltage

test at the appropriate test voltage given in column 5 of table 5.

6.6.2.3 The performance under lightning overvoltages shall be checked by a lightning impulse voltage test at the appropriate test voltage given in column 7 of table 5. In certain cases, the lightning impulse voltage test shall include chopped waves.

NOTE Under special conditions, the relevant equipment specification may specify test voltages that differ from those given in table 5 in accordance with SANS 60071-1.

7 Direct current and alternating current traction systems

The nominal standard voltage e.g. extra high voltage, high voltage, low voltage, medium voltage, ultra-high voltage and its associated highest and lowest voltages for a d.c. or an a.c. traction system shall be the appropriate combination of values given in columns 2, 3 and 4 of table 6.

NOTE The values given in table 6 are those agreed upon by the "Comité Mixte International du Matériel de Traction Electrique" (CMT) (International Mixed Committee on Electric Traction Equipment) and published in IEC 60038.

Table 6 — Standard voltages for d.c. and a.c. traction systems

1	2	3	4	5
Type of system	Standard voltage			Rated frequency
	V			
	Lowest	Nominal	Highest	Hz
D.C.	400 ^a	600 ^a	720 ^a	—
	500	750	900	—
	1 000	1 500	1 800	—
	2 000	3 000	4 000	—
A.C. (r.m.s., single-phase)	4 750 ^a	6 250 ^a	6 900 ^a	50
	19 000	25 000	27 500	50
	38 000	50 000	55 000	50
^a In terms of international standardization these are non-preferred values and should not be used for new systems to be erected in the future. In a.c. single-phase systems in particular, the nominal voltage of 6 250 V should be used only where local conditions make it impossible to adopt a nominal voltage of 25 000 V.				

8 Standard currents

For equipment where the current rating is not determined by a combination of other quantities (for example, apparent power and voltage), the standard current rating, in amperes, shall be one of the following values² multiplied by 10 to the power of n, where n is a positive or negative integer or zero:

1,00; 1,25; 1,60; 2,00; 2,50; 3,15; 4,00; 5,00; 6,30; or 8,00.

2) See annex B for guidance on the principles of insulation co-ordination.

Annex A
(informative)

**Test procedures for the simultaneous testing
of internal and external insulation**

A.1 Atmospheric correction factor

Determine the atmospheric correction factor k_a for external insulation in accordance with SANS 60060-1.

**A.2 Internal and external insulation that are assigned the same value
of insulation level U_{IL}**

A.2.1 External insulation

Test the external insulation at a voltage corresponding to the appropriate insulation level U_{IL} multiplied by k_a .

NOTE The design of external insulation is generally assessed by means of a type test and this need not be repeated when testing internal insulation by means of a routine test.

A.2.2 Internal insulation

A.2.2.1 Test the internal insulation at a voltage corresponding to the appropriate insulation level U_{IL} without a correction factor being applied to it.

A.2.2.2 If k_a is less than 0,95, determine whether the internal insulation can be tested without danger of a disruptive discharge taking place in the external insulation.

A.2.2.3 Alternatively, suppress external disruptive discharges by suitable means.

**A.3 External insulation that is assigned an additional insulation level
 U_{ILext}**

A.3.1 External insulation

A.3.1.1 If $k_a \cdot U_{ILext} < U_{IL}$, test the external insulation at a voltage corresponding to $k_a \cdot U_{ILext}$.

A.3.1.2 If $k_a \cdot U_{ILext} > U_{IL}$, prepare a sample of the external insulation that simulates service conditions, and test it at a voltage corresponding to $k_a \cdot U_{ILext}$.

A.3.2 Internal insulation

A.3.2.1 Test the internal insulation at a voltage corresponding to the appropriate insulation level U_{IL} without a correction factor being applied to it.

A.3.2.2 If $U_{IL} > k_a U_{ILext}$, determine whether the internal insulation can be tested without danger of a disruptive discharge taking place in the external insulation. Alternatively, suppress external disruptive discharges by suitable means.

