



Substations and high voltage installations exceeding 1 kV a.c.



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 - Bureau of Steel Manufacturers of Australia
 - CIGRE
 - Communications, Electrical and Plumbing Union—Electrical Division
 - Consult Australia
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 - Department of Mines and Petroleum, WA
 - Electrical Regulatory Authorities Council
 - Energy Networks Association
 - Engineers Australia
 - Institute of Electrical Inspectors
-

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Australian Standard[®]

Substations and high voltage installations exceeding 1 kV a.c.

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PREFACE

This Standard was prepared by the Standards Australia Committee EL-043, High Voltage Installations, to supersede AS 2067—2008, *Substations and high voltage installations exceeding 1 kV a.c.*

The objective of this Standard is to provide common rules for the design and the erection of electrical power installations in systems with nominal voltages above 1 kV a.c. and nominal frequency up to and including 60 Hz.

The objective of this revision is to incorporate changes derived from experience and feedback following the issue of the 2008 edition of this Standard, amendments that have been made to IEC 61936, and to incorporate review of consideration of fire issues, requirements related to the mining area for fixed installations, as considered by EL-023, Electrical Equipment in Mines and Quarries, and substantially expand the sections and clauses on earthing, following reference to ENA's Handbook ENA Doc 025, EG-0 on earthing.

This Standard is based on but not equivalent to IEC 61936-1:2010, *Power installations exceeding 1 kV a.c.*, Part 1: *Common rules*, and its Amendment 1 (2014).

Where a reference is made to 'national regulations', it is intended to encompass national, state or territory and local regulations.

The terms 'normative' and 'informative' are used to define the application of the appendix to which they apply. A normative appendix is an integral part of a standard, whereas an informative appendix is only for information and guidance.

Statements expressed in mandatory terms in notes to figures and tables are deemed to be requirements of this Standard.

CONTENTS

	<i>Page</i>
SECTION 1 SCOPE AND GENERAL	
1.1 SCOPE.....	5
1.2 APPLICATION	6
1.3 NORMATIVE REFERENCES	6
1.4 DEFINITIONS.....	8
SECTION 2 FUNDAMENTAL REQUIREMENTS	
2.1 GENERAL.....	18
2.2 ELECTRICAL REQUIREMENTS	19
2.3 CIVIL AND STRUCTURAL REQUIREMENTS.....	21
2.4 CLIMATIC AND ENVIRONMENTAL CONDITIONS	27
2.5 SPECIAL REQUIREMENTS	30
2.6 SITE SELECTION	31
2.7 RISK MANAGEMENT	31
SECTION 3 INSULATION	
3.1 GENERAL.....	33
3.2 SELECTION OF INSULATION LEVEL	33
3.3 VERIFICATION OF WITHSTAND VALUES	33
3.4 MINIMUM CLEARANCES OF LIVE PARTS	34
3.5 MINIMUM CLEARANCES BETWEEN PARTS UNDER SPECIAL CONDITIONS	39
3.6 TYPE TESTED EQUIPMENT	40
SECTION 4 EQUIPMENT	
4.1 GENERAL REQUIREMENTS.....	41
4.2 SPECIFIC REQUIREMENTS	42
SECTION 5 INSTALLATIONS	
5.1 MINIMUM REQUIREMENTS	52
5.2 OUTDOOR INSTALLATIONS OF OPEN DESIGN	57
5.3 INDOOR INSTALLATIONS OF OPEN DESIGN	64
5.4 INSTALLATION OF PREFABRICATED TYPE-TESTED SWITCHGEAR	65
5.5 REQUIREMENTS FOR BUILDINGS	66
5.6 HIGH VOLTAGE/LOW VOLTAGE PREFABRICATED SUBSTATIONS	71
5.7 ELECTRICAL INSTALLATIONS ON A MAST, POLE OR TOWER.....	71
SECTION 6 SAFETY MEASURES	
6.1 GENERAL.....	72
6.2 PROTECTION AGAINST DIRECT CONTACT	72
6.3 MEANS TO PROTECT PERSONS FROM INDIRECT CONTACT	74
6.4 MEANS TO PROTECT PERSONS WORKING ON OR NEAR ELECTRICAL INSTALLATIONS	74
6.5 PROTECTION FROM DANGER RESULTING FROM ARC FAULT.....	77
6.6 PROTECTION AGAINST DIRECT LIGHTNING STRIKES.....	77
6.7 PROTECTION AGAINST FIRE AND EXPLOSION	78
6.8 PROTECTION AGAINST LEAKAGE OF INSULATING LIQUIDS AND SF ₆	91
6.9 IDENTIFICATION AND MARKING.....	96
6.10 PROTECTION AGAINST UNAUTHORIZED ACCESS	97

SECTION 7 PROTECTION, CONTROL AND AUXILIARY SYSTEMS	
7.1	PROTECTION SYSTEMS 98
7.2	MONITORING AND CONTROL SYSTEMS..... 99
7.3	A.C. AND D.C. SUPPLY CIRCUITS..... 100
7.4	COMPRESSED AIR SYSTEMS 101
7.5	SF ₆ GAS HANDLING PLANT 102
7.6	BASIC RULES FOR ELECTROMAGNETIC COMPATIBILITY OF CONTROL SYSTEMS 102
SECTION 8 EARTHING SYSTEMS	
8.1	GENERAL..... 105
8.2	FUNDAMENTAL REQUIREMENTS 105
8.3	RISK MANAGEMENT AND DUE DILIGENCE 106
8.4	DESIGN 107
8.5	CONSTRUCTION..... 121
8.6	COMMISSIONING AND ONGOING MONITORING..... 122
8.7	MAINTENANCE, MODIFICATION AND REFURBISHMENT 123
8.8	TESTING..... 124
8.9	DOCUMENTATION..... 124
SECTION 9 INSPECTION AND TESTING	
9.1	INSPECTIONS AND TESTS 126
9.2	DOCUMENTATION AND RECORDS 127
9.3	VERIFICATION OF SPECIFIED PERFORMANCES..... 127
9.4	TESTS DURING INSTALLATION AND COMMISSIONING..... 127
9.5	TRIAL RUN 127
SECTION 10 OPERATION AND MAINTENANCE MANUAL 128	
APPENDICES	
A	VOLTAGE LIMITS AND RISK LEVEL 129
B	SUBSTATION EARTHING SYSTEM..... 134
C	FIRE RISK ZONES FOR DISTRIBUTION SUBSTATIONS 145
D	EMF AND SAFETY ISSUES—OBLIGATIONS RELATED TO THE DESIGN OF THE INSTALLATION 154
E	TYPICAL SYSTEM FOR FUNCTIONAL IDENTIFICATION OF SMALL WIRING 155
F	POWER SYSTEM PROTECTION..... 158
G	EARTHING VOLTAGE LIMIT CASE STUDIES 175
H	EARTH SYSTEM TESTING 204
BIBLIOGRAPHY 220	

STANDARDS AUSTRALIA

Australian Standard

Substations and high voltage installations exceeding 1 kV a.c.

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard provides minimum requirements for the design and erection of high voltage installations in systems with nominal voltages above 1 kV a.c. and nominal frequency up to and including 60 Hz, so as to provide safety and proper functioning for the use intended.

For the purposes of this Standard, a high voltage installation is considered to be:

- (a) An electricity network substation, under the control of an electricity network operator or entity authorized by a licence or other legal instrument to convey electricity.
- (b) The high voltage parts of an electrical installation of a power station including all auxiliary systems and interconnecting lines and cables between power stations if on the same site.
- (c) Electrical installations built at offshore platforms, e.g. offshore wind power farms.
- (d) The high voltage parts of an electrical installation that are not covered in (a) or (b) above. This may include but not be limited to consumer and customer electrical installations serving premises such as factories, commercial facilities, industrial plants, institutional facilities and mine sites.

A high voltage installation includes, but is not limited to, the following equipment:

- (i) High voltage electrical installations on masts, poles and towers.
- (ii) Switchgear and/or transformers and/or electrical equipment located outside a closed electrical operating area.
- (iii) Rotating electrical machines.
- (iv) Switchgear, controlgear and assemblies.
- (v) Transformers and reactors.
- (vi) Converters.
- (vii) Cables.
- (viii) Lines.
- (ix) Wiring systems.
- (x) Batteries, battery chargers and associated d.c. supply systems.
- (xi) Capacitors.
- (xii) Earthing systems.
- (xiii) Buildings and fences that are part of a closed electrical operating area.
- (xiv) Associated protection, control, auxiliary and ancillary systems.
- (xv) Structures, foundations, earthworks and drainage.

NOTE: In general, a product Standard for an item of equipment takes precedence over this Standard.

This Standard does not apply to the design and erection of any of the following:

- (A) Overhead lines and underground cables between separate installations.
- (B) Installations on ships and off-shore installations in accordance with IEC 61892 series.
- (C) Underground parts of mine site electrical installations, or parts of such installations, for which mining industry specific legislation sets other requirements.
- (D) Switchgear and/or transformers and/or electrical equipment located within a closed electrical operating area supplied at low voltage and where contact cannot be made with high voltage conductors.
- (E) Test sites.

1.2 APPLICATION

1.2.1 General

Substations and HV installations shall be designed to fulfil their functional aspects and also to allow safe operation and maintenance. Operational and maintenance requirements are covered in documents such as AS 5804 series and the ENA NENS guidelines.

This Standard does not apply to the design of factory-built, type-tested equipment for which separate Australian Standards exist (or IEC Standards where Australian Standards do not exist) to the extent of the scope of the Standards. However, all other requirements of this Standard not covered by the type tests for the type-tested equipment shall comply with this Standard. In particular, ground safety clearances and section safety clearances shall comply with this Standard.

The relevant regulatory authority or electricity network operator may require proof that the design and construction of the high voltage electrical installation complies with this Standard and other relevant Standards and regulatory requirements, including local service and installation rules. Therefore the relevant regulatory authority or electricity network operator should be consulted prior to commencement of the design of the installation.

NOTES:

- 1 Users of this Standard should be aware of existing local, state territory and national regulations.
- 2 Further requirements for specific locations may also be referenced or applied through legislation.
- 3 High voltage a.c. installations associated with electric traction systems are included in the scope of this Standard.

1.2.2 Existing installations

Existing installations are not automatically required to comply with this Standard.

In recognition of changes introduced, existing installations should be reviewed against the requirements of this Standard.

1.3 NORMATIVE REFERENCES

The following are the normative documents referenced in this Standard:

NOTE: Documents for informative purposes are listed in the Bibliography.

