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Requirements for electrical installations

Part 5: **Selection and Erection of Equipment**

First Edition 2026

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Requirements for electrical installations

Part 5: **Selection and Erection of the Electrical Equipment**

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Foreword

This Kenya Standard was prepared by the Electrical Installations and Distribution Systems Technical Committee under the guidance of the Standards Projects Committee, and it is in accordance with the procedures of the Kenya Bureau of Standards.

Kenya Bureau of Standards (KEBS) has established Technical Committees (TCs) mandated to develop Kenya Standards (KS). The Committees are composed of representatives from the public and private sector organizations in Kenya.

Kenya Standards are developed through Technical Committees that are representative of key stakeholders including government, academia, consumer groups, private sector and other interested parties. Draft Kenya Standards are circulated to stakeholders through the KEBS website and notifications to World Trade Organization (WTO). The comments received are discussed and incorporated before finalization of the standards, in accordance with the Procedures for Development of Kenya Standards.

Kenya Standards are subject to review, to keep pace with technological advances. Users of the Kenya Standards are therefore expected to ensure that they always have the latest versions of the standards they are implementing.

The development of the **First Edition** of this standard is based on BS 7671:2018 (18th Edition) with its several amendments and the different parts of IEC 60364 and is split into the following parts:

Part 1, Scope, object and fundamental principles.

Part 2. Definitions.

Part 3. Assessment of general characteristics. Part 4: Protection for safety.

Part 5. Selection and erection of electrical equipment.

Part 6. Verification.

Part 7. Requirements for special installations or locations.

These parts are in line with those of IEC 60364.

During the preparation of this standard, reference was made to the following documents:

IEC 60364 (All parts): Low-voltage installations.

BS 7671. (18th Edition) Requirements for electrical installations. Acknowledgement is hereby made for

the assistance derived from these sources.

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Scope

This part of KS 662 ensures that electrical systems are designed and installed with safety in mind, preventing electrical hazards like overcurrent, fault currents, and fire risks. It includes a comprehensive set of guidelines for wiring methods, protection, earthing, bonding, and inspection to ensure a safe, effective, and compliant electrical installation.
It provides common rules for compliance with measures of protection for safety, requirements for proper functioning for intended use of the installation, and requirements appropriate to the external influences.

Normative References

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part 6 of this standard. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of this standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60073: Basic and safety principles for man-machine interface, marking and identification - Coding principles for indicators and actuators
IEC 60447: Basic and safety principles for man-machine interface, marking and identification - Actuating principles
KS IEC 60684: Flexible insulating sleeving
IEC 60617: Graphical symbols for diagrams
IEC 60364: Low-voltage electrical installations
KS IEC 61000: Electromagnetic compatibility (EMC)
IEC 61535: Installation couplers intended for permanent connection in fixed installations
KS IEC 61439-6: Low-voltage switchgear and controlgear assemblies – Part 6: Busbar trunking systems (busways)
IEC 61534: Powertrack systems.
KS IEC 61386: Conduit systems for cable management.
IEC 61084: Cable trunking systems and cable ducting systems for electrical installations
IEC 61537: Cable management - Cable tray systems and cable ladder systems
KS IEC 60670-22: Boxes and enclosures for electrical accessories for household and similar fixed electrical installations - Part 22: Particular requirements for connecting boxes and enclosures
KS IEC 62821- Electric Cables
KS IEC 60529: Degrees of protection provided by enclosures (IP Code)
IEC 60702-1: Mineral insulated cables and their terminations with a rated voltage not exceeding 750 V - Part 1: Cables
KS IEC 61386-21: Conduit systems for cable management - Part 21: Particular requirements - Rigid conduit systems
KS IEC 61386-24: Conduit systems for cable management - Part 24: Particular requirements - Conduit systems buried underground
KS IEC 60502-1: Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV) - Part 1: Cables for rated voltages of 1 kV (Um = 1,2 kV) and 3 kV (Um = 3,6 kV)
KS IEC 60287: Electric cables

KS IEC 60947-7: Low-voltage switchgear and controlgear - Part 7-1: Ancillary equipment - Terminal blocks for copper conductors
KS IEC 60998: Connecting devices for low-voltage circuits for household and similar purposes - Part 1: General requirements
IEC 61535: Installation couplers intended for permanent connection in fixed installations
IEC 63172: Electrical accessories - Methodology for determining the energy efficiency class of electrical accessories
ISO 1182, titled "Reaction to fire tests for products – Non-combustibility test
KS IEC 60332-1-2: Tests on electric and optical fibre cables under fire conditions - Part 1-2: Test for vertical flame propagation for a single insulated wire or cable - Procedure for 1 kW pre-mixed flame
KS IEC 60332-3: Tests on electric and optical fibre cables under fire conditions
KS IEC 61386: Conduit systems for cable management
KS IEC 61439-6: Low-voltage switchgear and controlgear assemblies - Part 6: Busbar trunking systems (busways)
KS IEC 62305: Protection against lightning
IEC 60364-4-41 – Low-voltage electrical installations – Protection for safety – Protection against electric shock
IEC 60364-5-52 – Electrical installations of buildings – Part 5-52: Selection and
KS ISO 8100 series: Lifts for the transport of persons and goods
IEC 62208: Empty enclosures for low-voltage switchgear and controlgear assemblies - General requirements
IEC 60669-2-1: Switches for household and similar fixed electrical installations – Part 2-1: Particular requirements – Electronic switches.
IEC 60947-2: Low-voltage switchgear and controlgear - Part 2: Circuit-breakers
IEC /TR 62350: Guidance for the correct use of residual current-operated protective devices (RCDs) for household and similar use
IEC 62423: Type F and type B residual current operated circuit-breakers with and without integral overcurrent protection for household and similar uses
IEC 62020: Electrical accessories - Residual current monitors (RCMs)
IEC /TR 61641: Enclosed low-voltage switchgear and controlgear assemblies - Guide for testing under conditions of arcing due to internal fault
IEC 62606: General requirements for arc fault detection and protection devices (AFDDs)
IEC 60269: Low-voltage fuses
IEC 60269: Low-voltage fuses
IEC 60947: Low-voltage switchgear and controlgear
IEC HD 60269-2 : Low-voltage fuses - Part 2: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application) - Examples of standardized systems of fuses A to K
IEC HD 60269-3: Low-voltage fuses - Part 3: Supplementary requirements for fuses for operation by unskilled persons (fuses mainly for household and similar applications) - Examples of standardized systems of fuses A to F
IEC 61643: Low-voltage surge protective devices
IEC 61095: Electromechanical contactors for household and similar purposes
IEC 60947-3: Low-voltage switchgear and controlgear - Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units
IEC 60669-2-4: Switches for household and similar fixed electrical installations - Part 2-4: Particular requirements - Isolating switches
IEC 60947-6-1: Low-voltage switchgear and controlgear - Part 6-1: Multiple function equipment - Transfer switching equipment
IEC 60669-2-2: Switches for household and similar fixed electrical installations - Part 2-2: Particular requirements - Electromagnetic remote-control switches (RCS)
IEC 60669: Switches for household and similar fixed electrical installations.

IEC 60669-2-6 : Switches for household and similar fixed electrical installations - Part 2-6: Particular requirements - Fireman's switches for exterior and interior signs and luminaires
IEC 61557-8: Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. - Equipment for testing, measuring or monitoring of protective measures - Part 8: Insulation monitoring devices for IT systems
IEC 60269-1: Low-voltage fuses - Part 1: General requirements
IEC 60364-5-54: Low-voltage electrical installations - Part 5-54: Selection and erection of electrical equipment - Earthing arrangements and protective conductors
IEC 60949: Calculation of thermally permissible short-circuit currents, taking into account non-adiabatic heating effects
IEC 61557: Electrical safety in low voltage distribution systems up to 1 000 V AC and 1 500 V DC - Equipment for testing, measuring or monitoring of protective measures
IEC 60309-2: Plugs, fixed or portable socket-outlets and appliance inlets for industrial purposes - Part 2: Dimensional compatibility requirements for pin and contact-tube accessories
IEC 61727:2004: Photovoltaic (PV) systems – Characteristics of the utility interface.
IEC 60309: Plugs, fixed or portable socket-outlets and appliance inlets for industrial purposes
KS EAS 495: 13 A plugs, socket-outlets, adaptors and connection units
IEC 61558-2-5: Safety of transformers, reactors, power supply units and combinations thereof - Part 2-5: Particular requirements and tests for transformers for shavers, power supply units for shavers and shaver supply units
IEC 60320-1: Appliance couplers for household and similar general purposes - Part 1: General requirements
IEC 60332-1-1:Tests on electric and optical fibre cables under fire conditions - Part 1-1: Test for vertical flame propagation for a single insulatedwire or cable - Apparatus
IEC 60598-2-14: Luminaires – Part 2-14: Particular requirements – Luminaires for cold cathode tubular discharge lamps (neon tubes) and similar equipment,
IEC 60570: Electrical supply track systems for luminaires
IEC 61995: Devices for the connection of luminaires for household and similar purposes
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IEC 61995-1: Devices for the connection of luminaires for household and similar purposes - Part 1: General requirements
IEC 60598: Luminaires
IEC 61995: Devices for the connection of luminaires for household and similar purposes
IEC 60884-1: Plugs and socket-outlets for household and similar purposes – Part 1: General requirements
IEC 61048: Auxiliaries for lamps - Capacitors for use in tubular fluorescent and other discharge lamp circuits - General and safety requirements
IEC 60598-2-13: Luminaires - Part 2-13: Particular requirements - Ground recessed luminaires
IEC 60623: Secondary cells and batteries containing alkaline or other non-acid electrolytes - Vented nickel-cadmium prismatic rechargeable single cells
IEC 62040-1: Uninterruptible power systems (UPS) - Part 1: Safety requirements
IEC 62040-3: Uninterruptible power systems (UPS) - Part 3: Method of specifying the performance and test requirements
IEC 60702-2 : Mineral insulated cables and their terminations with a rated voltage not exceeding 750 V - Part 2: Terminations
IEC 60331-2 : Tests for electric cables under fire conditions - Circuit integrity - Part 2: Test method for fire with shock at a temperature of at least 830°C for cables of rated voltage up to and including 0,6/1,0 kV and with an overall diameter not exceeding 20mm

IEC 60331-3 : Tests for electric cables under fire conditions - Circuit integrity - Part 3: Test method for fire with shock at a temperature of at least 830°C for cables of rated voltage up to and including 0,6/1,0 kV tested in a metal enclosure

IEC 60228: Conductors of insulated cables

IEC 60331-1: Tests for electric cables under fire conditions - Circuit integrity - Part 1: Test method for fire with shock at a temperature of at least 830°C for cables of rated voltage up to and including 0,6/1,0 kV and with an overall diameter exceeding 20 mm
IEC 60269: Low-voltage fuses.
KS IEC 61386-24: Conduit systems for cable management – Part 24: Particular requirements – Conduit systems buried underground.
KS IEC 60287: Electric cables
IEC 60721: Classification of environmental conditions
IEC 60038:1983, IEC standard voltages
IEC 60664-1:1992, Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests
IEC 61008: Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs)
IEC 61009: Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs)
IEC 60947-4-1: Low-voltage switchgear and controlgear - Contactors and motor-starters - Electromechanical contactors and motor-starters
IEC 60898: Electrical accessories - Circuit-breakers for overcurrent protection for household and similar installations
IEC 61557-9: Electrical safety in low voltage distribution systems up to 1 000 V AC and 1 500 V DC - Equipment for testing, measuring or monitoring of protective measures - Equipment for insulation fault location in IT systems
IEC 61184: Bayonet lampholders
IEC 60238: Edison screw lampholders
IEC 60079-14: Explosive atmospheres - Part 14: Electrical installation design, selection and installation of equipment, including initial inspection
IEC 60598-2-24: Luminaires - Part 2-24: Particular requirements - Luminaires with limited surface temperatures
IEC 60204: Safety of machinery - Electrical equipment of machines
KS KS IEC 60287-Electric cables - Calculation of the current rating Part 1-1: Current rating equations (100 % load factor) and calculation of losses – General

PART 5

SELECTION AND ERECTION OF EQUIPMENT

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CHAPTER 51: COMMON RULES

510 INTRODUCTION

510.1 General

This chapter deals with the selection of equipment and its erection. It provides common rules for compliance with measures of protection for safety, requirements for proper functioning for intended use of the installation, and requirements appropriate to the external influences.

510.2 Every item of equipment shall be selected and erected so as to allow compliance with the Section s stated in this chapter and the relevant Section s in other parts of KS 662 and shall take account of manufacturers' instructions.

511 COMPLIANCE WITH STANDARDS

511.1 Every item of equipment shall comply with the relevant requirements of the applicable Kenyan Standard, appropriate to the intended use of the equipment. The edition of the standard shall be the current edition, with those amendments pertaining at a date to be agreed by the parties to the contract concerned (see Appendix 1).

Alternatively, if equipment complying with a foreign national standard based on an IEC Standard is to be used, the designer or other person responsible for specifying the installation shall verify that any differences between that standard and the corresponding Kenyan Standard will not result in a lesser degree of safety than that afforded by compliance with the Kenyan Standard. Such use shall be recorded on the appropriate electrical certification specified in Part 6.

511.2 Where equipment to be used is not covered by a Kenya Standard or is to be used outside the scope of its standard, the designer or other person responsible for specifying the installation shall confirm that the equipment provides at least the same degree of safety as that afforded by compliance with the Section s. Such use shall be noted and appended to the appropriate documentation specified in Part 6.

512 OPERATIONAL CONDITIONS AND EXTERNAL INFLUENCES

512.1 Operational conditions

512.1.1 Voltage

Every item of equipment shall be suitable for the nominal voltage (U_0) of the installation or the part of the installation concerned, where necessary taking account of the highest and/or lowest voltage likely to occur in normal service. In an IT system, equipment shall be insulated for the nominal voltage between lines.

512.1.2 Current

Every item of equipment shall be suitable for:

(i) the design current, taking into account any capacitive and inductive effects, and

(ii) the current likely to flow in abnormal conditions for such periods of time as are determined by the characteristics of the protective devices concerned.

512.1.3 Frequency

If frequency has an influence on the characteristics of the equipment, the rated frequency of the equipment shall correspond to the nominal frequency of the supply to the circuit concerned.

512.1.4 Power

Every item of equipment selected on the basis of its power characteristics shall be suitable for the duty demanded of the equipment.

512.1.5 Compatibility

Every item of equipment shall be selected and erected so that it will neither cause harmful effects to other equipment nor impair the supply during normal service including switching operations.

Switchgear, protective devices, accessories and other types of equipment shall not be connected to conductors intended to operate at a temperature exceeding 70 °C at the equipment in normal service unless the equipment manufacturer has confirmed that the equipment is suitable for such conditions, or the conductor size shall be chosen based on the current ratings for 70 °C cables of a similar construction. See also Section 523.1 and Table 4A3.

The designer of the fixed installation shall verify that the installed fixed equipment, where relevant, is designed and manufactured in accordance with EMC Directive 2014/30/EU and, upon request, the responsible person for the fixed installation shall provide the required documentation as specified by EMC Directive 2014/30/EU.

NOTE 1: Information on the parameters to be considered is given in Section 444. The level of detail of the documentation may vary from very simple information to much more detailed documentation for complex installations involving important potential EMC aspects.

NOTE 2: The responsible person referred to in this Section is as defined in the relevant national legislation implementing EMC Directive 2014/30/EU. In the UK, this is the Electromagnetic Compatibility Section s 2016. The responsible person is the installer.

NOTE 3: Where installations are composed solely of CE-marked equipment placed on the market in conformity with the EMC Directive, the responsible person satisfies the documentation requirements by being able to provide, on request, the instructions for installation, use and maintenance provided by the supplier of each item of equipment.

NOTE 4: Where the current rating is to be based on 70 °C, current-carrying capacities given in Tables 4D1 to 4D5 or 4H1 to 4H4 of Appendix 2 may be used for 90 °C thermosetting insulated cables.

512.1.6 Impulse withstand voltage

Equipment shall be selected so that its impulse withstand voltage is at least equal to the required minimum impulse withstand voltage according to the overvoltage category at the point of installation as defined in Section 443.

512.2 External influences

512.2.1 Equipment shall be of a design appropriate to the situation in which it is to be used or its mode of installation shall take account of the conditions likely to be encountered.

512.2.2 If the equipment does not, by its construction, have the characteristics relevant to the external influences of its location, it may nevertheless be used on condition that it is provided with appropriate additional protection in the erection of the installation. Such protection shall not adversely affect the operation of the equipment thus protected.

512.2.3 Where different external influences occur simultaneously, they may have independent or mutual effects and the degree of protection shall be provided accordingly.

512.2.4 The selection of equipment according to external influences is necessary not only for proper functioning, but also for the reliability of the measures of protection for safety complying with these Section s generally. Measures of protection afforded by the construction of equipment are valid only for the given conditions of external influence if the corresponding equipment specification tests are made in these conditions of external influence.

NOTE: For the purpose of these Section s, the following classes of external influence are conventionally regarded as normal:

AA Ambient temperature	AA4
AB Atmospheric humidity	AB4
Other environmental conditions (AC to AS)	XX1 of each parameter
Utilization and construction of buildings (B and C)	{ XX1 of each parameter, except XX2 for the parameter BC

513 ACCESSIBILITY

513.1 Except for a joint in cables where Section 526 allows such a joint to be inaccessible, every item of equipment shall be arranged so as to facilitate its operation, inspection and maintenance and access to each connection. Such facility shall not be significantly impaired by mounting equipment in an enclosure or a compartment.

514 IDENTIFICATION AND NOTICES

514.1 General

514.1.1 Except where there is no possibility of confusion, a label or other suitable means of identification shall be provided to indicate the purpose of each item of switchgear and controlgear. Where the operator cannot observe the operation of switchgear and controlgear and where this might lead to danger, a suitable indicator complying, where applicable, with IEC 60073and IEC 60447, shall be fixed in a position visible to the operator.

514.1.2 So far as is reasonably practicable, wiring shall be so arranged or marked that it can be identified for inspection, testing, repair or alteration of the installation.

514.1.3 Except where there is no possibility of confusion, unambiguous marking shall be provided at the interface between conductors identified in accordance with these Section s and conductors identified to previous versions of the Section s.

NOTE: Appendix 7 gives guidance on how this can be achieved.

514.2 Not used

514.3 Identification of conductors

514.3.1 Except where identification is not required by Section 514.6, cores of cables shall be identified by:

(i) colour as required by Section 514.4 and/or

(ii) letters and/or numbers as required by Section 514.5.

514.3.2 Every core of a cable shall be identifiable at its terminations and preferably throughout its length. Binding and sleeves for identification purposes shall comply with KS IEC 60684 where appropriate.

514.4 Identification of conductors by colour

514.4.1 Neutral or midpoint conductor

Where a circuit includes a neutral or midpoint conductor identified by colour, the colour used shall be blue.

514.4.2 Protective conductor

The bi-colour combination green-and-yellow shall be used exclusively for identification of a protective conductor and this combination shall not be used for any other purpose. In this combination one of the colours shall cover at least 30 % and at most 70 % of the surface being coloured, while the other colour shall cover the remainder of the surface.

Single-core cables identified by green-and-yellow throughout their length shall only be used as a protective conductor and shall not be overmarked at their terminations, except as permitted by Section 514.4.3.

A bare conductor or busbar used as a protective conductor shall be identified, where necessary, by equal green-and-yellow stripes, each not less than 15 mm and not more than 100 mm wide, close together, either throughout the length of the conductor or in each compartment and unit and at each accessible position.

514.4.3 PEN conductor

A PEN conductor shall, when insulated, be marked by one of the following methods:

(i) Green-and-yellow throughout its length with, in addition, blue markings at the terminations

(ii) Blue throughout its length, with green-and-yellow markings at the terminations.

514.4.4 Other conductors

Other conductors shall be identified by colour in accordance with Table 51.

514.4.5 The single colour green shall not be used for the identification of:

(i) live conductors in power circuits

(ii) protective conductors

(iii) functional earthing and bonding conductors.

514.4.6 Bare conductors

A bare conductor shall be identified, where necessary, by the application of tape, sleeve or disc of the appropriate colour prescribed in Table 51 or by painting with such a colour.

514.5 Identification of conductors by letters and/or numbers

514.5.1 The lettering or numbering system applies to identification of individual conductors and of conductors in a group. The identification shall be clearly legible and durable. All characters shall be in strong contrast to the colour of the insulation. The identification shall be given in letters and/or Arabic numerals. In order to avoid confusion, unattached numerals 6 and 9 shall be underlined.

514.5.2 Protective conductor

Conductors with green-and-yellow colour identification shall not be numbered other than for the purpose of circuit identification.

514.5.3 Alphanumeric

The preferred alphanumeric system is described in Table 51.

514.5.4 Numeric

Conductors may be identified by numbers, the number 0 being reserved for the neutral or midpoint conductor.

514.6 Omission of identification by colour or marking

514.6.1 Identification by colour or marking is not required for:

(i) concentric conductors of cables

(ii) metal sheath or armour of cables when used as a protective conductor

(iii) bare conductors where permanent identification is not practicable

(iv) extraneous-conductive-parts used as a protective conductor

(v) exposed-conductive-parts used as a protective conductor.

TABLE 51 – Identification of conductors

Function	Alphanumeric	Colour
Protective conductors		Green-and-yellow
Functional earthing conductor		Cream
AC power circuit (1)		
Line of single-phase circuit	L	Brown
Neutral of single- or three-phase circuit	N	Blue
Line 1 of three-phase AC circuit	L1	Brown
Line 2 of three-phase AC circuit	L2	Black
Line 3 of three-phase AC circuit	L3	Grey
Two-wire unearthed DC power circuit		
Positive of two-wire circuit	L+	Brown
Negative of two-wire circuit	L-	Grey
Two-wire earthed DC power circuit		
Positive (of negative earthed) circuit	L+	Brown
Negative (of negative earthed) circuit(2)	M	Blue
Positive (of positive earthed) circuit(2)	M	Blue
Negative (of positive earthed) circuit	L-	Grey
Three-wire DC power circuit		
Outer positive of two-wire circuit derived from three-wire system	L+	Brown
Outer negative of two-wire circuit derived from three-wire system	L-	Grey
Positive of three-wire circuit	L+	Brown
Mid-wire of three-wire circuit(2)(3)	M	Blue
Negative of three-wire circuit	L-	Grey
Control circuits, ELV and other applications		
Line conductor	L	Brown, Black, Red, Orange, Yellow, Violet, Grey, White, Pink or Turquoise
Neutral or mid-wire(4)	N or M	Blue

NOTE: (1) Power circuits include lighting circuits.
(2) M identifies either the mid-wire of a three-wire DC circuit, or the earthed conductor of a two-wire earthed DC circuit.
(3) Only the middle wire of three-wire circuits may be earthed.
(4) An earthed PELV conductor is blue.

514.7 Not used

514.8 Identification of a protective device

514.8.1 A protective device shall be arranged and identified so that the circuit protected may be easily recognized.

514.9 Diagrams and documentation

514.9.1 A legible diagram, chart or table or equivalent form of information shall be provided indicating in particular:

(i) the type and composition of each circuit (points of utilization served, number and size of conductors, type of wiring), and

(ii) the method used for compliance with Section 410.3.2, and

(iii) the information necessary for the identification of each device performing the functions of protection, isolation and switching, and its location, and

(iv) any circuit or equipment vulnerable to the electrical tests as required by Part 6.

For simple installations the foregoing information may be given in a schedule. A durable copy of the schedule relating to a distribution board shall be provided within or adjacent to each distribution board.

Any symbol used shall comply with IEC 60617.

514.10 Warning notice: voltage

514.10.1 Every item of equipment or enclosure within which a nominal voltage exceeding 230 volts to earth exists and where the presence of such a voltage would not normally be expected, shall be so arranged that before access is gained to a live part, a warning of the maximum voltage to earth present is clearly visible.

514.11 Warning notice: isolation

514.11.1 A notice of such durable material as to be likely to remain easily legible throughout the life of the installation shall be fixed in each position where there are live parts which are not capable of being isolated by a single device. The location of each disconnector (isolator) shall be indicated unless there is no possibility of confusion.

514.12 Notices: periodic inspection and testing

514.12.1 A notice of such durable material as to be likely to remain easily legible throughout the life of the installation shall be fixed in a prominent position at or near the origin of every installation upon completion of the work carried out in accordance with Chapter 64 or 65. The notice shall be inscribed in indelible characters not smaller than those illustrated here and shall read as follows:

IMPORTANT
This installation should be periodically inspected and tested and a report on its condition obtained, as prescribed in the Kenyan standard KS 662:Requirements for Electrical Installations.
Date of last inspection ....
Recommended date of next inspection ....

514.12.2 Where an installation incorporates an RCD a notice shall be fixed in a prominent position at or near each RCD in the installation. The notice shall be inscribed in indelible characters not smaller than those illustrated here and shall read as follows:

> This installation, or part of it, is protected by a device which automatically switches off the supply if an earth fault develops. Test six-monthly by pressing the button marked 'T' or 'Test'. The device should switch off the supply and should then be switched on to restore the supply. If the device does not switch off the supply when the button is pressed, seek expert advice.

NOTE: Testing frequencies of RCDs in temporary installations may need increasing.

514.13 Warning notices: earthing and bonding connections

514.13.1 A durable label to IEC 60364 with the words 'Safety Electrical Connection – Do Not Remove' shall be permanently fixed in a visible position at or near:

(i) the point of connection of every earthing conductor to an earth electrode, and

(ii) the point of connection of every bonding conductor to an extraneous-conductive-part, and

(iii) the main earthing terminal, where separate from main switchgear.

514.13.2 Where Section 418.2.5 or 418.3 applies, the warning notice specified shall be durably marked in legible type not smaller than that illustrated here and shall read as follows:

> The protective bonding conductors associated with the electrical installation in this location MUST NOT BE CONNECTED TO EARTH.
>
> Equipment having exposed-conductive-parts connected to earth must not be brought into this location.

514.14 Warning notice: non-standard colours

514.14.1 If wiring additions or alterations are made to an installation such that some of the wiring complies with Section 514.4 but there is also wiring to a previous version of these Section s, a warning notice shall be affixed at or near the appropriate distribution board with the following wording:

> CAUTION
>
> This installation has wiring colours to two versions of KS 662. Great care should be taken before undertaking extension, alteration or repair that all conductors are correctly identified.

514.15 Warning notice: alternative supplies

514.15.1 Where an installation includes alternative or additional sources of supply, warning notices shall be affixed at the following locations in the installation:

(i) At the origin of the installation

(ii) At the meter position, if remote from the origin

(iii) At the consumer unit or distribution board to which the alternative or additional sources are connected

(iv) At all points of isolation of all sources of supply.

The warning notice shall be durably marked in legible type not smaller than that illustrated here and shall read as follows:

WARNING – MULTIPLE SUPPLIES
Isolate all electrical supplies before carrying out work.
Isolate the mains supply at ....
Isolate the alternative supplies at ....

514.16 Notice: high protective conductor current

See Section 543.7.1.205.

515 PREVENTION OF MUTUAL DETRIMENTAL INFLUENCE

515.1 Prevention of mutual detrimental influence

Electrical equipment shall be selected and erected so as to avoid any harmful influence between the electrical installation and any non-electrical installations envisaged.

NOTE: For EMC see Sections 332 and 444.

515.2 Where equipment carrying current of different types or at different voltages is grouped in a common assembly (such as a switchboard, a cubicle or a control desk or box), all the equipment belonging to any one type of current or any one voltage shall be effectively segregated wherever necessary to avoid mutual detrimental influence.

The immunity levels of equipment shall be chosen taking into account the electromagnetic disturbances that can occur when connected and erected as for normal use, and taking into account the intended level of continuity of service necessary for the application. See the specific equipment standard or the relevant part of KS IEC 61000 series.

CHAPTER 52

SELECTION AND ERECTION OF WIRING SYSTEMS

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CHAPTER 52: SELECTION AND ERECTION OF WIRING SYSTEMS

520 INTRODUCTION

520.1 Scope

This chapter deals with the selection and erection of wiring systems. |

NOTE: These Section s also apply in general to protective conductors. Chapter 54 contains further requirements for those conductors.

520.2 Not used

520.3 Not used

520.4 General

Consideration shall be given to the application of the fundamental principles of Chapter 13 as it applies to:

(i) cables and conductors

(ii) their connections, terminations and/or jointing

(iii) their associated supports or suspensions, and

(iv) their enclosure or methods of protection against external influences.

521 TYPES OF WIRING SYSTEM

The requirements of Section s 521.1 to 521.201 do not apply to busbar and powertrack systems covered by Section 521.4. |

521.1 The installation method of a wiring system in relation to the type of conductor or cable used shall be in accordance with Table 4A1 of Appendix 2, provided the external influences are taken into account according to Section 522.

521.2 The installation method of a wiring system in relation to the situation concerned shall be in accordance with Table 4A2 of Appendix 2. Other methods of installation of cables and conductors not included in Table 4A2 are permitted provided that they fulfil the requirements of this chapter.

521.3 Examples of wiring systems, excluding systems covered by Section 521.4, are shown in Table 4A2. Table 4A2 gives examples of installation methods of cables including reference method for obtaining current-carrying capacity where it is considered that the same current-carrying capacities can safely be used. It is not implied that such methods must be employed or that other methods are prohibited.

521.201 Prefabricated wiring systems intended for permanent connection in fixed installations incorporating installation couplers conforming to IEC 61535, shall comply with IEC 61535.

521.4 Busbar trunking systems and powertrack systems

A busbar trunking system shall comply with KS IEC 61439-6 and a powertrack system shall comply with the appropriate part of the IEC 61534 series. A busbar trunking system or a powertrack system shall be installed in accordance with the manufacturer's instructions, taking account of external influences. See also Appendix 4.

521.5 AC circuits: electromagnetic effects |

521.5.1 Ferromagnetic enclosures: electromagnetic effects

The conductors of an AC circuit installed in a ferromagnetic enclosure shall be arranged so that all line conductors and the neutral conductor, if any, and the appropriate protective conductor are contained within the same enclosure. |

Where such conductors enter a ferrous enclosure, they shall be arranged such that the conductors are only collectively surrounded by ferromagnetic material.

These requirements do not preclude the use of an additional protective conductor in parallel with the steel wire armouring of a cable where such is required to comply with the requirements of the appropriate Section s in Chapters 41 and 54. It is permitted for such an additional protective conductor to enter the ferrous enclosure individually.

521.5.2 Single-core cables armoured with steel wire or steel tape shall not be used for an AC circuit.

NOTE: The steel wire or steel tape armour of a single-core cable is regarded as a ferromagnetic enclosure. For single-core armoured cables, the use of aluminium armour may be considered.

521.5.201 Electromechanical stresses

Every conductor or cable shall have adequate strength and be so installed as to withstand the electromechanical forces that may be caused by any current, including fault current, it may have to carry in service.

521.6 Conduit, ducting, trunking, tray and ladder systems

Two or more circuits are allowed in the same conduit, ducting or trunking system provided the requirements of Section 528 are met.

Cable conduits shall comply with the appropriate part of the KS IEC 61386 series, cable trunking or ducting shall comply with the appropriate part of the IEC 61084 series and cable tray and ladder systems shall comply with IEC 61537.

521.7 Multicore cables: two or more circuits

Two or more circuits are allowed in the same cable provided the requirements of Section 528 are met.

521.8 Circuit arrangements

521.8.1 Each part of a circuit shall be arranged such that the conductors are not distributed over different multicore cables, conduits, ducting systems, trunking systems or tray or ladder systems.

This requirement need not be met where a number of multicore cables, forming one circuit, are installed in parallel. Where multicore cables are installed in parallel each cable shall contain one conductor of each line.