Annex B

(informative)

Basic principles of insulation co-ordination

B.1 Insulation co-ordination

Insulation co-ordination comprises the selection of both the electric strength of equipment and its application, in relation to the voltages which can appear on the system for which the equipment is intended, and taking into account the characteristics of available protective devices, so as to reduce to an economically and operationally acceptable level the probability that the resulting dielectric stresses imposed on the equipment will cause damage to equipment insulation or affect continuity of service.

B.2 Dielectric stresses and other factors affecting insulation

B.2.1 The following classes of dielectric stress may be encountered during the operation of equipment:

- a) power-frequency voltages, under normal operating conditions, i.e. not exceeding the highest voltage for equipment;
- b) temporary overvoltages;
- c) switching overvoltages; and
- d) lightning overvoltages.

NOTE Further details of the principles governing insulation coordination are covered in SANS 60071-1 and SANS 60071-2.

B.2.2 For a given dielectric stress, the behaviour of internal insulation may be influenced by its degree of aging, and that of external insulation by its degree of atmospheric contamination.

B.3 Dielectric tests

B.3.1 The following types of dielectric test are considered in this document:

- a) short duration (60 s) power-frequency voltage tests (see SANS 60060-1);
- b) long duration power-frequency voltage tests;
- c) switching impulse voltage tests (see SANS 60060-1); and
- d) lightning impulse voltage tests (see SANS 60060-1).

B.3.2 Switching and lightning impulse voltage tests may be either withstand tests, with a suitable number of voltage impulses at rated impulse withstand voltage applied to the insulation, or 50 % disruptive discharge tests in which the ability of the insulation to withstand impulses at the rated impulse withstand voltage is inferred from the measurement of its 50 % disruptive discharge voltage (see SANS 60060-1), the latter tests being possible only in the case of self-restoring insulation.

B.3.3 Short duration power-frequency tests are withstand tests.

B.4 Selection of the dielectric tests

The basis of selection of the dielectric tests according to this document is different in voltage ranges A, B and C, and may depend upon the type of equipment to be tested.

B.4.1 Ranges A and B

B.4.1.1 The performance under power-frequency operating voltages, temporary overvoltages and switching overvoltages is checked in general by a short duration power-frequency voltage test.

B.4.1.2 The performance under lightning overvoltages is checked by a lightning impulse voltage test.

B.4.1.3 Aging of internal insulation and contamination of external insulation, when they may affect performance under power-frequency operating voltages and overvoltages, generally necessitate long duration power-frequency tests.

NOTE It is accepted that the traditional short duration power-frequency voltage test generally provides a suitable safety margin with respect to normal operating voltages, switching overvoltages, temporary overvoltages (of duration much shorter than 60 s) and moderate temporary overvoltages (the duration of which may be longer but with a lower amplitude). This test at the relevant voltage given in either table 3 or 4 is, therefore, a compromise, since overvoltages comparable both in duration and amplitude with the values applied in the test rarely occur on normal systems. If for some types of internal insulation this test is inappropriate, the relevant equipment specification should lay down the appropriate voltage level and the duration of the test.

B.4.2 Range C

B.4.2.1 In this voltage range, the performance of insulation under power-frequency operating voltages and temporary overvoltages on the one hand, and under switching overvoltages on the other, is demonstrated by different tests.

B.4.2.2 The performance under power-frequency operating voltages and temporary overvoltages is checked by long duration power-frequency voltage tests, aimed at demonstrating the suitability of the equipment with respect to either aging of internal insulation or contamination of external insulation.

B.4.2.3 The performance under power-frequency operating voltages and temporary overvoltages can also be checked by a short duration power-frequency voltage test which is either substituted for long duration power-frequency tests or applied in addition to those tests.

B.4.2.4 The performance under switching overvoltages is checked by a switching impulse voltage test.

B.4.2.5 The performance under lightning overvoltages is checked by a lightning impulse voltage test.