AS

1170	Structural design actions
1170.4	Part 4: Earthquake actions in Australia
1210	Pressure vessels
1319	Safety signs for the occupational environment

AS	
1824	Insulation co-ordination
1824.1	Part 1: Definitions, principles and rules
1824.2	Part 2: Application guide
1905	Components for the protection of openings in fire-resistant walls
1905.1	Part 1: Fire-resistant doorsets
1931	High-voltage test techniques
1931.1	Part 1: General definitions and test requirements
1940	The storage and handling of flammable and combustible liquids
2293	Emergency escape lighting and exit signs for buildings
2293.3	Part 3: Emergency escape luminaires and exit signs
2676	Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings (series)
2865	Confined spaces
3600	Concrete structures
3700	Masonry structures
4100	Steel structures
60529	Degrees of protection provided by enclosures (IP Code)
62271	High-voltage switchgear and controlgear
62271.1	Part 1 Common specifications
62271.200	Part 200: a.c. metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV (IEC 62271-200, Ed. 1 (2003) MOD)
62271.201	Part 201: High-voltage switchgear and controlgear—AC insulation enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV
62271.202	Part 202: High-voltage switchgear and controlgear—High-voltage/low voltage prefabricated substation
62271.203	Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV
AS ISO	
10007	Quality management systems—Guidelines for configuration management
AS/NZS	
1170	Structural design actions
1170.0	Part 0: General principles
1170.1	Part 1: Permanent, imposed and other actions
1170.2	Part 2: Wind actions
1170.3	Part 3: Snow and ice actions
1768	Lightning protection
2344	Limits of electromagnetic interference from overhead a.c. powerlines and high voltage equipment installations in the frequency range 0.15 to 1000 MHz
2802	Electric cables—Reeling and trailing for mining and general use (other than underground coal mining)
3000	Electrical installations (known as the Australian/New Zealand Wiring Rules)

AS/NZS	
3008	Electrical installations—Selection of cables
3008.1.1	Part 1.1: Cables for alternating voltages up to and including 0.6/1 kV— Typical Australian installation conditions
7000	Overhead line design—Detailed procedures
60076	Power transformers
60076.2	Part 2: Temperature rise for liquid-immersed transformers (IEC 60076-2, Ed.3.0 (2011) MOD)
60079	Explosive atmospheres
60079.10.1	Part 10.1: Classification of areas—Explosive gas atmospheres (IEC 60079-10-1, Ed.1.0 (2008) MOD)
60079.10.2	Part 10.2: Classification of areas—Combustible dust atmospheres
60479	Effects of current on human beings and livestock
60479.1	Part 1: General aspects
IEC	
60071	Insulation co-ordination
60071-1	Part 1: Definitions, principles and rules
60071-2	Part 2: Application guide
60255	Measuring relays and protective equipment (series)
60287	Electric cables—Calculation of the current rating (series)
60865	Short-circuit currents—Calculation of effects
60865-1	Part 1: Definitions and calculation methods
60909	Short-circuit currents in three-phase a.c. systems (series)
60949	Calculation of thermally permissible short-circuit currents, taking into account non-adiabatic heating effects
61219	Live working—Earthing or earthing and short-circuiting equipment using lances as a short-circuiting device—Lance earthing
61230	Live working—Portable equipment for earthing or earthing and short- circuiting
IEC/TS	
60815	Selection and dimensioning of high-voltage insulators intended for use in polluted conditions
60815-1	Part 1: Definitions, information and general principles
60815-2	Part 2: Ceramic and glass insulators for a.c. systems
60815-3	Part 3: Polymer insulators for a.c. systems
IEC/TR	
61000	Electromagnetic compatibility (EMC)
61000-5-2	Part 5-2: Installation and mitigation guidelines—Earthing and cabling
Australian Building Code Board (ABCB)	
NCC	National Construction Code

1.4 DEFINITIONS

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

1.4.1 Automatic reclosing

Automatic reclosing of a circuit-breaker associated with a faulted section of a network after an interval of time that permits that section to recover from a transient fault.

1.4.2 Boundary clearance

The smallest permissible clearance between an external fence and live parts or those parts that may be subject to a hazardous voltage.

1.4.3 Bund

An embankment or wall that may form part or all of the perimeter of a compound.

1.4.4 Busbar

In a substation, the assembly necessary to make a common connection for several circuits.

Example: Three busbars for a three-phase system.

1.4.5 Circulating transformer neutral current

Portion of fault current that flows back to the transformer neutral point via the metallic parts and/or the earthing system without ever discharging into ground.

1.4.6 Clearance

Distance between two conductive parts along a string stretched the shortest way between these conductive parts (the taut string distance).

1.4.7 Closed electrical operating area

A room or location for operation of electrical installations and equipment to which access is intended to be restricted to skilled or instructed persons or to lay personnel under the supervision of skilled or instructed persons, e.g. by opening of a door or removal of protective barrier only by the use of a key or tool, and which is clearly marked by appropriate warning signs.

1.4.8 Common earthing system (combined earthing system)

An earthing system where the earthed components from the various parts of the asset are directly electrically connected by conductor or conductors.

Example: A common 11 kV/LV earthing system.

1.4.9 Common multiple earth neutral (CMEN)

A system of supply in which the LV neutral conductor on an MEN system interconnects a number of common or bonded substation earths, HV distribution equipment earths (including gas switches, poles, etc.), LV earths and consumer earths.

1.4.10 Confined space

An enclosed or partially enclosed space that is not intended or designed primarily for human occupancy, as defined in AS 2865.

1.4.11 Containment tank/system

Tank or bund around equipment to prevent the escape into the environment of insulating liquid.

1.4.12 Cross country fault

A phase-to-phase fault occurring when an earth fault on an impedance or resonant earthed system in one location leads to an earth fault at another location on a different phase.

1.4.13 Danger zone

Area limited by the non-flash over distance (N) around live parts that are without complete protection against direct contact.

NOTE: Infringing the danger zone is considered the same as touching live parts.

1.4.14 Earth electrode

Conductive part that is in electric contact with the earth and that may be embedded in a specific conductive medium (e.g. in concrete).

1.4.15 Earth fault

Fault caused by a conductor being connected to earth or by the insulation resistance to earth becoming less than a specified value.

[IEC 60050-151:1978, 151-03-40]

NOTE: Earth faults of two or several phase conductors of the same system at different locations are designated as double or multiple earth faults.

1.4.16 Earth fault current, (I_F)

Current that flows from the main circuit to earth or earthed parts at the fault location (earth fault location).

NOTES:

- 1 For single or double line to earth faults, this is in systems with—
 - (a) isolated neutral, the capacitive earth fault current;
 - (b) high resistive earthing, the earth fault current;
 - (c) resonant earthing, the earth fault residual current; and
 - (d) solid or low impedance neutral earthing, the line-to-earth short-circuit current.
- 2 Further earth fault current may result from double earth fault and line to line to earth.

1.4.17 Earth potential rise (EPR)

Voltage between an earthing system and remote earth.

1.4.18 Earth rod

Earth electrode consisting of a metal rod installed into the ground, commonly vertically.

1.4.19 Earthing conductor

Conductor that provides a conductive path, or part of the conductive path, between a given point in a system or in an installation or in equipment and an earth electrode.

[IEC 60050-195:1998, 195-02-03—modified]

NOTE: Where the connection between part of the installation and the earth electrode is made via a disconnecting link, disconnecting switch, surge arrester counter, surge arrester control gap, etc., then only that part of the connection permanently attached to the earth electrode is an earthing conductor.

1.4.20 Earthing system

Arrangement of connections and devices necessary to earth equipment or a system separately or jointly.

[IEC 60050-604:1987, 604-04-02]

1.4.21 Effective step voltage (V_{SE}) (loaded step voltage)

Voltage between two points on the earth's surface that are 1 m apart when a person has one foot in contact with each point.

NOTE: 1 m is considered to be the stride length of a person.

1.4.22 Effective touch voltage (V_{TE}) (loaded touch voltage)

Voltage between conductive parts when touched simultaneously.

NOTE: The value of the effective touch voltage may be appreciably influenced by the impedance of the person in electric contact with these conductive parts.

[IEC 60050-195:1998, 195-05-11, modified]

1.4.23 Electrical equipment

Any item used for such purposes as generation, conduction, conversion, transmission, distribution and utilization of electrical energy, such as machines, transformers, apparatus, measuring instruments, protective devices, equipment for wiring systems and appliances.

1.4.24 Electric resistivity of soil (ρ_E)

Resistivity of a typical sample of soil.

1.4.25 Enclosure

Part providing protection of equipment against certain external influences and, in any direction, protection against direct contact.

1.4.26 Everyday load

The loads on the structural system with a conductor temperature equivalent to the mean of the local area temperature in the coldest month with negligible wind loads, i.e. in still air.

1.4.27 Exposed conductive part

Conductive part of equipment that can be touched and that is not normally live, but which can become live when basic insulation fails.

[IEC 60050-826:2004, 826-12-10, modified]

1.4.28 Extraneous conductive part

Conductive part not forming part of the electrical installation and liable to introduce an electric potential, generally the electric potential of a local earth.

[IEC 60050-826:2004, 826-12-11, modified]

1.4.29 Feeder

Electric line originating at a main substation and supplying one or more secondary substations, or one or more branch lines, or any combination of these two types of installations.

1.4.30 Ferroresonance

Resonance of the capacitance of an apparatus with the inductance of the saturable magnetic circuit of an adjacent apparatus.

1.4.31 Gas-insulated equipment (GIE)—Also referred to as ‘gas-insulated metal enclosed equipment’

Equipment in which the insulation is obtained, at least partly, by an insulating gas other than air.

1.4.32 Global earthing system

Equivalent earthing system created by the interconnection of local earthing systems that ensures, by the proximity of the earthing systems, that there are no dangerous touch voltages. Such systems permit the division of the earth fault current in a way that results in a reduction of the earth potential rise at the local earthing system.

NOTE: Such a system could be said to form a quasi equipotential surface.

1.4.33 Ground safety clearance (G)

The minimum distance required between the earthed end of any exposed insulator carrying or containing live parts and ground or the floor of permanent walkways used for normal inspection and operational functions. This distance is equivalent to the reach of a person at ground level (2440 mm), which includes an allowance of 300 mm for tools.

1.4.34 High voltage (HV)

Voltage exceeding 1000 V a.c.

1.4.35 Highest voltage for installation (U_m)

Highest r.m.s. value of phase-to-phase voltage for which the installation is designed in respect of its insulation.

1.4.36 Horizontal work safety clearance (H)

The minimum distance measured horizontally between live parts and the work object. Where work is to be carried out from a ladder, the horizontal work safety clearance is applied from extremities of the work object horizontally to the nearest live parts. This distance includes an allowance of 300 mm for tools.

1.4.37 Impedance earthed (low or high, resistor, reactor or transformer)

A system where the neutral point is connected to earth via an impedance greater than a direct bond.

Example: NERs and earthing transformers.

1.4.38 Impedance to earth (Z_E)

Impedance at a given frequency between a specified point in a system or in an installation or in equipment and remote earth.

NOTE: The impedance to earth is determined by the directly connected earth electrodes and also by connected overhead earth wires and wires buried in earth of overhead lines, by connected cables with earth electrode effect and by other earthing systems that are conductively connected to the relevant earthing system by conductive cable sheaths, shields, PEN conductors or in another way.

1.4.39 Indoor installations

Electrical installations within a building or room in which the equipment is protected against the weather.

1.4.40 Installations of enclosed design

Installations where the equipment has protection against direct contact.

NOTE: For degrees of enclosure protection, see AS 60529.

1.4.41 Installations of open design

Installations where the equipment does not have protection against direct contact.

1.4.42 Interlocking device

Device that makes the operation of a switching device dependent upon the position or operation of one or more other pieces of equipment.

1.4.43 Isolated neutral (unearthed)

A system in which the neutrals of transformers and generators are not intentionally connected to earth, except for high impedance connections for signalling, measuring or protection purposes.

[IEC 60050-601:1995, 601-02-24, modified]

1.4.44 Isolating distance

Clearance between open contacts meeting the safety requirements specified for equipment.

1.4.45 Isolation

Switching off or disconnection of an installation, a part of an installation or an equipment from all non-earthed conductors by creating isolating gaps or distances.

1.4.46 Line (electric)

An arrangement of conductors, insulating materials and accessories for transferring electricity between two points of a system.

1.4.47 Live part

Conductor or conductive part intended to be energized in normal operation, including a neutral conductor but by convention not a PEN conductor or PEM conductor or PEL conductor.

NOTE: For definitions of PEM and PEL, see IEC 60050-195:2005, 195-02-13 and 195-02-14.

1.4.48 Local control

Control of operation from a point on or adjacent to the controlled switching device.

1.4.49 Local earth

Part of the Earth that is in electric contact with an earth electrode.

NOTE: The potential of the local earth is not necessarily equal to zero.

1.4.50 Low voltage (LV)

Voltage exceeding 50 V a.c. but not exceeding 1000 V a.c.

1.4.51 Maximum sag

The lowest point of a flexible conductor measured during maximum design load conditions and under maximum design fault conditions.

1.4.52 Minimum height

Smallest permissible vertical clearance between accessible surfaces and live parts without protection against direct contact or those parts that may be subject to a hazardous voltage.

1.4.53 Minimum phase to earth clearance

Smallest permissible clearance in air between live parts and earth or between live parts and parts at earth potential.