521.8.2 The line and neutral conductors of each final circuit shall be electrically separate from those of every other final circuit, so as to prevent the indirect energizing of a final circuit intended to be isolated.

521.8.3 Where two or more circuits are terminated in a single junction box this shall comply with KS IEC 60670-22.

521.9 Use of flexible cables

521.9.1 A flexible cable shall be used for fixed wiring only where the relevant provisions of the Section s are met. Flexible cables used for fixed wiring shall be of the heavy duty type unless the risk of damage during installation and service, due to impact or other mechanical stresses, is low or has been minimized or protection against mechanical damage is provided.

NOTE: Descriptions of light, ordinary and heavy duty types are given in KS IEC 62821.

521.9.2 Equipment that is intended to be moved in use shall be connected by flexible cables, except equipment supplied by contact rails.

521.9.3 Stationary equipment which is moved temporarily for the purposes of connecting, cleaning etc., e.g. cookers or flush-mounting units for installations in false floors, shall be connected with flexible cable. If the equipment is not subject to vibration then non-flexible cables may be used.

521.10 Installation of cables

521.10.1 Non-sheathed cables for fixed wiring shall be enclosed in conduit, ducting or trunking. This requirement does not apply to a protective conductor complying with Section 543.

Non-sheathed cables are permitted if the cable trunking system provides at least the degree of protection IPXXD or IP4X, and if the cover can only be removed by means of a tool or a deliberate action.

NOTE: For a cable trunking system to meet IP4X requirements, IP4X trunking and related system components would need to be installed. If a system includes site-fabricated joints the installer must confirm the completed item meets at least the degree of protection IPXXD.

521.10.201 A bare live conductor shall be installed on insulators.

521.10.202 Wiring systems shall be supported such that they will not be liable to premature collapse in the event of a fire.

NOTE 1: Wiring systems hanging across access or egress routes may hinder evacuation and firefighting activities.

NOTE 2: Cables installed in or on steel cable containment systems are deemed to meet the requirements of this Section .

NOTE 3: This Section precludes, for example, the use of non-metallic cable clips or cable ties as the sole means of support where cables are clipped direct to exposed surfaces or suspended under cable tray, and the use of non-metallic cable trunking as the sole means of support of the cables therein.

NOTE 4: Suitably spaced steel or copper clips, saddles or ties are examples that will meet the requirements of this Section .

522 SELECTION AND ERECTION OF WIRING SYSTEMS IN RELATION TO EXTERNAL INFLUENCES

The installation method selected shall be such that protection against the expected external influences is provided in all appropriate parts of the wiring system. Particular care shall be taken at changes in direction and where wiring enters into equipment.

NOTE: The external influences categorized in Appendix 3 which are of significance to wiring systems are included in this section.

522.1 Ambient temperature (AA)

522.1.1 A wiring system shall be selected and erected so as to be suitable for the highest and lowest local ambient temperatures and so that the limiting temperature in normal operation (see Table 52.1) and the limiting temperature in case of a fault (see Table 43.1) will not be exceeded.

522.1.2 Wiring system components, including cables and wiring accessories, shall only be installed or handled at temperatures within the limits stated in the relevant product specification or as given by the manufacturer.

522.2 External heat sources

522.2.1 In order to avoid the effects of heat from external sources, one or more of the following methods or an equally effective method shall be used to protect a wiring system:

(i) Shielding
(ii) Placing sufficiently far from the source of heat
(iii) Selecting a system with due regard for the additional temperature rise which may occur
(iv) Local reinforcement or substitution of insulating material.

NOTE: Heat from external sources may be radiated, conducted or convected, e.g.:

- from hot water systems
- from plant, appliances and luminaires
- from a manufacturing process
- through heat conducting materials
- from solar gain of the wiring system or its surrounding medium.

522.2.201 Parts of a cable within an accessory, appliance or luminaire shall be suitable for the temperatures likely to be encountered, as determined in accordance with Section 522.1.1, or shall be provided with additional insulation suitable for those temperatures.

522.3 Presence of water (AD) or high humidity (AB)

522.3.1 A wiring system shall be selected and erected so that no damage is caused by condensation or ingress of water during installation, use and maintenance. The completed wiring system shall comply with the IP degree of protection (see KS IEC 60529) relevant to the particular location.

NOTE: Special considerations apply to wiring systems liable to frequent splashing, immersion or submersion.

522.3.2 Where water may collect or condensation may form in a wiring system, provision shall be made for its escape.

522.3.3 Where a wiring system may be subjected to waves (AD6), protection against mechanical damage shall be afforded by one or more of the methods of Section s 522.6 to 8.

522.4 Presence of solid foreign bodies (AE)

522.4.1 A wiring system shall be selected and erected so as to minimize the danger arising from the ingress of solid foreign bodies. The completed wiring system shall comply with the IP degree of protection (see KS IEC 60529) relevant to the particular location.

522.4.2 In a location where dust in significant quantity is present (AE4), additional precautions shall be taken to prevent the accumulation of dust or other substances in quantities which could adversely affect heat dissipation from the wiring system.

NOTE: A wiring system which facilitates the removal of dust may be necessary (see Section 529).

522.5 Presence of corrosive or polluting substances (AF)

522.5.1 Where the presence of corrosive or polluting substances, including water, is likely to give rise to corrosion or deterioration, parts of the wiring system likely to be affected shall be suitably protected or manufactured from a material resistant to such substances.

NOTE: Suitable protection for application during erection may include protective tapes, paints or grease.

522.5.2 Dissimilar metals liable to initiate electrolytic action shall not be placed in contact with each other, unless special arrangements are made to avoid the consequences of such contact.

522.5.3 Materials liable to cause mutual or individual deterioration or hazardous degradation shall not be placed in contact with each other.

522.6 Impact (AG)

522.6.1 Wiring systems shall be selected and erected so as to minimize the damage arising from mechanical stress, e.g. by impact, abrasion, penetration, tension or compression during installation, use or maintenance.

522.6.2 In a fixed installation where impacts of medium severity (AG2) or high severity (AG3) can occur protection shall be afforded by:

(i) the mechanical characteristics of the wiring system, or

(ii) the location selected, or

(iii) the provision of additional local or general protection against mechanical damage, or

(iv) any combination of the above.

NOTE: Examples are areas where the floor is likely to be penetrated and areas used by forklift trucks.

522.6.3 *Not used*

522.6.4 The degree of protection of electrical equipment shall be maintained after installation of the cables and conductors.

522.6.201 A cable installed under a floor or above a ceiling shall be run in such a position that it is not liable to be damaged by contact with the floor or ceiling or their fixings.

A cable passing through a joist within a floor or ceiling construction or through a ceiling support (e.g. under floorboards), shall:

(i) be installed at least 50 mm measured vertically from the top, or bottom as appropriate, of the joist or batten, or

(ii) comply with Section 522.6.204.

522.6.202 A cable installed in a wall or partition at a depth of less than 50 mm from a surface of the wall or partition shall:

(i) be installed in a zone within 150 mm from the top of the wall or partition or within 150 mm of an angle formed by two adjoining walls or partitions. Where the cable is connected to a point, accessory or switchgear on any surface of the wall or partition, the cable may be installed in a zone either horizontally or vertically, to the point, accessory or switchgear. Where the location of the accessory, point or switchgear can be determined from the reverse side, a zone formed on one side of a wall of 100 mm thickness or less or partition of 100 mm thickness or less extends to the reverse side, or

(ii) comply with Section 522.6.204.

Where indent (i) but not indent (ii) applies, the cable shall be provided with additional protection by means of an RCD having the characteristics specified in Section 415.1.1.

522.6.203 Irrespective of its buried depth, a cable concealed in a wall or partition, the internal construction of which includes metallic parts, other than metallic fixings such as nails, screws and the like, shall:

(i) be provided with additional protection by means of an RCD having the characteristics specified in Section 415.1.1, or

(ii) comply with Section 522.6.204.

For a cable installed at a depth of less than 50 mm from the surface of a wall or partition the requirements of Section 522.6.202(i) shall also apply.

522.6.204 For the purposes of Section 522.6.201(ii), Section 522.6.202(ii) and Section 522.6.203(ii), a cable shall:

(i) incorporate an earthed metallic covering which complies with the requirements of these Section s for a protective conductor of the circuit concerned, the cable complying with IEC 60702-1, or

(ii) be installed in earthed conduit complying with KS IEC 61386-21 and satisfying the requirements of these Section s for a protective conductor, or

(iii) be enclosed in earthed trunking or ducting complying with IEC 61084-2-1 and satisfying the requirements of these Section s for a protective conductor, or

(iv) be provided with mechanical protection against damage sufficient to prevent penetration of the cable by nails, screws and the like, or

(v) form part of a SELV or PELV circuit meeting the requirements of Section 414.4.

522.7 Vibration (AH)

522.7.1 A wiring system supported by or fixed to a structure or equipment subject to vibration of medium severity (AH2) or high severity (AH3) shall be suitable for such conditions, particularly where cables and cable connections are concerned.

522.7.2 For the fixed installation of suspended current-using equipment, e.g. luminaires, connection shall be made by cable with flexible cores. Where no vibration or movement can be expected, cable with non-flexible cores may be used.

522.8 Other mechanical stresses (AJ)

522.8.1 A wiring system shall be selected and erected to avoid during installation, use or maintenance, damage to the sheath or insulation of cables and their terminations. The use of any lubricants that can have a detrimental effect on the cable or wiring system are not permitted.

522.8.2 Where buried in the structure, a conduit system or cable ducting system, other than a pre-wired conduit assembly specifically designed for the installation, shall be completely erected between access points before any cable is drawn in.

522.8.3 The radius of every bend in a wiring system shall be such that conductors or cables do not suffer damage and terminations are not stressed.

522.8.4 Where conductors or cables are not supported continuously due to the method of installation, they shall be supported by suitable means at appropriate intervals in such a manner that the conductors or cables do not suffer damage by their own weight.

522.8.5 Every cable or conductor shall be supported in such a way that it is not exposed to undue mechanical strain and so that there is no appreciable mechanical strain on the terminations of the conductors, account being taken of mechanical strain imposed by the supported weight of the cable or conductor itself.

NOTE: Consumer unit meter tails are included in the requirements of this Section .

522.8.6 A wiring system intended for the drawing in or out of conductors or cables shall have adequate means of access to allow this operation.

522.8.7 A wiring system buried in a floor shall be sufficiently protected to prevent damage caused by the intended use of the floor.

522.8.8 *Not used*

522.8.9 *Not used*

522.8.10 Except where installed in a conduit or duct which provides equivalent protection against mechanical damage, a cable buried in the ground shall incorporate an earthed armour or metal sheath or both, suitable for use as a protective conductor. The location of buried cables shall be marked by cable covers or a suitable marker tape. Buried conduits and ducts shall be suitably identified. Buried cables, conduits and ducts shall be at a sufficient depth to avoid being damaged by any reasonably foreseeable disturbance of the ground.

NOTE: KS IEC 61386-24 is the standard for underground conduits.

522.8.11 Cable supports and enclosures shall not have sharp edges liable to damage the wiring system.

522.8.12 A cable or conductors shall not be damaged by the means of fixing.

522.8.13 Cables, busbars and other electrical conductors which pass across expansion joints shall be so selected or erected that anticipated movement does not cause damage to the electrical equipment.

522.8.14 No wiring system shall penetrate an element of building construction which is intended to be load bearing unless the integrity of the load-bearing element can be assured after such penetration.

522.9 Presence of flora and/or mould growth (AK)

522.9.1 Where the conditions experienced or expected constitute a hazard (AK2), the wiring system shall be selected accordingly or special protective measures shall be adopted.

NOTE 1: An installation method which facilitates the removal of such growths may be necessary (see Section 529).

NOTE 2: Possible preventive measures are closed types of installation (conduit or channel), maintaining distances to plants and regular cleaning of the relevant wiring system.

522.10 Presence of fauna (AL)

522.10.1 Where conditions experienced or expected constitute a hazard (AL2), the wiring system shall be selected accordingly or special protective measures shall be adopted, for example, by:

(i) the mechanical characteristics of the wiring system, or
(ii) the location selected, or
(iii) the provision of additional local or general protection against mechanical damage, or
(iv) any combination of the above.

522.11 Solar radiation (AN) and ultraviolet radiation

522.11.1 Where significant solar radiation (AN2) or ultraviolet radiation is experienced or expected, a wiring system suitable for the conditions shall be selected and erected or adequate shielding shall be provided. Special precautions may need to be taken for equipment subject to ionising radiation.

NOTE: See also Section 522.2.1 dealing with temperature rise.

522.12 Seismic effects (AP)

522.12.1 The wiring system shall be selected and erected with due regard to the seismic hazards of the location of the installation.

522.12.2 Where the seismic hazards experienced are low severity (AP2) or higher, particular attention shall be paid to the following:

(i) The fixing of wiring systems to the building structure
(ii) The connections between the fixed wiring and all items of essential equipment, e.g. safety services, shall be selected for their flexible quality.

522.13 Movement of air (AR)

522.13.1 See Section 522.7, Vibration (AH), and Section 522.8, Other mechanical stresses (AJ).

522.14 Nature of processed or stored materials (BE)

522.14.1 See Section 527, Selection and erection of wiring systems to minimize the spread of fire and Section 422, Precautions where particular risks of fire exist.

522.15 Building design (CB)

522.15.1 Where risks due to structural movement exist (CB3), the cable support and protection system employed shall be capable of permitting relative movement so that conductors and cables are not subjected to excessive mechanical stress.

522.15.2 For a flexible structure or a structure intended to move (CB4), a flexible wiring system shall be used.

523 CURRENT-CARRYING CAPACITIES OF CABLES

523.1 The current, including any harmonic current, to be carried by any conductor for sustained periods during normal operation shall be such that the appropriate temperature limit specified in Table 52.1 is not exceeded. The value of current shall be selected in accordance with Section 523.2, or determined in accordance with Section 523.3.

TABLE 52.1 – Maximum operating temperatures for types of cable insulation

Type of insulation	Temperature limit[a]
Thermoplastic	70 °C at the conductor
Thermosetting	90 °C at the conductor[b]
Mineral (Thermoplastic covered or bare exposed to touch)	70 °C at the sheath
Mineral (bare not exposed to touch and not in contact with combustible material)	105 °C at the sheath[b, c]

[a] The maximum permissible conductor temperatures given in Table 52.1 on which the tabulated current-carrying capacities given in Appendix 2 are based, have been taken from IEC 60502-1 and IEC 60702-1 and are shown on these tables in Appendix 2.

[b] Where a conductor operates at a temperature exceeding 70 °C it shall be ascertained that the equipment connected to the conductor is suitable for the resulting temperature at the connection.

[c] For mineral insulated cables, higher operating temperatures may be permissible dependent upon the temperature rating of the cable, its terminations, the environmental conditions and other external influences.

NOTE: For the temperature limits for other types of insulation, refer to cable specification or manufacturer.

523.2 The requirement of Section 523.1 is considered to be satisfied if the current for non-sheathed and sheathed cables does not exceed the appropriate values selected from the tables of current-carrying capacity given in Appendix 2 with reference to Table 4A2, subject to any necessary rating factors.

NOTE: The current-carrying capacities given in the tables are provided for guidance. It is recognized that there will be some tolerance in the current-carrying capacities depending on the environmental conditions and the precise construction of the cables.

523.3 The appropriate value of current-carrying capacity may also be determined as described in KS IEC 60287 series or by test, or by calculation using a recognized method, provided that the method is stated. Where appropriate, account shall be taken of the characteristics of the load and, for buried cables, the effective thermal resistance of the soil.

523.4 The ambient temperature shall be considered to be the temperature of the surrounding medium when the non-sheathed or sheathed cable(s) under consideration are not loaded.

523.5 Groups containing more than one circuit

The group rating factors, see Tables 4C1 to 4C6 of Appendix 2, are applicable to groups of non-sheathed or sheathed cables having the same maximum operating temperature.

For groups containing non-sheathed or sheathed cables having different maximum operating temperatures, the current-carrying capacity of all the non-sheathed or sheathed cables in the group shall be based on the lowest maximum operating temperature of any cable in the group together with the appropriate group rating factor.

If, due to known operating conditions, a non-sheathed or sheathed cable is expected to carry a current not greater than 30 % of its grouped current-carrying capacity, it may be ignored for the purpose of obtaining the rating factor for the rest of the group.

523.6 Number of loaded conductors

523.6.1 The number of conductors to be considered in a circuit are those carrying load current. Where conductors in polyphase circuits carry balanced currents, the associated neutral conductor need not be taken into consideration. Under these conditions a four-core cable is given the same current-carrying capacity as a three-core cable having the same conductor cross-sectional area for each line conductor. The neutral conductor shall be considered as a loaded conductor in the case of the presence of third harmonic current or multiples of the third harmonic presenting a total harmonic distortion greater than 15 % of the fundamental line current.

523.6.2 Where the neutral conductor in a multicore cable carries current as a result of an imbalance in the line currents, the temperature rise due to the neutral current is offset by the reduction in the heat generated by one or more of the line conductors. In this case the conductor size shall be chosen on the basis of the highest line current.

In all cases the neutral conductor shall have a cross-sectional area adequate to afford compliance with Section 523.1.

523.6.3 Where the neutral conductor carries current without a corresponding reduction in load of the line conductors, the neutral conductor shall be taken into account in ascertaining the current-carrying capacity of the circuit. Such currents may be caused by a significant harmonic current in three-phase circuits. If the total harmonic distortion due to third harmonic current or multiples of the third harmonic is greater than 15 % of the fundamental line current the neutral conductor shall not be smaller than the line conductors. Thermal effects due to the presence of third harmonic or multiples of third harmonic currents and the corresponding rating factors for higher harmonic currents are given in Appendix 2, section 5.5.

523.6.4 Conductors which serve the purpose of protective conductors only are not to be taken into consideration. PEN conductors shall be taken into consideration in the same way as neutral conductors.

523.6.201 The tabulated current-carrying capacities in Appendix 2 are based on the fundamental frequency only and do not take account of the effect of harmonics.

523.7 Conductors in parallel

Where two or more live conductors or PEN conductors are connected in parallel in a system, either:

(i) measures shall be taken to achieve equal load current sharing between them

This requirement is considered to be fulfilled if the conductors are of the same material, have the same cross-sectional area, are approximately the same length and have no branch circuits along their length, and either:

(a) the conductors in parallel are multicore cables or twisted single-core cables or non-sheathed cables, or

(b) the conductors in parallel are non-twisted single-core cables or non-sheathed cables in trefoil or flat formation and where the cross-sectional area is greater than 50 mm^2 in copper or 70 mm^2 in aluminium, the special configuration necessary for such formations is adopted. These configurations consist of suitable groupings and spacings of the different lines or poles

or

(ii) special consideration shall be given to the load current sharing to meet the requirements of Section 523.1.

This Section does not preclude the use of ring final circuits with or without spur connections.

Where adequate current sharing is not possible or where four or more conductors have to be connected in parallel consideration shall be given to the use of busbar trunking.

523.8 Variation of installation conditions along a route

Where the heat dissipation differs from one part of a route to another, the current-carrying capacity of cables at each part of the route shall be appropriate for that part of the route.

523.9 Cables in thermal insulation

A cable should preferably not be installed in a location where it is liable to be covered by thermal insulation. Where a cable is to be run in a space to which thermal insulation is likely to be applied it shall, wherever practicable, be fixed in a position such that it will not be covered by the thermal insulation. Where fixing in such a position is impracticable the cross-sectional area of the cable shall be selected to meet the requirements of Chapter 43. Where necessary, the nature of the load (e.g. cyclic) and diversity may be taken into account.

For a cable installed in a thermally insulated wall or above a thermally insulated ceiling, the cable being in contact with a thermally conductive surface on one side, current-carrying capacities are tabulated in Appendix 2.

For a single cable likely to be totally surrounded by thermally insulating material over a length of 0.5 m or more, the current-carrying capacity shall be taken, in the absence of more precise information, as 0.5 times the current-carrying capacity for that cable clipped direct to a surface and open (Reference Method C).

Where a cable is to be totally surrounded by thermal insulation for less than 0.5 m the current-carrying capacity of the cable shall be reduced appropriately depending on the size of cable, length in insulation and thermal properties of the insulation. The derating factors in Table 52.2 are appropriate to conductor sizes up to 10 mm^2 in thermal insulation having a thermal conductivity (λ) greater than 0.04 Wm^{-1}K^{-1}.

TABLE 52.2 – Cable surrounded by thermal insulation

Length in insulation (mm)	Derating factor
50	0.88
100	0.78
200	0.63
400	0.51

523.201 Armoured single-core cables

The metallic sheaths and/or non-magnetic armour of single-core cables in the same circuit shall normally be bonded together at both ends of their run (solid bonding). Alternatively, the sheaths or armour of such cables having conductors of cross-sectional area exceeding 50 mm^2 and a non-conducting outer sheath may be bonded together at one point in their run (single point bonding) with suitable insulation at the unbonded ends, in which case the length of the cables from the bonding point shall be limited so that voltages from sheaths and/or armour to Earth:

(i) do not cause corrosion when the cables are carrying their full load current, for example by limiting the voltage to 25 V, and

(ii) do not cause danger or damage to property when the cables are carrying short-circuit current.

524 CROSS-SECTIONAL AREAS OF CONDUCTORS

524.1 The cross-sectional area of each conductor in a circuit shall be not less than the values given in Table 52.3, except as provided for extra-low voltage lighting installations according to Section 715.524.201.

524.2 Neutral conductors

524.2.1 The neutral conductor, if any, shall have a cross-sectional area not less than that of the line conductor:

(i) in single-phase, two-wire circuits, whatever the cross-sectional area

(ii) in polyphase and single-phase three-wire circuits, where the size of the line conductors is less than or equal to 16 mm^2 for copper, or 25 mm^2 for aluminium

(iii) in circuits where it is required according to Section 523.6.3.

524.2.2 If the total harmonic content due to triplen harmonics is greater than 33 % of the fundamental line current, an increase in the cross-sectional area of the neutral conductor may be required (see Section 523.6.3 and Appendix 2, section 5.5).

524.2.3 For a polyphase circuit where each line conductor has a cross-sectional area greater than 16 mm^2 for copper or 25 mm^2 for aluminium, the neutral conductor is permitted to have a smaller cross-sectional area than that of the line conductors provided that the following conditions are simultaneously fulfilled:

(i) The expected maximum current including harmonics, if any, in the neutral conductor during normal service is not greater than the current-carrying capacity of the reduced cross-sectional area of the neutral conductor, and

NOTE: The load carried by the circuit under normal service conditions should be practically equally distributed between the lines.

(ii) the neutral conductor is protected against overcurrents according to Section 431.2, and

(iii) the size of the neutral conductor is at least equal to 16 mm^2 for copper or 25 mm^2 for aluminium, account being taken of Section 523.6.3.

TABLE 52.3 – Minimum cross-sectional area of conductors

Type of wiring system	Use of the circuit	Conductor	
		Material	Cross-sectional area mm^2
Non-sheathed and sheathed cables	Lighting circuits	Copper	1.0 (see Note 4)
		Aluminium	16 (see Note 3)
	Power circuits	Copper	1.5
		Aluminium	16 (see Note 3)
	Signalling and control circuits	Copper	0.5 (see Note 1)

Type of wiring system	Use of the circuit	Conductor	
		Material	Cross-sectional area mm^2
Bare conductors	Power circuits	Copper	10
		Aluminium	16 (see Note 3)
	Signalling and control circuits	Copper	4
Non-sheathed and sheathed flexible cables	For a specific appliance	Copper	As specified in the product standard
	For any other application		0.75[a]
	Extra-low voltage circuits for special applications (see Note 2)		0.75

NOTE 1: In information technology, signalling and control circuits intended for electronic equipment a minimum cross-sectional area of 0.1 mm^2 is permitted.

NOTE 2: For special requirements for ELV lighting see Section 715.

NOTE 3: Connectors used to terminate aluminium conductors shall be tested and approved for this specific use.

NOTE 4: For lighting circuits and associated small items of current-using equipment, such as a bathroom extractor fan.

[a] In multicore flexible cables containing seven or more cores, Note 1 applies.

525 VOLTAGE DROP IN CONSUMERS' INSTALLATIONS

525.1 In the absence of any other consideration, under normal service conditions the voltage at the terminals of any fixed current-using equipment shall be greater than the lower limit corresponding to the product standard relevant to the equipment.

525.201 Where fixed current-using equipment is not the subject of a product standard the voltage at the terminals shall be such as not to impair the safe functioning of that equipment.

525.202 The above requirements are deemed to be satisfied if the voltage drop between the origin of the installation (usually the supply terminals) and a socket-outlet or the terminals of fixed current-using equipment does not exceed that stated in Appendix 2, section 6.4.

525.203 A greater voltage drop than stated in Appendix 2, section 6.4 may be accepted for a motor during starting periods and for other equipment with high inrush currents, provided that it is verified that the voltage variations are within the limits specified in the relevant product standard for the equipment or, in the absence of a product standard, in accordance with the manufacturer's recommendations.

526 ELECTRICAL CONNECTIONS

526.1 Every connection between conductors or between a conductor and other equipment shall provide durable electrical continuity and adequate mechanical strength and protection.

NOTE: See Section 522.8 – Other mechanical stresses.

526.2 The selection of the means of connection shall take account of, as appropriate:

(i) the material of the conductor and its insulation
(ii) the number and shape of the wires forming the conductor
(iii) the cross-sectional area of the conductor
(iv) the number of conductors to be connected together
(v) the temperature attained at the terminals in normal service such that the effectiveness of the insulation of the conductors connected to them is not impaired
(vi) the provision of adequate locking arrangements in situations subject to vibration or thermal cycling.

Where a soldered connection is used the design shall take account of creep, mechanical stress and temperature rise under fault conditions.

NOTE 1: Applicable standards include KS IEC 60947-7, the KS IEC 60998 series and IEC 61535.

NOTE 2: Terminals without the marking 'r' (only rigid conductor), 'f' (only flexible conductor), 's' or 'sol' (only solid conductor) are suitable for the connection of all types of conductors.

526.3 Every connection shall be accessible for inspection, testing and maintenance, except for the following:

(i) A joint designed to be buried in the ground
(ii) A compound-filled or encapsulated joint

(iii) A connection between a cold tail and the heating element as in ceiling heating, floor heating or a trace heating system

(iv) A joint made by welding, soldering, brazing or appropriate compression tool

(v) Joints or connections made in equipment by the manufacturer of the product and not intended to be inspected or maintained

(vi) Equipment complying with IEC 63172 for a maintenance-free accessory and marked with the MF symbol and installed in accordance with the manufacturer's instructions.

526.4 Where necessary, precautions shall be taken so that the temperature attained by a connection in normal service shall not impair the effectiveness of the insulation of the conductors connected to it or any insulating material used to support the connection. Where a cable is to be connected to a bare conductor or busbar its type of insulation and/or sheath shall be suitable for the maximum operating temperature of the bare conductor or busbar.

526.5 Every termination and joint in a live conductor or a PEN conductor shall be made within one of the following or a combination thereof:

(i) A suitable accessory complying with the appropriate product standard

(ii) An equipment enclosure complying with the appropriate product standard

(iii) An enclosure partially formed or completed with building material which is non-combustible when tested to ISO 1182.

526.6 There shall be no appreciable mechanical strain on the connections of conductors.

526.7 Where a connection is made in an enclosure the enclosure shall provide adequate mechanical protection and protection against relevant external influences.

526.8 Cores of sheathed cables from which the sheath has been removed and non-sheathed cables at the termination of conduit, ducting or trunking shall be enclosed as required by Section 526.5.

526.9 Connection of multiwire, fine wire and very fine wire conductors

526.9.1 In order to avoid inappropriate separation or spreading of individual wires of multiwire, fine wire or very fine wire conductors, suitable terminals shall be used or the conductor ends shall be suitably treated.

526.9.2 Soldering (tinning) of the whole conductor end of multiwire, fine wire and very fine wire conductors is not permitted if screw terminals are used.

526.9.3 Soldered (tinned) conductor ends on fine wire and very fine wire conductors are not permissible at connection and junction points which are subject in service to a relative movement between the soldered and the non-soldered part of the conductor.

527 SELECTION AND ERECTION OF WIRING SYSTEMS TO MINIMIZE THE SPREAD OF FIRE

527.1 Precautions within a fire-segregated compartment

527.1.1 The risk of spread of fire shall be minimized by the selection of appropriate materials and erection in accordance with Section 527.

NOTE: A fire-segregated compartment (fire compartment) is considered to be an enclosed space, which may be subdivided, separated from adjoining spaces within a building by elements of construction having a specified fire resistance.

527.1.2 A wiring system shall be installed so that the general building structural performance and fire safety are not reduced.

527.1.3 Cables complying with, at least, the requirements KS IEC 60332-1-2 may be installed without special precautions.

Where the fire-segregated compartment provides a means of evacuation in an emergency then the cable shall meet the requirements of the appropriate part of KS IEC 60332-3 series.

527.1.4 Cables not complying with the cable requirements of Section 527.1.3 shall be limited to short lengths for connection of appliances to the permanent wiring system and shall not pass from one fire-segregated compartment to another.

527.1.5 Products having the necessary resistance to flame propagation as specified in the KS IEC 61386 series, the appropriate part of IEC 61084 series, KS IEC 61439-6, IEC 61534 series, IEC 61537 or IEC 60570 may be installed without special precautions. Other products complying with standards having similar requirements for resistance to flame propagation may be installed without special precautions.

527.1.6 Parts of wiring systems other than cables which do not comply, as a minimum, with the flame propagation requirements as specified in the KS IEC 61386 series, the appropriate part of IEC 61084 series, KS IEC 61439-6, IEC 61534 series or IEC 61537 but which comply in all other respects with the requirements of their respective product standard shall, if used, be completely enclosed in suitable non-combustible building materials.

527.2 Sealing of wiring system penetrations

527.2.1 Where a wiring system passes through elements of building construction such as floors, walls, roofs, ceilings, partitions or cavity barriers, the openings remaining after passage of the wiring system shall be sealed according to the degree of fire-resistance (if any) prescribed for the respective element of building construction before penetration.

This requirement is satisfied if the sealing of the wiring system concerned has passed a relevant type test meeting the requirements of Section 527.2.3.

527.2.1.1 During the erection of a wiring system temporary sealing arrangements shall be provided as appropriate.

527.2.1.2 During alteration work, sealing which has been disturbed shall be reinstated as soon as practicable.

527.2.2 A wiring system such as a conduit system, cable ducting system, cable trunking system, busbar or busbar trunking system which penetrates elements of building construction having specified fire-resistance shall be internally sealed to the degree of fire-resistance of the respective element before penetration as well as being externally sealed as required by Section 527.2.1.

This requirement is satisfied if the sealing of the wiring system concerned has passed a relevant type test meeting the requirements of Section 527.2.3.

527.2.3 A conduit system, cable trunking system or cable ducting system classified as non-flame propagating according to the relevant product standard and having a maximum internal cross-sectional area of 710 mm^2 need not be internally sealed provided that:

(i) the system satisfies the test of KS IEC 60529 for IP33, and

(ii) any termination of the system in one of the compartments, separated by the building construction being penetrated, satisfies the test of KS IEC 60529 for IP33.

527.2.4 Any sealing arrangement intended to satisfy Section 527.2.1 or 527.2.1.1 shall resist external influences to the same degree as the wiring system with which it is used and, in addition, it shall meet all of the following requirements:

(i) It shall be resistant to the products of combustion to the same extent as the elements of building construction which have been penetrated

(ii) It shall provide the same degree of protection from water penetration as that required for the building construction element in which it has been installed

(iii) It shall be compatible with the material of the wiring system with which it is in contact

(iv) It shall permit thermal movement of the wiring system without reduction of the sealing quality

(v) It shall be of adequate mechanical stability to withstand the stresses which may arise through damage to the support of the wiring system due to fire.