NOTE The values of the traditional short duration power-frequency withstand test voltages have been high enough in this range to take some account of the effects of switching overvoltages and temporary overvoltages. With the introduction of switching impulse tests and the availability of tests specific to partial discharges, the values of the power-frequency test voltages can be reduced, and their nature reconsidered so as to be more representative of normal operating voltages and temporary overvoltages only; this aspect should be covered by the relevant equipment specifications. Until this can be done, the short duration power-frequency voltage tests at present prescribed in table 5 should continue to apply.

B.5 Co-ordination for voltages under normal operating conditions and for temporary overvoltages

B.5.1 When the behaviour of equipment under normal operating voltages and temporary overvoltages has to be demonstrated by a short duration power-frequency voltage test, the values of the test voltage given in this standard should be used.

B.5.2 Long duration power-frequency voltage tests, intended to demonstrate the behaviour of equipment with respect to aging of internal insulation or to contamination of external insulation, should be set out in the relevant equipment specification. In specifying tests representative of stresses under normal operating conditions and temporary overvoltages, it should be assumed that

- a) the insulation withstands permanent operation under normal operating conditions at the highest voltage for equipment,
- b) power-frequency tests, intended to verify the ability of the insulation to withstand surface contamination, are carried out at the appropriate highest voltage for equipment to earth, i.e. either $U_m/\sqrt{3}$, or in the case of a system which may operate with a phase earthed for long periods, U_m ,
- c) the peak value of temporary phase-to-earth overvoltages in range C does not exceed 1,5 p.u. and their duration does not exceed 1 s on each occasion, and
- d) power-frequency tests, intended to verify, as far as practicable, that there will be no significant deterioration of the insulation due to partial discharges during the expected working life of equipment and that, in the most severe conditions, the insulation is not liable to thermal instability, are performed at some phase-to-earth voltage exceeding $U_m/\sqrt{3}$ and for a duration appropriate to system conditions, and in such a manner that all elements are stressed in the same proportions as in service.

B.6 Co-ordination for switching and lightning overvoltages

B.6.1 General

B.6.1.1 In voltage ranges A and B, insulation co-ordination for switching overvoltages can generally be disregarded, as indicated in C.1.4, and no switching impulse voltage test is required in this standard. In voltage range C, co-ordination has to be considered for switching and for lightning overvoltages, which have to be treated separately. In every case, insulation coordination presupposes some knowledge of the magnitude of the overvoltages to be expected at the equipment location, considering credible system contingencies, the electrical characteristics of the system (highest or lowest voltages) and of the equipment, and experience of comparable systems as well as the overvoltage limiting effect of any protective devices. Where surge arresters are installed, their choice should take into consideration the magnitude and duration of the temporary overvoltages during which they may be required to operate satisfactorily while continuing to provide an adequate margin of protection (see also annex C).

B.6.1.2 The insulation strength of equipment for switching and lightning stresses should then be chosen on the basis of the predicted overvoltages to ensure that the requisites of insulation co-ordination are satisfied.

B.6.1.3 Some general rules for procedure in statistical and conventional approaches to insulation co-ordination can be found in SANS 60071-2.

NOTE SANS 60060-1 covers the determination of voltage withstand capabilities of insulation by either statistical or conventional procedures whereas SANS 60071-2 deals mainly with the appraisal of satisfactory system operation in terms of statistical insulation characteristics.

B.6.2 Choice of procedure

B.6.2.1 The need for thorough studies of system overvoltages, as well as the need to carry out tests based on the application of a rather high number of impulses, sets practical limits to the use of the statistical procedure of insulation co-ordination.

B.6.2.2 A statistical approach is particularly valuable where there is a strong economic incentive towards a reduction of insulation strength, especially when switching overvoltages are a problem. For these reasons, the statistical procedure covered in SANS 60060-1, SANS 60071-1 and SANS 60071-2 is mainly appropriate to voltage range C and is not usually employed in ranges A and B.

B.6.2.3 Furthermore, in all voltage ranges, when the equipment insulation is essentially non-self-restoring, usually only a small number of impulse applications can be accepted to check that the withstand strength is ensured and therefore, at the present state of the art, it is impossible to consider failure probability as a design variable subject to quantitative control. Therefore, the use of the statistical procedure is at present practically restricted to self-restoring insulation.