The clearances to earth between live parts and earthed material apply to any structure or surface substantially at earth potential, including any fixed or portable screens which may be provided. Earthed material includes a poor conductor such as concrete.

1.4.54 Minimum phase-to-phase clearance

Smallest permissible clearance in air between live parts of different phases or between the same phase that are electrically separate from each other.

1.4.55 Multi-earthed (multi-grounded) high voltage neutral conductor

Neutral conductor of a distribution line connected to the earthing system of the source transformer and at regular intervals along its length.

1.4.56 Multiple earth neutral (MEN)

A method of multiple connections between an LV system neutral and earth and the general mass of earth such that the reticulated neutral can return earth fault current and earth paths can return neutral current.

1.4.57 Nominal value

Value of a quantity used to designate and identify a component, device, equipment or system.

1.4.58 Nominal voltage of a system (U_n)

Suitable approximate value of r.m.s. phase-to-phase voltage used to designate or identify a system.

1.4.59 Non-flashover distance (N)

The minimum phase to earth clearance that includes a margin of 10% (for clearances of 1300 mm or less) and 6% (for clearances of greater than 1300 mm) to allow for variations in construction dimensions.

1.4.60 Oil containment tank/system

See Clause 1.4.11, Containment tank/system.

1.4.61 Operating areas subject to fire hazard

Rooms, areas or locations, indoors or outdoors, where there is a danger due to local or operating conditions that hazardous quantities of easily combustible solid materials may come so close to the electrical equipment as to cause a fire hazard resulting from the high temperature of the equipment or due to arcing.

1.4.62 Outdoor installations

Electrical installations that are outdoors.

1.4.63 PEN conductor

Conductor combining the functions of both protective earthing conductor and neutral conductor.

[IEC 60050-826:2004, 826-13-25]

1.4.64 Potential

Voltage between an observation point and remote earth.

1.4.65 Power station

Installation whose purpose is to generate electricity and which includes civil engineering works, energy conversion equipment and all the necessary ancillary equipment.

1.4.66 Power transformer

A static piece of apparatus with two or more windings which, by electromagnetic induction, transforms a system of alternating voltage and current into another system of voltage and current usually of different values and at the same frequency for the purpose of transmitting electrical power.

1.4.67 Prospective step voltage (V_{SP})

Voltage between two points on the earth's surface that are 1 m apart when no person is present.

NOTE: The stride length of a person is considered to be 1 m.

1.4.68 Prospective touch voltage (V_{TP})

Voltage between simultaneously accessible conductive parts when those conductive parts are not being touched.

[IEC 60050-195:1998, 195-05-09, modified]

1.4.69 Protection against direct contact

Measures that prevent persons coming into hazardous proximity to live parts or those parts that could carry a hazardous voltage, with parts of their bodies or objects (reaching the danger zone).

1.4.70 Protection in case of indirect contact

Protection of persons from hazards that could arise, in the event of a fault, from contact with exposed conductive parts of electrical equipment or extraneous conductive parts.

1.4.71 Protective barrier

Part providing protection against direct contact from any usual direction of access.

1.4.72 Protective barrier clearance

Smallest permissible clearance between a protective barrier and live parts or those parts that may become live subject to a hazardous voltage.

1.4.73 Protective obstacle

Part preventing unintentional access to an area where safety clearances will be infringed, but not preventing access to this area by deliberate action.

1.4.74 Protective obstacle clearance

Smallest permissible clearance between a protective obstacle and live parts or those parts that may become live subject to a hazardous voltage.

1.4.75 Rated value

Value of a quantity used for specification purposes, established for a specified set of operating conditions of a component, device, equipment, or system.

1.4.76 Rated voltage (U_r)

The voltage assigned by a manufacturer for a specified operating condition of a component, device or equipment and which it will withstand when tested in accordance with the appropriate Australian Standard.

1.4.77 Remote earth

Part of the Earth considered as conductive, the electric potential of which is conventionally taken as zero, being outside the zone of influence of the relevant earthing arrangement.

NOTE: The concept 'Earth' means the planet and all its physical matter.

[IEC 60050-195:1998, 195-01-01, modified]

1.4.78 Remote control

Control of operation at a point distant from the controlled switching device.

1.4.79 Resonant earthed

A system in which one or more neutral points are connected to earth through reactances which approximately compensate the capacitive component of a single phase-to-earth fault current.

[IEC 60050-601:1995, 601-02-27]

NOTE: With resonant earthing of a system, the residual current in the fault is limited to such an extent that an arcing fault in air is usually self-extinguishing.

[IEC 60071-1]

1.4.80 Segregated earthing systems (separated earthing systems)

Earthing systems that are not electrically connected other than via the general mass of earth.

1.4.81 Section safety clearance (S)

Safety clearance required for access for operational purposes. The non-flashover distance (N) plus the ground safety clearance (G) measured along a taut string between the ground or operating platform and the live part.

1.4.82 Solidly earthed

A system where the neutral point is directly bonded to the system earth via a minimal impedance.

1.4.83 Short-circuit time constant of primary windings (primary time constant)

Time required for the d.c. component present in the short-circuit primary winding current, following a sudden change in operating conditions, to decrease to $1/e$, that is 0.368 of its initial value, the machine running at rated speed.

1.4.84 Structural earth electrode

Metal part, that is in conductive contact with the earth or with water directly or via concrete, whose original purpose is not earthing, but which fulfils all requirements of an earth electrode without impairment of the original purpose.

Examples: Pipelines, sheet piling, concrete reinforcement bars in foundations and the steel structure of buildings, etc.

1.4.85 Substation

Part of a power system, concentrated in a given place, including mainly the terminations of transmission or distribution lines, switchgear and housing and which may also include transformers. It generally includes facilities necessary for system security and control (e.g. the protective devices).

Examples: Transmission substation (of a transmission system), distribution substation, 400 kV substation, 20 kV substation.

NOTE: According to the nature of the system within which the substation is included, a prefix may qualify it.

1.4.86 Sump

Receptacle that is intended to receive the insulating liquid of a transformer or other equipment in case of leakage.

1.4.87 Taut string distance

The distance between two parts measured along a taut string stretched the shortest way between those parts.

1.4.88 Tested connection zone

Zone in the vicinity of equipment terminals that has passed a dielectric type test with the appropriate withstand value(s), the applicable conductors being connected to the terminals in a manner specified by the manufacturer of the equipment.

1.4.89 Transferred potential

Potential rise of an earthing system caused by a current to earth transferred by means of a connected conductor (e.g. a metallic cable sheath, PEN conductor, pipeline, rail, fences) into areas with low or no potential rise relative to remote earth, resulting in a potential difference occurring between the conductor and its surroundings.

NOTE: The definition also applies where a conductor, which is connected to remote earth, leads into the area of the potential rise.

1.4.90 Transient overvoltage

Short duration overvoltage of a few milliseconds, or less, oscillatory or non-oscillatory, usually highly damped.

1.4.91 Vertical work safety clearance (V)

The minimum distance measured vertically between live parts and the highest part of the work object. Where work is to be carried out from a ladder, the vertical work safety clearance shall be applied from the highest parts of the work object vertically to the nearest live parts. This distance includes an allowance of 300 mm for tools.

1.4.92 Voltage Range I

Voltage in the range $1 \text{ kV} < U_m \leq 245 \text{ kV}$.

1.4.93 Voltage Range II

Voltage in range $U_m > 245 \text{ kV}$.

1.4.94 Working clearance

Minimum safe distance to be observed between normally exposed live parts and any person working in a high voltage installation or any conductive tool (or object) directly handled.

NOTE: Values for electrically skilled or instructed persons are given in Figure 5.8. This refers only to non-live working. Specific definitions related to live working practices are found in IEC 60050-651.

1.4.95 Work section

A defined space where a person can work safely provided that some part of the person always remains within that space.

SECTION 2 FUNDAMENTAL REQUIREMENTS

2.1 GENERAL

2.1.1 General requirements

Installations and equipment shall be capable of withstanding electrical, mechanical, climatic and environmental influences anticipated on site.

The design shall take into account—

- (a) the purpose of the installation;
- (b) the users requirements such as power quality, reliability, availability, and ability of the electrical network to withstand the effects of transient conditions such as starting of large motors, short power outages and re-energization of the installation;
- (c) the safety of the operators and the public;
- (d) the environmental influence;
- (e) the possibility for extension (if required) and maintenance; and
- (f) continuous full load, maximum design short circuit fault levels with respect to fault time.

The user should define preferences for specific maintenance features and should identify the safety requirements to be met for levels of segregation of the switchgear and control gear to ensure minimal plant shutdown. Where necessary, the levels of segregation of switchgear shall be provided to secure safety during operation, inspection, cleaning and maintenance and be arranged to minimize the spread of a fault, including a fire, occurring in any defined module into adjacent modules.

There are operating conditions of low occurrence or low cumulative duration which can occur and for which specific design criteria may be agreed between the user and the manufacturer.

In such cases measures required to prevent unsafe conditions and to avoid damage to electrical or plant equipment are to be taken.

Unless the installation is intended to operate solely in an islanded mode, the generators shall be capable of meeting the requirements for connection to the power system grid, e.g. for voltage regulation, frequency response, etc.

Design of substations and high voltage installations is a multidisciplinary activity involving several specialized engineering disciplines. Design in each of these disciplines shall be carried out by personnel who are qualified and competent in the particular discipline. The specialized disciplines include high voltage engineering, protection, control, high voltage testing, metering, civil and structural. The requirement for qualified and competent personnel extends to field activities such as installation, testing, commissioning and maintenance.

2.1.2 Agreements between supplier (manufacturer) and user

The working procedures of the user shall be taken into account in the design of the installation.

For design and erection of high voltage installations, additional agreements between manufacturer/contractor/planner and user/orderer/owner may impose contractual obligations. These agreements may also cover issues relating to essential operational requirements.

2.2 ELECTRICAL REQUIREMENTS

2.2.1 Methods of neutral earthing

The method of neutral earthing of a system is important with regard to—

- (a) selection of insulation level;
- (b) characteristics of overvoltage limiting devices such as spark gaps or surge arresters;
- (c) selection of protective relays; and
- (d) design of the earthing system.

The following are examples of neutral earthing methods:

- (i) Isolated neutral.
- (ii) Resonant earthing.
- (iii) Impedance earthing.
- (iv) Solid (low impedance) earthing.

The choice of the type of neutral earthing is normally based on the following criteria:

- (A) Local regulations (if any).
- (B) Continuity of service required for the network.
- (C) Limitation of damage to equipment caused by earth faults.
- (D) Selective elimination of faulty sections of the network.
- (E) Detection of fault location.
- (F) Touch and step voltages.
- (G) Inductive interference.
- (H) Operation and maintenance aspects.

One galvanically connected system has only one method of neutral earthing. Different galvanically independent systems may have different methods of neutral earthing. If different neutral earthing configurations can occur during normal or abnormal operating conditions, equipment and protective system should be designed to operate under these conditions.

The requirements of this Standard apply for all systems of earthing, including systems that are earthed with methods other than neutral earthing.

Refer to Appendix B for further details regarding methods of neutral earthing.

2.2.2 Voltage classification

The user shall define the nominal voltage and the maximum operating voltage of the system. Based on the maximum operating voltage the highest voltage for the installation (U_m) shall be selected either from Tables 3.1 or 3.2.

2.2.3 Current in normal operation

Every part of an installation shall be designed and constructed to withstand currents under defined operating conditions.

2.2.4 Short-circuit current

2.2.4.1 Mechanical and thermal effects

Installations shall be designed, constructed and erected to safely withstand the mechanical and thermal effects resulting from short-circuit currents.

Where an installation has on-site generation, motors or parallel operation with a network (co-generation), allowance shall be made for the increased fault levels.

Where the high voltage installation is connected to a transmission or distribution network, information regarding design prospective short-circuit and fault currents at the point of supply may be obtained from the local electricity distributor.

2.2.4.2 *Types*

For the purpose of this Standard all types of short-circuit shall be considered, e.g.—

- (a) three-phase;
- (b) phase-to-phase;
- (c) phase-to-earth; and
- (d) double phase-to-earth.