The seal and the wiring system shall be protected from dripping water which may travel along the wiring system or which may otherwise collect around the seal unless the materials used in the seal are all resistant to moisture when finally assembled for use.

NOTE: This Section may be satisfied if:

- either cable cleats, cable ties or cable supports are installed within 750 mm of the seal, and are able to withstand the mechanical loads expected following the collapse of the supports on the fire side of the seal to the extent that no strain is transferred to the seal, or
- the design of the sealing system itself provides adequate support.

528 PROXIMITY OF WIRING SYSTEMS TO OTHER SERVICES

528.1 Proximity to electrical services

Except where one of the following methods is adopted, neither a voltage Band I nor a voltage Band II circuit shall be contained in the same wiring system as a circuit of nominal voltage exceeding that of low voltage, and a Band I circuit shall not be contained in the same wiring system as a Band II circuit:

(i) Every cable or conductor is insulated for the highest voltage present

(ii) Each conductor of a multicore cable is insulated for the highest voltage present in the cable

(iii) The cables are insulated for their system voltage and installed in a separate compartment of a cable ducting or cable trunking system

(iv) The cables are installed on a cable tray system where physical separation is provided by a partition

(v) A separate conduit, trunking or ducting system is employed

(vi) For a multicore cable, the cores of the Band I circuit are separated from the cores of the Band II circuit by an earthed metal screen of equivalent current-carrying capacity to that of the largest core of a Band II circuit.

For SELV and PELV systems the requirements of Section 414.4 shall apply.

NOTE 1: In the case of proximity of wiring systems and lightning protection systems, KS IEC 62305 should be considered.

NOTE 2: Recommendations for separation and segregation in relation to safety services are given in IEC 60364-4-41

528.2 Proximity of communications cables

In the event of crossing or proximity of underground telecommunication cables and underground power cables, a minimum clearance of 100 mm shall be maintained, or the requirements according to (i) or (ii) shall be fulfilled:

(i) A fire-retardant partition shall be provided between the cables, e.g. bricks, cable protecting caps (clay, concrete), shaped blocks (concrete), protective cable conduit or troughs made of fire-retardant materials

(ii) For crossings, mechanical protection between the cables shall be provided, e.g. cable conduit, concrete cable protecting caps or shaped blocks.

NOTE 1: Special considerations of electrical interference, both electromagnetic and electrostatic, may apply to telecommunication circuits, data transfer circuits and the like.

NOTE 2: Segregation requirements for communications services are given in IEC 6199501 and IEC 60364-5-52 series.

528.3 Proximity to non-electrical services

528.3.1 A wiring system shall not be installed in the vicinity of services which produce heat, smoke or fumes likely to be detrimental to the wiring, unless it is protected from harmful effects by shielding arranged so as not to affect the dissipation of heat from the wiring.

In areas not specifically designed for the installation of cables, e.g. service shafts and cavities, the cables shall be laid so that they are not exposed to any harmful influence by the normal operation of adjacent installations (e.g. gas, water or steam lines).

528.3.2 Where a wiring system is routed below services liable to cause condensation (such as water, steam or gas services), precautions shall be taken to protect the wiring system from deleterious effects.

528.3.3 Where an electrical service is to be installed in proximity to one or more non-electrical services it shall be so arranged that any foreseeable operation carried out on the other services will not cause damage to the electrical service or the converse.

NOTE: This may be achieved by:

(i) suitable spacing between the services, or

(ii) the use of mechanical or thermal shielding.

528.3.4 Where an electrical service is located in close proximity to one or more non-electrical services, both the following conditions shall be met:

(i) The wiring system shall be suitably protected against the hazards likely to arise from the presence of the other services in normal use

(ii) Fault protection shall be afforded in accordance with the requirements of Section 411.

528.3.5 No cable shall be run in a lift or hoist well unless it forms part of the lift installation as defined in KS ISO 8100 series.

529 SELECTION AND ERECTION OF WIRING SYSTEMS IN RELATION TO MAINTAINABILITY, INCLUDING CLEANING

529.1 With regard to maintainability, reference shall be made to Section 132.12.

529.2 Where it is necessary to remove any protective measure in order to carry out maintenance, provision shall be made so that the protective measure can be reinstated without reduction of the degree of protection originally intended.

529.3 Provision shall be made for safe and adequate access to all parts of a wiring system which may require maintenance.

NOTE: In some situations, it may be necessary to provide permanent means of access by ladders, walkways, etc.

CHAPTER 53
PROTECTION, ISOLATION, SWITCHING, CONTROL AND MONITORING

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CHAPTER 53:PROTECTION, ISOLATION, SWITCHING, CONTROL AND MONITORING

530 INTRODUCTION

530.1 Scope

This chapter deals with general requirements for protection, isolation, switching, control and monitoring and with the requirements for selection and erection of the devices provided to fulfil such functions.

NOTE: In Chapter 53, reference to short-circuit, where relevant, includes earth fault. Short-circuit Protective Device (SCPD), where relevant, also means earth fault current protective device.

530.2 Not used

530.3 General and common requirements

530.3.1 Every item of equipment shall be selected and erected so as to allow compliance with the requirements stated in the following Section s.

530.3.2 The moving contacts of multipole switching devices marked for the connection of the neutral or midpoint may close before and open after the other contacts.

530.3.3 A switching device shall not be inserted in the neutral conductor alone.

530.3.4 Devices embodying more than one function, as defined in the following Section s, shall comply with the relevant requirements of this chapter appropriate to each separate function.

530.3.5 Equipment intended for protection only shall not be provided for functional switching of circuits.

NOTE: See Table 537.4 – Guidance on the selection of protective, isolation and switching devices.

530.4 Fixing of equipment

530.4.1 Taking into account the manufacturer's instructions, if any, equipment shall be erected in such a way that connections between wiring and equipment shall not be subject to undue stress or strain resulting from the normal use of the equipment.

530.4.2 Unenclosed equipment shall be mounted in a suitable mounting box or enclosure in compliance with the relevant part of IEC 60670, IEC 62208 or other relevant standards such as IEC 61439 series. Socket- outlets, connection units, plate switches and similar accessories shall be fitted to a mounting box complying with the relevant part of IEC 60670.

530.4.3 Equipment such as circuit-breakers, switches, socket-outlets, control equipment, etc. may be installed on or in a cable trunking system complying with IEC 61084 series. Wherever equipment is fixed on or in cable trunking, skirting trunking or in mouldings it shall not be fixed on covers which can be removed inadvertently.

531 DEVICES FOR PROTECTION AGAINST ELECTRIC SHOCK BY AUTOMATIC DISCONNECTION OF SUPPLY

531.1 General

531.1.1 Devices for protection against electric shock by automatic disconnection of supply shall be suitable for isolation in accordance with Chapter 46 and Section 537.

Automatic reclosing of devices for protection against electric shock by automatic disconnection of supply shall only be installed in the associated part of the installation where access is restricted to instructed persons or skilled persons only.

A warning notice shall be clearly displayed near the point of access to the associated part of the installation controlled by the auto-reclosing device, indicating its automatic reclose function must be disengaged prior to entry.

NOTE: Automatic Reclosing Devices are intended to reclose circuit-breakers, RCBOs and RCCBs after tripping, in order to re-establish continuity of service.

Requirements for the selection of devices for protection against electric shock by automatic disconnection of supply are given in the Section s listed below.

In TN, TT and IT systems the following protective devices may be used:

(i) overcurrent protective devices, in accordance with Section 531.2

(ii) residual current devices (RCDs), in accordance with Section 531.3.

Devices according to IEC 60947-2 marked with the voltage value followed by the symbol in (IT) shall not be used IT systems for such voltage.

In addition, in IT systems the following monitoring devices may be used to detect insulation fault conditions:

(iii) insulation monitoring devices (IMDs), in accordance with Section 538.1

(iv) equipment for insulation fault location, in accordance with Section 538.2

(v) residual current monitors (RCMs), in accordance with Section 538.4.

531.2 Overcurrent protective devices

531.2.1 General

Where overcurrent protective devices are used for protection against electric shock by automatic disconnection of supply they shall be selected in accordance with Section 533.

531.2.2 TN systems

In TN systems, overcurrent protective devices when used as devices for fault protection shall be selected and erected in order to comply with the requirements specified in Chapter 41 (see in particular Section 411.4.4).

If, for certain equipment or for certain parts of the installation, the maximum disconnection times in Table 41.1 cannot be fulfilled by the overcurrent protective devices, those parts shall be protected by an RCD in compliance with Section 531.3.5.2.

In TN-S systems, the neutral need not be disconnected if the supply conditions are such that the neutral conductor can be considered to be reliably at earth potential.

In TN-C systems, the PEN conductor shall not be disconnected.

531.2.2.201 Except in certain special installations or locations (Part 7), there is no requirement under overcurrent conditions to disconnect/switch the neutral in TT or TN systems.

531.2.3 TT systems

In TT systems, overcurrent protective devices may be used for fault protection provided that a suitably low value of Z_S is permanently and reliably assured (see Section 411.5.4) so that in case of a fault, tripping of the overcurrent protective device in compliance with the required disconnection times is achieved.

531.2.4 IT systems

Overcurrent protective devices, when used as devices for fault protection in the event of a second fault, shall comply with:

(i) Section 531.2.2, taking into account the requirements of Section 411.6.5(i), where exposed-conductive-parts are interconnected, or

(ii) Section 531.2.3, taking into account the requirements of Section 411.6.5(ii), where exposed-conductive-parts are earthed in groups or individually.

In IT systems, if disconnection required by Chapter 41 in the event of the second fault to earth cannot be achieved by an overcurrent protective device, one or more RCDs shall be used to provide the required fault protection within the installation.

NOTE: Reference is also made to Section 419.3 where supplementary protective equipotential bonding is required in those cases where automatic disconnection according to Section 411.3.2.1 cannot be achieved.

Overcurrent protective devices used in IT systems shall have line poles suitable for line-to-line voltage applications and a neutral pole, if applicable, suitable for the line-to-neutral voltage for operation in case of a second insulation fault.

In IT systems, in the event of a second fault, the operation of the overcurrent protective device shall result in the disconnection of all corresponding live conductors, including the neutral conductor, if any (see also Section 431.2.2).

531.3 Residual current devices (RCDs)

531.3.1 General

Except where Section 531.3.1.201 applies, an RCD shall disconnect all live conductors of the circuit protected.

The protective conductor shall not pass through the sensor of the RCD except where this is unavoidable, e.g. in the case of armoured cables. In such exceptional cases, the protective conductor alone has to be passed again through the sensor but in the reverse direction. The protective conductor shall be insulated and shall not be earthed either at the first or at the second passing through the sensor.

A protective conductor current shall not contribute to the measurement of the residual current.

531.3.1.201 For protection against electric shock, there is no requirement to disconnect/switch the neutral in TT or TN systems.

531.3.1.202 It is not permissible to introduce an external connection for the purpose of intentionally creating a residual current to trip an RCD.

NOTE 1: This does not preclude the use of an RCD with a functional earth connection.

NOTE 2: This does not preclude the use of a test instrument in accordance with Part 6.

531.3.2 Unwanted tripping

Residual current protective devices shall be selected and erected such as to limit the risk of unwanted tripping. The following shall be considered:

(i) subdivision of circuits with individual associated RCDs. RCDs shall be selected and the circuits subdivided in such a way that any earth leakage current likely to occur during normal operation of the connected load will not cause unwanted tripping of the device. See also Section 314

(ii) in order to avoid unwanted tripping by protective conductor currents and/or earth leakage currents, the accumulation of such currents downstream of the RCD shall be not more than 30 % of the rated residual operating current

NOTE 1: This will also allow a better selection of the type of RCDs according to the nature of the circuit or the load.

NOTE 2: RCDs may operate at any value of residual current in excess of 50 % of the rated residual current.

(iii) use of short time-delayed RCDs, provided the applicable requirements of Chapter 41 are met

NOTE 3: In the case of transient effects, tripping of the RCD may occur by charging of bypass capacitors or by other electromagnetic disturbances.

(iv) coordination of general type RCDs, selective type RCDs and time-delayed RCDs (CBRs according to IEC 60947-2) as covered in Section 536

NOTE 4: CBR is a circuit-breaker incorporating residual current protection.

(v) coordination of RCDs with surge protective devices (SPD) according to Section 534.4.7.

531.3.3 Types of RCD

Different types of RCD exist, depending on their behaviour in the presence of DC components and frequencies. The appropriate RCD shall be selected from the following:

(i) RCD Type AC: RCD tripping on alternating sinusoidal residual current, suddenly applied or smoothly increasing

(ii) RCD Type A: RCD tripping on alternating sinusoidal residual current and on residual pulsating direct current, suddenly applied or smoothly increasing.

NOTE 1: For RCD Type A, tripping is achieved for residual pulsating direct currents superimposed on a smooth direct current up to 6 mA.

(iii) RCD Type F: RCD for which tripping is achieved as for Type A and in addition:

(a) for composite residual currents, whether suddenly applied or slowly rising, intended for circuit supplied between line and neutral or line and earthed middle conductor

(b) for residual pulsating direct currents superimposed on smooth direct current.

NOTE 2: For RCD Type F, tripping is achieved for residual pulsating direct currents superimposed on a smooth direct current up to 10 mA.

(iv) RCD Type B: RCD for which tripping is achieved as for Type F and in addition:

(a) for residual sinusoidal alternating currents up to 1 kHz

(b) for residual alternating currents superimposed on a smooth direct current

(c) for residual pulsating direct currents superimposed on a smooth direct current

(d) for residual pulsating rectified direct current which results from two or more phases

(e) for residual smooth direct currents, whether suddenly applied or slowly increased, independent of polarity.

NOTE 3: For RCD Type B, tripping is achieved for residual pulsating direct currents superimposed on a smooth direct current up to 0.4 times the rated residual current ($I_{\Delta n}$) or 10 mA, whichever is the highest value.

For general purposes, Type AC RCDs may be used.

NOTE 4: For guidance on the correct use of RCDs for household and similar use, see IEC TR 62350

NOTE 5: Some typical fault currents in circuits comprising semiconductors are given in Annex A53, Figure A53.1.

531.3.4 Selection according to the accessibility to the installation

531.3.4.1 In AC installations having RCDs that are intended to be operated by ordinary persons, the RCDs shall comply with:

- IEC 61008 series for RCCBs, or
- IEC 61009 series for RCBOs, or
- IEC 62423 for Type F and Type B RCCBs and RCBOs.

NOTE: RCCB is a Residual Current operated Circuit-Breaker without integral overcurrent protection. RCBO is a Residual Current operated Circuit-Breaker with integral overcurrent protection.

531.3.4.201 Where an RCD may be operated by an ordinary person, it shall be designed or installed so that it is not possible to modify or adjust the setting or the calibration of its rated residual operating current ($I_{\Delta n}$) or time delay mechanism without a deliberate act involving the use of either a key or a tool and resulting in a visible indication of its setting or calibration.

531.3.4.2 In AC installations having RCDs that are intended to be operated by instructed persons or skilled persons, the RCDs shall comply with:

- IEC 61008 series for RCCBs, or
- IEC 61009 series for RCBOs, or
- IEC 62423 for Type F and Type B RCCBs and RCBOs, or
- IEC 60947-2 for CBRs and MRCDs.

531.3.5 RCDs for fault protection

531.3.5.1 General

The use of RCDs shall provide protection against faults in compliance with Section 411.3.

The selection of RCDs depends on the type of earthing system (see Section s 531.3.5.2, 531.3.5.3 and 531.3.5.4), the presence of DC components and frequencies (Section 531.3.3).

531.3.5.2 TN system

RCDs shall be installed at the origin of that part of the installation to be protected. The requirements for unwanted tripping in accordance with Section 531.3.2 shall also be taken into account.

NOTE: Except where particular restriction for selectivity applies, several circuits may be protecfted by the same device.

The division of the PEN conductor into neutral conductor and protective conductor shall take place at the supply side of the RCDs.

On the load side of the RCD, connection between the protective and neutral conductors is not permitted.

An RCD shall not be used in a TN-C system.

531.3.5.3 TT system

531.3.5.3.1 Location of RCDs

RCDs shall be erected at the origin of that part of the installation to be protected. The requirements for unwanted tripping, in accordance with Section 531.3.2, shall also be taken into account.

NOTE: Where there is more than one origin, this requirement applies to each origin.

531.3.5.3.2 Selection of the rated residual operating current of the RCD

The rated residual operating current value ($I_{\Delta n}$) of an RCD shall not exceed the $I_{\Delta n}$ corresponding to the maximum value of the earth resistance R_A to the exposed-conductive-parts, taking into account the possible seasonal variations, including soil freezing and drying, of the part of the installation protected by this device, as shown in Table 53.1.

R_A is the sum of the resistances in ohms of the earth electrode and the protective conductor connecting it to the exposed-conductive-parts.

Table 53.1 – Correlation between the maximum value of earth resistance R_A and the maximum rated residual operating current $I_{\Delta n}$ of the RCD

Maximum value of R_A (Ω)	Maximum $I_{\Delta n}$ of the RCD
2.5	20 A
5	10 A
10	5 A
17	3 A
50	1 A
100	500 mA
167	300 mA
500	100 mA
1667	30 mA

531.3.5.3.2.201 For Class I enclosures in TT systems where RCD protection is used on outgoing circuits, double or reinforced insulation of all live conductors (incoming cables, extension terminals, etc.) on the supply side of the incoming device, e.g. main switch, shall be used. Insulated and non-metallic sheathed cables are deemed to meet the requirements of double or reinforced insulation.

NOTE 1: When selecting equipment, consideration should be given to the assembly manufacturer's internal line interconnecting cable links on the supply side of an RCD being insulated and non-metallic sheathed, or having reinforced insulation or equivalent mechanical protection.

NOTE 2: Only the assembly manufacturer's approved internal interconnecting cable links should be used.

531.3.5.4 IT system

531.3.5.4.1 General

In IT systems, protection of the neutral conductor by RCD is permitted provided that the requirements of Section 431.2.2 are fulfilled.

531.3.5.4.2 Case of second fault on another live conductor when exposed-conductive-parts are interconnected

Where RCDs are used according to Section 411.6.3(v), one RCD per circuit shall be used. The

operating characteristics of this RCD shall be selected according to Table 41.1 of Chapter 41.

531.3.5.4.3 Case of second fault on another live conductor when exposed-conductive-parts are not interconnected

Where, in an installation, all exposed-conductive-parts are not interconnected, one RCD shall protect each group of interconnected exposed-conductive-parts.

The conditions for determining the characteristics of the RCD shall be those for TT systems defined in Section 411.5:

- The rated residual operating current $I_{\Delta n}$ has to be selected according to Table 53.1.

- The disconnection time has to comply with the values given in Section 411.3.

In addition, fault protection for every circuit located downstream of this RCD shall be provided in accordance with the requirements of Section 411.6.3(v). In this case every final circuit shall be individually protected by an RCD.

531.3.6 RCDs for additional protection

The use of RCDs with a rated residual operating current not exceeding 30 mA is recognized as additional protection in compliance with Section 415.1. These RCDs shall be provided to comply with the requirements of Section 411.3.3.

RCDs for additional protection in AC installations shall comply with:

- IEC 61008 series, or
- IEC 61009 series, or
- IEC 62423.

Where installed at the origin of a final circuit or a group of final circuits, an RCD with a rated residual current not exceeding 30 mA may provide fault protection and additional protection simultaneously.

NOTE: Consideration shall be given to the division of the installation (see Section s 531.3.2 and 314.2).

532 DEVICES FOR PROTECTION AGAINST THE RISK OF FIRE

532.1 General

In locations where, in accordance with Chapter 42, a particular risk of fire exists, preventive protection measures against the risk of fire are required. This may also apply to other locations of the electrical installation, depending on a risk analysis.

NOTE: A suitable evaluation of the risk should be carried out by one or more persons competent in fire risk assessments.

The selection of protective and monitoring devices shall take into account the nature of the load and the likelihood of the device to operate, e.g. fault currents of higher frequencies, DC fault currents or increased leakage currents. (See also Section 331.1.)

532.2 Residual current devices (RCDs) for protection against the risk of fire

RCDs shall comply with Section s 531.3.1 to 531.3.4 and with the applicable requirements of Section 531.3.5.

RCDs with a rated residual operating current not exceeding 300 mA shall be used. RCDs shall be installed at the origin of the circuit to be protected.

532.3 Residual current monitoring devices (RCMs) for protection against the risk of fire in IT systems

In IT systems, RCMs may be used as an alternative to RCDs in accordance with Section 532.2, provided that the location is supervised by one or more skilled or instructed person(s).

RCMs shall be in accordance with IEC 62020 and operate in conjunction with switchgear suitable for isolation.

RCMs shall be installed at the origin of final circuits. The rated residual operating current shall not exceed 300 mA. Audible and visual signals shall be provided by the RCMs.

532.4 Insulation monitoring devices (IMDs) for protection against the risk of fire in IT systems

Insulation monitoring devices applied in IT systems for protection against the risk of fire shall comply with the requirements of Section 538.

A fault location system in accordance with the requirement of Section 538.2 able to locate the faulty circuit, may also be used.

532.5 Internal arc fault protection in a switchgear and controlgear assembly

Where required for special applications, internal arc fault protection (e.g. optical detection system) detecting a fault arc together with a protection system can be selected in order to extinguish the arc.

Alternatively, an assembly with arc ignition protected zone(s) can be selected to minimise the risk of an arcing fault. (Arcing class I in accordance with IEC /TR 61641.)

NOTE: Internal arc fault protection is typically associated with a switchboard used in special applications. An assembly that has been subject to an internal arcing fault can require maintenance or replacement.

532.6 Arc fault detection devices (AFDDs)

Where specified, arc fault detection devices shall be installed:

(i) at the origin of the final circuits to be protected, and

(ii) in AC single-phase circuits not exceeding 230 V.

AFDDs shall comply with IEC 62606. Coordination of AFDDs with overcurrent protective devices, if necessary, shall take account of the manufacturer's instructions.

533 DEVICES FOR PROTECTION AGAINST OVERCURRENT

533.1 General requirements

533.1.1 Compliance with standards

A device for protection against overcurrent shall comply with one or more of the following:

- IEC 60269 series
- IEC 60898 series
- IEC 60947 series
- IEC 61009 series
- IEC 62423.

The use of another device is not precluded provided that its time/current characteristics provide a level of protection not less than that given by the devices listed above.

The following protective devices shall be used only for protection against short-circuit current:

- instantaneous trip circuit-breakers (ICB) in accordance with Annex O of IEC 60947-2
- aM and aR type fuses in accordance with IEC IEC 60269-2 or IEC IEC 60269-3.

For every fuse and circuit-breaker there shall be provided on or adjacent to it an indication of its intended rated current as appropriate to the circuit it protects. For a semi-enclosed fuse, the intended rated current to be indicated is the value to be selected in accordance with Section 533.1.2.3.

533.1.2 Fuses

533.1.2.1 A fuse base shall be arranged so as to exclude the possibility of the fuse carrier making contact between conductive parts belonging to two adjacent fuse bases.

A fuse base using screw-in fuses shall be connected so that the centre contact is connected to the conductor from the supply and the shell contact is connected to the conductor to the load.

533.1.2.2 Fuses having fuse links likely to be removed or replaced by an ordinary person shall be of a type which complies with IEC 60269-3. Such a fuse link shall either:

(i) have marked on or adjacent to it an indication of the type of fuse link intended to be used, or

(ii) be of a type such that there is no possibility of inadvertent replacement by a fuse link having the intended rated current but a higher fusing factor than that intended.

NOTE: In polyphase systems additional measures may be needed, e.g. an all-pole switch on the supply side, in order to prevent the risk of unintentional contact with live parts on the load side.

Fuses or combination units having fuse links likely to be removed and replaced only by skilled or instructed person(s) shall be installed in such a manner that the fuse links can be removed or replaced without unintentional contact with live parts.

533.1.2.3 A fuse shall preferably be of the cartridge type. Where a semi-enclosed fuse is selected, it shall be fitted with an element in accordance with the manufacturer's instructions, if any. In the absence of such instructions, it shall be fitted with a single element of tinned copper wire of the appropriate diameter specified in Table 533.1.

TABLE 533.1 – Sizes of tinned copper wire for use in semi-enclosed fuses

Rated current of fuse element (A)	Nominal diameter of wire (mm)
3	0.15
5	0.2
10	0.35
15	0.5
20	0.6
25	0.75
30	0.85
45	1.25
60	1.53
80	1.8
100	2.0

533.1.3 Circuit-breakers

Where a circuit-breaker may be operated by an ordinary person, it shall be designed or installed so that it is not possible to modify the setting or the calibration of its overcurrent release without a deliberate act involving the use of either a key or a tool and resulting in a visible indication of its setting or calibration.

Where a screw-in type circuit-breaker is used in a fuse base, the requirements of Section 533.1.2.1 also apply.

According to the requirements of Annex H of IEC 60947-2, devices marked with the voltage value followed by the symbol  shall not be used in IT systems for such voltage.

533.2 Selection of devices for overload protection of wiring systems

533.2.1 The rated current (or current setting) of the protective device shall be chosen in accordance with Section 433.1.

In certain cases, to avoid unintentional operation, the peak current values of the loads may have to be taken into consideration.

In the case of a cyclic load, the values of I_n and I_2 shall be chosen on the basis of values of I_b and I_z for the thermally equivalent constant load

where:

- I_b is the current for which the circuit is designed
- I_z current-carrying capacity of a cable for continuous service under the particular installation conditions concerned
- I_n is the rated current or current setting of the protective device
- I_2 is the current causing effective operation of the overload protective device within the conventional time as stated in the product standard.

NOTE: The current causing effective operation in the conventional time of protective devices may also be named I_t (for circuit-breakers) or I_f (for fuses) according to the product standards. Both I_t and I_f are multiples of I_n and attention should be given to the correct representation of values and indexes.

533.2.2 Additional requirements for protection against overload when harmonic currents are present

When selecting an overload protective device to comply with Section 433.1, account shall be taken of harmonic currents in accordance with Section 431.2.3.

NOTE: See also Appendix 2 for further details on harmonics.

533.3 Selection of devices for protection of wiring systems against fault current

The application of the Section s of Chapter 43 shall take into account both the minimum and maximum fault current conditions, so that the highest energy let-through is taken into account.

Where the standard covering a protective device specifies both a rated service short-circuit breaking capacity and a rated ultimate short-circuit breaking capacity, it is acceptable to select the protective device on the basis of the ultimate short-circuit breaking capacity for the maximum fault current conditions. Operational circumstances may, however, make it desirable to select the protective device on the service short-circuit breaking capacity, e.g. where a protective device is placed at the origin of the installation.

Where the short-circuit breaking capacity of the protective device is lower than the maximum prospective short-circuit or earth fault current that is expected at its point of installation, it is necessary to comply with the requirements of the last paragraph of Section 536.1 and Section 536.5.

NOTE: To calculate the maximum and minimum fault currents, See also Appendix 2, paragraph 2.5.

534 DEVICES FOR PROTECTION AGAINST OVERVOLTAGE

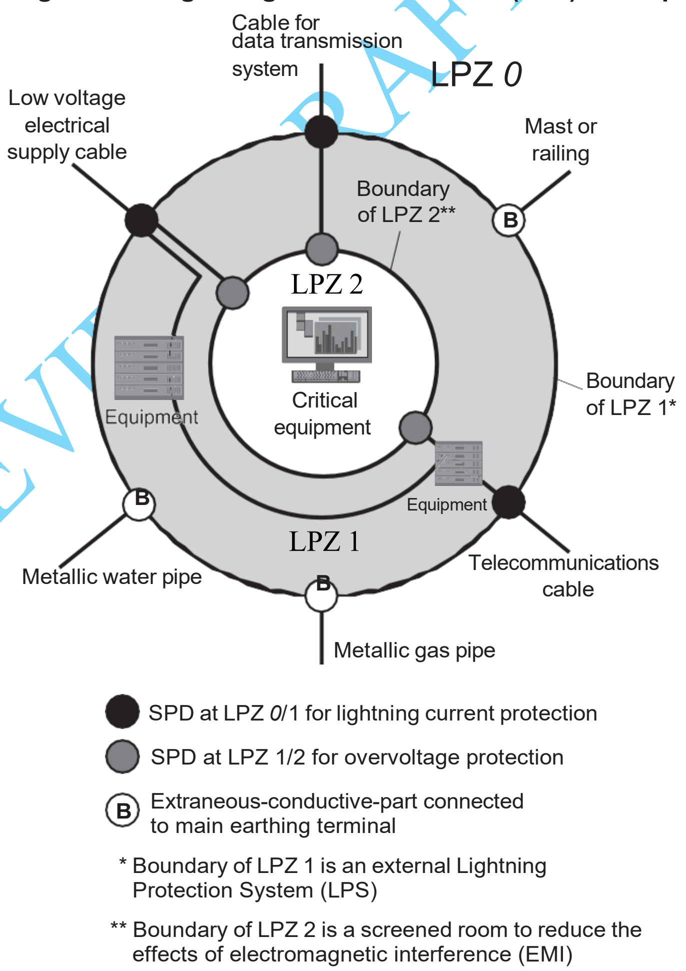
For further information see Appendix 6.

534.1 General

This section contains provisions for the application of voltage limitation in order to obtain insulation coordination in the cases described in Section 443, IEC 60664-1, KS IEC 62305 series and IEC 61643 series. This section focuses mainly on the requirements for the selection and erection of SPDs for protection against transient overvoltages where required by Section 443, the KS IEC 62305 series, or as otherwise stated.

KS IEC 62305-4 and IEC 61643-12 series deal with the protection against the effects of direct lightning strokes or strokes near to the supply system. Both documents describe the selection and the application of surge protective devices (SPDs) according to the Lightning Protection Zones (LPZ) concept. The LPZ concept describes the installation of Type 1, Type 2 and Type 3 SPDs. See Figure 534.1.

Fig 534.1 – Lightning Protection Zones (LPZ) concept



NOTE 1: SPDs with more than one Type of classification are available, e.g. combined Type 1+2 or combined Type 2+3.

Section 534 does not take into account:

- surge protective components incorporated in appliances connected to the installation
- portable surge protective devices (SPD).

NOTE 2: Further information can be found in DD CLC/TS 61643-12.

Section 534 applies to AC power circuits. As far as it is applicable, the requirements of Section 534 may be followed for DC power circuits.

NOTE 3: Overvoltages of atmospheric origin and electrical switching events can affect metallic data, signal and telecommunication lines. Protection measures for these systems are detailed within IEC 61643-22.

534.2 Not used

534.3 Not used

534.4 Selection and erection of SPDs

534.4.1 SPD types and location

534.4.1.1 Where SPDs are required:

(i) SPDs installed at the origin of the electrical installation shall be Type 1 or Type 2

(ii) SPDs installed close to sensitive equipment to further protect against switching transients originating within the building shall be Type 2 or Type 3.

NOTE: Type 1 SPDs are often referred to as equipotential bonding SPDs and are fitted at the origin of the electrical installation to specifically prevent dangerous sparking which could lead to fire or electric shock hazards. In accordance with KS IEC 62305-4, a lightning protection system which only employs equipotential bonding SPDs provides no effective protection against failure of sensitive electrical and electronic systems. Further SPDs (Type 2 and Type 3) are required to protect sensitive and critical equipment (for example, hospital equipment and fire/security alarm systems) downstream of the origin of the electrical installation.