Annex C

(informative)

Surge protection of equipment

C.1 Protection of equipment with surge arresters

C.1.1 General

The protective level of a surge arrester should be chosen taking into account the reduced electric strength of the external insulation of equipment when installed at high altitudes.

C.1.2 Surge arresters

C.1.2.1 The lightning impulse protective level of a surge arrester is the maximum of

- a) maximum sparkover voltage with a 1,2/50 impulse (gapped arresters only),
- b) maximum front-of-wave sparkover voltage divided by 1,15 (gapped arresters only), and
- c) maximum residual voltage at rated discharge current.

C.1.2.2 The switching impulse protective level of a surge arrester is the maximum of

- a) maximum sparkover voltage for specified switching impulse waveshapes (gapped arresters only), and
- b) maximum surge arrester discharge voltage (if specified).

NOTE Surge arresters are assumed to be so sealed that the internal pressure is independent of atmospheric pressure.

C.1.3 Effective protective level of a surge arrester

C.1.3.1 The effective protective level of a surge arrester as installed U_{arr} , is the protective level of the surge arrester plus the inductive voltage drop in the arrester connections and in the link between the arrester and the equipment to be protected. In addition, if the length of the link is such that the duration of propagation of a surge between the arrester and the equipment is not negligible compared to the duration of the wave-front of the incoming surge, the voltage at the terminals of the equipment is momentarily increased with respect to the effective protective level of the arrester.

C.1.3.2 Unless the arrester is mounted on the equipment and in close proximity to the voltage sensitive parts of the equipment, a minimum voltage drop of the order of 10 kV for range A, 25 kV for range B and 35 kV for range C would normally have to be allowed.

C.1.4 Determination of external and internal insulation levels

C.1.4.1 The effective protective level of a surge arrester U_{arr} (obtained as in C.1.3) shall be less by a suitable margin than the electric strength of both external and internal insulation.

C.1.4.2 Therefore, if k_a is less than unity (as is normally the case at higher altitudes)

$$k_a \cdot U_{IL} \geq f \cdot U_{arr}$$

where

U_{arr} is the effective protective level of surge arrester

U_{IL} is the appropriate insulation level assigned to internal insulation

f is the safety factor

k_a is the air density correction factor (see SANS 60060-1)

SANS 60071-2 recommends the following value for f :

Ranges A and B: $f = 1,2$

Range C : $f = 1,25$ for lightning impulses
 $f = 1,15$ for switching impulses

C.1.4.3 If it is not possible to adopt the same insulation level for internal and external insulation, the external insulation level should be so selected that

$$k_a \cdot U_{ILext} \geq f \cdot U_{arr}$$

$$U_{IL} \geq f \cdot U_{arr}$$

where

U_{ILext} is the appropriate insulation level assigned to external insulation.

C.2 Spark gaps

Because of

- a) the dispersion of the sparkover voltage of spark gaps, and
- b) the possibility of an increase in the sparkover voltage with increasing amplitude of the incoming surge when sparkover takes place on the front of the wave,

the protection obtained using such protective devices is less precise and the protective level cannot be determined as accurately as for surge arresters of the sealed type. As the shape of the voltage-time characteristic of a spark gap is more curved than that of a surge arrester, the distance over which protection is ensured for all surges is very small, usually not more than a few metres for steep-fronted waves.

Annex D
(informative)

Three-phase supply system balance

A three-phase supply system is commonly considered to be balanced if the continuous negative sequence voltage does not exceed 2 % of the nominal positive sequence voltage.

NOTE For further information on this subject, see High Voltage Co-ordinating Committee: Document No. 2, issued by the National Electrical Engineering Research Institute of the CSIR, Pretoria.

Bibliography

Standards

SANS 780, *Distribution transformers*.

SANS 60137/IEC 60137, *Insulated bushings for alternating voltages above 1 000 V*.

Other publications

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