Installations shall be protected with automatic devices to disconnect three-phase and phase-to-phase short-circuits.

Installations shall be protected either with automatic devices to disconnect earth faults or to indicate the earth fault condition. The selection of the device is dependent upon the method of neutral earthing.

Protection co-ordination shall be designed to take into account minimum and maximum short circuit currents.

2.2.4.3 *Rated duration*

The standard value of rated duration of the short-circuit is 1.0 s.

NOTES:

- 1 If a value other than 1 s is appropriate, recommended values would be 0.5 s, 2.0 s and 3.0 s.
- 2 The rated duration should be determined taking into consideration the fault switching time.

2.2.4.4 *Calculation*

Methods for the calculation of short-circuit currents in three-phase a.c. systems are given in IEC 60909.

2.2.4.5 *Effects*

Methods for the calculation of the effects of short-circuit current are given in IEC 60865-1 and, for power cables, in IEC 60949.

2.2.5 *Rated frequency*

Installations shall be designed for the rated frequency of the system in which they shall operate.

2.2.6 *Corona*

2.2.6.1 *General*

The design of installations shall be such that radio interference, e.g. caused by corona effects, will not exceed a specified level.

NOTES:

- 1 Maximum permissible levels of radio interference may be given by national or local authorities.
- 2 Guidance on acceptable levels of radio interference voltage for switchgear and controlgear can be found in AS 62271.1.

When the acceptable value is exceeded, the corona level may be controlled, for example, by the installation of corona rings or the recessing of fasteners on fittings for high voltage suspension insulator assemblies, busbar support assemblies, busbar connections and equipment terminals.

2.2.6.2 Radio and television interference

Corona generates interference over a wide band of frequencies.

The degree of annoyance caused by radio and television interference is determined by the 'signal-to-noise ratio' at the receiving installation. When establishing limits for the emission of radio noise, the radio and television signal strengths to be protected have to be determined.

The allowable levels of radio interference voltage (RIV) and television interference (TVI) are given in AS/NZS 2344.

2.2.6.3 Audible noise

The most common form of audible noise is a hissing or frying sound (broadband crackle) audible in wet weather. During fair weather, a constant low frequency (100 Hz) hum may also be heard.

Designers need to take into account the requirements of the relevant environmental protection agencies, government authority or local council regulations. The total random audible noise consisting of both broadband and 100 Hz hum needs to be addressed in the design process.

2.2.7 High voltage design practices with respect to EMF

High voltage installations shall be designed with consideration to Electrical and Magnetic Fields (EMF). EMF limits shall comply with those in ICNIRP, *Guidelines for limits exposure to magnetic and electric fields* (1 Hz to 100 kHz).

NOTE: Further details are provided in Appendix D.

2.2.8 Overvoltages

Equipment shall be protected against overvoltages resulting from switching operations or lightning that could exceed the withstand values according to IEC 60071-1 and IEC 60071-2.

2.2.9 Harmonics

Consideration should be given to the effect of harmonic currents and harmonic voltages on the installation (e.g. in industrial installations). Harmonic analyses may be required to determine what corrective measures are needed to meet local regulations and/or to ensure correct operation of the whole electrical system.

2.3 CIVIL AND STRUCTURAL REQUIREMENTS

2.3.1 General

This Clause provides the basis for the structural design of structures associated with HV installations and should be read in conjunction with AS/NZS 1170 series.

The general principles of structural design are based on the limit state concept used in conjunction with a load and material strength reduction factor appropriate to the reference limit state.

The values of these factors depend on the degree of uncertainty for the loads, resistances, material properties, geotechnical parameters, geometrical quantities, design model, the type of structure and the type of limit state. These factors can also depend on the strength co-ordination and failure containment principles envisaged for the installation.

Any element of the installation that carries a structural load or is a secondary structural or framing element should be considered as a 'structural element' in the context of this Clause.

Structures and components should be designed using a reliability-based (risk of failure) approach. The selection of load factors in particular for weather related loads, and component strength reduction factors are based on achieving acceptable risk of failure for the selected importance level and operational performance.

The AS/NZS 1170 series and Table 2.1 provide the relevant load factors and strength reduction factors for the various structural elements used in HV installations.

Refer also to AS/NZS 1170 series for suitable annual exceedance probabilities based on the importance level and design working life of the structures (see Note 1).

The material reduction factors do vary for each component in the tension chain (conductor, fitting, insulator and structure). The performance of the structural system shall be evaluated for an appropriate combination of serviceability and strength states as set out in the following clauses.

Structural steel design shall be carried out in accordance with AS 4100. Concrete structure design shall be carried out in accordance with AS 3600.

NOTES:

- 1 AS/NZS 7000 provides guidance on the application of this Clause. It also contains component strength reduction factors for various components.
- 2 HB 331 contains application information and worked examples.

2.3.2 Equipment and structures

2.3.2.1 General

Equipment and structures, including their foundations shall withstand all the anticipated load combinations.

The AS/NZS 1170 series contains the structural design actions to be considered, including permanent (dead loads-long term), imposed (live loads-short term), including wind, seismic, snow and ice. Additional loads such as short circuit, switching, and special loads, such as impact, construction and maintenance are provided in this Standard or shall be determined by the designer.

2.3.2.2 Permanent loads (G)

Self-weight of structures, insulators, equipment and conductors act as permanent loads as defined in AS/NZS 1170.1.

G_s represents the vertical load on the structures and shall be the vertical force due to the structures' own mass plus the mass of all equipment, ancillaries and attachments.

G_c represents the vertical loads of conductors and attachments such as spacers, insulators and droppers.

2.3.2.3 Imposed and other loads (Q , W , E)

The following imposed and other loads shall be considered:

(a) Wind loads

All structures shall be designed for a peak gust regional wind speed for the relevant region and average recurrence interval as defined in AS/NZS 1170.2. AS/NZS 7000 provides further guidance on the selection of the wind return period for structures that support flexible conductors as well as defining the regions where synoptic and/or downdraft winds shall be considered.

Wind loads, which can be very different depending on the local topographic influences and the height of the structures above the surrounding ground, shall be taken into account. The most unfavourable wind direction shall be considered. The design wind pressure, p_z shall be calculated for the site location. This pressure will depend on factors such as terrain, topography, regional wind speed, return period, structure height and wind direction. If designing a suite of structures it may be advisable to use a wind direction multiplier of $M_d = 1$ and a shielding factor of $M_s = 1.0$ to enable flexible location and orientation of the structures.

AS/NZS 1170.2 contains a table of drag factors for various structural sections and shapes and dynamic response factors.

(b) *Seismic loads*

Where HV installations are to be constructed in seismically active regions, consideration shall be given to the forces on the structures due to earthquakes and/or seismic tremors. Reference shall be made to AS 1170.4 for relevant design provisions.

(c) *Snow and ice loads*

Snow and ice loads S_y shall be applied to all elements of the HV installation in the appropriate regions. AS 1170.3 provides snow and ice loads.

In regions where icing can occur, the resulting load on flexible conductors and on rigid busbars shall be taken into account.

If local experience or statistics are not available, the minimum design loads shall be based on a radial ice thickness of 10 mm with a density of 900 kg/m^3 and coincident with a wind pressure of 100 Pa at a conductor temperature of -5°C . These loads may be taken as corresponding to a return period of 50 years although the appropriateness is uncertain. Useful guidance is available in Appendix EE of AS/NZS 7000.

(d) *Short-circuit loads*

The mechanical effects of a short circuit can be estimated by the methods detailed in IEC 60865-1. Alternatively, finite element analysis permits a generally more detailed and precise analysis of the structure under dynamic loading.

NOTE: The CIGRE Technical Brochures No.105 and No.214 parts I and II, as well as IEEE Std 605, give additional advice.

(e) *Switching loads*

Switching forces shall be considered when designing supports. The forces shall be determined by the designer of the equipment.

2.3.2.4 Special loads

Consideration shall be given to the following loads:

(a) *Maintenance/construction loads*

The structural supports shall be able to withstand all imposed construction and maintenance loads Q_m , which are likely to be imposed on them with an appropriate load factor, taking into account working procedures, temporary guying and lifting arrangements. Overstressing of the structure shall be prevented by specification of allowable procedures and/or load capacities.

The conditions shall be based on the worst weather conditions (wind and temperature) under which maintenance will be carried out. The design wind pressure for general outdoor maintenance work is recommended to be 100 Pa, with a minimum of 50 Pa. The designer needs to consider all potential aspects that may arise from maintenance practices. For example, lowering a strung bus may result in approximate doubling of the conductor tension and weight G_c on the structure under consideration.

For all structural elements that can be climbed and are inclined with an angle less than 30 degrees to the horizontal, a characteristic imposed load of 1.5 kN acting vertically at any point along the member shall be considered without any other coincident loads.

In addition for all structures which are designed to be climbed, anchorages to provide for limited fall arrest system ultimate loads shall be considered. Refer to AS/NZS 5532 and AS/NZS 1891 series for further guidance.

An imposed erection load of 1 kN at the most critical position of the supporting structure shall be considered.

(b) *Loss of conductor tension*

A structure with tension insulator strings shall be designed to withstand the loss of conductor tension resulting from breakage of the insulator or conductor that gives the most unfavourable load case.

NOTES:

- 1 General practice is to base the calculation on 0°C, no ice and no wind load.
- 2 For bundle conductors, only one conductor is assumed to fail.

(c) *Vibration*

Vibration caused by wind, electromagnetic stresses, traffic (e.g. temporary road and railway traffic) shall be considered. The withstand capability of equipment against vibration shall be given by the manufacturer.

(d) *Other loads*

The loads due to forces such as ground water and flood flows shall also be considered where appropriate. The effect of buoyancy on below ground structures shall be taken into account.

2.3.3 Coincident temperatures

For structures that are subject to temperature dependent loads, such as those that support flexible conductors, the temperature effects for the following conditions shall be considered:

- (a) Minimum temperature with no other climatic conditions.
- (b) Ambient temperature for ultimate wind speed condition.
- (c) A temperature shall be assumed for icing.

NOTE: For the main types of icing, a temperature of 0°C may be used.

In addition, a temperature of -5°C with 100 Pa wind pressure with ice load should be considered. Refer to Clause 2.3.2.3.

2.3.4 Load components

This Clause applies to structures and attachments that support flexible conductor loadings and should be read in conjunction with Table 2.1.

Although any attached conductor (wire) will impose a single force on the structure, this force is resolved into orthogonal components with respect to the structure geometry. This allows the longitudinal, transverse and vertical components to be calculated and appropriate load factors applied to each component.

F_{sc} is the horizontal component of the conductor tension in the longitudinal direction when subject to short circuit.

F_{tw} is the horizontal component of the conductor tension in the longitudinal direction when subject to design wind pressure.

F_{tm} is the horizontal component of the conductor tension in the longitudinal direction when subject to maintenance calculated for a wind pressure of 100 Pa.

F_{te} is the horizontal component of the conductor tension in the longitudinal direction when subject to no wind.

2.3.5 Load combinations

In the design of the structures, a range of loading conditions shall be considered that will provide due consideration for all possible service conditions that the structure may be subjected to throughout its service life.

The required load factors and load combinations to be used shall be in accordance with AS/NZS 1170 for general structures, and with Table 2.1. The most unfavourable load case(s) shall be used to determine the design of the structure.

The load factors given in AS/NZS 1170 and Table 2.1 reflect the uncertainty in the derivation of the particular load. The value of each load component shall be calculated separately for each loading condition.

For structures that support flexible conductors, the load components shall include the potential effects of differential tensions across the structure due to the effects of unequal spans and wind pressures that may exist at the structure.