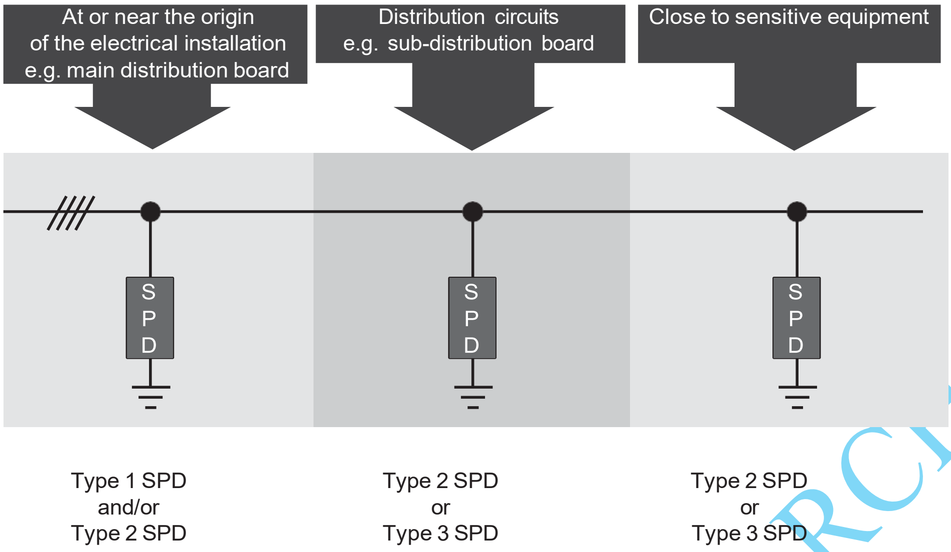
534.4.1.2 In accordance with the LPZ concept, where a cable crosses the zonal interface, further SPDs shall be installed to preserve the zone integrity.

534.4.1.3 Where the installation of SPDs is required by Section 443 and the structure is equipped with an external lightning protection system or protection against the effects of direct lightning, Type 1 SPDs shall be installed as close as possible to the origin of the electrical installation.

534.4.1.4 Where the installation of SPDs is required by Section 443 and the structure is not equipped with an external lightning protection system or does not require protection against the effects of direct lightning, Type 2 SPDs shall be installed as close as possible to the origin of the electrical installation.

534.4.1.5 Type 2 or Type 3 SPDs shall be located in the fixed electrical installation, for example, in sub-distribution boards or close to the equipment to be protected, to achieve the required voltage protection level; see Figure 534.2. These SPDs shall be coordinated with Type 1 and/or Type 2 SPDs being installed at the origin of the electrical installation (see Section 534.4.4.5).

Fig 534.2 – Example of installation of Type 1, Type 2 and Type 3 SPDs



534.4.1.6 Consideration shall be given to the provision of SPDs to protect from other sources, such as:

(i) switching overvoltages produced by current-using equipment located within the installation

(ii) overvoltages on other incoming services such as metallic telecommunication and signalling services

(iii) overvoltages on other services feeding other structures such as secondary buildings, external installations/lighting, power lines feeding external sensors.

These SPDs shall be installed and located as close as possible to the origin of such events.

NOTE: For further information see IEC 61643-12 series and KS IEC 62305-4.

534.4.1.7 The presence of SPDs installed downstream of a distribution board (e.g. in a socket-outlet) shall be permanently indicated (e.g. by a label) at or near the distribution board.

534.4.2 Connection modes of SPDs

Protection against transient overvoltages shall be provided:

- between live conductors and PE (common mode protection), and/or
- between live conductors (differential mode protection).

NOTE: For further information see DD CLC/TS 61643-12.

534.4.3 Connection types

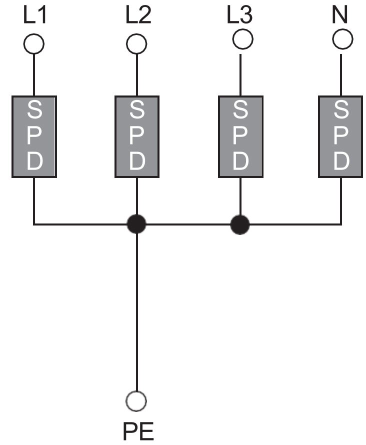
534.4.3.1 Connection Type CT1

Connection Type CT1 (e.g. 4+0 configuration):

- SPD assembly providing a mode of protection between each live conductor (line and neutral conductors, if available) and PE.

An example of connection Type CT1 for application in a three-phase system is given in Figure 534.3.

Fig 534.3 – Connection Type CT1 (4+0-configuration) for a three-phase system with neutral



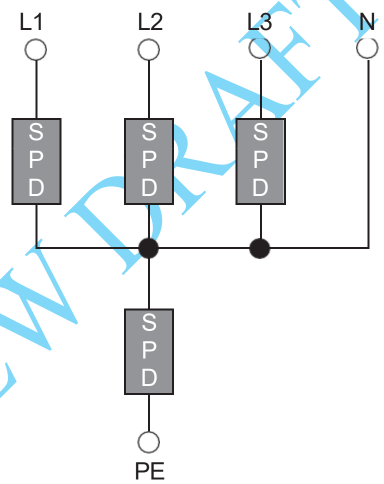
534.4.3.2 Connection Type CT2

Connection Type CT2 (e.g. 3+1-configuration):

- SPD assembly providing a mode of protection between each line conductor and the neutral conductor, and between the neutral conductor and PE.

An example of connection Type CT2 for application in a three-phase system is given in Figure 534.4.

Fig 534.4 – Connection Type CT2 (e.g. 3+1-configuration) for a three-phase system with neutral



534.4.4 Selection of SPDs

534.4.4.1 General

The following parameters shall be considered for SPD protection:

- voltage protection level (U_p) of the SPD and rated impulse withstand voltage (U_W) of the equipment to be protected (see Section 534.4.4.2)
- continuous operating voltage (U_c) of the SPD, i.e. supply system (TT, TN, IT) (see Section 534.4.4.3)
- nominal discharge current (I_{nspd}) and/or impulse discharge current (I_{imp}) of the SPD (see Section 534.4.4.4)
- SPD coordination (see Section 534.4.4.5)
- expected short-circuit current (I_{SCCR}). (see Section 534.4.4.6)
- follow current interrupt rating (I_{fi}) (SPDs shall comply with the requirements of IEC 61643-11).

NOTE: Additional information regarding selection and application is given in DD CLC/TS 61643-12. Annex D of DD CLC/TS 61643-12 provides application examples of selecting SPDs.

534.4.4.2 Selection with regard to voltage protection level (U_p)

The voltage protection level (U_p) of SPDs shall be selected in accordance with impulse withstand voltage Category II of Table 443.2 and in no case exceed the required rated impulse voltage of the equipment.

NOTE 1: In some cases, for example where the continuous operation of the equipment is critical, the voltage protection level (U_p) of SPDs can be selected to be lower than the impulse immunity of equipment. The impulse immunity voltage of equipment is lower than the impulse withstand of equipment and requires SPDs with lower voltage protection level U_p between live conductors (e.g. line to neutral) to avoid equipment malfunction, particularly against switching transients. For further information see DD CLC/TS 61643-12.

In installations operating at 230/400 V, the voltage protection level of the installed SPD assembly shall not exceed 2.5 kV, as the SPD's connecting leads have additional inductive voltage drop across them (see Section 534.4.8). It may, therefore, be necessary to select an SPD with a lower voltage protection level.

If the distance between the SPD and equipment to be protected (protective distance) is greater than 10 m, oscillations could lead to a voltage at the equipment terminals of up to twice the SPD's voltage protection level. Consideration shall be given to the provision of additional coordinated SPDs, closer to the equipment, or the selection of SPDs with a lower voltage protection level.

NOTE 2: It is recommended that the voltage protection level provided by SPDs does not exceed a safety margin of 80 % of the required rated impulse voltage for equipment according to Table 443.2 and corresponding to overvoltage category II.

This safety margin is not necessary where one of the following cases applies:

- where the equipment is connected directly to the SPD terminals
- where a protection scheme according to Figure 534.9 is already applied
- where the voltage drop across the overcurrent protection in the SPD branch circuit is already taken into account for the voltage protection level U_p
- where protection according to overvoltage category II is provided but only overvoltage category III or IV equipment is installed at this location.

NOTE 3: DD CLC/TS 61643-12 gives additional information about the rated impulse voltage of equipment and the given U_p for the SPD.

Table 534.1 Not used

534.4.4.3 Selection of SPDs with regard to continuous operating voltage (U_c)

In AC installations, the maximum continuous operating voltage U_c of SPDs shall be equal to or higher than required by Table 534.2.

Table 534.2 – Minimum required U_c of the SPD dependent on the supply system configuration

SPD connected between (as applicable)	System configuration of distribution network		
	TN system	TT system	IT system
Line conductor and neutral conductor	$\frac{1.1\,U}{\sqrt{3}}$ or (0.64 × U)	$\frac{1.1\,U}{\sqrt{3}}$ or (0.64 × U)	$\frac{1.1\,U}{\sqrt{3}}$ or (0.64 × U)
Line conductor and PE conductor	$\frac{1.1\,U}{\sqrt{3}}$ or (0.64 × U)	$\frac{1.1\,U}{\sqrt{3}}$ or (0.64 × U)	1.1 U
Neutral and PE conductor	$\frac{U}{\sqrt{3}}$[a]	$\frac{U}{\sqrt{3}}$[a]	$\frac{1.1\,U}{\sqrt{3}}$ or (0.64 × U)
Line conductors	1.1 U	1.1 U	1.1 U
NOTE: U is the line-to-line voltage of the low voltage system.			
a These values are related to worst-case fault conditions, therefore, the tolerance of 10 % is not taken into account.			

534.4.4.4 Selection of SPDs with regard to discharge current (I_{nspd}) and impulse discharge current (I_{imp})

At or near the origin of the electrical installation, SPDs shall comply with one of the following cases, as applicable:

- where the building is protected against direct lightning strike, SPDs at the origin of the electrical installation shall be selected according to Section 534.4.4.4.2 and Table 534.4
- in other cases, SPDs shall be selected according to Section 534.4.4.4.1.

SPDs installed downstream of the SPDs at or near the origin of the electrical installation shall also comply with the coordination requirements in Section 534.4.4.5.

NOTE: Overvoltages due to switching can be longer in duration and can contain more energy than the transient overvoltages of atmospheric origin. This has to be considered for the selection of SPDs with regard to nominal discharge current and impulse discharge current. For further information see DD CLC/TS 61643-12.

534.4.4.4.1 Type 2 SPDs

Where Type 2 SPDs are required at or near the origin of the electrical installation, their nominal discharge current (I_{nspd}) shall be not less than that given in Table 534.3.

Table 534.3 – Nominal discharge current (I_{nspd}) depending on supply system and connection Type

Connection	I_{nspd} in kA			
	Supply system			
	Single-phase		Three-phase	
	CT1	CT2	CT1	CT2
L - N		5		5
L - PE	5		5	
N - PE	5	10	5	20

534.4.4.4.2 Type 1 SPDs

Where Type 1 SPDs are required at or near the origin of the electrical installation, one of the following cases applies:

(i) Where no risk analysis according to KS IEC 62305-2 has been carried out, the impulse discharge current (I_{imp}) shall be not less than as given in Table 534.4.

Table 534.4 – Selection of impulse discharge current (I_{imp}) where the building is protected against direct lightning strike

Connection	I_{imp} in kA			
	Supply system			
	Single-phase		Three-phase	
	CT1	CT2	CT1	CT2
L - N		12.5		12.5
L - PE	12.5		12.5	
N - PE	12.5	25	12.5	50
NOTE: This table refers to lightning protection levels (LPL) III and IV.				

(ii) Where the risk analysis according to KS IEC 62305-2 has been carried out, the impulse discharge current (I_{imp}) shall be determined according to the KS IEC 62305 series.

534.4.4.5 Coordination of two or more SPDs

SPDs shall be selected and erected such as to provide coordination in operation by reference to the manufacturer's data.

534.4.4.6 Selection of SPDs with regard to the short-circuit current rating (I_{SCCR})

In general, the short-circuit current rating I_{SCCR} of an SPD, as stated by the manufacturer, shall not be lower than the maximum prospective short-circuit current at the connection points of the SPD assembly; see Figure 534.5.

NOTE 1: The SPD alone, or as an assembly in conjunction with its disconnector and/or overcurrent protective device (OCPD), is required to withstand the short-circuit current rating I_{SCCR} as stated by the manufacturer. This value is defined and tested according to IEC 61643-11, in conjunction with the disconnector and/or OCPD as stated by the manufacturer.

NOTE 2: This requirement does not apply to SPDs connected between the neutral conductor and PE in TN or TT systems, for which this is already covered by the product standard IEC 61643-11.

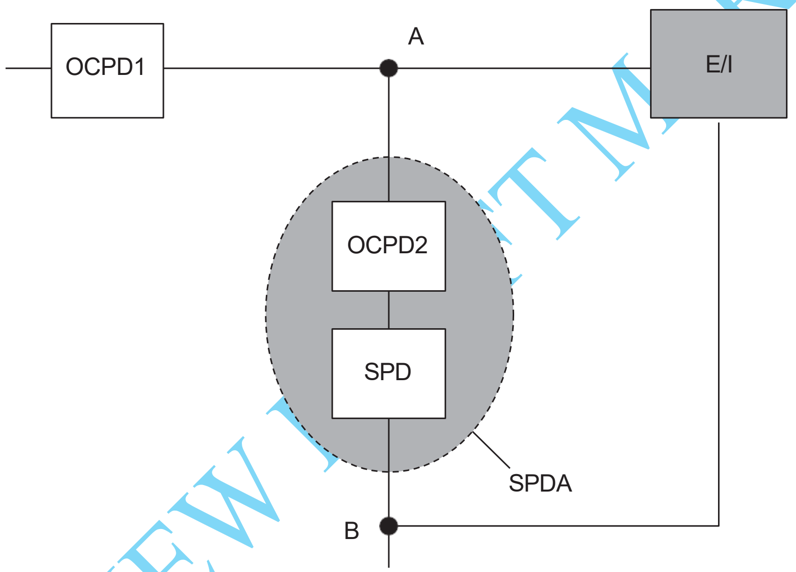
For SPDs connected between the neutral conductor and PE in IT systems, the short-circuit current rating I_{SCCR} of the SPD shall not be lower than the maximum prospective short-circuit current at the connection points of this SPD in case of a second fault.

534.4.4.7 Selection of SPDs with regard to the follow current interrupt rating (I_{fi})

In general, the follow current interrupt rating I_{fi} of the SPD, if declared by the manufacturer, shall not be lower than the maximum prospective short-circuit current at the connection points of the SPD assembly. See Figure 534.5.

For SPDs connected between the neutral conductor and PE in IT systems, the follow current interrupt rating I_{fi} of the SPD, if declared by the manufacturer, shall not be lower than the maximum prospective short-circuit current at the connection points of this SPD in case of a second fault.

Fig 534.5 – Connection points of an SPD assembly



Key

OCPD 1	overcurrent protective device in the installation
OCPD 2	overcurrent protective device specified by the SPD manufacturer
SPD	surge protective device
SPDA	SPD assembly
A & B	connection points of SPD assembly
E/I	equipment or installation to be protected.

534.4.5 Protection of the SPD against overcurrent

534.4.5.1 General

SPD installations shall be protected against overcurrent with respect to short-circuit currents.

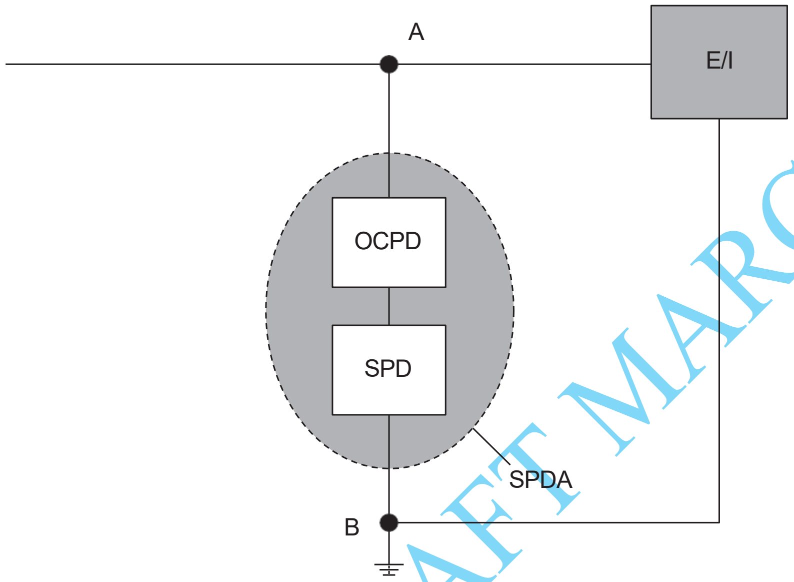
This protection may be internal and/or external to the SPD according to the manufacturer's instructions.

The ratings and characteristics of external OCPDs for protecting the SPD assembly shall be selected in accordance with Section 434 and be the highest permissible rating to provide a high surge current capability for the complete assembly whilst not exceeding the ratings and characteristics as required in the SPD manufacturer's installation instructions for the maximum overcurrent protection.

534.4.5.2 Arrangement of SPDs with relation to overcurrent protection

In case of OCPD operation arising from SPD failure, the continuity of the supply to the equipment is unaffected. However, neither the installation nor the equipment is protected against possible further overvoltages (see Figure 534.6). In such an arrangement, the effective voltage protection level within the installation is increased due to the additional voltage drop at the external OCPD connected in series with the SPD.

Fig 534.6 – Example of overcurrent protection in the SPD branch by using a dedicated external overcurrent protective device



Key

OCPD	overcurrent protective device specified by the SPD manufacturer
SPD	surge protective device
SPDA	SPD assembly
A & B	connection points of SPD assembly
E/I	equipment or installation to be protected.

534.4.5.3 Selectivity between OCPDs

Where selectivity between OCPDs is necessary to prevent danger and where required for proper functioning of the installation, the manufacturer's instructions shall be taken into account; see Section 536.4.

534.4.6 Fault protection

Fault protection, as defined in Chapter 41, shall remain effective in the protected installation even in the event of SPD failure.

In the case of automatic disconnection of supply:

- in TN systems, this may generally be fulfilled by the OCPD on the supply side of the SPD (See Figure 16A1 of Appendix 6);
- in TT systems, this may be fulfilled by:
  - (a) the installation of SPDs downstream (load side) of an RCD (See Figure 16A2 of Appendix 6), or
  - (b) the installation of SPDs upstream (supply side) of the main RCD. Owing to the possibility of a failure of an SPD connected between neutral conductor and PE, the conditions of Section 411.4.1 shall be met and the SPDs shall be installed in accordance with connection Type CT2 (See Figure 16A3 of Appendix 6).
- in IT systems, no additional measure is needed (See Figure 16A4 of Appendix 6).

Table 534.5 – Connection of the SPD dependent on supply system

Supply system at the connection point of the SPD assembly	Connection Type	
	CT1	CT2
TN system	Y	Y
TT system	SPD only downstream of RCD	Y
IT system with neutral	Y	Y
IT system without neutral	Y	N/A
NOTE 1: Y = applicable		
NOTE 2: N/A = not applicable		

NOTE: Additional requirements might apply for SPDs installed in the area of influence of applications such as railway systems, HV power systems, mobile units, etc.

534.4.7 SPD installation in conjunction with RCDs

Where SPDs are installed in accordance with Section 534.4.1 and are on the load side of an RCD, an RCD having an immunity to surge currents of at least 3 kA 8/20 shall be used.

NOTE 1: Type S RCDs in accordance with IEC 61008-1 and IEC 61009-1 satisfy this requirement.

Installation of Type 1 SPDs downstream of an RCD is not recommended.

NOTE 2: In the case of a surge current higher than 3 kA 8/20, the RCD may trip causing interruption of the supply.

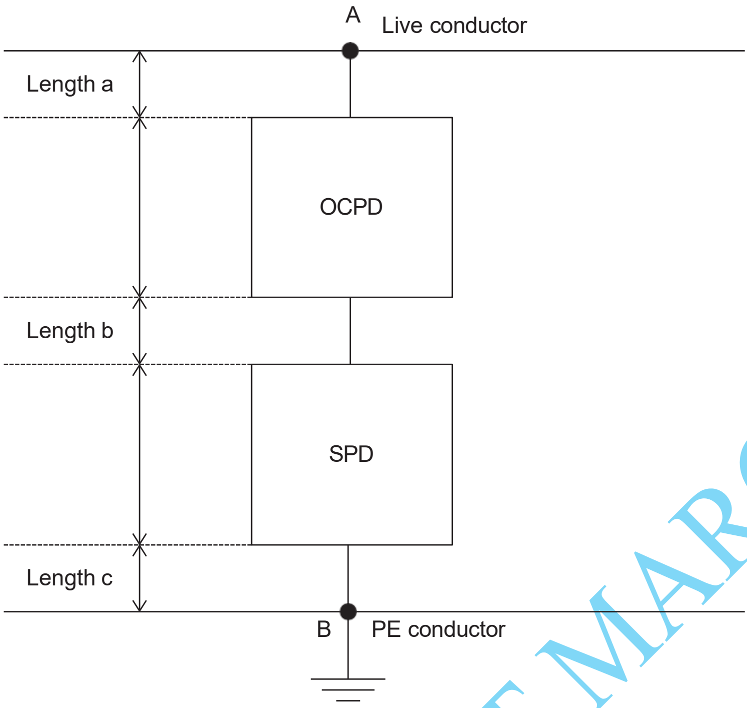
534.4.8 Connection of SPDs

All conductors and interconnections to the relevant line to be protected, together with the connections between the SPD and any external OCPD, shall be kept as short and as straight as possible and any unnecessary cable loops shall be avoided.

The length of the connecting conductors is defined as the sum of the path length of conductors used from the live conductor to the PE in between connection points A and B as shown in Figure 534.8 (for example, a + b + c).

Fig 534.7 Not used

Fig 534.8 – Connection of the SPD



Key

OCPD	overcurrent protective device
SPD	surge protective device
PE conductor	protective earthing conductor
A and B	connection points of SPD assembly.

NOTE: When the OCPD is not present, length b is equal to 0.

Consideration shall be given to limit the total wiring length of conductors between connection points of the SPD assembly, which should preferably not exceed 0.5 m and in no case exceed 1.0 m.

To meet these requirements, the main protective conductor shall be connected to the earthing terminal located as near as possible to the SPD by adding, if necessary, an intermediate earthing terminal (see Figure 534.9).

To determine the total length of the connecting conductors according to Figure 534.9, the following conductor lengths shall not be taken into account:

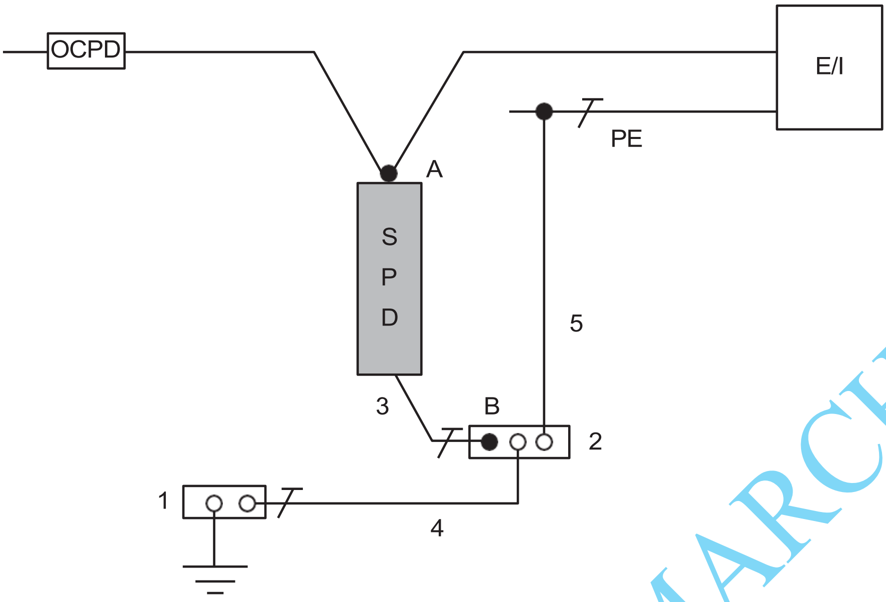
- between the main earthing terminal and the intermediate earthing terminal
- between the intermediate earthing terminal and the PE conductor.

The length (and therefore inductance) of the conductors between the SPDs and the main earthing terminal shall be kept to a minimum. SPDs may be connected to the main earthing terminal or to the protective conductor via metallic parts, e.g. the metallic enclosures of the assembly (see Section 534.4.2), provided it is connected to PE and meets the requirements for a protective conductor in accordance with Chapter 54. Connection of the relevant SPD(s) to the main earthing terminal, and in addition to the main protective conductor, may improve the voltage protection level.

If the total wiring length (a +b +c) as defined in Figure 534.8 exceeds 0.5 m, at least one of the following options shall be chosen:

- select an SPD with a lower voltage protection level U_p (a 1 m length of rectilinear conductor carrying a discharge current of 10 kA (8/20) adds a voltage drop of about 1 000 V)
- install a second coordinated SPD close to the equipment to be protected so as to adapt the voltage protection level U_p to the rated impulse voltage of the equipment to be protected
- use the installation method as shown in Figure 534.9.

Fig 534.9 – Example of installation of an SPD in order to decrease lead length of SPD supply conductors



Key

OCPD	overcurrent protective device
SPD	surge protective device
PE conductor	protective earthing
E/I	equipment/installation to be protected
1	main earthing terminal
2	intermediate earthing terminal
3	length c (to be considered)
4	cable length need not be considered
5	cable length need not be considered
A and B	connection points of SPD assembly.

NOTE: For further information see DD CLC/TS 61643-12.

534.4.9 *Not used*

534.4.10 Connecting conductors of SPDs

Conductors between SPDs and the main earthing terminal or the protective conductor shall have a cross-sectional area not less than:

- 6 mm^2 copper or equivalent for Type 2 SPDs installed at or near the origin of the installation
- 16 mm^2 copper or equivalent for Type 1 SPDs installed at or near the origin of the installation.

Referring to Section 433.3.1(ii), conductors connecting SPDs and the OCPDs to live conductors shall be rated to withstand the prospective short-circuit current to be expected and shall have a cross-sectional area not less than:

- 2.5 mm^2 copper or equivalent for Type 2 SPDs installed at or near the origin of the installation
- 6 mm^2 copper or equivalent for Type 1 SPDs installed at or near the origin of the installation.

535 DEVICES FOR PROTECTION AGAINST UNDERVOLTAGE

Devices for protection against undervoltage shall comply with the relevant requirements of Section 445.

For protection of persons and property, devices for protection against undervoltage may be required.

Protective devices against undervoltage are selected as follows:

(i) direct operating undervoltage release:
- lower value of the relay operating voltage
- higher value of the relay operating voltage
- time delay (if required)

(ii) indirect operating undervoltage release:
- lower value of the operating voltage
- higher value of the operating voltage
- time delay (if required)

(iii) automatic reclosing when the voltage is restored:
- with reclosing prevention
- without reclosing prevention.

The characteristics of the protective devices against undervoltage shall be coordinated with the requirements in the relevant standards for switching on (inrush current) operation and switching off of the electrical equipment.

536 CO-ORDINATION OF ELECTRICAL EQUIPMENT FOR PROTECTION, ISOLATION, SWITCHING AND CONTROL

536.1 General

This section covers co-ordination in the case of a fault and overload conditions and also takes into consideration aspects in Section 133 relevant to the co-ordination of electrical devices as follows:
- overcurrent protective device (OCPD)
- control and protective switching device (CPS)
- residual current device (RCD)
- contactor and starter
- switch and disconnector.

NOTE 1: Co-ordination of monitoring devices is under consideration.

NOTE 2: Reference to the meaning of some of the abbreviations used in this section may be found in Table A53.1 in Annex A53 located at the end of this chapter.

Section 536 does not provide requirements for the selection of an electrical device alone, but provides requirements for the selection of electrical devices to achieve electrical co-ordination between them.

The requirements also cover aspects of continuity of supply of the installation.

536.2 Electrical devices considered and function provided

NOTE: Table A53.1 in Annex A53 shows the functions provided by different electrical devices.

536.3 Co-ordination requirements

For selecting electrical devices as covered by the following Section s, the mutual interaction between those devices shall be considered so that they do not adversely affect the safety of the installation.

The co-ordination of electrical devices considers requirements in case of:
- short-circuit
- overload
- residual currents.

Aspects for co-ordination of electrical devices are:
- selectivity
- short-circuit protection
- overload protection.

Electrical devices shall be selected taking into account the co-ordination characteristics as given by the manufacturers.

536.4 Requirements for selectivity

536.4.1 General

Selectivity between OCPDs is defined in Section 536.4.1.2 for overload conditions and in Section 536.4.1.3 for short-circuit conditions. Selectivity between RCDs is defined in Section 536.4.1.4 and selectivity between OCPD and RCD is defined in Section 536.4.1.5.

In this Section , the OCPD could be replaced by an SCPD.

536.4.1.2 Selectivity under overload conditions between OCPDs

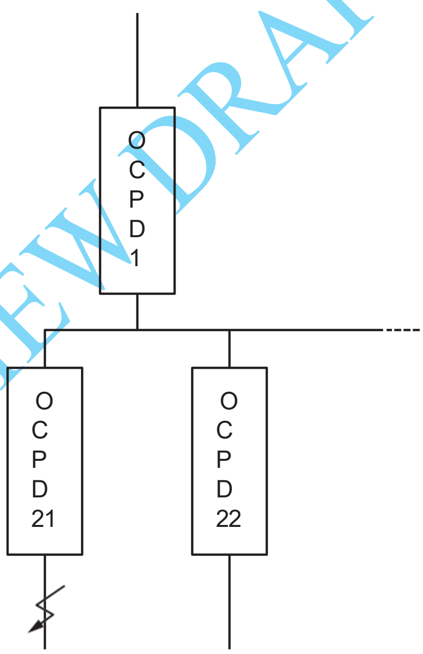
536.4.1.2.1 General requirements

Where selectivity is required, as shown in Figure 536.1, the design shall be verified either by:

- desk study, taking into account the relevant product standards and the manufacturer's literature, or
- appropriate software tools where information is provided by the manufacturer for this specific use, or
- tests in accordance with the applicable product standard (in order to achieve the correct test performances and reproducibility), or
- manufacturer’s declaration.

In the case of a desk study, when time/current characteristics are used to verify selectivity, account shall be taken of the reference ambient temperature for which the tripping curves are given and to load conditions before the overcurrent.

Fig 536.1 – Selectivity between OCPDs



536.4.1.3 Selectivity under short-circuit conditions between OCPDs

536.4.1.3.1 General requirements

Where selectivity is required (see Figure 536.1), verification shall be made either by:

- desk study, taking into account the relevant product standard and the manufacturer’s literature, or
- appropriate software tools where information is provided by the manufacturer for this specific use, or
- tests in accordance with the applicable product standard (in order to achieve the correct test performances and reproducibility), or
- manufacturer’s declaration.

In the case of a desk study, when energy limitation curves are used to verify selectivity, account shall be taken of the voltage for which the curves are given.

In cases given in A53.7 and A53.10 in Annex A53, selectivity will be obtained for short-circuit currents up to a specific value, the selectivity limit current. The value of this limit will be given by the manufacturer. In a particular installation selectivity may be total or partial.

NOTE: Generally, manufacturers provide tables giving information on selectivity in case of short-circuit.

536.4.1.4 Selectivity between RCDs

(i) General requirements

Where selectivity is required (see Figure 536.2), verification shall be made either by:

- desk study, taking into account the relevant product standard and the manufacturer's literature, or
- appropriate software tools where information is provided by the manufacturer for this specific use, or
- tests in accordance with the applicable product standard (in order to achieve the correct test performances and reproducibility), or
- manufacturer's declaration.