TABLE 2.1
LOAD COMBINATIONS AND LOAD FACTORS

Loading condition	Load factors								
	Wind load W_u	S_y	G_s	G_c	F_{tm}	F_{tw}	F_{te}	F_{sc}	Q
Maximum wind (design wind pressure)	p_z (see Note 1)		1.1	1.25		1.25			
Everyday condition			1.1	1.25			1.1		
Snow and ice (see Note 6)	$100 P_a$	1.0	1.1	1.25		1.1			
Serviceability—Deflection limit (see Note 3)	$500 P_a$		1.1	1.1		1.0			
Serviceability—Damage limit (see Note 3)	$500 P_a$		1.1	1.1		1.0			
Maintenance	$100 P_a$		1.1	1.5 (see Note 2)	1.5 (see Note 2)				2.0
Seismic			1	1.3			1.25		
Short circuit	$0.25 p_z$		1.1	1.25			1.25 (see Note 5)	1.0 (see Note 4)	

NOTES:

- Design wind pressure p_z is derived from AS/NZS 1170. Loads from all wind directions to be considered.
- Conductor tensions and weight of conductors under maintenance shall be treated as a live load with a corresponding load factor.
- To be determined based on structure material and location (less flexibility may be required in some areas). The serviceability damage limit shall be used where the damage is of a ductile nature.
- This is the tension at no wind and with a short circuit.
- Tension F_{te} for conductors not in short circuit should be based on a temperature corresponding to everyday load conditions with a nominal wind pressure of 0.25 times the ultimate design wind pressure.
- See Appendix EE of AS/NZS 7000:2010 for further guidance.
- Due to the very dynamic nature of short circuit forces, they may be reduced from the foundation action calculations.

2.3.6 Deflections and serviceability limits

Ultimate and serviceability limit state loads shall be considered in determining structure deflections.

Under ultimate and normal service conditions, structure deflections shall not result in infringement of electrical clearances. Refer to Clauses 3.4 and 3.5 for clearance requirements details.

The serviceability damage limit loading conditions shall be used where the damage is of a ductile nature.

2.4 CLIMATIC AND ENVIRONMENTAL CONDITIONS

2.4.1 General

Installations, including all devices and auxiliary equipment that form an integral part of them, shall be designed for operation under the climatic and environmental conditions listed below.

The presence of condensation, precipitation, particles, dust, corrosive elements and hazardous atmospheres shall be specified in such a manner that appropriate electrical equipment can be selected. Zone classification for hazardous areas shall be performed in accordance with AS/NZS 60079.10.1 and AS/NZS 60079.10.2.

2.4.2 Normal conditions

2.4.2.1 Indoor

For indoor installations, normal conditions shall be as follows:

- (a) The ambient air temperature does not exceed 40°C and its average value, measured over a period of 24 h, does not exceed 35°C.

The minimum ambient air temperature is –5°C for Class ‘–5 indoor’, –15°C for Class ‘–15 indoor’ and –25°C for Class ‘–25 indoor’.

On auxiliary equipment, such as relays and control switches, intended to be used in ambient air temperature below –5°C, an agreement between supplier and user is necessary.

NOTE: In many parts of Australia, special service conditions apply (see Clause 2.4.3.4).

- (b) The influence of solar radiation may be neglected.
- (c) The altitude does not exceed 1000 m above sea level.
- (d) The ambient air is not significantly polluted by dust, smoke, corrosive and/or combustible gases, vapours or salt.
- (e) The average value of the relative humidity, measured over a period of 24 h, does not exceed 95%.

NOTES:

- 1 Condensation may occasionally occur. Condensation can be expected where sudden temperature changes occur in periods of high humidity.
- 2 To avoid breakdown of insulation and/or corrosion of metallic parts due to high humidity and condensation, equipment designed for such conditions and tested accordingly should be used.
- 3 Condensation may be prevented by special design of the building or housing, by suitable ventilation and heating of the station or by the use of dehumidifying equipment.
- 4 In many parts of Australia, special service conditions apply (see Clause 2.4.3.4).

- (f) Vibration due to causes external to the equipment or to earth tremors is negligible.
NOTE: In many parts of Australia, special service conditions apply (see Clauses 2.4.3.5 and 2.4.3.6).

- (g) Electromagnetic disturbances shall be considered as described in IEC Guide 107.

2.4.2.2 Outdoor

For outdoor installations, normal conditions shall be as follows:

- (a) The ambient air temperature does not exceed 40°C and its average value, measured over a period of 24 h, does not exceed 35°C.

The minimum ambient air temperature is –10°C for Class ‘–10 outdoor’, –25°C for Class ‘–25 outdoor’ and –40°C for Class ‘–40 outdoor’.

Rapid temperature changes shall be taken into account.

NOTE: Examples of rapid temperature changes are sudden drops in temperature of up to 20°C in a period of 20 min.

Auxiliary equipment, such as relays and control switches, intended to be used in ambient air temperatures below –5°C, shall be the subject of an agreement between supplier and user.

NOTE: In many parts of Australia, special service conditions apply (see Clause 2.4.3.4).

- (b) Maximum solar radiation does not exceed 1.1 kW/m² (equivalent to a black body temperature of 80°C).

NOTES:

- 1 Under certain conditions of solar radiation, appropriate measures, for example roofing, forced ventilation, etc., may be necessary, or derating may be used in order not to exceed the specified temperature rises.
- 2 Details of global solar radiation are given in IEC 60721-2-4.
- 3 UV radiation can damage some synthetic materials. For more details, see AS 60068.2.9.

- (c) The altitude does not exceed 1000 m above sea level.
- (d) The ambient air is not significantly polluted by dust, smoke, corrosive gases, vapours or salt. Pollution does not exceed pollution Class c—Medium, according to IEC/TS 60815-1.
- (e) The ice coating does not exceed 1 mm for Class 1, 10 mm for Class 10 and 20 mm for Class 20. Additional information is given in Clause 2.3.2.3(c).
- (f) The wind speed does not exceed the Region A 50 year average recurrence interval wind speed (see Clause 2.4.3.7).
- (g) Account shall be taken of the presence of condensation or precipitation. Precipitation in form of dew, condensation, fog, rain, snow, ice or hoar frost is to be taken into account.
NOTE: Precipitation characteristics for insulation are described in AS 1931.1 and AS 1824.1. For other properties, precipitation characteristics are described in IEC 60721-2-2.
- (h) Vibration due to causes external to the equipment or to earth tremors is negligible.
NOTE: In many parts of Australia, special service conditions apply (see Clauses 2.4.3.5 and 2.4.3.6).
- (i) Electromagnetic disturbances shall be considered as described in IEC Guide 107.

2.4.3 Special conditions

2.4.3.1 General

When high voltage equipment is used under conditions different from the normal environmental conditions given in Clause 2.4.2, the user's requirements shall refer to the standardized steps given in Clauses 2.4.3.2 to 2.4.3.7.

2.4.3.2 Altitude

For installations situated at an altitude higher than 1000 m above sea level, the insulation level of external insulation under the standardized reference atmospheric conditions shall be determined by multiplying the insulation withstand voltages required at the service location by a factor K_a in accordance with AS 62271.1.

NOTES:

- 1 For internal pressurized insulation, the dielectric characteristics are identical at any altitude and no special precautions need be taken.
- 2 For low voltage auxiliary and control equipment, no special precautions need be taken if the altitude is lower than 2000 m above sea level. For higher altitudes, see IEC 60664-1.
- 3 The pressure variation due to altitude is given in IEC 60721-2-3. Regarding this phenomenon, particular attention should be given to—
 - (a) thermal exchanges by convection, conduction or radiation;
 - (b) efficiency of heating or air-conditioning;
 - (c) operating level of pressure devices;
 - (d) efficiency of diesel generating set or compressed air station; and
 - (e) increase of corona effect.
- 4 The correction factor K_a of AS 62271.1 reflects the fact that modification is not required for altitudes below 1000 m.

2.4.3.3 Pollution

For equipment in polluted ambient air, a pollution class d (heavy), or class e (very heavy), as defined in IEC/TS 60815-1, shall be specified.

2.4.3.4 Temperature and humidity

For equipment in a place where the ambient temperature can be significantly outside the normal service condition range stated in Clause 2.4.2, the preferred ranges of minimum and maximum temperature to be specified should be as follows:

- (a) -50°C and $+40^{\circ}\text{C}$ for very cold climates.
- (b) -5°C and $+50^{\circ}\text{C}$ for very hot climates.

In certain regions with frequent occurrence of warm, humid winds, sudden changes of temperature may occur, resulting in condensation, even indoors.

In tropical indoor conditions, the average value of relative humidity measured during a period of 24 h can be 98%.

In some underground installations, equipment might be located under water. Such equipment shall be designed accordingly and proper operating procedures defined.

2.4.3.5 Vibration

Special conditions and requirements are the subject of agreement between user and supplier (see also Clause 2.4.3.6 for seismic loads).

Vibration caused by wind, electromagnetic stresses, traffic (e.g. temporary road and railway traffic) and industrial processes shall be considered. The withstand capability of equipment against vibrations shall be given by the manufacturer.

The service stresses of equipment, which may be transmitted through a common monolithic foundation or floor (e.g. opening/reclosing of circuit-breakers), shall be taken into account.

2.4.3.6 Seismic vibration

Installations situated in a seismic environment shall be designed to take this into account as defined in AS 1170.4. This shall be achieved by applying the following measures:

- (a) Any individual equipment shall be designed to withstand the dynamic forces resulting from the vertical and horizontal motions of the soil. These effects may be modified by the response of the foundation and/or the supporting frame and/or the floor in which this equipment is installed. The spectrum of the impulse earthquake shall be considered for the design of the equipment.
- (b) The layout shall be chosen in order to limit the following loads to acceptable values:
 - (i) Loads due to interconnections between adjoining devices needing to accommodate large relatively axial, lateral, torsional or other movements, bearing in mind that other stresses may develop during an earthquake.
 - (ii) The service stresses of equipment which may be transmitted through a common monolithic foundation or floor (for example, opening/reclosing of circuit-breakers).

Where load specifications apply to the installation of civil work or equipment to meet seismic conditions, then these specifications shall be observed.

2.4.3.7 The effect of wind

The effect of wind in excess of the Region A 50 year average recurrence interval wind speed shall be determined in accordance with AS/NZS 1170.2 for the particular location involved.

2.5 SPECIAL REQUIREMENTS

2.5.1 Effects of small animals and micro-organisms

If biological activity through birds (such as cockatoos), small animals, termites or micro-organisms is a hazard, measures against such damage shall be taken. These may include appropriate choice of materials, measures to prevent access and adequate heating and ventilating (for more details see IEC 60721-2-7).

2.5.2 Noise level

If noise level limits are given (usually by regulatory or administrative authorities), they shall be achieved by appropriate measures such as—

- (a) using sound attenuating enclosures or barriers;
- (b) using low noise equipment; and
- (c) providing sufficient distance to sensitive noise receptors.

Criteria for noise evaluation for different places and different periods of day are given in AS 1055.1.

NOTE: Consideration should be given to—

- (a) impact on the local environment (see environmental protection agencies guidelines);
- (b) impact on the working environment (local occupational health and safety guidelines); and
- (c) equipment noise (see AS/NZS 60076.10 for transformers).

2.5.3 Transport

Transport to site, e.g. large transformers, and storage constraints may have consequences on the design of the high-voltage electrical installation.

2.6 SITE SELECTION

HV installations range from simple pole mounted substations to major transmission installations. The selection of a suitable site will include many considerations and these will vary for each installation. This Clause provides the ideal site characteristics, and where these cannot be met, the basic design should be amended to provide mitigation for the undesirable features of the site.

The location should be near the load and appropriate electricity easements (for both cables and overhead lines), have appropriate land title or tenure, zoning and ordinance and compliance with national, state and local regulations.

The site should consider the impact of airborne pollution and the need for appropriate ventilation for indoor installations.

The proposed site should have space for future development, have minimum earth movement and disposal requirements, be able to be drained and be above the local flood level.

The site should have adequate access ways to allow safe operation, egress and maintenance activities.

The soil should be suitable for the construction of roads and foundations, preferably have low thermal and electrical resistivity and not have any contamination.

The topography should be a low slope with minimum cut to fill, not be located in or near earthquake zones, fault lines, flood paths or swamps.