NOTE 1: Generally, manufacturers provide information specifying selectivity between RCDs.

(ii) Selectivity in case of residual currents

Selectivity in case of residual currents, as shown in Figure 536.2, is given under the following conditions:

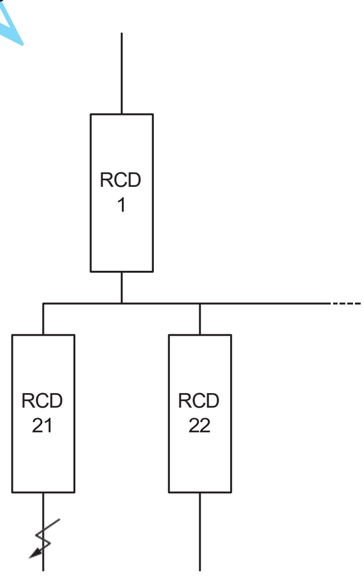
- the upstream RCD is of selective type (type S or time-delayed type with appropriate time delay setting), and
- the ratio of the rated residual operating current of the upstream RCD to that of the downstream RCD is at least 3:1.

In the case of RCDs with adjustable rated residual operating current and time delay, reference shall be made to manufacturer's instructions for selectivity.

NOTE 2: RCD type S is in accordance with IEC 61008 series or IEC 61009 series.

NOTE 3: A time-delay type RCD in accordance with IEC 60947-2, Annex B or Annex M will be marked with the symbol Δt followed by the limiting non-actuating time in ms or marked with an [S]

Fig 536.2 – Selectivity between RCDs in case of residual current



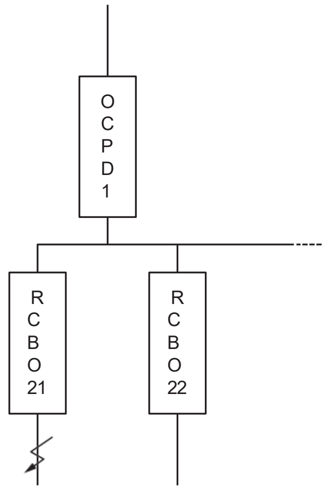
NOTE 4: RCD1 is type S or time-delayed type.

536.4.1.5 Selectivity between OCPDs and RCDs

536.4.1.5.1 Selectivity between RCD(s) and upstream OCPD

In the event of an earth fault, current may reach a high value that could exceed the instantaneous tripping current of the upstream OCPD. Therefore, when selectivity between RCD(s) and upstream OCPD is required, an RCBO or CBR shall be used and the requirements of selectivity according to Section 536.4.1.2 shall be applied.

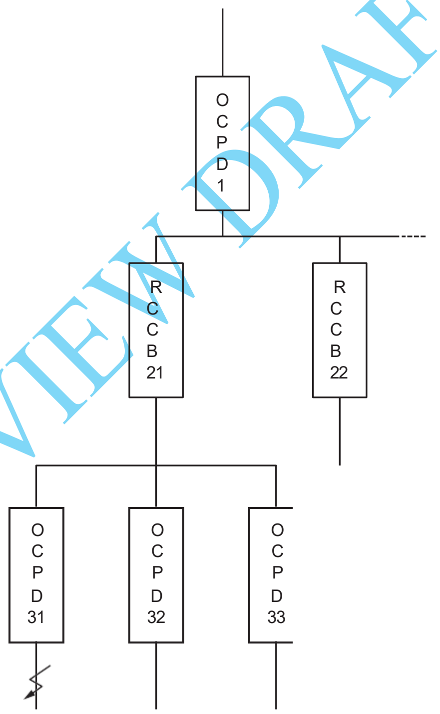
Fig 536.3 – Selectivity between OCPD and RCD using RCBOs



In Figure 536.3, if RCCBS are used instead of RCBOs, selectivity cannot be guaranteed. In this case, if there are OCPDs downstream of the RCCB, as shown in Figure 536.4, selectivity may be achieved provided that the requirements of Section 536.4.1.2 and Section 536.4.1.3 are fulfilled. In addition, the connection between the RCCB and the downstream OCPD shall be selected and erected so as to minimize the risk of earth faults.

NOTE: In order to minimize the risk of faults between RCCB and downstream OCPD, specific wiring accessories may be used (e.g. specific busbars).

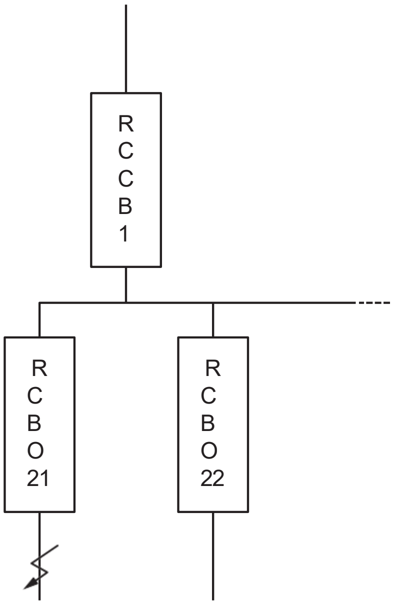
Fig 536.4 – Selectivity between OCPD and RCD using RCCBs



536.4.1.6 Selectivity between RCDs and downstream OCPDs

In the event of an earth fault, the earth fault current may be lower than the instantaneous tripping current of the downstream OCPD. In this case, the upstream RCD will trip and selectivity may not be achieved. Therefore, when selectivity between RCDs and downstream OCPD is required, RCBOs shall be used and selectivity requirements according to Section 536.4.1.4 shall be applied.

Fig 536.5 – Selectivity between upstream RCCB and RCBOs



NOTE: RCCB1 is type S or time-delay type.

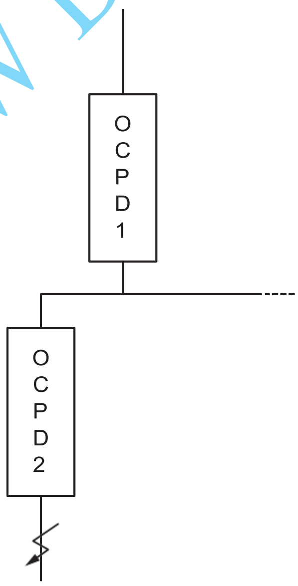
536.4.2 Requirements for protection in case of short-circuit

536.4.2.1 Combined short-circuit protection of OCPDs

In this Section , the OCPD could be replaced by an SCPD.

This breaking technique allows the use of short-circuit protective devices with a lower breaking capacity than required in Chapter 43. It is only applicable to short-circuit protective devices.

Fig 536.6 – Typical configuration for combined short-circuit protection of OCPDs



Section 434.5.1 permits a device with a lower rated breaking capacity than the prospective short-circuit current at its point of installation to be used in specific conditions.

When selecting two OCPDs for combined short-circuit protection, reference shall be made to the instructions of the manufacturer of the downstream OCPD. These instructions are derived from tests performed according to relevant product standards, as applicable (e.g. IEC 60947-2 and IEC 60898-1). Where no information is available from the manufacturer, combined short-circuit protection of OCPDs shall not be used, and each OCPD shall have the required short-circuit capability at the point of installation.

If declared by the manufacturer of both devices, the combined short-circuit capability of OCPD1 and OCPD2 may be higher than the breaking capacity of either OCPD. In this case, the connection between the two devices has to minimize the risk of short-circuits and there shall not be any short-circuit contributions by other active equipment in parallel to OCPD1.

NOTE 1: Co-ordination of an OCPD with a separate current limiter to increase the short-circuit breaking capacity of an OCPD may be used according to the manufacturer's instructions.

NOTE 2: Combined short-circuit protection may be used for manual motor starter having a short-circuit capability in combination with OCPD, when declared in the manufacturer documentation.

536.4.2.2 Back-up protection of contactors or overload relays

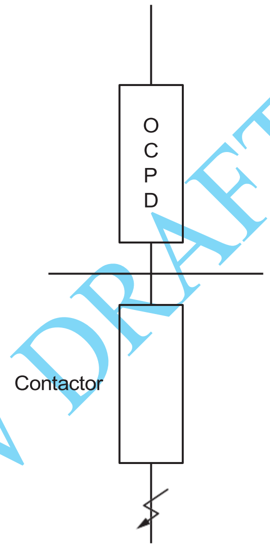
In this Section , the OCPD could be replaced by an SCPD.

Contactors complying with IEC 60947-4-1 or IEC 61095 do not provide protection against short-circuit, thus they shall be protected by an upstream overcurrent protective device (OCPD).

NOTE 1: Control and Protective Switching Devices (CPS) provide protection against short-circuit, and therefore provide intrinsic co-ordination.

Figure 536.7 gives a typical schematic for co-ordination of a contactor with a short-circuit protective device (OCPD).

Fig 536.7 – Co-ordination between OCPD and contactor in case of short-circuit



Section 512.1.2 requires equipment to be selected for the design current which it has to carry in normal service and the current likely to flow in abnormal conditions. In the event of short-circuit, the let-through energy and the peak current may cause the contactor to open its contacts at a level of current beyond its making and breaking capacity. Co-ordination of the contactor and the OCPD is needed to achieve safe operation in case of short-circuit.

Co-ordination between a contactor and an OCPD is verified by mandatory short-circuit tests according to IEC 60947-4-1 or to IEC 61095, as applicable.

Contactors shall be selected and erected in conjunction with the short-circuit protective device declared by the manufacturer, such that the rated conditional short-circuit current is higher than the prospective short-circuit current at the point of installation.

The rated conditional short-circuit current can only be obtained by type-testing and thus the data for the selection of the OCPD shall be obtained from the manufacturer of the contactor, taking into account the rated operational current, rated operational voltage and the corresponding utilization category.

NOTE 2: This information is generally provided in co-ordination tables which summarize the combination of devices (OCPD, contactor or motor starter) able to maintain a safe behaviour for a given rated conditional short-circuit.

In a motor circuit the overload current protection may be provided by separate overload relay electrically connected with the contactor. In such a case protection of the overload relay shall also be achieved, since the overload relay may be damaged by the let-through energy (I^2t) of the OCPD. This information is generally provided in the manufacturer's co-ordination tables.

536.4.2.3 Back-up protection of switches, Transfer Switching Equipment (TSE) or impulse relays

Switches complying with IEC 60947-3 or IEC 60669-2-4, Transfer Switching Equipment (TSE) complying with IEC 60947-6-1 and impulse relays complying with IEC 60669-2-2 are used to switch loads or circuits (e.g. distribution switchboard, lighting circuit, specific load). These devices do not provide protection against short-circuit, thus they shall be protected by an overcurrent protective device (OCPD).

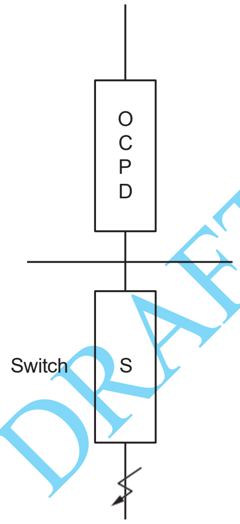
NOTE: Fuse combination units to IEC 60947-3 consist of a switch and integral fuse(s) and have a short-circuit capability declared by the manufacturer which does not require the use an upstream OCPD.

Should a short-circuit occur on the load side of a switch, the current will flow through both devices (OCPD and switch); therefore the let-through energy and the peak current limited by the OCPD need to be compatible with the short-circuit withstand of the switch, the TSE or the impulse relay.

Figure 536.9 gives a typical schematic for co-ordination of a switch with a short-circuit protective device (OCPD).

Figure 536.8 Not used

Fig 536.9 – Co-ordination between OCPD and switch



The OCPD may also be situated downstream of the switch, TSE or impulse relay provided that the connection between the switch and the downstream OCPD is selected and erected so as to minimize the risk of earth faults and short-circuits.

Switches, Transfer Switching Equipment and impulse relays shall be selected and erected in conjunction with the short-circuit protective device declared by the manufacturer in order that their rated conditional short-circuit current is equal to or higher than the prospective short-circuit current at the point of installation.

The rated conditional short-circuit current of the switch can only be obtained by type-testing and thus the data for the selection of the OCPD shall be obtained from the manufacturer of the switch, taking into account the rated operational current and the rated operational voltage.

For switches according to IEC 60947-3, where the OCPD is not specified by the switch manufacturer, an alternative method for co-ordination between the OCPD and the switch is as follows:

- the rated short-circuit making capacity of the switch is higher than the peak value of the prospective short-circuit current at the point of installation, and
- the OCPD time-current characteristic is within the limits of I_{cw} of the switch, as stated by the manufacturer, or
- the rated short-circuit making capacity is higher than the peak value of the prospective short-circuit current at the point of installation, and
- the rated short time withstand current is higher than the prospective short-circuit current at the point of installation and the corresponding withstand time is longer than the operating time of the SCPD, if applicable, or
- if at the prospective short-circuit current, the protective device has an energy let-through (I^2t) and cut-off current not exceeding the values for the switch provided by the manufacturer.

536.4.2.4 Back-up protection of RCCBs

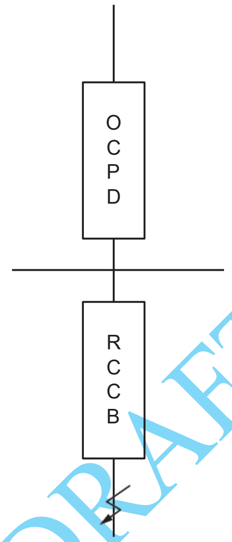
In this Section , the OCPD could be replaced by an SCPD.

RCCBS complying with IEC 61008 series are intended to protect persons against electric shocks. They may also be used to provide protection against fire hazards due to a persistent earth fault. These devices have a limited short-circuit current withstand capability, thus they shall be protected by an upstream overcurrent protective device.

Should a short-circuit occur on the load side of a RCCB, the current will flow through both devices (OCPD and RCCB); therefore the let-through energy and the peak current limited by the OCPD need to be compatible with the short-circuit withstand capability of the RCCB.

Figure 536.10 gives a typical schematic for co-ordination of a RCCB with a short-circuit protective device.

Fig 536.10 – Co-ordination between OCPD and RCCB



RCCBS shall be selected and erected in conjunction with the OCPD declared by the manufacturer in order that their rated conditional short-circuit current is higher than the prospective short-circuit current at the point of installation.

The rated conditional short-circuit current of the RCCB with the OCPD, related to the relevant rated operational current and rated operational voltage, is given by the manufacturer based on tests results according to IEC 61008 series.

The OCPD may also be situated downstream of the RCCB provided that the connection between RCCB and downstream OCPD is selected and erected so as to minimize the risk of earth faults and short-circuits.

536.4.3 Requirements for protection in case of overload

536.4.3.1 Overload protection of contactor or SCPDs

Contactors complying with IEC 60947-4-1 or IEC 61095 and SCPDs without integral overload protection, such as ICBs complying with IEC 60947-2, shall be protected by an overload protective device.

Devices for overload protection are selected for the protection of cables. For overload protection of contactors or SCPDs, the rated current of the OCPD shall be selected according to manufacturers' information.

NOTE: In cases where Section 433.3 permits omission of overload protection, co-ordination in case of overload does not apply.

536.4.3.2 Overload protection of RCCB, switch, Transfer Switching Equipment (TSE) or impulse relay

Residual current circuit-breakers (RCCB) complying with IEC 61008 series are intended to protect persons against electric shock. Switches complying with IEC 60947-3 or IEC 60669-2-4, impulse relays complying with IEC 60669-2-2 and TSEs complying with IEC 60947-6-1 are used to switch loads or circuits. None of these devices provide protection against overload, therefore they shall be protected by an overcurrent protective device (OCPD).

Section 433.1 requires that devices for overload protection be selected for the protection of cables. For overload protection of RCCBS and switches, the rated current of the OCPD shall take account of the manufacturer's information; in general, the OCPD is installed upstream of the RCCB or the switch.

The rated current of a switch or RCCB may also be based on the application of diversity factors to the downstream circuits according to Section 311.1, and the rated current of the OCPD shall be selected according to the manufacturer's instructions. See also Section 536.4.202.

NOTE: When using an RCBO instead of an RCCB, no further consideration regarding overload protection of the RCBO is necessary.

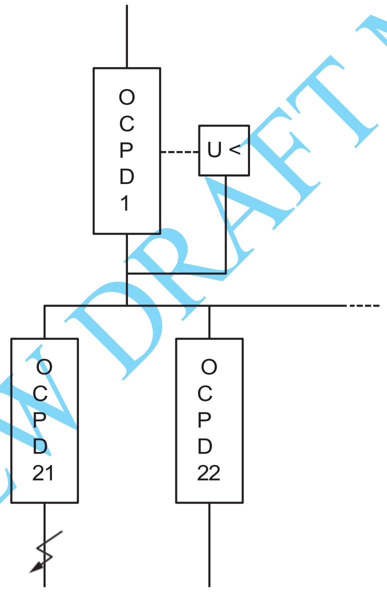
Section 433.3 specifies conditions for omission of overload protection. In such cases overload co-ordination does not require verification.

536.4.4 Requirements for selectivity between OCPDs equipped with under voltage relay

In case of fault (short-circuit or earth fault) a high fault current may generate a voltage drop through the installation. Voltage drop may also occur in the installation for other reasons (for example, switching and reclosing of HV switching device).

Where one undervoltage relay is installed in the OCPD on the supply side or elsewhere in the installation, possible undervoltage relay operation shall not impair selectivity achieved between OCPDs and/or RCDs in series.

Fig 536.11 – Selectivity with OCPD and undervoltage relays



For selectivity, undervoltage relay operation shall be time-delayed according to the maximum short-circuit or earth fault clearance time. In all cases, instructions provided by the manufacturer shall be fulfilled in order not to impair the safety of the electrical installation.

536.4.5 Low voltage assemblies according to IEC 61439 series

The interface characteristics of an assembly conforming to IEC 61439 series shall be compatible with the ratings of the circuits to which it is connected and with the installation conditions. The characteristics of the assembly shall be declared by the manufacturer, taking into account the interface characteristics of the relevant IEC 61439 product standard.

536.4.201 Fault current (short-circuit) ratings

The relevant fault current (short-circuit) rating of the assembly should be equal to or exceed the maximum prospective fault current at the point of connection to the system.

The terminology used to define the short-circuit rating of an assembly is given in the IEC 61439 series as follows:

- rated short-time withstand current, I_{cw}
- rated peak withstand current, I_{pk}
- rated conditional short-circuit current, I_{cc}.

The assembly manufacturer's ratings and instructions shall be taken into account.

For an installation with a 230 V single-phase supply rated up to 100 A that is under the control of ordinary persons, switchgear and controlgear assemblies shall either comply with IEC 61439-3 having a suitable fault current (short-circuit) rating for the maximum prospective fault current at the point of connection to the system or be a consumer unit incorporating components and protective devices specified by the manufacturer complying with IEC 61439-3, including the 16kA conditional short-circuit test described in Annex ZB of the standard.

NOTE: When the single-phase PSCC value of 19.6 kA is cited from Engineering Recommendation P25, the 16 kA conditional rating described in Annex ZB of IEC 61439-3, for incoming service equipment, will satisfy design requirements where the service cable is at least 2 metres in length.

536.4.202 Current ratings

The relevant design current shall not exceed the rated current of an assembly (I_{nA}) or rated current of a circuit (I_{nc}) of the associated assembly, having taken any applicable diversity/loading factors into account.

The terminology used to define the rating of an assembly in relation to load/design current used in IEC 61439 can be summarized as follows:

- The rated current of an assembly (I_{nA}) (A)o is the maximum load current that it is designed to manage and distribute.
- The rated current of a circuit (I_{nc}) (A) is stated by the assembly manufacturer, taking into consideration the ratings of the devices within the circuits, their disposition and application.

The current rating(s) of an assembly circuit may be lower than the rated current(s) of the device(s) according to their respective device standard, when installed in the assembly; therefore, the assembly manufacturer's ratings and instructions shall be taken into account.

Rated diversity (loading factor) can be stated by the assembly manufacturer, e.g. for groups of circuits.

The rated current of a switch or RCCB (I_{nA} and I_{nc}) shall be based upon:

- the sum of final circuit current demand after any applicable load diversity factors, or
- the sum of final circuit current demand after any applicable load diversity factors together with allowances for diversity between final circuits, or
- the sum of the downstream OCPDs/circuit rated current multiplied by a diversity factor.

However, overload protection shall not solely be based on the use of diversity factors of the downstream circuits. To achieve overload protection of RCCBS or switches, the rated current of the OCPD shall be selected according to the manufacturer's instructions.

536.4.203 Integration of devices and components

The relevant part of the IEC 61439 series shall be applied to the integration of mechanical and electrical devices and components, e.g. circuit-breakers, control devices, busbars into an empty enclosure or existing low voltage assembly.

In low voltage assemblies to the IEC 61439 series, e.g. consumer units, distribution boards, incorporated devices and components shall only be those declared suitable according to the assembly manufacturer's instructions or literature.

NOTE 1: The use of individual components complying with their respective product standard(s) does not indicate their compatibility when installed with other components in a low voltage switchgear and controlgear assembly.

NOTE 2: Incorporated components inside the assembly can be from different manufacturers. It is essential that all incorporated components should have had their compatibility for the final enclosed arrangements verified by the original manufacturer of the assembly and be assembled in accordance with their instructions e.g. the consumer unit, distribution board manufacturer. The original manufacturer is the organization that carried out the original design and the associated verification of the low voltage switchgear and controlgear assembly to the relevant part of the IEC 61439 series. If an assembly deviates from its original manufacturer's instructions, or includes components not included in the original verification, the person introducing the deviation becomes the original manufacturer with the corresponding obligations.

536.5 Documentation

The information mentioned in the previous Section s for co-ordination of electrical devices may be found in manufacturers' documentation (e.g. catalogue, instruction sheets, calculation software).

When the initial verification is made, the documentation concerning the selection of devices for co-ordination shall be added to the design documentation in accordance with the requirements of Section 132.13.

537 ISOLATION AND SWITCHING

537.1 General

This section provides requirements for:

(i) non-automatic local and remote isolation and switching measures for the prevention or removal of dangers associated with electrical installations or electrically-powered equipment and machines, and

(ii) functional switching and control.

537.1.1 Any device for isolation and switching according to Sections 462 to 465 shall comply with the relevant requirements included in this section.

In certain instances, additional requirements may be necessary for combined functions.

NOTE 1: Table 537.4 summarizes the functions provided by the devices for isolation and switching, together with indication of the relevant product standards.

NOTE 2: For some applications such as motor control, the switching device needs to withstand the inrush current.

NOTE 3: Table 537.4 provides information on selection.

TABLE 537.4 – Guidance on the selection of protective, isolation and switching devices

Device	Standard	Isolation[4]	Emergency switching[2]	Functional switching[5]
Switching device	IEC 60669-2-1	No	No	Yes
	IEC 60669-1	No	Yes	Yes
	IEC 60669-2-1	No	No	Yes
	IEC 60669-2-2	No	Yes	Yes
	IEC 60669-2-3	No	Yes	Yes
	IEC 60669-2-4	Yes[3]	Yes	Yes
	IEC 60947-3	Yes[1,3]	Yes	Yes
	IEC 60947-5-1	No	Yes	Yes
Contactor	IEC 60947-4-1	Yes[1,3]	Yes	Yes
	IEC 61095	No	No	Yes
Circuit-breaker	IEC 60898	Yes[3]	Yes	Yes
	IEC 60947-2	Yes[1,3]	Yes	Yes
	IEC 61009-1	Yes[3]	Yes	Yes
RCD	IEC 60947-2	Yes[1,3]	Yes	Yes
	IEC 61008 series IEC	Yes[3]	Yes	Yes
	61009 series	Yes[3]	Yes	Yes
Isolating switch	IEC 60669-2-4	Yes[3]	Yes	Yes
	IEC 60947-3	Yes[1,3]	Yes	Yes
Plug and socket-outlet (≤ 32 A)	IEC 60309	Yes[3]	No	Yes
Plug and socket-outlet (> 32 A)	IEC 60309	Yes[3]	No	No
Device for the connection of luminaire	IEC 61995-1	Yes[3]	No	No
Control and protective switching device for equipment (CPS)	IEC 60947-6-1	Yes[1,3]	Yes	Yes
	IEC 60947-6-2	Yes[1,3]	Yes	Yes
Fuse	IEC 60269 series	Yes	No	No
Device with semiconductors	IEC 60669-2-1	No	No	Yes
	IEC 60669-2-1	No	No	Yes
Luminaire Supporting Coupler	IEC 61995	Yes[3]	No	No
Plug and unswitched socket-outlet	KS EAS 495-1	Yes[3]	No	Yes
	KS EAS 495-2	Yes[3]	No	Yes

Device	Standard	Isolation(4)	Emergency switching(2)	Functional switching(5)
Plug and switched socket-outlet	KS EAS 495-1 KS EAS 495-2	Yes(3) Yes(3)	No No	Yes Yes
Plug and socket-outlet	IEC 60884-1	Yes(3)	No	Yes
Switched fused connection unit	KS EAS 495-4	Yes(3)	Yes	Yes
Unswitched fused connection unit	KS EAS 495-4	Yes(3) (Removal of fuse link)	No	No
Fuse	IEC 60269	Yes	No	No
Cooker Control Unit switch	IEC 60669	Yes(3)	Yes	Yes

Yes = Function provided, No = Function not provided

(1) Function provided if the device is suitable and marked with the symbol for isolation (see IEC 60617 identity number S00288)

(2) See Section 537.3.3.6.

(3) Device is suitable for on-load isolation, i.e. disconnection whilst carrying load current.

(4) In an installation forming part of a TT or IT system, isolation requires disconnection of all the live conductors. See Section 462.2.

(5) Circuit-breakers and RCDs are primarily circuit protective devices and, as such, they are not intended for frequent load switching. Infrequent switching of circuit-breakers on-load is admissible for the purposes of isolation or emergency switching. For a more frequent duty, the number of operations and load characteristics according to the manufacturer's instructions should be taken into account or an alternative device from those listed as suitable for functional switching in Table 537.4 should be employed.

NOTE 1: An entry of (1,3) means that the device is suitable for on-load isolation only if it is marked with the symbol for **on-load** isolation

NOTE 2: In the above table, the functions provided by the devices for isolation and switching are summarized, together with an indication of the relevant product standards.

537.1.2 Where an installation or an item of equipment or enclosure contains live parts connected to more than one supply, a durable warning notice shall be placed in such a position that any person, before gaining access to live parts, will be warned of the need to isolate those parts from the various supplies unless an interlocking arrangement is provided to isolate all the circuits concerned.

537.1.3 Plugs and socket-outlets, connectors and devices for connection of luminaires may be used for providing the isolation and switching functions in accordance with Table 537.4.

The isolation and switching functions are provided by the disconnection of the plug from the outlet or connector from the inlet, as applicable.

537.1.4 *Not used*

537.1.5 Where an installation is supplied from more than one source of energy, one of which requires a means of earthing independent of the means of earthing of other sources and it is necessary to provide that not more than one means of earthing is applied at any time, a switching device may be inserted in the connection between the neutral point and the means of earthing, provided that the device is:

(i) a multipole, linked switching device arranged to disconnect and connect the earthing conductor for the appropriate source at substantially the same time as the related live conductors, or

(ii) a switching device interlocked with a multipole, linked switching device inserted in the related live conductors such that the earthing conductor for the appropriate source shall not be interrupted before the related live conductors and shall be re-established not later than when the live conductors are reconnected.

Switching devices provided in accordance with (i) and (ii) shall meet the requirements of Chapter 46 for a device for isolation.

537.2 Devices for isolation

537.2.1 Devices for isolation shall be of a type for which the isolation function is explicitly recognized by the relevant product standard or as identified in Table 537.4.

537.2.2 Semiconductor devices shall not be used as isolating devices.

537.2.3 Devices suitable for isolation shall be selected according to the requirements which are based on the overvoltage categories applicable at their point of installation.

Devices for isolation shall be designed for over voltage category III or IV except the plug of a plug and socket-outlet combination identified in Table 537.4 as suitable for isolation.

NOTE: Where electrically powered equipment is within the scope of IEC 60204, the requirements for isolation of that standard apply.

537.2.4 Devices for isolation shall be selected and/or installed so as to prevent unwanted or unintentional closure (see Section 462.3).

This may be achieved by locating the device in a lockable space or lockable enclosure or by padlocking or by other suitable means.

537.2.5 Provision shall be made for securing off-load isolating devices against unwanted or unintentional opening.

This may be achieved, for example, by locating the device in a lockable space or lockable enclosure or by padlocking. Alternatively, the off-load device may be interlocked with a load-breaking one.

537.2.6 Means of isolation shall preferably be provided by a multipole switching device which disconnects all applicable poles of the relevant supply but single-pole devices situated adjacent to each other are not excluded, subject to the provisions of Section 461.2.

537.2.7 Each device used for isolation shall be clearly identified by position or durable marking to indicate the installation or circuit it isolates.

537.2.8 Where a link is inserted in the neutral conductor for isolating purposes, the link shall comply with the following requirements

- it cannot be removed without the use of a tool, and
- it is accessible to one or more skilled persons only.

537.3 Devices for switching

537.3.1 Functional switching and control devices

537.3.1.1 The devices for functional switching and control shall be selected in accordance with Table 537.4.

537.3.1.2 Functional switching devices shall be suitable for the most onerous duty they are intended to perform. The characteristic of the load to be switched shall be considered (e.g. utilization category).

537.3.1.3 Functional switching devices may control the current without necessarily opening the corresponding poles.

NOTE: Semiconductor switching devices and some control auxiliaries are examples of devices capable of interrupting the current in the circuit but not opening the corresponding poles.

537.3.2 Devices for switching off for mechanical maintenance

537.3.2.1 Selection and erection of devices for switching off for mechanical maintenance shall be in accordance with the following Section s and shall comply with Section group 537.2.

NOTE: Where electrically powered equipment is within the scope of IEC 60204, the requirements for switching off for mechanical maintenance of that standard apply.

537.3.2.2 Devices for switching off for mechanical maintenance shall be inserted in the main supply circuit.

Where a switch is provided for this purpose, it shall be capable of cutting off the full load current of the relevant part of the installation.

Interruption of a circuit for the control of mechanical movement is permitted only where a condition equivalent to the direct interruption of the main supply is provided by one of the following:

(i) Supplementary safeguards, such as mechanical retainers

(ii) Compliance with the requirements of a Kenyan Standard specification for the control devices used.

NOTE: Switching off for mechanical maintenance may be achieved, for example, by one of the following:

- multipole switch
- circuit-breaker
- control and protective switching device (CPS)
- control switch operating a contactor
- plug and socket-outlet.

537.3.2.3 Devices for switching off for mechanical maintenance or control switches for such devices shall require manual operation.

The open position of the contacts of the device shall be visible or be clearly and reliably indicated.

The indication required by this Section may be achieved by the use of the symbols 'O' and 'I' to indicate the open and closed positions respectively.

537.3.2.4 Devices for switching off for mechanical maintenance shall be clearly identified by position or durable marking so as to be identifiable for their intended use.

537.3.3 Devices for emergency switching off

NOTE: Emergency switching off is an emergency operation intended to switch off the supply of electrical energy to all or part of an installation where a risk of electric shock or another risk of electrical origin is involved.

537.3.3.1 Selection and erection of devices for emergency switching off shall be in accordance with the following Section s and shall comply with Section 537.2.

NOTE: Where electrically powered equipment is within the scope of IEC 60204, the requirements for emergency switching off of that standard apply.