Community requirements should be met including the following:

- (a) Special design consideration for sensitive sites such as schools, day care centres, preschools and swimming pools.
- (b) Have minimal visual, noise, amenity and traffic impacts.
- (c) Be sensitive to heritage and cultural issues.

Site selection should meet environmental requirements including increasing the run off from site, minimizing the impact on local fauna and flora, and not polluting the local environment. Consideration should also be given for any future vegetation control or soil treatment.

2.7 RISK MANAGEMENT

Asset owners, designers and others carry common law and legislative obligations to manage risks to health and safety of personnel. The following hierarchy of risk controls provide guidance on meeting these obligations:

- (a) Elimination of the hazard.
- (b) Minimization of the risk by the following means:
 - (i) Substitution (to get a lower hazard).
 - (ii) Isolation (from persons).
 - (iii) Engineering controls.
- (c) Administrative controls.
- (d) Personal protective equipment (PPE).

Elimination of the hazard is rarely an option given the utility/amenity involved. Minimizing the risk is non-trivial with fundamentally hazardous substances such as electricity. Duty of care is demonstrated when all reasonably practicable precautions have been taken. What is reasonably practicable includes a measure of the significance of the risk versus the effort required to reduce it. The risk that is assessed in this process includes the risk imposed on any individual (commonly determined for the maximally exposed, reasonably behaved individual) and for the risk imposed on society (commonly determined for multiple fatality risk for a single event). For further guidance on risk management see AS/NZS ISO 31000.

Nominal risk targets for hazards in HV installations, even those within levels recognized by the international safety industry as being 'safe' may not be sufficient to meet a duty of care obligation. It is, however, reasonable that all known and commonly applied precautions have been assessed, and applied so far as is reasonably practicable (SFAIRP) or as low as reasonably practicable (ALARP) where the cost/risk reduction is not grossly disproportionate. A risk target below the assessed mean risk for all other hazards across all asset classes of the enterprise could also be used to help decide when seeking further precautions for a particular hazard will no longer be required.

High voltage installations require a detailed quantitative risk assessment, based on industry or enterprise data including previous assessments. Realistic estimates of the associated cost increments are required to ensure the decision to not use a risk treatment, where the cost is disproportionate to the risk reduction, is soundly based.

SECTION 3 INSULATION

3.1 GENERAL

As conventional (air-insulated) installations are normally not impulse tested, the installation requires minimum clearances between live parts and earth and between live parts of phases in order to avoid flashover below the impulse withstand level selected for the installation.

Insulation coordination shall be in accordance with AS 1824, Parts 1 and 2.

For minimum phase-to-phase and phase-to-earth clearances required refer to Tables 3.1 and 3.2.

NOTES:

- 1 AS 1824.1 relates values for the highest voltage for equipment U_m to rated lightning impulse withstand voltages as well as rated short-duration power-frequency withstand voltages or rated switching impulse withstand voltages.
- 2 Standard nominal voltages for traction systems are also given in AS 60038. Other relevant values for traction systems can be interpolated from those in Table 3.1 of this Standard.

3.2 SELECTION OF INSULATION LEVEL

3.2.1 General

The insulation level shall be chosen according to the established highest voltage for equipment U_m and/or impulse withstand voltage.

3.2.2 Consideration of methods of neutral earthing

The choice should be made primarily to ensure reliability in service, taking into account the method of neutral earthing in the system and the characteristics and locations of overvoltage limiting devices to be installed.

In installations in which a high level of safety is required or in which the configuration of the system, due to the adopted method of neutral earthing or the protection by surge arresters, makes it appropriate to increase the level of insulation, one of the higher alternative values of Tables 3.1 and 3.2 shall be chosen.

In installations in which the configuration of the system, due to the adopted method of neutral earthing or the protection by surge arresters, makes it appropriate to lower the level of insulation, the lower alternative values of Tables 3.1 and 3.2 may be applied.

3.2.3 Consideration of rated withstand voltages

In the voltage Range I ($1 \text{ kV} < U_m \leq 245 \text{ kV}$) the choice shall be based on the rated lightning impulse withstand voltages and the rated short-duration power-frequency withstand voltages of Table 3.1.

In the voltage Range II ($U_m > 245 \text{ kV}$) the choice shall be based on the rated switching impulse withstand voltages (SIWV) and the rated lightning impulse withstand voltages given in Tables 3.1 or 3.2 for rod to structure and conductor to structure geometry respectively.

NOTE: The application of the safety clearances included in Tables 3.1 and 3.2 is discussed further in Clauses 5.1 and 5.2.

3.3 VERIFICATION OF WITHSTAND VALUES

If the minimum clearances in air given in Tables 3.1 and 3.2 are maintained, it is not necessary to apply dielectric tests to the air-gap.

If the minimum clearances in air are not maintained the ability to withstand the test voltages of the chosen insulation level shall be established by applying the appropriate dielectric tests in accordance with AS 1931.1 for the withstand voltage values given in Tables 3.1 and 3.2.

If the minimum clearances referenced in Tables 3.1 and 3.2 are not maintained in parts or areas of an installation, dielectric tests restricted to these parts or areas will be required.

3.4 MINIMUM CLEARANCES OF LIVE PARTS

3.4.1 General

The minimum clearances in air given in Tables 3.1 and 3.2 apply for altitudes up to 1000 m above sea level. For higher altitudes, see Clause 2.4.3.2.

NOTE: The values in Tables 3.1 and 3.2 have their origin primarily in AS 60038 and AS 1824.1.

If parts of an installation can be separated from each other by a disconnect, the parts shall be tested at the rated impulse withstand voltage for the isolating distance (see AS 62271.1). If between such parts of an installation the minimum phase-to-phase clearances of Table 3.1 for Range I, and Table 3.2 for Range II, in this Standard are increased by 25% or more, it is not necessary to apply dielectric tests.

3.4.2 Minimum clearances in voltage range I

In the voltage Range I (see Table 3.1), the minimum clearances in air are based on unfavourable electrode configurations with small radii of curvature (that is rod-plate or rod structure).

The minimum clearances in air between phases or between conductors of the same phase that are separable electrically from each other shall be at least 15% greater than the values given in Column 6 of Table 3.1 (for voltages up to and including $U_m = 245$ kV).

At $U_m > 245$ kV, phase-to-phase clearances may need to be more than 15% greater than phase-to-earth clearances.

3.4.3 Minimum clearances in voltage range II

In voltage Range II the clearances in air are determined by the rated SIWV. They depend substantially on the electrode configurations. Table 3.2 shows clearances for Range II voltages based on a conductor-structure geometry. In cases of difficulty in classifying the electrode configuration, it is recommended to make a choice based on the phase-to-earth clearances of the most unfavourable configuration, such as the arm of a disconnect against the tower construction (rod-structure). These clearances are shown for Range I and Range II voltage levels in Table 3.1. See also Figure 3.1.

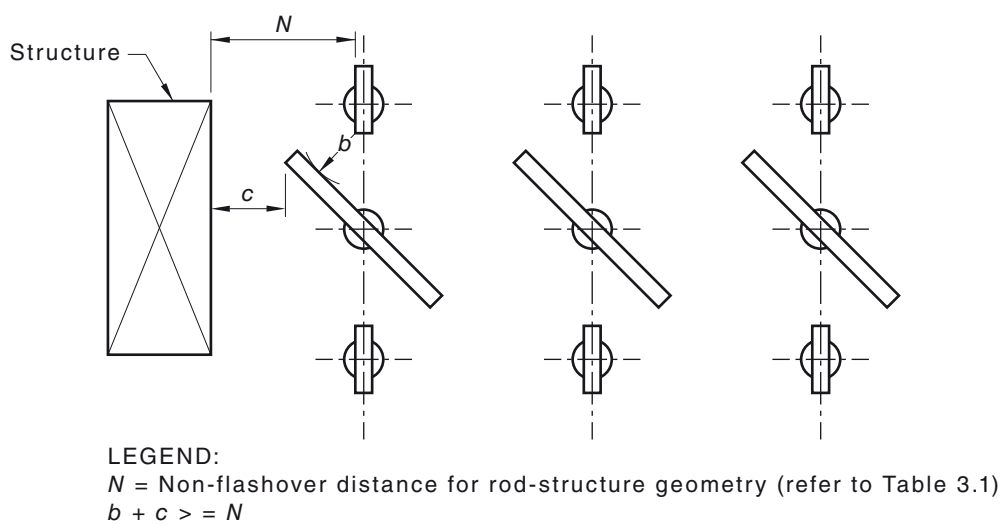


FIGURE 3.1 MINIMUM DISCONNECTOR CLEARANCES TO EARTH

TABLE 3.1

DESIGN AND SAFETY CLEARANCES ROD TO STRUCTURE/PLATE GEOMETRY (VOLTAGE RANGE I AND VOLTAGE RANGE II)

1	2	3	4	5	6	7	8	9	10	11	12
Nominal voltage U_n	Highest voltage U_m r.m.s. (see note 6)	Rated short duration power frequency withstand voltage U_d r.m.s.	Rated lightning impulse withstand voltage U_p 1.2/50 μ s (peak value)	Rated switching impulse withstand voltage U_s Phase-to-earth 250/2500 μ s (peak value)	Design clearances			Ground safety clearance G	Safety clearances for operational purposes and maintenance work		
					Minimum phase-to-earth clearance	Minimum phase-to-phase clearance	Non-flashover distance N		Section safety clearance $S = N + G$	Horizontal work safety clearance $H = N + 1900$	Vertical work safety clearance $V = N + 1340$
kV r.m.s.	kV r.m.s.	kV r.m.s.	kV peak	kV peak	mm	mm	mm	mm	mm	mm	mm
Up to 3.3	Up to 3.6	10	40		60	70	65	2440	2505	1965	1405
6.6	7.2	20	60		90	105	100		2540	2000	1440
11	12	28	75		120	140	130		2570	2030	1470
		28	(95)		(160)	185	175		2615	2075	1515
22	24	50	125		220	255	240		2680	2140	1580
		50	(145/150)		(270/280)	325	310		2750	2210	1650
33	36	70	170		320	370	350		2790	2250	1690
		70	(200)		(380)	440	420		2860	2320	1760
66	72.5	140	325		630	725	695		3135	2595	2035
110	123	185	450		900	1035	990		3430	2890	2330
		230	550		1100	1265	1210		3650	3110	2550

(continued)

TABLE 3.1 (continued)

1	2	3	4	5	6	7	8	9	10	11	12
Nominal voltage U_n	Highest voltage U_m r.m.s. (see note 6)	Rated short duration power frequency withstand voltage U_d r.m.s.	Rated lightning impulse withstand voltage U_p 1.2/50 μ s (peak value)	Rated switching impulse withstand voltage U_s Phase-to-earth 250/2500 μ s (peak value)	Design clearances			Ground safety clearance G	Safety clearances for operational purposes and maintenance work		
					Minimum phase-to-earth clearance	Minimum phase-to-phase clearance	Non-flashover distance N		Section safety clearance $S = N + G$	Horizontal work safety clearance $H = N + 1900$	Vertical work safety clearance $V = N + 1340$
kV r.m.s.	kV r.m.s.	kV r.m.s.	kV peak	kV peak	mm	mm	mm	mm	mm	mm	mm
132	145	230	550		1100	1265	1210		3650	3110	2550
		275	650		1300	1495	1430		3870	3330	2770
220	245	360	850		1700	1955	1800		4240	3700	3140
		395	950		1900	2185	2015		4455	3915	3355
		460	1050		2100	2415	2225		4665	4125	3565
275	300	395	950	750	1900	2600	2015		4455	3915	3355
		460	1050	850	2400	3100	2545		4985	4445	3885
330	362	460	1050	850	2400	3100	2545		4985	4445	3885
		510	1175	950	2900	3600	3075		5515	4975	4415
500	550	630	1425	1050	3400	4600	3605		6045	5505	4945
		680	1550	1175	4100	5000	4345		6785	6245	5685

NOTE: Refer to Notes following Table 3.2.

TABLE 3.2

DESIGN AND SAFETY CLEARANCES CONDUCTOR TO STRUCTURE GEOMETRY, $U_m > 245$ kV (VOLTAGE RANGE II)

1	2	3	4	5	6	7	8	9	10	11	12
Nominal voltage U_n	Highest voltage U_m r.m.s. (see Note 6)	Rated short duration power frequency withstand voltage U_d r.m.s.	Rated lightning impulse withstand voltage U_p 1.2/50 μ s (peak value)	Rated switching impulse withstand voltage U_s Phase-to-earth 250/2500 μ s (peak value)	Design clearances			Ground safety clearance G	Safety clearances for operational purposes and maintenance work		
					Minimum phase-to-earth clearance	Minimum phase-to-phase clearance	Non-flashover distance N'		Section safety clearance $S = N + G$	Horizontal work safety clearance $H = N + 1900$	Vertical work safety clearance $V = N + 1340$
kV r.m.s.	kV r.m.s.	kV r.m.s.	kV peak	kV peak	mm	mm	mm	mm	mm	mm	mm
275	300	395	950	750	1700	2300	1800	2440	4240	3700	3140
		460	1050	850	1900	2600	2015		4455	3915	3355
330	362	460	1050	850	1900	2600	2015		4455	3915	3355
		510	1175	950	2200	3100	2330		4770	4230	3670
500	550	630	1425	1050	2600	3900	2755		5195	4655	4095
		680	1550	1175	3100	4200	3285		5725	5185	4625

NOTES TO TABLES 3.1 AND 3.2

- 1 The clearances in Table 3.1 and 3.2 are based on the climatic conditions described in Clause 2.4.
- 2 The phase-to-earth clearances given in Column 6 of Table 3.1 are for unfavourable configurations of live and earthed parts, i.e. the 'rod-structure' arrangement, and may be used for determining clearances to earth from live parts of any configuration.
- 3 The phase-to-earth clearances given in Column 6 of Table 3.2 for $U_m > 245$ kV r.m.s. are for 'conductor-structure' configurations normally employed at the higher voltages. (For background information on electrode configurations, refer to CIGRE Technical Brochure 72-1992 and to AS 1824.2.)
- 4 The higher values shown in parentheses in Column 4 are included to cover those distribution installations that may be exposed to higher than normal overvoltages or where a higher level of safety or withstand is required. For other installations the lower values are preferred.
- 5 The values shown in parentheses in Column 6 correspond to the rated lightning impulse withstand voltages shown in parentheses in Column 4.
- 6 For $U_m < 36$ kV r.m.s., it may be desirable to increase the phase-to-earth and phase-to-phase clearances where the presence of birds or vermin could cause a hazard or for constructional or other reasons.
- 7 The non-flashover distances given in Column 8 include a margin of 10% up to an air clearance of 1300 mm in Column 6 and 6% for 1400 mm and above to allow for variations in construction dimensions. This margin may be deleted when the conditions for carrying out the work are adequate to ensure that the minimum phase-to-earth air clearance is observed in all cases.
- 8 If considered desirable, the section safety clearance given in Column 10 may be increased to 3000 mm as a minimum for air clearances up to 380 mm, in Column 6.
- 9 For voltages up to and including 245 kV (Range I), the minimum clearances in air between phases or between conductors of the same phase separable electrically from each other, are 15% greater than the corresponding Ph-E minimum clearances in Table 3.1 (refer to Clause 3.4.2 and AS 1824).
- 10 For voltages greater than 245 kV, because of the greater phase stresses that are present (>15%) due to switching impulses, the switching impulse withstand voltages (Ph-Ph) are between 1.5 to 1.8 times the Ph-E (pk) value than the corresponding Ph-Ph clearances listed in column 7 of Tables 3.1 and 3.2 (refer to Clause 3.4.2 and AS 1824).

3.5 MINIMUM CLEARANCES BETWEEN PARTS UNDER SPECIAL CONDITIONS

The minimum clearances between parts of an installation that may be subject to phase opposition shall be 20% higher than the values given in Tables 3.1 and 3.2.

The minimum clearances between parts of an installation, which are assigned to different insulation levels, shall be at least 125% of the clearances of the higher insulation level.

When conductors swing under the influence of short-circuit forces, 50% of the minimum clearances of Tables 3.1 and 3.2 shall be maintained as a minimum phase-to-phase and/or phase-to-earth clearance.

When conductors swing under the influence of wind, 75% of the minimum clearances of Tables 3.1 and 3.2 shall be maintained as a minimum phase-to-phase and/or phase to earth clearance.

In the event of rupture of one sub-chain in a multiple insulator chain, 75% of the minimum clearances of Tables 3.1 and 3.2 shall be maintained as a minimum phase-to-phase and/or phase-to-earth clearance.

If neither the neutral point nor a phase conductor is effectively earthed in an installation that is fed via auto transformers, the insulation of the lower voltage side shall be rated according to the highest voltage for equipment on the higher voltage side. Attention should be paid to neutral point insulation according to the method of neutral earthing.

3.6 TYPE TESTED EQUIPMENT

Information on mounting and service conditions supplied by the manufacturer shall be observed on-site.

NOTE: For type tested equipment, the minimum clearances according to Tables 3.1 and 3.2 need not be maintained because the ability to withstand the test voltage is established by a dielectric type test. See Clause 1.2.1.

SECTION 4 EQUIPMENT

4.1 GENERAL REQUIREMENTS

4.1.1 Selection

Equipment shall be selected and installed to satisfy the following requirements:

- (a) Safe physical arrangement when properly assembled, installed and connected to supply.
- (b) Safe and proper performance taking into account the external influences that can be expected at the intended location.
- (c) Safe and proper performance during normal operation and in the event of reasonably expected conditions of overload, abnormal operation and fault, without resulting in damage that would render the equipment unsafe.
- (d) Protection of personnel during use and maintenance of the equipment.

Consideration should be given to the whole-of-life costs and impact on the environment during normal operation use and end-of-life disposal.

4.1.2 Equipment Safety

All electrical equipment shall—

- (a) be safe to use when properly assembled, installed and connected to the supply in accordance with this Standard; and
- (b) not cause a danger from electric shock, fire, high temperature or physical injury in the event of reasonably expected conditions of overload, abnormal operation, and fault or external influences.

NOTE: Electrical equipment is deemed to comply with this Clause if it satisfies one or more of the following conditions:

- (a) The safe design, construction, installation and performance provisions of an Australian, New Zealand or Australian/New Zealand Standard that is appropriate and relevant to the type of electrical equipment.
- (b) The safe design, construction, installation and performance provisions of a recognized international or equivalent national Standard that is appropriate and relevant to the type of electrical equipment and to the electrical installation conditions in Australia.

Operational and safety procedures specific to a certain installation shall be in accordance with additional requirements specified by the user.

4.1.3 Personnel safety

Particular attention shall be given to the safety of personnel during the installation, operation and maintenance of equipment. Clear and adequate space shall be provided for the safe operation, isolation, earthing and manipulation of all switchgear including fuses.

Control of circuits shall be provided for the safe opening and closing of switchgear by appropriately trained and authorized personnel. Protective devices shall automatically disconnect under fault conditions to protect the operator.

Personnel safety measures may include—

- (a) manuals and instructions for transport, storage, installation, operation and maintenance;
- (b) special tools required for operation, maintenance and testing;

- (c) safe working and access procedures developed for specific locations (e.g. basement or other below ground indoor substations);
- (d) safe earthing measures; and
- (e) operating procedures, training and authorization for qualified operating personnel.

NOTE: Section 6 provides requirements for safety measures.

4.1.4 Labels

All labels required for the safe operation and maintenance of the equipment shall be provided and secured in a visible position adjacent to the means of operation when the equipment is mounted in its normal operating position.

Labels shall be indelibly and legibly marked in English and, including their fasteners, shall be suitable for the environment in which the equipment is mounted.

NOTE: Clause 5.1.8 specifies additional requirements for labelling.

4.2 SPECIFIC REQUIREMENTS

4.2.1 Switching devices

All high voltage circuits, including the incoming supply, shall be controlled by appropriate switching devices.

The switching device shall be capable of performing at least the following operational functions:

- (a) Make and break full load current.
- (b) Carry the prospective fault current.
- (c) Make prospective fault current.

Switches that are not capable of making prospective fault current may be used where satisfactory interlocking or switching procedures are provided.

A facility shall be provided to indicate the contact position of the interrupting or isolating equipment (including earthing switches). The method of indication in accordance with the equipment Standard should be specified by the user.

The position indicator shall provide an unambiguous indication of the actual position of the equipment primary contacts.

The device indicating the open/close position shall be easily visible to the operator.

Disconnectors and earthing switches shall be installed in such a way that they cannot be inadvertently operated by tension or pressure exerted manually on operating linkages.

Where specified by the user, interlocking devices and/or locking facilities shall be installed to provide a safeguard against inappropriate operation of either primary plant or control and protection devices.

If an interlocking device is provided that prevents the earthing switch from carrying the full short-circuit current, it is permissible, by agreement with the user, to specify a reduced rating for the switch that reflects its possible short-circuit-current stress.

Equipment shall be installed in such a way that ionized gas released during switching does not result in damage to the equipment or endanger operating personnel. 'Damage' is considered to be any failure of the equipment that impairs its function.

Ratings of switchgear shall be based on the AS/NZS 62271 series of high voltage standards. The switching of certain circuits may however require the use of more severe constraints than defined in those standards. Examples of such circuits are filter banks and loads having very high X/R ratios such as large transformers and generators. The specific requirements of switchgear for such circuits will be agreed between the user and supplier.

All switching equipment should be adequately rated for its intended use and not overstressed intentionally.

4.2.2 Power transformers and reactors

Unless otherwise stated, this Clause applies to both transformers and reactors even if only transformers are referred to in the text.

The main selection criteria for transformers are given in Section 2 and Section 6.

The transformers are classified taking into account the dielectric in contact with the winding and the type of internal or external cooling as described in AS/NZS 60076.2.

When designing the transformer or reactor installation, the possibility of fire propagation and explosion (see Clause 6.7) shall be considered. Similarly, means shall be implemented to limit, if necessary, the acoustic noise level (see Clause 2.5.2).

For transformers installed indoors, suitable ventilation shall be provided (see Clause 5.5.7).

Water (ground water, surface water and waste water) shall not be polluted by transformer installations. This shall be achieved by the choice of the design of transformer type and/or site provisions. For measures see Clause 6.7.

If it is necessary to take samples (oil sampling) or to read monitoring devices (such as fluid level, temperature, or pressure) which are important for the operation of the transformer whilst the transformer is energized, it shall be possible to perform this safely and without damage to the equipment.

Air-core reactors shall be installed in such a way that the magnetic field of the short-circuit current will not be capable of drawing objects into the coil. Adjacent equipment shall be designed to withstand the resulting electromagnetic forces. Adjacent metal parts such as foundation reinforcements, fences and earthing grids shall not be subject to excessive temperature rise under normal load conditions.

NOTE: Refer to Appendix D for additional information on EMF.

The risk of damage to transformers from overstresses resulting from ferroresonance, harmonics and other causes should be minimized by undertaking appropriate system studies and implementing appropriate control/protection measures.

Transformer pressure relief devices, if used, shall be arranged to direct the oil discharge downwards and away from the operational controls where personnel are likely to be standing.

4.2.3 Gas-insulated metal-enclosed equipment (GIE), metal-enclosed switchgear, insulation-enclosed switchgear and other prefabricated type-tested switchgear and fusegear assemblies

The requirements for gas insulated metal-enclosed switchgear (GIS), metal enclosed switchgear, insulation-enclosed switchgear and other prefabricated type-tested switchgear assemblies are given in Clause 5.4. For safety of personnel and gas handling, refer to Clauses 6.8.2 and 7.5.

Provision of suitable access shall be made for maintenance and testing of GIE, in particular, for indoor installations.