537.3.3.2 The devices for emergency switching off shall be capable of breaking the full load current of the relevant parts of the installation taking into account stalled motor currents where appropriate.

537.3.3.3 Means for emergency switching off may consist of:

- one switching device capable of directly cutting off the appropriate supply, or
- a combination of devices activated by a single action for the purpose of cutting off the appropriate supply.

Plugs and socket-outlets shall not be provided for use as means for emergency switching off.

537.3.3.4 Devices for emergency switching off shall provide the switching of the main circuit.

Hand-operated switching devices for direct interruption of the main circuit shall be selected where practicable.

Remote control switching of circuit-breakers, control and protective switching devices or residual current devices (RCD) shall be opened by de-energization of coils, or other equivalent failure-to-safety techniques/actuators.

537.3.3.5 The means of operating (handles, push-buttons, etc.) devices for emergency switching off shall be clearly identified, preferably by colour. If a colour is used for identification, this shall be RED with a contrasting background (e.g. yellow).

NOTE: The contrasting background may or may not include text.

537.3.3.6 The means of operating shall be readily accessible at places where a danger might occur and, where appropriate, at any additional remote position from which that danger can be removed.

Devices for emergency switching off shall be so placed as to be readily identifiable and convenient for their intended use.

537.3.3.7 The means of operation of a device for emergency switching off shall be capable of latching in the 'OFF' position, unless both the means of operation for emergency switching off and for re-energizing are under the control of the same person.

The release of an emergency switching device operated remotely shall not re-energize the relevant part of the installation.

The operation of the emergency switching device shall have priority over any other function relative to safety and shall not be inhibited by any other operation of the installation.

537.4 Firefighter's switches

537.4.1 Firefighter's switches shall comply with IEC 60669-2-6 or IEC 60947-3.

537.4.2 A firefighter's switch shall be provided in the low voltage circuit supplying:

(i) outdoor lighting installations operating at a voltage exceeding low voltage, and

(ii) indoor discharge lighting installations operating at a voltage exceeding low voltage.

This requirement does not apply to a portable discharge lighting luminaire or to a sign of rating not exceeding 100 W and fed from an accessible socket-outlet.

NOTE: Installations in certain premises subject to licensing conditions, such as petrol station forecourts, may require the installation of a firefighter's switch.

537.4.2.1 Every outdoor installation on each single premises should wherever practicable be controlled by a single firefighter's switch. Similarly, every internal installation in each single premises should be controlled by a single firefighter's switch independent of the switch for any outdoor installation.

537.4.2.2 Every firefighter's switch should comply with the following requirements, where applicable:

(i) for an outdoor installation, the switch should be outside the building and adjacent to the equipment, or alternatively a notice indicating the position of the switch should be placed adjacent to the equipment and a notice should be fixed near the switch so as to render it clearly distinguishable

(ii) for an indoor installation, the switch should be in the main entrance to the building or in another position to be agreed with the local fire authority

(iii) the switch should be placed in a conspicuous position, reasonably accessible to firefighters, at not more than 2.75 m from the ground or the standing beneath the switch.

537.4.3 A firefighter's switch shall be easily visible, accessible and marked to indicate the installation or part of the installation which it controls.

537.4.4 The following information shall be distinctly and durably marked on the firefighter's switch in a position where it can be seen clearly by a person standing on the ground at the intended site, without opening the enclosure and when the switch is installed:

- 'ON' and 'OFF' positions, in letters not less than 10 mm high;
- letters reading 'FIREFIGHTER'S SWITCH' or 'FIRE SWITCH' in letters not less than 10 mm high.

Once installed, the handle off position shall be up.

NOTE: The 'ON' position means powered and the 'OFF' position means unpowered.

538 MONITORING DEVICES

538.1 Insulation monitoring devices (IMDs) for IT systems

538.1.1 General

IMDs shall be in accordance with IEC 61557-8.

An IMD is intended to permanently monitor the insulation resistance of an IT system and provides an alarm where the insulation resistance R_f is below the response value R_a.

R_a is the response value of the IMD as described in IEC 61557-8.

R_f is the insulation resistance between the system to which it is connected and either the earth, the PE connection or another reference point for protective equipotential bonding.

Examples of these systems would be an electrical installation, a mobile generator or a safety service.

An IMD shall be installed in an IT system where selected to meet with the requirement of Section 411.6.4.

IMDs shall be installed as close as practicable to the origin of the part of the installation to be monitored.

Instructions shall be provided indicating that when the IMD detects an insulation fault to earth, the insulation fault shall be located and eliminated in order to restore normal operating conditions with the shortest practicable delay.

Where the IT system is used for continuity of supply, the occurrence of a first insulation fault shall be indicated at a suitable location so it is audible and/or visible by instructed or skilled person(s).

NOTE: This alarm may be relayed through a building management system (BMS).

It is recommended to use an IMD that signals an interruption of the measurement connections to the system conductors and earth.

538.1.2 Installation of insulation monitoring devices

Where a neutral conductor is distributed, an insulation monitoring device (IMD) may be connected to the neutral conductor. In this case, no overcurrent protective device shall be inserted in the conductor connecting the IMD to the neutral.

An IMD shall be connected symmetrically or unipolarly between the live conductors and earth or the PE connection or another reference point for protective equipotential bonding.

Where the neutral conductor is not distributed, the 'line' terminal of the IMD may be connected:

(i) either to an artificial neutral point with the three impedances connected to line conductors, or

(ii) to a line conductor.

Where, in a polyphase system, the IMD is connected between one line conductor and earth, it shall be suitable to withstand at least the line-to-line voltage between its 'line' terminal and its 'earth' terminal.

NOTE: This voltage appears across these two terminals in the case of a single insulation fault on another line conductor.

For DC installations, the 'line' terminal(s) of the IMD shall be connected either directly to the midpoint, if any, or to one or all of the supply conductors.

The supply circuit of IMD shall be connected either to the installation on the same circuit of the connecting point of the 'line' terminal and as close as possible to the origin of the system, or to an auxiliary source.

The connecting point to the installation shall be selected in such a way that the IMD is able to monitor the insulation of the installation in all operating conditions.

Where the installation is supplied from more than one power supply, connected in parallel, one IMD per supply shall be used, provided they are interlocked in such a way that only one IMD remains connected to the system. All other IMDs monitor the disconnected power supply, enabling the reconnection of this supply without any pre-existing insulation fault.

IMDs shall be able to measure the insulation resistance of the system if DC components caused by electronic equipment, e.g. rectifiers or convertors, are contained in the fault current.

538.1.3 Setting of the insulation monitoring device

The IMD shall have a selection of setting values and be adjusted to suit the respective installation.

When operating normally with the maximum of loads connected, the IMD shall be set to a lower value corresponding to the normal insulation of the system.

NOTE: A value of 100 Ω/V (300 Ω/V for pre-warning) of the rated system voltage is an example of typical setting values.

Where IMDs are installed in locations where ordinary persons have access to their use they shall be selected and/or installed in such a way that it shall be impossible to modify the settings except by the use of a key, a tool or a password.

538.2 Equipment for insulation fault location in IT systems

Equipment for insulation fault location shall be in accordance with IEC 61557-9. Where an IT system has been selected for continuity of service, it is recommended to combine the IMD with devices enabling the fault location on load. Their function is to indicate the faulty circuit when the IMD has detected an insulation fault.

538.3 Monitoring of off-line circuits

The insulation monitoring of circuits switched off may be carried out in TN, TT and IT systems with insulation monitoring devices (IMDs) provided that the IMD is automatically deactivated whenever the safety equipment is activated. A prerequisite for it is that the monitored electrical circuits are isolated from all poles of the system.

NOTE: As an example, this can be applicable to a circuit comprising safety equipment which is normally de-energized such that the safety equipment is allowed to work without intervention of supply during the emergency.

The reduction of the insulation level shall be indicated locally by either a visual or an audible signal with the option of remote indication.

If the equipment is disconnected from the installation during the off-load insulation measuring process, the insulation levels to be measured are generally very high. The alarm threshold should be above 300 kΩ.

538.4 Residual current monitors (RCMs)

538.4.1 General

RCMs shall comply with IEC 62020.

An RCM permanently monitors leakage and fault currents to earth of the downstream installation or part there of and is intended to inform the user about the level of these currents of that part of the installation being monitored.

RCMs are not intended to provide protection against electric shock.

Where an RCD is installed upstream of the RCM, it is recommended that the RCM be set to a residual actuating current no higher than half of the rated residual operating current ($I_{\Delta n}$) of the RCD.

It is recommended that RCMs are installed at the origin of the outgoing circuits.

RCMs shall initiate an audible and/or visual signal, which shall continue as long as the fault persists.

538.4.2 RCMs installed in IT systems

In IT systems where interruption of the supply in case of a first insulation fault to earth is not required or not permitted, RCMs may be installed to indicate the occurrence of a first insulation fault from a live part to exposed-conductive-parts or to earth in accordance with Section 411.6.4.

Where used in IT systems, it is recommended to use directionally discriminating RCMs, in order to avoid unwanted signalling of leakage current when high leakage capacitances are liable to exist downstream from the point of installation of the RCM.

Annex A53

(Informative)

Device functions and coordination

Table A53.1 – Devices and associated functions

Devices					Functions			
Product	**OCPD**[2]	**SCPD**[2]	**RCD**[2]	**Standard**	**Overload protection**	**Short-circuit protection**	**Residual current protection**	**Switching only**
Circuit-breaker	X			IEC 60947-2 IEC 60898-1 IEC 60898-2	Yes	Yes	No	No
RCCB			X	IEC 61008 series IEC 62423	No	No	Yes	No
RCBO	X		X	IEC 61009 series IEC 62423	Yes	Yes	Yes	No
CBR	X		X	IEC 60947-2, Annex B	Yes	Yes	Yes	No
MRCD[3]	X		X	IEC 60947-2, Annex M	Yes	Yes	Yes	No
ICB		X		IEC 60947-2, Annex O	No	Yes	No	No
Fuse with full range breaking capacity (e.g. gG, gM)[1]	X			IEC 60269 series	Yes	Yes	No	No
Fuse with partial range breaking capacity (e.g. aM)[1]		X		IEC 60269 series	No	Yes	No	No
CPS	X			IEC 60947-6-2	Yes	Yes	No	No
Contactor				IEC 60947-4-1 IEC 61095	No	No	No	Yes
Overload relay				IEC 60947-4-1	Yes	No	No	No
Switch or switch -disconnector				IEC 60947-3 IEC 60669-2-2 IEC 60669-2-4	No	No	No	Yes
TSE				IEC 60947-6-1	No	No	No	Yes

(1) fuse combination units according to IEC 60947-3 are considered in this row

(2) generic abbreviations used in this document for devices

(3) when associated with a circuit-breaker.

A53.1 Basis of correct co-ordination

The basis of the co-ordination between electrical equipment is to take advantage of the correct combination of their electrical characteristics in order not to impair:

- the safety of an installation (i.e. to avoid equipment combustion due to an electrical fault). Combined short-circuit protection of OCPDs and back-up protection by an OCPD relate to the safety of an installation
- the safety due to continuity of service, if needed (i.e. to restrict disconnection to the faulty circuit in case of overcurrent or fault to earth).

Selectivity between electrical devices provides continuity of service and thus avoids dangers linked to the loss of supply of specific circuits.

A53.2 Parameters

The parameters for the correct co-ordination between electrical devices may be:

- design current
- prospective short-circuit or fault current
- operating time of devices
- system voltage
- energy (let-through I^2t values)
- peak let-through current.

In addition, for fuses, the following parameters should be considered:

- pre-arcing I^2t and pre-arcing time
- operating I^2t and operating time.

Device co-ordination table

Table A53.2 shows the types of combination of devices and cells to show how various modes of co-ordination can affect safety.

Table A53.2 – Device co-ordination in a LV electrical installation

	Section	Modes of co-ordination	Devices involved	Impact on safety of installation	Impact on safety due to continuity of service
Current or time based conditions	536.4.1.2 536.4.1.3	Selectivity	Between OCPDs		Yes
	536.4.1.4		Between RCDs		Yes
	536.4.1.5		Between OCPD and RCD		Yes
	536.4.2.1	Combined short-circuit protection	OCPDs	Yes	
	536.4.2.2	Back-up protection in case of short-circuit	Between OCPD and contactors, overload relays	Yes	
	536.4.2.3		Between OCPD and switched TSE or impulse relays	Yes	
	536.4.2.4		Between OCPD and RCCB	Yes	
	536.4.3.1	Protection in case of overload	Between OCPD and contactor or SCPD	Yes	
	536.4.3.2		Between OCPD and switched TSE or impulse relays	Yes	
	536.4.3.2		Between OCPD and RCCB	Yes	
Voltage based conditions	536.4.4	Selectivity	Between OCPDs equipped with under-voltage relay		Yes

A53.3 Between circuit-breakers or circuit-breaker and CPS or circuit-breaker and overload relay or circuit-breaker and motor starter

Selectivity in case of overload is verified by the comparison of time/current characteristics of the devices involved. The maximum operating time of the device on the load side must be lower than the non-tripping time of the circuit-breaker for any overload current. Separation of the characteristics in both the time and current axes provides selective operation in this zone.

A53.4 Between fuses

Selectivity in case of overload is verified by the comparison of time/current characteristics of the fuses involved. The total operating time of the fuse on the load side must be lower than the pre-arcing time of the fuse on the supply side. Fuses to IEC 60269-2 of the same utilization category (e.g. type gG) with rated current of 16 A and above will provide total selectivity if the ratio of the rated currents is 1.6:1 or greater. Separation of the characteristics in both the time and current axes provides selective operation in this zone.

A53.5 Between circuit-breaker (upstream) and fuse (downstream)

Selectivity in case of overload is verified by comparison of the time/current characteristics, taking into account the trip setting of the circuit-breaker where applicable. When using published time-current characteristics, the maximum operating time curve must be taken for the downstream device and the minimum operating time curve must be taken for the upstream device. Separation of the characteristics in both the time and current axes provides selective operation in this zone.

A53.6 Between fuse (upstream) and circuit-breaker (downstream)

Selectivity in case of overload is verified by comparison of the time/current characteristics, taking into account the trip setting of the circuit-breaker where applicable. The maximum operating time of the circuit-breaker as given by the manufacturer must be lower than the minimum pre-arcing time of the fuse as given by the product standard. Separation of the characteristics in both the time and current axes provides selective operation in this zone.

A53.7 Between circuit-breakers

Generally, reference should be made to the manufacturers' documentation.

In principle, selectivity is assured up to the fault current level at which the peak current let-through of the downstream circuit-breaker is less than the peak value corresponding to the instantaneous tripping level of the upstream circuit-breaker. Where the upstream circuit-breaker has dedicated selective behaviour, the selectivity limit might be higher.

A53.8 Between fuses

Selectivity in case of short-circuit is verified by comparison of the I^2t values. The maximum operating I^2t value of the fuse on the load side should be lower than the minimum pre-arcing I^2t value of the fuse on the supply side. Fuses to IEC 60269-1 of the same utilization category (e.g. type gG) with rated current of 16 A and above will provide total selectivity if the ratio of the rated currents is 1.6:1 or greater.

A53.9 Between circuit-breaker (upstream) and fuse (downstream)

The peak let-through current of the fuse should be lower than the minimum instantaneous tripping current of the circuit-breaker.

Data for peak values of fuses should be taken from the relevant standard or the manufacturers' documentation. If data is taken from the manufacturer, this should be stated in the documentation of the installation.

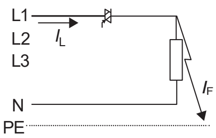
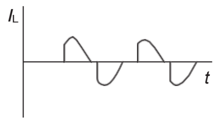
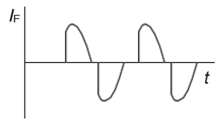
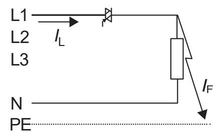
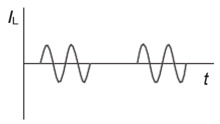
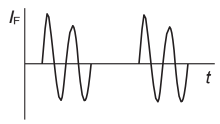
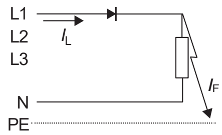
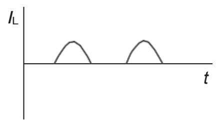
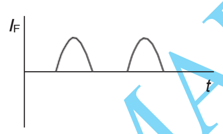
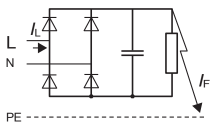
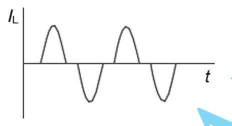
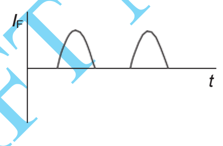
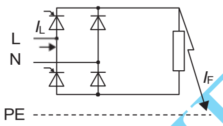
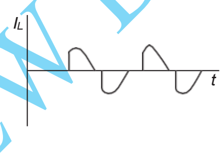
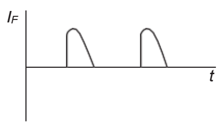
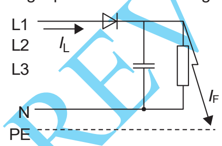
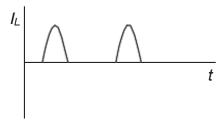
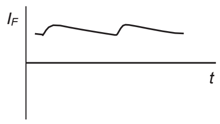
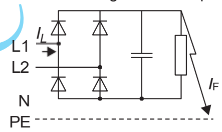
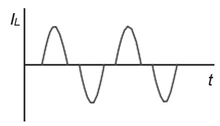
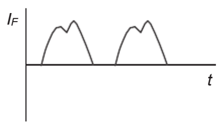
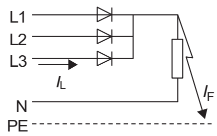
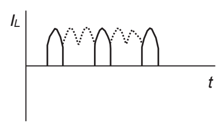
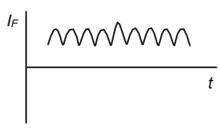
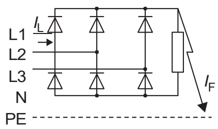
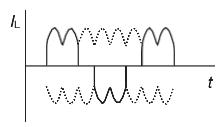
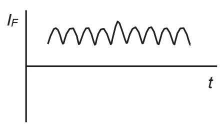
A53.10 Between fuse (upstream) and circuit-breaker (downstream)

The minimum pre-arcing I^2t value of the fuse should be higher than the maximum let-through I^2t value of the circuit-breaker for any short-circuit current up to the maximum prospective short-circuit current to be considered. Data for I^2t values of fuses should be taken from the relevant standard/or the manufacturers' documentation. If data is taken from the manufacturer, this should be stated in the documentation of the installation. The maximum let-through I^2t value of the circuit-breaker should be obtained from the manufacturers' data.

Possible fault currents in systems with semiconductors

In the diagrams of the following Figure A53.1, circuits with most likely fault currents in connection with semiconductor devices are shown.

Figure A53.1 – Possible fault currents in systems with semiconductors

	Circuit diagram with fault location	Shape of load current I_L	Shape of earth fault current I_F	Protection provided by RCD tripping characteristic
1	Phase control 			AC, A, F, B
2	Burst control 			AC, A, F, B
3	Single phase 			A, F, B
4	Two-pulse bridge 			A, F, B
	Circuit diagram with fault location	Shape of load current I_L	Shape of earth fault current I_F	Protection provided by RCD tripping characteristic
5	Two-pulse bridge, half controlled 			A, F, B
6	Single-phase with smoothing 			B
7	Two-Pulse bridge between phases 			B
8	Three-phase star 			B
9	Six-pulse bridge 			B

CHAPTER 54

EARTHING ARRANGEMENTS AND PROTECTIVE CONDUCTORS

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CHAPTER 54:EARTHING ARRANGEMENTS AND PROTECTIVE CONDUCTORS

541 GENERAL

541.1 Every means of earthing and every protective conductor shall be selected and erected so as to satisfy the requirements of the Section s.

541.2 The earthing system of an installation may be subdivided, in which case each part thus divided shall comply with the requirements of this chapter.

541.3 Where there is also a lightning protection system, reference shall be made to KS IEC 62305.

542 EARTHING ARRANGEMENTS

542.1 General requirements

542.1.1 The earthing arrangements may be used jointly or separately for protective and functional purposes, according to the requirements of the installation.

542.1.201 The main earthing terminal shall be connected with Earth by one of the methods described in Section s 542.1.2.1 to 542.1.2.3, as appropriate to the type of system of which the installation is to form a part and in compliance with Section s 542.1.3.1 and 542.1.3.2.

NOTE: Refer to Part 2 and Appendix 5 for definitions of systems.

542.1.2 Supply arrangements

542.1.2.1 For a TN-S system, means shall be provided for the main earthing terminal of the installation to be connected to the earthed point of the source of energy. Part of the connection may be formed by the distributor's lines and equipment.

542.1.2.2 For a TN-C-S system, where protective multiple earthing is provided, means shall be provided for the main earthing terminal of the installation to be connected by the distributor to the neutral of the source of energy.

542.1.2.3 For a TT or IT system, the main earthing terminal shall be connected via an earthing conductor to an earth electrode complying with Section 542.2.

542.1.2.4 Where the supply to an installation is at high voltage, protection against faults between the high voltage supply and earth shall be provided in accordance with Section 442.

542.1.3 Installation earthing arrangements

542.1.3.1 The earthing arrangements shall be such that:

(i) the value of impedance from the consumer's main earthing terminal to the earthed point of the supply for TN systems, or to Earth for TT and IT systems, is in accordance with the protective and functional requirements of the installation, and considered to be continuously effective, and

(ii) earth fault currents and protective conductor currents which may occur are carried without danger, particularly from thermal, thermomechanical and electromechanical stresses, and

(iii) they are adequately robust or have additional mechanical protection appropriate to the assessed conditions of external influence.

542.1.3.2 Precautions shall be taken against the risk of damage to other metallic parts through electrolysis.

542.1.3.3 Where a number of installations have separate earthing arrangements, any protective conductors common to any of these installations shall either be capable of carrying the maximum fault current likely to flow through them or be earthed within one installation only and insulated from the earthing arrangements of any other installation. In the latter circumstances, if the protective conductor forms part of a cable, the protective conductor shall be earthed only in the installation containing the associated protective device.

542.2 Earth electrodes

542.2.1 The design used for, and the construction of, an earth electrode shall be such as to withstand damage and to take account of possible increase in resistance due to corrosion.

542.2.2 Suitable earth electrodes shall be used. The following types of earth electrode are recognized for the purposes of the Section s:

(i) Earth rods or pipes
(ii) Earth tapes or wires
(iii) Earth plates
(iv) Underground structural metalwork embedded in foundations or other metalwork installed in the foundations
(v) Welded metal reinforcement of concrete (except pre-stressed concrete) embedded in the ground
(vi) Lead sheaths and other metal coverings of cables, where not precluded by Section 542.2.5
(vii) other suitable underground metalwork.

NOTE: Further information on earth electrodes can be found in IEC 60364-5-54.

542.2.3 Where foundation earth electrodes are installed, the materials and dimensions of the earth electrodes shall be selected to withstand corrosion and to have adequate mechanical strength.

NOTE: If a lightning protection system (LPS) is present, KS IEC 62305-1 applies.

542.2.4 The type and embedded depth of an earth electrode shall be such that soil drying and freezing will not increase its resistance above the required value.

542.2.5 The use, as an earth electrode, of the lead sheath or other metal covering of a cable shall be subject to all of the following conditions:

(i) Adequate precautions shall be taken to prevent excessive deterioration by corrosion
(ii) The sheath or covering shall be in effective contact with Earth
(iii) The consent of the owner of the cable shall be obtained
(iv) Arrangements shall exist for the owner of the electrical installation to be warned of any proposed change to the cable which might affect its suitability as an earth electrode.

542.2.6 A metallic pipe for gases or flammable liquids shall not be used as an earth electrode. The metallic pipe of a water utility supply shall not be used as an earth electrode. Other metallic water supply pipework shall not be used as an earth electrode unless precautions are taken against its removal and it has been considered for such a use.

542.2.7 An earth electrode shall not consist of a metal object immersed in water.

542.2.8 Where an earth electrode consists of parts that must be connected together, connections shall be made by welding, pressure connectors, clamps or other suitable mechanical connectors.

542.3 Earthing conductors

542.3.1 Every earthing conductor shall comply with Section 543 and, where PME conditions apply, shall meet the requirements of Section 544.1.1 for the cross-sectional area of a main protective bonding conductor. In addition, where buried in the ground, the earthing conductor shall have a cross-sectional area not less than that stated in Table 54.1. For a tape or strip conductor, the thickness shall be such as to withstand mechanical damage and corrosion.

NOTE: For further information see IEC 60364-5-54.

TABLE 54.1 –
Minimum cross-sectional area of a buried earthing conductor

	Protected against mechanical damage	Not protected against mechanical damage
Protected against corrosion by a sheath	2.5 mm^2 copper 10 mm^2 steel	16 mm^2 copper 16 mm^2 coated steel
Not protected against corrosion	25 mm^2 copper 50 mm^2 steel	

542.3.2 The connection of an earthing conductor to an earth electrode or other means of earthing shall be soundly made and be electrically and mechanically satisfactory, and labelled in accordance with Section 514.13.1(i). It shall be suitably protected against corrosion.

542.4 Main earthing terminals or bars

542.4.1 In every installation a main earthing terminal shall be provided to connect the following to the earthing conductor:

(i) The circuit protective conductors

(ii) The protective bonding conductors

(iii) Functional earthing conductors (if required)

(iv) Lightning protection system bonding conductor, if any (see Section 411.3.1.2).

542.4.2 To facilitate measurement of the resistance of the earthing arrangements, means shall be provided in an accessible position for disconnecting the earthing conductor. Such means may conveniently be combined with the main earthing terminal or bar. Any joint shall be capable of disconnection only by means of a tool.

543 PROTECTIVE CONDUCTORS

543.1 Cross-sectional areas

543.1.1 The cross-sectional area of every protective conductor, other than a protective bonding conductor, shall be:

(i) calculated in accordance with Section 543.1.3, or

(ii) selected in accordance with Section 543.1.4.

Calculation in accordance with Section 543.1.3 is necessary if the choice of cross-sectional area of line conductors has been determined by considerations of short-circuit current and if the earth fault current is expected to be less than the short-circuit current.

If the protective conductor:

(iii) is not an integral part of a cable, or

(iv) is not formed by conduit, ducting or trunking, or

(v) is not contained in an enclosure formed by a wiring system,

the cross-sectional area shall be not less than 2.5 mm^2 copper equivalent if protection against mechanical damage is provided, and 4 mm^2 copper equivalent if mechanical protection is not provided (see also Section 543.3.1).

For a protective conductor buried in the ground Section 542.3.1 for earthing conductors also applies. The cross-sectional area of a protective bonding conductor shall comply with Section 544.

543.1.2 Where a protective conductor is common to two or more circuits, its cross-sectional area shall be:

(i) calculated in accordance with Section 543.1.3 for the most onerous of the values of fault current and operating time encountered in each of the various circuits, or

(ii) selected in accordance with Section 543.1.4 so as to correspond to the cross-sectional area of the largest line conductor of the circuits.

543.1.3 The cross-sectional area, where calculated, shall be not less than the value determined by the following formula or shall be obtained by reference to IEC 60949:

$$S = \frac{\sqrt{I^2 t}}{k}$$

NOTE: This equation is an adiabatic equation and is applicable for disconnection times not exceeding 5s.

where:

S is the nominal cross-sectional area of the conductor in mm^2

I is the value in amperes (rms for AC) of fault current for a fault of negligible impedance, which can flow through the associated protective device, due account being taken of the current limiting effect of the circuit impedances and the limiting capability (I^2t) of that protective device

t is the operating time of the protective device in seconds corresponding to the fault current I amperes

k is a factor taking account of the resistivity, temperature coefficient and heat capacity of the conductor material, and the appropriate initial and final temperatures.

Values of k for protective conductors in various use or service are as given in Tables 54.2 to 6. The values are based on the initial and final temperatures indicated in each table.

Where the application of the formula produces a non-standard size, a conductor having a larger standard cross-sectional area shall be used.

TABLE 54.2 –
Values of k for insulated protective conductor not incorporated in a cable and not bunched with cables, or for seperate bare protective conductor in contact with cable covering but not bunched with cables, where the assumed initial temperature is 30 °C

Material of conductor	Insulation of protective conductor or cable covering		
	70 °C thermoplastic	90 °C thermoplastic	90 °C thermosetting
Copper	143/133*	143/133*	176
Aluminium	95/88*	95/88*	116
Steel	52	52	64
Assumed initial temperature	30 °C	30 °C	30 °C
Final temperature	160 °C/140 °C*	160 °C/140 °C*	250 °C

* Above 300 mm^2

TABLE 54.3 –
Values of k for protective conductor incorporated in a cable or bunched with cables, where the assumed initial temperature is 70 °C or greater

Material of conductor	Insulation material		
	70 °C thermoplastic	90 °C thermoplastic	90 °C thermosetting
Copper	115/103*	100/86*	143
Aluminium	76/68*	66/57*	94
Assumed initial temperature	70 °C	90 °C	90 °C
Final temperature	160 °C/140 °C*	160 °C/140 °C*	250 °C

* Above 300 mm^2

TABLE 54.4 –
Values of k for for the sheath or armour of a cable as the protective conductor

Material of conductor	Insulation material		
	70 °C thermoplastic	90 °C thermoplastic	90 °C thermosetting
Aluminium	93	85	85
Steel	51	46	46
Lead	26	23	23
Assumed initial temperature	60 °C	80 °C	80 °C
Final temperature	200 °C	200 °C	200 °C

TABLE 54.5 –
Values of k for steel conduit, ducting and trunking as the protective conductor

Material of protective conductor	Insulation material		
	70 °C thermoplastic	90 °C thermoplastic	90 °C thermosetting
Steel conduit, ducting and trunking	47	44	58
Assumed initial temperature	50 °C	60 °C	60 °C
Final temperature	160 °C	160 °C	250 °C

TABLE 54.6 –
Values of k for bare conductor where there is
no risk of damage to any neighbouring material by the temperature indicated

NOTE: The temperatures indicated are valid only where they do not impair the quality of the connections.

Material of conductor	Conditions		
	Visible and in restricted areas	Normal conditions	Fire risk
Copper	228	159	138
Aluminium	125	105	91
Steel	82	58	50
Assumed initial temperature	30 °C	30 °C	30 °C
Final temperature			
Copper conductor	500 °C	200 °C	150 °C
Aluminium conductor	300 °C	200 °C	150 °C
Steel conductor	500 °C	200 °C	150 °C

543.1.4 Where it is desired not to calculate the minimum cross-sectional area of a protective conductor in accordance with Section 543.1.3, the cross-sectional area may be determined in accordance with Table 54.7.

Where the application of Table 54.7 produces a non-standard size, a conductor having a larger standard cross-sectional area shall be used.

TABLE 54.7 –
Minimum cross-sectional area of protective conductor
in relation to the cross-sectional area of associated line conductor

Cross-sectional area of line conductor S	Minimum cross-sectional area of the corresponding protective conductor	
	If the protective conductor is of the same material as the line conductor	If the protective conductor is not of the same material as the line conductor
(mm^2)	(mm^2)	(mm^2)
$S \leq 16$	S	$\frac{k_1}{k_2} \times S$
$16 < S \leq 35$	16	$\frac{k_1}{k_2} \times 16$
$S > 35$	$\frac{S}{2}$	$\frac{k_1}{k_2} \times \frac{S}{2}$

where:

k_1 is the value of k for the line conductor, selected from Table 43.1 in Chapter 43 according to the materials of both conductor and insulation.

k_2 is the value of k for the protective conductor, selected from Tables 54.2 to 54.6, as applicable.

543.2 Types of protective conductor

543.2.1 A protective conductor may consist of one or more of the following:

(i) A single-core cable
(ii) A conductor in a cable
(iii) An insulated or bare conductor in a common enclosure with insulated live conductors
(iv) A fixed bare or insulated conductor
(v) A metal covering, for example, the sheath, screen or armouring of a cable
(vi) A metal conduit, metallic cable management system or other enclosure or electrically continuous support system for conductors
(vii) an extraneous-conductive-part complying with Section 543.2.6.

543.2.2 Where a metal enclosure or frame of a low voltage switchgear or controlgear assembly or busbar trunking system is used as a protective conductor, it shall satisfy the following three requirements:

(i) Its electrical continuity shall be assured, either by construction or by suitable connection, in such a way as to be protected against mechanical, chemical or electrochemical deterioration
(ii) Its cross-sectional area shall be at least equal to that resulting from the application of Section 543.1, or verified by test in accordance with the appropriate part of IEC 61439 series
(iii) It shall permit the connection of other protective conductors at every predetermined tap-off point.

543.2.3 A gas pipe, an oil pipe, flexible or pliable conduit, support wires or other flexible metallic parts, or constructional parts subject to mechanical stress in normal service, shall not be selected as a protective conductor.

543.2.4 A protective conductor of the types described in items (i) to (iv) of Section 543.2.1 and of cross-sectional area 10 mm^2 or less, shall be of copper.

543.2.5 The metal covering including the sheath (bare or insulated) of a cable, in particular the sheath of a mineral insulated cable, trunking and ducting for electrical purposes and metal conduit, may be used as a protective conductor for the associated circuit, if it satisfies both requirements of items (i) and (ii) of Section 543.2.2.

543.2.6 Except as prohibited by Section 543.2.3, an extraneous-conductive-part may be used as a protective conductor if it satisfies all the following requirements:

(i) Electrical continuity shall be assured, either by construction or by suitable connection, in such a way as to be protected against mechanical, chemical or electrochemical deterioration
(ii) The cross-sectional area shall be at least equal to that resulting from the application of Section 543.1.1
(iii) Unless compensatory measures are provided, precautions shall be taken against its removal
(iv) It has been considered for such a use and, if necessary, suitably adapted.

543.2.7 Where the protective conductor is formed by metal conduit, trunking or ducting or the metal sheath and/or armour of a cable, the earthing terminal of each accessory shall be connected by a separate protective conductor to an earthing terminal incorporated in the associated box or other enclosure.

543.2.8 *Not used*

543.2.9 Except where the circuit protective conductor is formed by a metal covering or enclosure containing all of the conductors of the ring, the circuit protective conductor of every ring final circuit shall also be run in the form of a ring having both ends connected to the earthing terminal at the origin of the circuit.

543.2.10 A separate metal enclosure for cable shall not be used as a PEN conductor.

543.3 Preservation of electrical continuity of protective conductors

543.3.1 A protective conductor shall be suitably protected against mechanical and chemical deterioration and electrodynamic effects.

543.3.2 Every connection and joint shall be accessible for inspection, testing and maintenance except as provided by Section 526.3.

543.3.201 A protective conductor having a cross-sectional area up to and including 6 mm^2 shall be protected throughout by a covering at least equivalent to that provided by the insulation of a single-core non-sheathed cable of appropriate size having a voltage rating of at least 450/750 V, except for the following:

(i) A protective conductor forming part of a multicore cable

(ii) A metal conduit, metallic cable management system or other enclosure or electrically continuous support system for conductors, where used as a protective conductor.

Where the sheath of a cable incorporating an uninsulated protective conductor of cross-sectional area up to and including 6 mm^2 is removed adjacent to joints and terminations, the protective conductor shall be protected by insulating sleeving complying with KS IEC 60684 series.

543.3.3.101 No switching device shall be inserted in a protective conductor, except:

(i) as permitted by Section 537.1.5

(ii) a multipole, linked switching in which the protective conductor circuit is not interrupted before the live conductors and is re-established not later than when the live conductors are reconnected

(iii) a switching device interlocked with a multipole, linked switching device inserted in the live conductors such that the protective conductor circuit shall not be interrupted before the live conductors and shall be re-established not later than when the live conductors are reconnected, or

(iv) a multipole plug-in device in which the protective conductor circuit shall not be interrupted before the live conductors and shall be re-established not later than when the live conductors are reconnected.

Switching devices provided in accordance with (i), (ii), (iii) and (iv) shall meet the requirements of Chapter 46 and Section 537 for a device for isolation.

Joints for test purposes that can be disconnected only by the use of a tool may be inserted in a protective conductor.

543.3.4 Where electrical earth monitoring is used, no dedicated devices (e.g. operating sensors, coils) shall be connected in series with the protective conductor (see IEC 61557).

543.3.5 An exposed-conductive-part of equipment shall not be used to form a protective conductor for other equipment except as provided by Section s 543.2.1, 543.2.2 and 543.2.5.

543.3.6 Every joint in metallic conduit shall be mechanically and electrically continuous.

543.4 Combined protective and neutral (PEN) conductors

543.4.1 PEN conductors shall not be used within an installation except as permitted by Section 543.4.2.

543.4.2 The provisions of Section s 543.4.3 to 543.4.8 may be applied only:

(i) where any necessary authorization for use of a PEN conductor has been obtained and where the installation complies with the conditions for that authorization, or

(ii) where the installation is supplied by a privately owned transformer or convertor in such a way that there is no metallic connection (except for the earthing connection) with the distributor's network, or

(iii) where the supply is obtained from a private generating plant.

543.4.3 If, from any point of the installation, the neutral and protective functions are provided by separate conductors, those conductors shall not then be reconnected together beyond that point. At the point of separation, separate terminals or bars shall be provided for the protective and neutral conductors. The PEN conductor shall be connected to the terminals or bar intended for the protective earthing conductor and the neutral conductor. The conductance of the terminal link or bar shall be not less than that specified in Section 543.4.5.

543.4.4 The outer conductor of a concentric cable shall not be common to more than one circuit. This requirement does not preclude the use of a twin or multicore cable to serve a number of points contained within one final circuit.

543.4.5 The conductance of the outer conductor of a concentric cable (measured at a temperature of 20 °C) shall:

(i) for a single-core cable, be not less than that of the internal conductor

(ii) for a multicore cable serving a number of points contained within one final circuit or having the internal conductors connected in parallel, be not less than that of the internal conductors connected in parallel.

543.4.6 At every joint in the outer conductor of a concentric cable and at a termination, the continuity of that joint shall be supplemented by a conductor additional to any means used for sealing and clamping the outer conductor. The conductance of the additional conductor shall be not less than that specified in Section 543.4.5 for the outer conductor.

543.4.7 No means of isolation or switching shall be inserted in the outer conductor of a concentric cable.

543.4.8 Excepting a cable to IEC 60702-1 installed in accordance with the manufacturer's instructions, the PEN conductor of every cable shall be insulated or have an insulating covering suitable for the highest voltage to which it may be subjected.

543.4.201 For a fixed installation, a conductor of a cable not subject to flexing and having a cross-sectional area not less than 10 mm^2 for copper or 16 mm^2 for aluminium may serve as a PEN conductor provided that the part of the installation concerned is not supplied through an RCD.

543.5 Earthing arrangements for combined protective and functional purposes

543.5.1 Where earthing for combined protective and functional purposes is required, the requirements for protective measures shall take precedence.

543.6 Earthing arrangements for protective purposes

543.6.1 Where overcurrent protective devices are used for fault protection, the protective conductor shall be incorporated in the same wiring system as the live conductors or in their immediate proximity.

543.7 Earthing requirements for the installation of equipment having high protective conductor currents

543.7.1 General

543.7.1.201 Equipment having a protective conductor current exceeding 3.5 mA but not exceeding 10 mA, shall be either permanently connected to the fixed wiring of the installation without the use of a plug and socket-outlet or connected by means of a plug and socket-outlet complying with IEC 60309-2.

543.7.1.202 Equipment having a protective conductor current exceeding 10 mA shall be connected to the supply by one of the following methods:

(i) Permanently connected to the wiring of the installation, with the protective conductor selected in accordance with Section 543.7.1.203. The permanent connection to the wiring may be by means of a flexible cable

(ii) A flexible cable with a plug and socket-outlet complying with IEC 60309-2, provided that either:

(a) the protective conductor of the associated flexible cable is of a cross-sectional area not less than 2.5mm^2 for plugs rated at 16 A and not less than 4 mm^2 for plugs rated above 16 A, or

(b) the protective conductor of the associated flexible cable is of a cross-sectional area not less than that of the line conductor

(iii) A protective conductor complying with Section 543 with an earth monitoring system to IEC 61557 installed which, in the event of a continuity fault occurring in the protective conductor, automatically disconnects the supply to the equipment.

543.7.1.203 The wiring of every final circuit and distribution circuit intended to supply one or more items of equipment, such that the total protective conductor current is likely to exceed 10 mA, shall have a high integrity protective connection complying with one or more of the following:

(i) A single protective conductor having a cross-sectional area of not less than 10 mm^2, complying with the requirements of Section s 543.2 and 543.3

(ii) A single copper protective conductor having a cross-sectional area of not less than 4 mm^2, complying with the requirements of Section s 543.2 and 543.3, the protective conductor being enclosed to provide additional protection against mechanical damage, for example, within a flexible conduit

(iii) Two individual protective conductors, each complying with the requirements of Section 543. The two protective conductors may be of different types, e.g. a metal conduit together with an additional conductor of a cable enclosed in the same conduit.

Where the two individual protective conductors are both incorporated in a multicore cable, the total cross-sectional area of all the conductors including the live conductors shall be not less than 10 mm^2. One of the protective conductors may be formed by the metallic sheath, armour or wire braid screen incorporated in the construction of the cable and complying with Section 543.2.5

(iv) An earth monitoring system to IEC 61557 may be installed which, in the event of a continuity fault occurring in the protective conductor, automatically disconnects the supply to the equipment

(v) Connection of the equipment to the supply by means of a double-wound transformer or equivalent unit, such as a motor-alternator set, the protective conductor of the incoming supply being connected to the exposed-conductive-parts of the equipment and to a point of the secondary winding of the transformer or equivalent device. The protective conductor(s) between the equipment and the transformer or equivalent device shall comply with one of the arrangements described in (i) to (iv) above.

543.7.1.204 Where two protective conductors are used in accordance with Section 543.7.1.203(iii), the ends of the protective conductors shall be terminated independently of each other at all connection points throughout the circuit, e.g. the distribution board, junction boxes and socket-outlets. This requires an accessory to be provided with two separate earth terminals.

543.7.1.205 At the distribution board information shall be provided indicating those circuits having a high protective conductor current. This information shall be positioned so as to be visible to a person who is modifying or extending the circuit.

543.7.2 Socket-outlet final circuits

543.7.2.201 For a final circuit with a number of socket-outlets or connection units intended to supply two or more items of equipment, where it is known or reasonably to be expected that the total protective conductor current in normal service will exceed 10 mA, the circuit shall be provided with a high integrity protective conductor connection complying with the requirements of Section 543.7.1. The following arrangements of the final circuit are acceptable:

(i) A ring final circuit with a ring protective conductor. Spurs, if provided, require high integrity protective conductor connections complying with the requirements of Section 543.7.1

(ii) A radial final circuit with a single protective conductor:

(a) the protective conductor being connected as a ring, or

(b) a separate protective conductor being provided at the final socket-outlet by connection to the metal conduit or ducting, or

(c) where two or more similar radial circuits supply socket-outlets in adjacent areas and are fed from the same distribution board, have identical means of short-circuit and overcurrent protection and circuit protective conductors of the same cross-sectional area, then a second protective conductor may be provided at the final socket-outlet on one circuit by connection to the protective conductor of the adjacent circuit

(iii) Other circuits complying with the requirements of Section 543.7.1.

544 PROTECTIVE BONDING CONDUCTORS

544.1 Main protective bonding conductors

544.1.1 Except where PME conditions apply, a main protective bonding conductor shall have a cross-sectional area not less than half the cross-sectional area required for the earthing conductor of the installation and not less than 6 mm^2. The cross-sectional area need not exceed 25 mm^2 if the bonding conductor is of copper or a cross-sectional area affording equivalent conductance in other metals.

Except for highway power supplies and street furniture, where PME conditions apply the main protective bonding conductor shall be selected in accordance with the PEN conductor of the supply and Table 54.8.

Where an installation has more than one source of supply to which PME conditions apply, a main protective bonding conductor shall be selected according to the largest PEN conductor of the supply.

TABLE 54.8 –
Minimum cross-sectional area of the main protective bonding conductor in relation to the PEN conductor of the supply

NOTE: Local distributor's network conditions may require a larger conductor.

Copper equivalent cross-sectional area of the PEN conductor	Minimum copper equivalent* cross-sectional area of the main protective bonding conductor
35 mm^2 or less	10 mm^2
over 35 mm^2 up to 50 mm^2	16 mm^2
over 50 mm^2 up to 95 mm^2	25 mm^2
over 95 mm^2 up to 150 mm^2	35 mm^2
over 150 mm^2	50 mm^2

* The minimum copper equivalent cross-sectional area is given by a copper bonding conductor of the tabulated cross-sectional area or a bonding conductor of another metal affording equivalent conductance.

The main protective bonding connection to any extraneous-conductive-part such as gas, water or other metallic pipework or service shall be made as near as practicable to the point of entry of that part into the premises. Where there is a meter, isolation point or union, the connection shall be made to the consumer's hard metal pipework and before any branch pipework. Where practicable the connection shall be made within 600 mm of the meter outlet union or at the point of entry to the building if the meter is external.

544.2 Supplementary bonding conductors

544.2.1 A supplementary bonding conductor connecting two exposed-conductive-parts shall have a conductance, if sheathed or otherwise provided with mechanical protection, not less than that of the smaller protective conductor connected to the exposed-conductive-parts. If mechanical protection is not provided, its cross-sectional area shall be not less than 4 mm^2.

544.2.2 A supplementary bonding conductor connecting an exposed-conductive-part to an extraneous-conductive-part shall have a conductance, if sheathed or otherwise provided with mechanical protection, not less than half that of the protective conductor connected to the exposed-conductive-part. If mechanical protection is not provided, its cross-sectional area shall be not less than 4 mm^2.

544.2.3 A supplementary bonding conductor connecting two extraneous-conductive-parts shall have a cross-sectional area not less than 2.5 mm^2 if sheathed or otherwise provided with mechanical protection or 4 mm^2 if mechanical protection is not provided, except that where one of the extraneous-conductive-parts is connected to an exposed-conductive-part in compliance with Section 544.2.2, that Section shall apply also to the conductor connecting the two extraneous-conductive-parts.

544.2.4 Except where Section 544.2.5 applies, supplementary bonding shall be provided by a supplementary conductor, a conductive part of a permanent and reliable nature, or by a combination of these.

544.2.5 Where supplementary bonding is to be applied to a fixed appliance which is supplied via a short length of flexible cable from an adjacent connection unit or other accessory, incorporating a flex outlet, the circuit protective conductor within the flexible cable shall be deemed to provide the supplementary bonding connection to the exposed-conductive-parts of the appliance, from the earthing terminal in the connection unit or other accessory.

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CHAPTER 55 OTHER EQUIPMENT

550.1 Scope

Chapter 55 specifies requirements and recommendations for the selection and erection of low voltage electrical equipment not covered by other parts of KS 662 except Part 7, intended to be part of the fixed installation.

551 LOW VOLTAGE GENERATING SETS

551.1 Scope

This section applies to low voltage and extra-low voltage installations which incorporate generating sets intended to supply, either continuously or occasionally, all or part of the installation. Requirements are included for installations with the following supply arrangements:

(i) Supply to an installation which is not connected to a system for distribution of electricity to the public

(ii) Supply to an installation as an alternative to a system for distribution of electricity to the public

(iii) Supply to an installation in parallel with a system for distribution of electricity to the public

(iv) Appropriate combinations of the above.

This section does not apply to self-contained items of extra-low voltage electrical equipment which incorporate both the source of energy and the energy-using load and for which a specific product standard exists that includes the requirements for electrical safety.

551.1.1 Generating sets with the following power sources are considered:

(i) Combustion engines

(ii) Turbines

(iii) Electric motors

(iv) Photovoltaic cells

(v) Electrochemical accumulators

(vi) Other suitable sources.

551.1.2 Generating sets with the following electrical characteristics are considered:

(i) Mains-excited and separately excited synchronous generators

(ii) Mains-excited and self-excited asynchronous generators

(iii) Mains-commutated and self-commutated static convertors with or without bypass facilities.

551.1.3 The use of generating sets for the following purposes is considered:

(i) Supply to permanent installations

(ii) Supply to temporary installations

(iii) Supply to mobile equipment which is not connected to a permanent fixed installation

(iv) Supply to mobile units (Section 717 also applies).

551.2 General requirements

551.2.1 The means of excitation and commutation shall be appropriate for the intended use of the generating set and the safety and proper functioning of other sources of supply shall not be impaired by the generating set.

551.2.2 The prospective short-circuit current and prospective earth fault current shall be assessed for each source of supply or combination of sources which can operate independently of other sources or combinations. The short-circuit rating of protective devices within the installation and, where appropriate, connected to a system for distribution of electricity to the public, shall not be exceeded for any of the intended methods of operation of the sources.

551.2.3 Where the generating set is intended to provide a supply to an installation which is not connected to a system for distribution of electricity to the public or to provide a supply as a switched alternative to such a system, the capacity and operating characteristics of the generating set shall be such that danger or damage to equipment does not arise after the connection or disconnection of any intended load as a result of the deviation of the voltage or frequency from the intended operating range. Means shall be provided to automatically disconnect such parts of the installation as may be necessary if the capacity of the generating set is exceeded.

NOTE 1: Consideration should be given to the intended duty cycle and size of individual connected loads as a proportion of the capacity of the generating set and to the starting characteristics of any connected electric motors.

NOTE 2: Consideration should be given to the power factor specified for protective devices in the installation.

NOTE 3: The installation of a generating set within an existing building or installation may change the conditions of external influence for the installation (see Part 3), for example by the introduction of moving parts, parts at high temperature or by the presence of flammable fluids and noxious gases, etc.

551.2.4 Provision for isolation shall meet the requirements of Chapter 46 and Section 537 for each source or combination of sources of supply.

551.3 Protective measure: Extra-low voltage provided by SELV or PELV

551.3.1 Additional requirements for SELV and PELV where the installation is supplied from more than one source

Where a SELV or PELV system may be supplied by more than one source, the requirements of Section 414.3 shall apply to each source. Where one or more of the sources is earthed, the requirements for PELV systems in Section 414.4 shall apply.

If one or more of the sources does not meet the requirements of Section 414.3, the system shall be treated as a FELV system and the requirements of Section 411.7 shall apply.

551.3.2 Where it is necessary to maintain the supply to an extra-low voltage system following the loss of one or more sources of supply, each source of supply or combination of sources of supply which can operate independently of other sources or combinations shall be capable of supplying the intended load of the extra-low voltage system. Provisions shall be made so that loss of the low voltage supply to an extra-low voltage source does not lead to danger or damage to other extra-low voltage equipment.

NOTE: Such provisions may be necessary in supplies for safety services (see Chapter 56).

551.4 Fault protection

551.4.1 Fault protection shall be provided for the installation in respect of each source of supply or combination of sources of supply that can operate independently of other sources or combinations of sources.

The fault protective provisions shall be selected or precautions shall be taken so that where fault protective provisions are achieved in different ways within the same installation or part of an installation according to the active sources of supply, no influence shall occur or conditions arise that could impair the effectiveness of the fault protective provisions.

NOTE: This might, for example, require the use of a transformer providing electrical separation between parts of the installation using different earthing systems.

551.4.2 The generating set shall be connected so that any provision within the installation for protection by RCDs in accordance with Chapter 41 remains effective for every intended combination of sources of supply.

NOTE: Connection of live parts of the generator with Earth may affect the protective measure.

551.4.3 Protection by automatic disconnection of supply

551.4.3.1 Protection by automatic disconnection of supply shall be provided in accordance with Section 411, except as modified for particular cases by Section 551.4.3.2, 551.4.3.3 or 551.4.4.

551.4.3.2 Additional requirements for installations where the generating set provides a switched alternative to system for distribution of electricity to the public (standby systems)

551.4.3.2.1 Protection by automatic disconnection of supply shall not rely upon the connection to the earthed point of the system for distribution of electricity to the public when the generator is operating as a switched alternative to a TN system. A suitable means of earthing shall be provided.

551.4.3.3 Additional requirements for installations incorporating static convertors

551.4.3.3.1 Where fault protection for parts of the installation supplied by the static convertor relies upon the automatic closure of the bypass switch and the operation of protective devices on the supply side of the bypass switch is not within the time required by Section 411, supplementary equipotential bonding shall be provided between simultaneously accessible exposed-conductive-parts and extraneous-conductive-parts on the load side of the static convertor in accordance with Section 415.2.

The resistance (R) of the supplementary protective bonding conductor required between simultaneously accessible exposed-conductive-parts and extraneous-conductive-parts shall fulfil the following condition:

$$R \leq 50/I_a$$

where:

I_a is the maximum earth fault current which can be supplied by the static convertor when the bypass switch is closed.

NOTE: Where such equipment is intended to operate in parallel with a system for distribution of electricity to the public, the requirements of Section 551.7 also apply.

551.4.3.3.2 Precautions shall be taken or equipment shall be selected so that the correct operation of protective devices is not impaired by DC currents generated by a static convertor or by the presence of filters.

551.4.3.3.3 A means of isolation shall be installed on both sides of a static convertor. This requirement does not apply on the power source side of a static convertor which is integrated in the same enclosure as the power source.

551.4.4 Additional requirements for protection by automatic disconnection where the installation and generating set are not permanently fixed

This Section applies to portable generating sets and to generating sets which are intended to be moved to unspecified locations for temporary or short-term use. Such generating sets may be part of an installation which is subject to similar use. This Section does not apply to permanent fixed installations.

NOTE: For suitable connection arrangements see IEC 60309 series.

551.4.4.1 Between separate items of equipment, protective conductors shall be provided which are part of a suitable cable and which comply with Table 54.7.

All protective conductors shall comply with Chapter 54.

551.4.4.2 In a TN, TT or IT system, every final circuit shall be provided with additional protection by means of an RCD having the characteristics specified in Section 415.1.

NOTE: In an IT system, an RCD may not operate unless one of the earth faults is on a part of the system on the supply side of the device.

551.5 Protection against overcurrent

551.5.1 Where overcurrent protection of the generating set is required, it shall be located as near as practicable to the generator terminals.

NOTE: The contribution to the prospective short-circuit current by a generating set may be time-dependent and may be much less than the contribution made by a system for distribution of electricity to the public.

551.5.2 Where a generating set is intended to operate in parallel with a system for distribution of electricity to the public, or where two or more generating sets may operate in parallel, circulating harmonic currents shall be limited so that the thermal rating of conductors is not exceeded.

The effects of circulating harmonic currents may be limited by one or more of the following:

(i) The selection of generating sets with compensated windings

(ii) The provision of a suitable impedance in the connection to the generator star points

(iii) The provision of switches which interrupt the circulatory circuit but which are interlocked so that at all times fault protection is not impaired

(iv) The provision of filtering equipment

(v) Other suitable means.

NOTE: Consideration should be given to the maximum voltage which may be produced across an impedance connected to limit circulating harmonic currents.

551.6 Additional requirements for installations where the generating set provides a supply as a switched alternative to the system for distribution of electricity to the public (standby systems)

551.6.1 Precautions complying with the relevant requirements of Chapter 46 and Section 537 for isolation shall be taken so that the generator cannot operate in parallel with the system for distribution of electricity to the public. Suitable precautions may include one or more of the following:

(i) An electrical, mechanical or electromechanical interlock between the operating mechanisms or control circuits of the changeover switching devices

(ii) A system of locks with a single transferable key

(iii) A three-position break-before-make changeover switch

(iv) An automatic changeover switching device with a suitable interlock

(v) Other means providing equivalent security of operation.

551.6.2 For a TN-S system where the neutral is not isolated, any RCD shall be positioned to avoid incorrect operation due to the existence of any parallel neutral-earth path.

NOTE: It may be desirable in a TN system to disconnect the neutral of the installation from the neutral or PEN of the system for distribution of electricity to the public to avoid disturbances such as induced voltage surges caused by lightning.

551.7 Additional requirements for installations where the generating set may operate in parallel with other sources including systems for distribution of electricity to the public

551.7.1 When a generating set is used as an additional source of supply in parallel with another source, both of the following conditions shall be fulfilled:

(i) Protection against thermal effects in accordance with Chapter 42 and protection against overcurrent in accordance with Chapter 43 shall remain effective in all situations

(ii) Where an RCD is providing additional protection in accordance with Section 415.1 for a circuit connecting the generator set to the installation, the RCD shall disconnect all live conductors, including the neutral conductor.

551.7.2 A generating set used as an additional source of supply in parallel with another source shall be installed:

– on the supply side of all the overcurrent protective devices for the final circuits of the installation, or

– on the load side of all the overcurrent protective devices for a final circuit of the installation, but in this case all the following additional requirements shall be fulfilled:

(i) The conductors of the final circuit shall meet the following requirement:

$I_z \geq I_n + I_g$

where:

I_z is the current-carrying capacity of the final circuit conductors

I_n is the rated current of the protective device of the final circuit

I_g is the rated output current of the generating set

(ii) A generating set shall not be connected to a final circuit by means of a plug and socket-outlet

(iii) The line and neutral conductors of the final circuit and of the generating set shall not be connected to Earth

(iv) Unless the device providing automatic disconnection of the final circuit in accordance with Section 411.3.2 disconnects the line and neutral conductors, it shall be verified that the combination of the disconnection time of the protective device for the final circuit and the time taken for the output voltage of the generating set to reduce to 50 V or less is not greater than the disconnection time required by Section 411.3.2 for the final circuit.

This Section does not apply to an uninterruptible power supply provided to supply specific items of current-using equipment within the final circuit to which it is connected.

551.7.3 In selecting and using a generating set to run in parallel with the system for distribution of electricity to the public, care shall be taken to avoid adverse effects to that system and to other installations in respect of power factor, voltage changes, harmonic distortion, unbalance, starting, synchronizing or voltage fluctuation effects. Where synchronization is necessary, the use of an automatic synchronizing system which considers frequency, phase and voltage is to be preferred.

551.7.4 Means of automatic switching shall be provided to disconnect the generating set from the system for distribution of electricity to the public in the event of loss of that supply or deviation of the voltage or frequency at the supply terminals from declared values.

For a generating set with an output exceeding 16 A, the type of protection and the sensitivity and operating times depend upon the protection of the system for distribution of electricity to the public and the number of generating sets connected and shall be agreed by the distributor. For a generating set with an output not exceeding 16 A, the settings shall comply with IEC 61727.

In the case of the presence of a static convertor, the means of switching shall be provided on the load side of the static convertor.

551.7.5 Means shall be provided to prevent the connection of a generating set to the system for distribution of electricity to the public in the event of loss of that supply or deviation of the voltage or frequency at the supply terminals from values required by Section 551.7.4.

NOTE: For a generating set with an output not exceeding 16 A intended to operate in parallel with a system for distribution of electricity to the public the requirements are given in IEC 61727.

551.7.6 Means shall be provided to enable the generating set to be isolated from the system for distribution of electricity to the public. For a generating set with an output exceeding 16 A, the accessibility of this means of isolation shall comply with national rules and distribution system operator requirements. For a generating set with an output not exceeding 16 A, the accessibility of this means of isolation shall comply with IEC 61727.

551.7.7 Where a generating set may operate as a switched alternative to the system for distribution of electricity to the public, the installation shall also comply with Section 551.6.

551.8 Requirements for installations incorporating stationary batteries

551.8.1 Stationary batteries shall be installed so that they are accessible only to skilled or instructed persons.

NOTE: This generally requires the battery to be installed in a secure location or, for smaller batteries, a secure enclosure.

The location or enclosure shall be adequately ventilated.

551.8.2 Battery connections shall have basic protection by insulation or enclosures or shall be arranged so that two bare conductive parts having between them a potential difference exceeding 120 volts cannot be inadvertently touched simultaneously.

552 ROTATING MACHINES

NOTE: See also Section 463.3 Motor control.

552.1 Rotating machines

552.1.1 All equipment, including cable, of every circuit carrying the starting, accelerating and load currents of a motor shall be suitable for a current at least equal to the full-load current rating of the motor when rated in accordance with the appropriate Kenyan Standard. Where the motor is intended for intermittent duty and for frequent starting and stopping, account shall be taken of any cumulative effects of the starting or braking currents upon the temperature rise of the equipment of the circuit.

552.1.2 Every electric motor having a rating exceeding 0.37 kW shall be provided with control equipment incorporating means of protection against overload of the motor. This requirement does not apply to a motor incorporated in an item of current-using equipment complying as a whole with an appropriate Kenyan Standard.

552.1.3 Except where failure to start after a brief interruption would be likely to cause greater danger, every motor shall be provided with means to prevent automatic restarting after a stoppage due to a drop in voltage or failure of supply, where unexpected restarting of the motor might cause danger. This requirement does not preclude arrangements for starting a motor at intervals by an automatic control device, where other adequate precautions are taken against danger from unexpected restarting.

553 ACCESSORIES

553.1 Plugs and socket-outlets

553.1.1 Every plug and socket-outlet shall comply with all the requirements of items (i) and (ii) below and, in addition, with the appropriate requirements of Section s 553.1.2 to 553.2.2:

(i) Except for SELV circuits, it shall not be possible for any pin of a plug to make contact with any live contact of its associated socket-outlet while any other pin of the plug is completely exposed

(ii) It shall not be possible for any pin of a plug to make contact with any live contact of any socket-outlet within the same installation other than the type of socket-outlet for which the plug is designed.

553.1.2 Except for SELV or a special circuit from Section 553.1.5, every plug and socket-outlet shall be of the non-reversible type, with provision for the connection of a protective conductor.

553.1.3 Except where Section 553.1.5 applies, in a low voltage circuit every plug and socket-outlet shall conform with the applicable Kenya Standard listed in Table 55.1.

TABLE 55.1 –
Plugs and socket-outlets for low voltage circuits

Type of plug and socket-outlet	Rating (amperes)	Applicable Standard
Fused plugs and shuttered socket-outlets, 2-pole and earth, for AC	13	KS EAS 495
Plugs and socket-outlets (industrial type)	16, 32, 63, 125	KS IEC 60309-2

553.1.201 Every socket-outlet for household and similar use shall be of the shuttered type and, for an AC installation, shall preferably be of a type complying with KS 495.

553.1.5 A plug and socket-outlet not complying with KS 495, or IEC 60309-2, may be used in single-phase AC or two-wire DC circuits operating at a nominal voltage not exceeding 250 volts for:

(i) the connection of an electric clock, provided that the plug and socket-outlet are designed specifically for that purpose, and that each plug incorporates a fuse of rating not exceeding 3 amperes complying with IEC 60269 as appropriate

(ii) the connection of an electric shaver, provided that the socket-outlet is either incorporated in a shaver supply unit complying with IEC 61558-2-5

(iii) a circuit having special characteristics such that danger would otherwise arise or it is necessary to distinguish the function of the circuit.

553.1.6 A socket-outlet on a wall or similar structure shall be mounted at a height above the floor or any working surface to minimize the risk of mechanical damage to the socket-outlet or to an associated plug and its flexible cable which might be caused during insertion, use or withdrawal of the plug.

553.1.7 Where mobile equipment is likely to be used, provision shall be made so that the equipment can be fed from an adjacent and conveniently accessible socket-outlet, taking account of the length of flexible cable normally fitted to portable appliances and luminaires.