4.2.4 Instrument transformers

4.2.4.1 *General*

The secondary circuits of instrument transformers shall be bonded to earth, or the secondary circuits shall be segregated by earthed metallic screening, in accordance with Clause 8.2.3.

The earthable point of the secondary circuit shall be determined in such a way that electrical interference is avoided.

Instrument transformers shall be installed in such a way that their secondary terminals are easily accessible when the switchgear assembly has been de-energized.

4.2.4.2 *Current transformers*

The rated overcurrent factor and the rated burden shall be selected so as to ensure correct functioning of the protective equipment and prevent damage to measuring equipment in the event of a short-circuit.

In high voltage networks where the primary time constant is long and where reclosing is practiced, it is recommended that the transient stress due to the aperiodic portion of the short-circuit current be taken into account: the recommendations of IEC 61869-2 should be considered.

If measuring devices are also connected to protective current transformer cores, the measuring devices shall, if necessary, be protected against the damage resulting from large short-circuit currents by means of suitable auxiliary transformers.

If necessary, an effective screen between the primary and secondary circuit shall be provided for the reduction of the transient overvoltages on secondary circuits arising from the switching operation.

To protect against dangerous overvoltages, provisions shall be made to facilitate shorting the secondary windings of current transformers.

4.2.4.3 *Voltage transformers*

Voltage transformers shall be selected in such a way that the nominal output and accuracy are adequate for the connected equipment and wiring. The effects of ferroresonance shall be considered.

The secondary side of voltage transformers shall be protected against the effects of short-circuits, and it is recommended that protective devices be monitored.

4.2.5 Surge arresters

Surge arresters shall be designed or positioned in such a way as to provide personnel safety in case of breaking of the housing or operating of any pressure relief device.

The volt-time characteristics of surge arresters installed in the same circuit as current-limiting fuses shall take into account the overvoltages produced by the fuses.

If monitors are provided in the earth conductor of non-linear resistor type arresters, then the conductor between an arrester and the monitor and the monitor itself shall be protected to prevent it being touched. It shall be possible to read the monitors and any counters with the equipment energized.

4.2.6 Capacitors

The risk of resonance and overvoltages due to harmonics shall be taken into consideration, and appropriate means for limitation of this risk shall be provided.

For the selection of the nominal voltage and the current capacity of capacitors, the voltage increase caused by inductive reactances connected in series such as damping reactors and sound frequency or filter circuits shall be considered.

Capacitors for coupling, voltage measuring and overvoltage protection shall be selected according to the rated voltage of the switchgear, even if the operating voltage is lower.

Safe discharge of power capacitors shall be guaranteed. Discharge units shall be thermally and mechanically capable of carrying out their task.

The short-circuiting and earthing facilities provided for a capacitor bank shall take into account the interconnection of units within the bank, the discharge resistors and the type of fusing.

4.2.7 Line traps

The bandwidth should be determined in accordance with the network frequency allocation.

4.2.8 Insulators

Unless otherwise specified, the minimum specific creepage distance of insulators shall comply with IEC/TS 60815-1, IEC 60815-2 and IEC 60815-3 for the level of pollution specified by the user.

The requirements of the wet test procedure of AS 62271.1 shall apply for all external insulation.

Insulator profiles and/or requirements for performance of outdoor insulators in polluted or heavy wetting conditions may be specified by the user.

4.2.9 Insulated cables other than for overhead lines

4.2.9.1 General requirements

Insulated cable shall be selected to suit the electrical duty required plus the method of installation and related physical protection. Notwithstanding requirements of special service conditions in substations and industrial installations such as mine sites the following general principles apply for high voltage cables:

- (a) Cables installed underground in areas accessible to the public (within a high voltage installation) shall be buried at a depth which ensures the top of the cable is at least 0.75 m below the finished ground level. Mechanical protection and cable marking in accordance with AS/NZS 3000 shall be used. In areas where access is restricted to authorized personnel or substation area, other types of installation methods may be used, for example, cables trays, cable trenches, troughing, etc. For these installations appropriate mechanical protection shall be provided based on a risk assessment.
NOTE: Local regulations may require increased depth of burial or additional mechanical protection.
- (b) Fault-rated screened or armoured type cables may be installed above ground in robust enclosures. If the enclosure is metallic, it shall be appropriately earthed along its route.
- (c) Cables without a fault-rated screen or with partial screening may be used only within substations or within fully enclosed and earthed high voltage switchboards.

The current rating of a cable depends on the installation method (in conduit, direct buried, in air, grouping, earthing arrangement, cable sheath bonding, etc.). Cable ratings shall be determined by reference to manufacturer's information or in accordance with IEC 60287 (or AS/NZS 3008.1.1 for LV cables), which provides appropriate current derating factors that ensure the design conductor temperature is not exceeded. The current rating of buried cables may be increased by the use of appropriate backfill materials.

NOTE: Heating due to eddy currents should be considered in the design of metallic enclosures.

4.2.9.2 *Temperature*

Insulated cables shall be selected and laid in such a way that the maximum permitted temperature is not exceeded for conductors, their insulation, the connections, the equipment terminals or the surroundings under the following conditions:

- (a) Normal operation.
- (b) Special operating conditions, subject to previous agreement between the supplier and the user.
- (c) Short-circuit.

The connection of a cable to equipment (for example motors, circuit-breakers) shall not result in the cable being subjected to temperatures higher than those admissible for the cable in the foreseeable operating conditions.

Refer to IEC 60287, IEC 60853 and IEC TR 62095 regarding the current rating of cables.

4.2.9.3 *Stress due to temperature changes*

The stress on equipment due to temperature-dependent changes in the length of conductors shall be taken into account. If necessary, the stress shall be relieved by suitable measures (for example flexible connections, expansion terminations or snaking). If these measures are not taken, the additional forces due to temperature changes shall be taken into account during verification of the design strength of the equipment.

4.2.9.4 *Flexible reeling and trailing cables*

Flexible reeling and trailing cables shall be selected in accordance with the following requirements and conditions:

- (a) Trailing cables or cables having at least equivalent mechanical and electrical characteristics shall be used for supplying power to hoisting, mobile or moveable equipment.
- (b) In the case of more severe mechanical stress, for example where the cables are subject to abrasion, tension, deflection or winding during operation, double-sheathed trailing cables or cables with at least equivalent mechanical and electrical characteristics shall be used.
- (c) Insulated cables for the power supply of hoisting, mobile or moveable equipment shall contain a protective earth conductor.
- (d) The design of any connection, be it a joint, termination or other connection arrangement shall be such that in the event of a strain being placed upon the cable the protective earth conductor shall be the last to part or separate.
- (e) Insulated cables that are to be wound on a drum shall be dimensioned so that when the conductor is fully wound and subject to the normal service loading, the maximum permitted temperature is not exceeded.

The terminal ends of flexible and trailing cables shall be free from tension and compression; cable sleeves shall be protected against stripping and cable ends against twisting. The terminals shall also be designed so that the cables will not kink.

AS/NZS 2802 specifies requirements for reeling and trailing cables.

4.2.9.5 Crossings and proximities

Where insulated cables cross or are near to gas, water or other pipes, an appropriate clearance shall be maintained between cables and the pipelines. Where this clearance cannot be maintained, contact between the cables and the pipelines shall be prevented, for example, by the insertion of insulating shells or plates. These measures shall be coordinated with the operator of the pipeline. In the case of a long parallel routing, a calculation of the overvoltage induced on the pipeline during a short-circuit shall be performed. It may be necessary to determine appropriate measures to reduce the induced voltage, for example, an alternative routing for the cables or pipelines, or a greater clearance between cables and pipelines.

NOTE: AS 4853 provides guidance on electrical hazards on metallic pipelines.

Where insulated cables cross or are near to telecommunication installations, an appropriate clearance shall be maintained between cables and telecommunication installations.

In the case of a long parallel routing, the overvoltage induced on the telecommunication installation during a short-circuit shall be calculated. HB 100, HB 101, HB 102, HB 103 and AS/NZS 3835 provide guidance on electrical hazards on telecommunication installations. It may be necessary to take appropriate measures to reduce this overvoltage (alternative routing for the cables or the telecommunication installations, greater clearance between cables and telecommunication installations).

Where insulated cables cross or are near to other insulated cables, the mutual thermal effects shall be calculated in order to determine the minimum clearance between cables or to determine other appropriate measures to reduce mutual heating effects to acceptable levels, for example, derating. Cables shall be installed at a sufficient distance from heat sources or shall be separated from such heat sources by means of thermal insulating shields.

NOTE: National regulations and standards may have additional requirements for crossing and proximity of insulated cables, gas and water pipes or other pipes and appropriate clearances.

4.2.9.6 Installation of cables

Provision of suitable access shall be made for the maintenance and testing of cables.

To protect the cable from mechanical damage during and after installation, the following measures shall be taken:

- (a) The laying operations shall be performed at the ambient temperature specified by the equipment standards or the manufacturer.
- (b) Single-core insulated cables shall be laid in such a way as to ensure that the forces resulting from short-circuit currents do not cause damage.
- (c) The method of laying shall be chosen to ensure that the external effects are limited to acceptable safe values. In addition, when buried in troughs, the cables shall be installed at a specific depth and covered by slabs or a warning grid to prevent any damage being caused by third parties.

NOTE: Underground and submarine cables should be mechanically protected where they emerge from the water or the soil.

- (d) Laying of cables in earth shall be carried out on the bottom of a cable trench free of stones. The bedding material shall be sand or soil, free of stones.

NOTE: Special constructions of cables may be chosen, if necessary, to protect against chemical effects.

- (e) Measures shall be taken to prevent cables in troughs from being damaged by vehicles running over them.
- (f) Ground movements and vibrations shall be taken into account.

- (g) For vertical installations the cable shall be supported by suitable cleats at intervals determined by the cable construction and information provided by the manufacturer.
- (h) If single-core cables are laid through reinforced ceilings and walls the possibility of heating the steel reinforcing bars must be considered. If necessary, suitable structural measures to limit the heating must be determined.
- (i) Insulated cables installed as overhead lines shall comply with the requirements of AS/NZS 7000.

AS/NZS 3013 provides guidance for mechanical and fire protection for cables.

Cables installed in metallic pipes shall be grouped in such a way that the conductors of all phases (and the neutral, if any) of the same circuit are laid in the same pipe to minimize eddy currents. Consideration should be given to the location of the earthing conductor.

Insulated cables shall be installed so that touch voltages are within the permissible values, or so that accessible parts with unacceptable touch voltages are protected against contact by adequate measures.

Metallic sheaths shall be earthed.

NOTES:

- 1 There may be a risk of high circulating currents in screens of sheathed single-core cables, especially when laid flat.
- 2 When earthing metallic screens and sheaths consideration should be given to issues such as circulating currents, induced voltages, fault ratings, transfer voltages and current transformer locations.

The length of cable connecting transformers and reactors to a circuit should be selected so as to minimize the occurrence of ferroresonance.

Care shall be taken to limit the mechanical stress on equipment when connecting power cables.

The position of cable risers should be such that personnel access is not impeded by the need to remove plant and equipment or be located within an area classified as hazardous or a confined space.

4.2.9.7 Bending radius

The minimum values of bend radius during and after installation are dependent on the type of cable. These are given in the relevant standards or shall be specified by the manufacturer.

4.2.9.8 Tensile stress

The maximum permissible tensile stress during laying depends on the nature of the conductor and on the type of cable. These are given in the relevant standards or shall be specified by the manufacturer.

The continuous static and peak tensile stress applied to the conductors of flexible and trailing cables shall be as small as possible, and shall not exceed the values given by the manufacturer.

4.2.10 Conductors and accessories

This Clause deals with conductors (rigid or flexible) and accessories which are part of outgoing feeders or busbars in installations.

Covered and bare conductors installed as overhead lines shall comply with relevant standards for overhead lines (refer to AS/NZS 7000).

Where conductors and accessories are directly associated with a circuit-breaker, fuse-switch or switch, the value and duration of the rated short-time withstand current of the conductors and accessories shall be not less than the design rating of the installation.