553.2 Cable couplers

553.2.1 Except for a SELV or a Class II circuit, a cable coupler shall comply where appropriate with IEC 61535, IEC 60309-2 or IEC 60320-1, shall be non-reversible and shall have provision for the connection of a protective conductor.

553.2.2 A cable coupler shall be arranged so that the connector of the coupler is fitted at the end of the cable remote from the supply.

554 CURRENT-USING EQUIPMENT

554.1 Electrode water heaters and boilers

554.1.1 Every electrode water heater and electrode boiler shall be connected to an AC system only, and shall be selected and erected in accordance with the appropriate requirements of this section.

554.1.2 The supply to the electrode water heater or electrode boiler shall be controlled by a linked circuit-breaker arranged to disconnect the supply from all electrodes simultaneously and provided with an overcurrent protective device in each conductor feeding an electrode.

554.1.3 The earthing of the electrode water heater or electrode boiler shall comply with the requirements of Chapter 54 and, in addition, the shell of the electrode water heater or electrode boiler shall be bonded to the metallic sheath and armour, if any, of the incoming supply cable. The protective conductor shall be connected to the shell of the electrode water heater or electrode boiler and shall comply with Section 543.1.1.

554.1.4 Where an electrode water heater or electrode boiler is directly connected to a supply at a voltage exceeding low voltage, the installation shall include an RCD arranged to disconnect the supply from the electrodes on the occurrence of a sustained earth leakage current in excess of 10 % of the rated current of the electrode water heater or electrode boiler under normal conditions of operation, except that if in any instance a higher value is essential for stability of operation of the electrode water heater or electrode boiler, the value may be increased to a maximum of 15 %. A time delay may be incorporated in the device to prevent unnecessary operation in the event of imbalance of short duration.

554.1.5 Where an electrode water heater or electrode boiler is connected to a three-phase low voltage supply, the shell of the electrode water heater or electrode boiler shall be connected to the neutral of the supply as well as to the earthing conductor. The current-carrying capacity of the neutral conductor shall be not less than that of the largest line conductor connected to the equipment.

554.1.6 Except as provided by Section 554.1.7, where the supply to an electrode water heater or electrode boiler is single-phase and one electrode is connected to a neutral conductor earthed by the distributor, the shell of the electrode water heater or electrode boiler shall be connected to the neutral of the supply as well as to the earthing conductor.

554.1.7 Where the electrode water heater or electrode boiler is not piped to a water supply or in physical contact with any earthed metal, and where the electrodes and the water in contact with the electrodes are so shielded in insulating material that they cannot be touched while the electrodes are live, a fuse in the line conductor may be substituted for the circuit-breaker required under Section 554.1.2 and the shell of the electrode water heater or electrode boiler need not be connected to the neutral of the supply.

554.2 Heaters for liquids or other substances having immersed heating elements

554.2.1 Every heater for liquid or other substance shall incorporate or be provided with an automatic device to prevent a dangerous rise in temperature.

554.3 Water heaters having immersed and uninsulated heating elements

554.3.1 Every single-phase water heater or boiler having an uninsulated heating element immersed in the water shall comply with the requirements of Section s 554.3.2 and 554.3.3. This type of water heater or boiler is deemed not to be an electrode water heater or electrode boiler.

554.3.2 All metal parts of the heater or boiler which are in contact with the water (other than current-carrying parts) shall be solidly and metallically connected to a metal water pipe through which the water supply to the heater or boiler is provided, and that water pipe shall be connected to the main earthing terminal by means independent of the circuit protective conductor.

554.3.3 The heater or boiler shall be permanently connected to the electricity supply through a double-pole linked switch which is either separate from and within easy reach of the heater or boiler or is incorporated therein, and the wiring from the heater or boiler shall be connected directly to that switch without the use of a plug and socket-outlet.

554.3.4 Before a heater or boiler of the type referred to in Section 554.3.1 is connected, the installer shall confirm that no single-pole switch, non-linked circuit-breaker or fuse is fitted in the neutral conductor in any part of the circuit between the heater or boiler and the origin of the installation.

554.4 Heating conductors and cables

NOTE: For electric floor and ceiling heating systems in buildings the requirements of Section 753 must also be met.

554.4.1 Where a heating cable is required to pass through, or be in close proximity to, material which presents a fire hazard, the cable shall be enclosed in material having the ignitability characteristic 'P' as specified in IEC 60332-1-1 and shall be adequately protected from any mechanical damage reasonably foreseeable during installation and use.

554.4.2 A heating cable intended for laying directly in soil, concrete, cement screed or other material used for road and building construction shall be:

(i) capable of withstanding mechanical damage under the conditions that can reasonably be expected to prevail during its installation, and

(ii) constructed of material that will be resistant to damage from dampness and/or corrosion under normal conditions of service.

554.4.3 A heating cable laid directly in soil, a road or the structure of a building shall be installed so that it:

(i) is completely embedded in the substance it is intended to heat, and

(ii) does not suffer damage in the event of movement normally to be expected in it or the substance in which it is embedded, and

(iii) complies in all respects with the manufacturer's instructions and recommendations.

554.4.4 The load of every floor-warming cable under operation shall be limited to a value such that the manufacturer's stated conductor temperature is not exceeded. Other factors can limit the maximum temperature at which the cable can be run, such as the temperature rating of any terminations or accessories, and any material with which it is in contact.

555 TRANSFORMERS

555.1 Autotransformers and step-up transformers

555.1.1 Where an autotransformer is connected to a circuit having a neutral conductor, the common terminal of the winding shall be connected to the neutral conductor.

555.1.2 A step-up autotransformer shall not be connected to an IT system.

555.1.3 Where a step-up transformer is used, a linked switch shall be provided for disconnecting the transformer from all live conductors of the supply.

556 Not used

557 AUXILIARY CIRCUITS

557.1 Scope

This section applies to auxiliary circuits, except those covered by specific product or system standards, e.g. the construction of assemblies of electrical equipment to the appropriate part of the IEC 61439 series.

557.2 Not used

557.3 Requirements for auxiliary circuits

557.3.1 General

The power supply, AC or DC, for an auxiliary circuit may be either dependent or independent of the main circuit according to its required function. If the status of the main circuit has to be signalled, then the signalling circuit shall be able to operate independently of that main circuit.

557.3.201 Control circuits

A control circuit shall be designed, arranged and protected to limit dangers resulting from a fault between the control circuit and other conductive parts liable to cause malfunction (e.g. inadvertent operation) of the controlled equipment.

557.3.2 Power supply for auxiliary circuits dependent on the main circuit

557.3.2.1 General

Auxiliary circuits with a power supply dependent on the main AC circuit shall be connected to the main circuit:

(i) directly (see Figure 55.1), or

(ii) via a rectifier (see Figure 55.2), or

(iii) via a transformer (see Figure 55.3).

It is recommended that auxiliary circuits supplying primarily electronic equipment or systems should not be supplied directly but at least via simple separation from the main circuit.

Fig 55.1 – Auxiliary circuit supplied directly from the main circuit

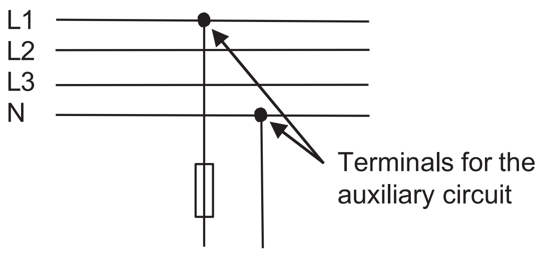


Fig 55.2 – Auxiliary circuit supplied from the main circuit via a rectifier

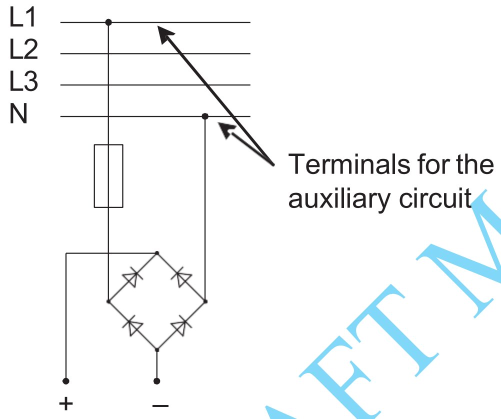
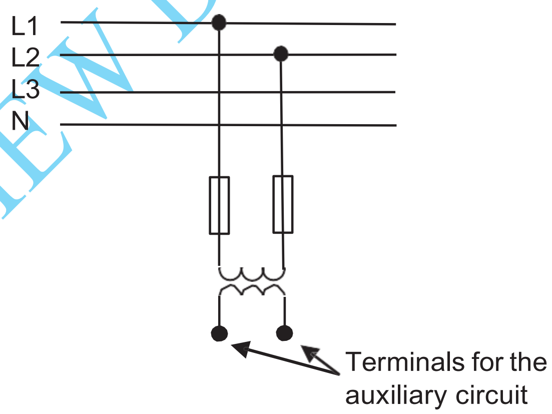


Fig 55.3 – Auxiliary circuit supplied from the main circuit via a transformer



NOTE: For an auxiliary circuit supplied from the main circuit, either directly or via a rectifier, the auxiliary circuit begins at the connection point to the main circuit, see Figures 55.1 and 55.2. In the case of a transformer supply, the auxiliary circuit begins on the secondary side of the transformer, see Figure 55.3.

557.3.2.2 Auxiliary circuit supplied from the main circuit via transformer

Where an auxiliary circuit is supplied by more than one transformer, they shall be connected in parallel both on the primary and secondary sides.

557.3.3 Auxiliary circuit supplied by an independent source

Where an independent source is used a loss of supply or undervoltage of the main circuit source shall be detected. An independent auxiliary circuit shall not create a hazardous situation.

NOTE: Batteries and a power supply system independent of the mains are examples of independent sources.

557.3.4 Auxiliary circuits with or without connection to earth

557.3.4.1 General

An auxiliary circuit shall comply with the earthing requirements of KS 662 except as modified by Section 557.3.4.2 or 557.3.4.3.

NOTE 1: It depends on the requirements for an auxiliary circuit as to whether it is operated earthed or unearthed. For example, in an earthed auxiliary circuit an earth fault in a non-earthed conductor leads to disconnection of the power supply of the auxiliary circuit; in an unearthed auxiliary circuit, an earth fault in a conductor leads only to a signal from the IMD (see Section 557.3.4.3).

NOTE 2: The use of unearthed auxiliary circuits should be considered where high reliability is required.

557.3.4.2 Earthed auxiliary circuit

An earthed auxiliary circuit supplied via a transformer shall be connected to earth only at one point on the secondary side of the transformer. The connection to earth shall be situated close to the transformer. The connection shall be easily accessible and capable of being isolated for insulation measurement.

557.3.4.3 Unearthed auxiliary circuit

Except in the case of a SELV or PELV circuit, if an auxiliary circuit is operated unearthed via a transformer, an insulation monitoring device (IMD) according to IEC 61557-8 shall be installed on the secondary side. Consideration shall be given to the use of risk assessment to determine whether the signal from the IMD is to initiate an acoustic and/or a flash alarm, or be transmitted to a monitoring system.

557.3.5 Power supplies for auxiliary circuits

557.3.5.1 General

The rated voltage of an auxiliary circuit, and the components used in the circuit, shall be compatible with the supply to that circuit.

NOTE 1: If the supply voltage is too low for the design of the circuit then the operation will not be reliable for the proper function of relays.

Account shall be taken of the effects of voltage drop on the electrical equipment of the auxiliary circuit, including inrush and starting currents.

NOTE 2: Motors starting direct-on-line can draw a starting current from the main circuit that will reduce the supply voltage to an auxiliary circuit dependent on the main circuit, below the minimum operating voltage of the associated switchgear.

557.3.5.2 Standby power supply or power supply for safety services

Where a standby power supply or a power supply from a generating set is used to supply auxiliary circuits, the frequency variation shall be taken into account.

557.3.5.3 AC supply

The nominal voltage of control circuits shall preferably not exceed 230 V for circuits with 50 Hz nominal frequency

respectively, taking into account voltage tolerances according to IEC 60038.

NOTE: The dimensioning of cable length with respect to the conductor capacitances, e.g. connection to a limit switch, needs to be coordinated with the selected relays or solenoid valves. The standing voltage caused by high conductor capacitances may impair the switching off of relays or solenoid valves.

557.3.5.4 DC supply

557.3.5.4.1 Supply by a power system

The nominal voltage of control circuits shall preferably not exceed 220 V.

557.3.5.4.2 Supply by batteries

Where batteries are used as a power supply for auxiliary circuits, the voltage fluctuation due to charging or discharging shall not exceed voltage tolerances specified in IEC 60038, unless the auxiliary circuit is specifically designed to compensate for such voltage fluctuation.

557.3.6 Protective measures

557.3.6.1 Protection of wiring systems

NOTE 1: In the case of extended auxiliary circuits it is necessary to check that the required operating current of the protective device will be achieved also at the far end of the respective cables or conductors, Section 433.1.

Single-phase earthed AC auxiliary circuits supplied on the secondary side of the transformer for an auxiliary supply and earthed DC auxiliary circuits are permitted to be protected by single-pole devices. The protective devices shall only be inserted in conductors which are not connected directly to earth.

In unearthed AC or DC auxiliary circuits, short-circuit protection shall be provided for all line conductors.

NOTE 2: The use of protective devices which disconnect all lines of an unearthed auxiliary circuit will aid fault diagnosis and maintenance activities.

If the short-circuit protective device on the primary side of the transformer for an auxiliary circuit is selected so that it also protects against short-circuit current on the secondary side, a protective device on the secondary side of the transformer may be omitted.

NOTE 3: For a fault on the transformer secondary side, the magnitude of the short-circuit current on the primary side depends also on the impedance of the transformer.

557.3.6.2 Protection against short-circuit

Switching contacts of electrical switching devices of the auxiliary circuit shall be protected against damage caused by short-circuit currents, according to the manufacturer's instructions.

557.4 Characteristics of cables and conductors

557.4.1 Minimum cross-sectional areas

In order to provide adequate mechanical strength, the following minimum cross-sectional areas indicated in Table 55.2 shall be met. If there are special mechanical strength requirements for cables or conductors, then a larger cross-sectional area of conductor, selected in accordance with Chapter 52, may be required.

TABLE 55.2 – Minimum cross-sectional area of copper conductors in mm²

Application	Type of cable				
	Single-core		Two-core		Multicore
	Single-wire	Stranded	Screened	Unscreened	Screened or unscreened
Control circuits[a]	0.5	0.5	0.5	0.5	0.1
Data transfer	–	–	–	–	0.1

[a] Other auxiliary circuits may need a larger cross-sectional area of copper conductor, e.g. for measuring.

NOTE: The cross-sectional area of copper conductors is derived from Section 524.

557.5 Requirements for auxiliary circuits used for measurement

557.5.1 General

Measuring circuits are auxiliary circuits with dedicated requirements which are given in the following subclauses.

557.5.2 Auxiliary circuits for direct measurement of electrical quantities

An auxiliary circuit for direct measurement of electrical quantities shall be protected against the effects of a fault by one of the following means:

(i) Provision of a device for protection against fault current in accordance with Section 434. Where operation of the device could cause danger, or lead to a hazardous situation, such operation shall also cause disconnection of the main circuit

(ii) Simultaneous fulfilment of conditions (a) and (b) of Section 434.3.

557.5.3 Auxiliary circuits for measurement of electrical quantities via a transformer

557.5.3.1 Current transformer

Where a measurement device is connected to the main circuit via a current transformer, the following requirements shall be taken into account:

(i) The secondary side of the transformer in a low voltage installation shall not be earthed, except where the measurement can only be carried out with a connection to earth

(ii) Protective devices interrupting the circuit shall not be used on the secondary side of the transformer

(iii) Conductors on the secondary side of the transformer shall be insulated for the highest voltage of any live parts or shall be installed such that their insulation cannot come into contact with other live parts, e.g. contact with busbars

(iv) Terminals for temporary measurements shall be provided.

The above requirements do not apply to summation current transformers where hazardous voltages do not occur, e.g. equipment for insulation fault location according to IEC 61557-9.

557.5.3.2 Voltage transformer

The secondary side of a voltage transformer shall be protected by a short-circuit protective device.

557.6 Functional considerations

557.6.1 Voltage supply

Where loss of voltage, i.e. voltage fluctuation, overvoltage or undervoltage, could cause the auxiliary circuit to be unable to perform its intended function, means to secure the continued operation of the auxiliary circuit shall be provided.

557.6.2 Quality of signals depending on the cable characteristics

The operation of an auxiliary circuit shall not be adversely affected by the characteristics, including impedance and length, of the cable between operational components.

The capacitance of the cable shall not impair the proper operation of an actuator in the auxiliary circuit. The cable characteristics and length shall be taken into account for the selection of switchgear and controlgear or electronic circuits.

NOTE: For an extensive auxiliary circuit, the use of a DC power supply or bus-system is recommended.

557.6.3 Measures to avoid the loss of functionality

An auxiliary circuit serving a special function where reliability is a concern will require additional design considerations to minimize the likelihood of wiring faults. These wiring faults could result in loss of function and/or loss of signal. Among the design considerations are:

(i) selection of appropriate installation methods for cables

(ii) selection of equipment where a fault from line to exposed-conductive-parts is not possible, e.g. Class II equipment

(iii) use of installation methods and equipment that are inherently short-circuit and earth fault proof.

For the design of installations and equipment that are inherently short-circuit and earth fault proof, the following shall be considered:

(a) Arrangements of single conductors with basic insulation, together with measures to prevent mutual contact and contact with exposed-conductive-parts. This may be achieved by:

- installation in (insulated) cable trunking systems, or
- installation in (insulated) conduit

(b) Arrangements of:

- single-core cables, or
- single-core, non-metallic-sheathed cables, or
- rubber-insulated flexible cables

(c) Provision of protection against mechanical damage and of safe distance from flammable material for non-metallic sheathed cables

(d) Arrangements of non-metallic-sheathed cables with nominal voltage U_0/U at least 0.6/1 kV (U_0 = conductor to Earth voltage, U = conductor to conductor voltage)

(e) Use of cables with an insulation which is self-extinguishing and flame-retardant

(f) Use of cables that are afforded physical protection by being buried, e.g. installation of cables in soil or concrete.

557.6.4 Current-limiting signal outputs

In earthed or unearthed auxiliary circuits with current-limiting signal outputs or electronically controlled protection against short-circuit conditions, respectively, the signal circuit shall be disconnected within 5 s if the respective measure operates. In special cases, a shorter disconnection time may be required.

For current-limiting signal outputs or electronically controlled protection of the signal output, respectively, automatic disconnection of supply may be omitted if a hazardous situation is not likely to occur.

557.6.5 Connection to the main circuit

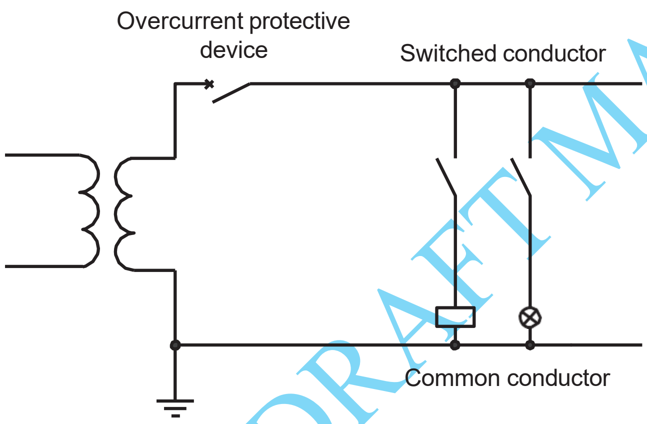
557.6.5.1 Auxiliary circuits without direct connection to the main circuit

Electrical actuators, e.g. actuating relays, contactors, signalling lights, electromagnetic locking devices, shall be connected to the common conductor (see Figure 55.4):

(i) in earthed auxiliary circuits, at the earthed (common) conductor

(ii) in unearthed auxiliary circuits, at the common conductor.

Fig 55.4 – Configuration of an auxiliary circuit



Exception: Switching elements of protective relays, e.g. overcurrent relays, may be installed between the earthed or the non-earthed conductor and a coil, provided that:

(a) this connection is contained inside a common enclosure, or

(b) it leads to a simplification of external control devices, e.g. conductor bars, cable drums, multiple connectors, and takes into account the requirements of Section 557.3.6.2.

557.6.5.2 Auxiliary circuits with direct connection to the main circuit

If the auxiliary circuit is:

(i) supplied between two line conductors (e.g. L1 and L2 of an IT system), two-pole switching contacts shall be used

(ii) connected to the earthed neutral of the main circuit, the requirements of Chapter 43 apply.

557.6.6 Plug-in connections

Interchangeability between multiple plug-in connections is permitted only where it will not result in mechanical damage or introduce a risk of fire, electric shock or injury to persons.

NOTE 1: These plug-in connections form a part of the auxiliary circuit(s) and may conduct different signals.

NOTE 2: Protection against interchangeability may be achieved by marking, polarization, design or electronic interlocking.

The connectors shall be secured by a means to prevent unintended disconnection.

558 Not used

559 LUMINAIRES AND LIGHTING INSTALLATIONS

559.1 Scope

This section applies to the selection and erection of luminaires and lighting installations intended to be part of the fixed installation.

NOTE 1: For outdoor lighting installations, extra-low voltage lighting installations and lighting installations in special locations, refer to Part 7.

The requirements of this section do not apply to:

(i) high voltage signs supplied at low voltage (such as neon tubes)

(ii) signs and luminous discharge tube installations operating from a no-load rated output voltage exceeding 1 kV but not exceeding 10 kV (IEC 60598-2-14)

(iii) temporary festoon lighting.

559.2 Not used

559.3 General requirements for installations

NOTE: See Table 55.3 for an explanation of the symbols used in luminaires, in controlgear for luminaires and in the installation of luminaires.

559.3.1 Every luminaire shall comply with the relevant standard for manufacture and test of that luminaire and shall be selected and erected to take account of the manufacturer's instructions.

559.3.2 For the purposes of this section, luminaires without transformers or convertors but which are fitted with extra-low voltage lamps connected in series to a low voltage supply shall be considered as low voltage equipment not extra-low voltage equipment. These luminaires shall be either Class I or Class II equipment.

559.3.3 Where a luminaire is installed in a pelmet, there shall be no adverse effects due to the presence or operation of curtains or blinds.

559.3.4 A track system for luminaires shall comply with the requirements of IEC 60570.

559.4 Protection of the surroundings against thermal effects

559.4.1 General

In the selection and erection of a luminaire the thermal effects of radiant and convected energy on the surroundings shall be taken into account, including:

(i) the maximum permissible power dissipated by the lamps

(ii) the fire-resistance of adjacent material

- at the point of installation, and
- in the thermally affected areas

(iii) the minimum distance to combustible materials, including material in the path of a spotlight beam

(iv) the relevant markings on the luminaire.

559.5 Wiring systems

559.5.1 Connection to the fixed wiring

At each fixed lighting point one of the following shall be used for the termination of the wiring system:

(i) A ceiling rose complying with IEC 61995

(ii) A luminaire supporting coupler (LSC) complying with IEC 61995

(iii) A batten lampholder or a pendant set complying with IEC 60598

(iv) A luminaire complying with IEC 60598

(v) A suitable socket-outlet complying with KS 495-2, or IEC 60309-2

(vi) A plug-in lighting distribution unit complying with IEC 60884-1

(vii) A connection unit complying with KS 495-4

(viii) Appropriate terminals enclosed in a box complying with the relevant part of IEC 60670 series

(ix) A device for connecting a luminaire (DCL) outlet complying with IEC 61995-1

(x) An installation coupler complying with IEC 61535.

NOTE: In suspended ceilings one plug-in lighting distribution unit may be used for a number of luminaires.

559.5.1.201 A ceiling rose or lampholder shall not be installed in any circuit operating at a voltage normally exceeding 250 volts.

559.5.1.202 A ceiling rose shall not be used for the attachment of more than one outgoing flexible cable unless it is specially designed for multiple pendants.

559.5.1.203 Luminaire supporting couplers and devices for the connection of luminaires are designed specifically for the electrical connection of luminaires and shall not be used for the connection of any other equipment.

559.5.1.204 Lighting circuits incorporating B15, B22, E14, E27 or E40 lampholders shall be protected by an overcurrent protective device of maximum rating 16 A.

559.5.1.205 Bayonet lampholders B15 and B22 shall comply with IEC 61184 and shall have the temperature rating T2 described in that standard.

559.5.1.206 In circuits of a TN or TT system, except for E14 and E27 lampholders complying with IEC 60238, the outer contact of every Edison screw or single centre bayonet cap type lampholder shall be connected to the neutral conductor. This Section also applies to track mounted systems.

559.5.1.207 A lighting installation shall be appropriately controlled.

NOTE: See Table 537.4 for guidance on the selection of suitable protective, isolation and switching devices. |

559.5.1.208 Consideration shall be given to the provision of the neutral conductor, at each switch position, to facilitate the installation of electronic switching devices.

559.5.2 Fixing of luminaires

Adequate means to fix luminaires shall be provided.

The fixing means may be mechanical accessories (e.g. hooks or screws), boxes or enclosures which are able to support luminaires or supporting devices for connecting a luminaire.

In places where the fixing means is intended to support a luminaire, the fixing means shall be capable of carrying a mass of not less than 5 kg. If the mass of the luminaire is greater than 5 kg, a fixing means capable of supporting the mass of the luminaire shall be installed. |

The installation of the fixing means shall be in accordance with the manufacturer's instructions.

The weight of luminaires and their eventual accessories, e.g. shades, shall be compatible with the mechanical capability of the ceiling or suspended ceiling or supporting structure where installed.

Any flexible cable between the fixing means and the luminaire shall be installed so that any expected stresses in the conductors, terminals and terminations will not impair the safety of the installation. (See also Table 4F3A of Appendix 2.)

559.5.3 Through wiring

559.5.3.1 The installation of through wiring in a luminaire is only permitted if the luminaire is designed for such wiring.

559.5.3.2 A cable for through wiring shall be selected in accordance with the temperature information on the luminaire or on the manufacturer's instruction sheet, if any, as follows:

(i) For a luminaire complying with IEC 60598 but with temperature marking, cables suitable for the marked temperature shall be used

(ii) Unless specified in the manufacturer's instructions, for a luminaire complying with IEC 60598 but with no temperature marking, heat-resistant cables are not required

(iii) In the absence of information, heat-resistant cables and/or insulated conductors of type H05S-U, H05S-K, H05SJ-K, H05SS-K (IEC 60277 series) or equivalent shall be used.

559.5.4 Devices for connection of luminaires to the supply

If the luminaire does not provide a connecting device for connection to the supply, the connecting device shall be:

(i) terminals according to KS IEC 60998, or

(ii) a device for connecting a luminaire (DCL) plug according to IEC 61995, or

(iii) an installation coupler according to IEC 61535, or

(iv) supporting coupler (LSC) plug according to IEC 61995 , or

(v) a male connector (plug) of a plug-in lighting distribution unit according to IEC 60884-1, or

(vi) another suitable and appropriate connecting device.

NOTE: For the installation of supply cables, see also Section 522.2.201.

559.5.5 Groups of luminaires

Groups of luminaires divided between the line conductors of a polyphase circuit with only one common neutral conductor shall be provided with at least one device disconnecting simultaneously all line conductors.

NOTE: See also Section 537.

559.5.6 Protection against heat and UV radiation effects within luminaires

External cables and cores of cables connected within a luminaire or passing through shall be so selected and erected that they will not suffer damage or deterioration due to heat and UV radiation generated by the luminaire or its lamps (e.g. shielding of the cable from heat and/or UV by means of heat/UV-resistant sleeving).

559.6 Independent lamp controlgear, e.g. ballasts

Only independent lamp controlgear marked as suitable for independent use, according to the relevant standard, shall be used external to a luminaire.

Only the following are permitted to be mounted on a flammable surface:

(i) A 'class P' thermally protected ballast/transformer.

(ii) A temperature declared thermally protected ballast/transformer.

NOTE: For an explanation of symbols used see Table 55.3.

559.7 Compensation capacitors

Compensation capacitors having a total capacitance exceeding 0.5 μF shall only be used in conjunction with discharge resistors. Capacitors and their marking shall be in accordance with IEC 61048. This

requirement does not apply to capacitors forming part of the equipment.

559.8 Protection against electric shock for display stands for luminaires

Protection against electric shock for circuits supplying display stands for luminaires shall be provided by either:

(i) a SELV or PELV supply, or

(ii) a residual current device having a rated residual operating current not exceeding 30 mA which provides both automatic disconnection of supply according to Section 411 and additional protection according to Section 415.1.

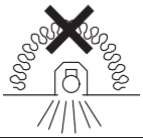
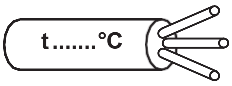
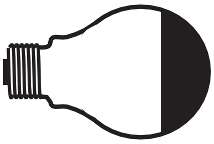
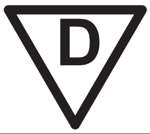
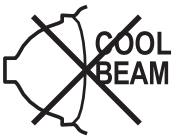
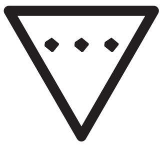
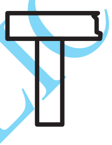
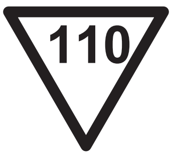
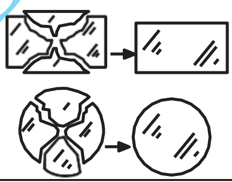
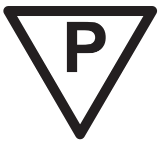
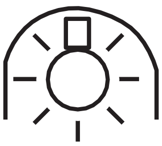
559.9 Stroboscopic effect

In the case of lighting for premises where machines with moving parts are in operation, consideration shall be given to stroboscopic effects which can give a misleading impression of moving parts being stationary. Such effects may be avoided by selecting luminaires with suitable lamp controlgear, such as high frequency controlgear, or by distributing lighting loads across all the phases of a polyphase supply.

559.10 Ground-recessed luminaires

For ground-recessed luminaires, the selection and erection shall take account of the guidance given in Table A.1 of IEC 60598-2-13.

TABLE 55.3 – Explanation of symbols used in luminaires, in controlgear for luminaires and in the installation of luminaires

BS EN 60598-1:2008			
		Recessed luminaire not suitable for direct mounting on normally flammable surfaces	
		Surface mounted luminaire not suitable for direct mounting on normally flammable surfaces	
		Luminaire not suitable for covering with thermally insulating material	
	Use of heat-resistant supply cables, interconnecting cables, or external wiring (number of conductors of cable is optional) (IEC 60598 series)		Luminaire for use with high pressure sodium lamps that require an external ignitor (IEC 60598 series)
	Luminaire designed for use with bowl mirror lamps (IEC 60598 series)		Luminaire for use with high pressure sodium lamps having an internal starting device (IEC 60598 series)
ta ....°C	Rated maximum ambient temperature (IEC 60598 series)		Luminaire with limited surface temperature (IEC 60598-2-24)
	Warning against the use of cool-beam lamps (IEC 60598 series)		Short-circuit proof (inherently or non-inherently) safety isolating transformer (IEC 61558-2-6)
	Minimum distance from lighted objects (metres) (IEC 60598 series)		Temperature declared thermally protected lamp controlgear (… replaced by temperature) (IEC 61347-1)
	Rough service luminaire (IEC 60598 series)		Electronic convertor for an extra-low voltage lighting installation
	Replace any cracked protective screen (IEC 60598 series)		Thermally protected lamp controlgear (class P) (IEC 61347-1)
	Luminaire designed for use with self-shielded tungsten halogen lamps or self-shielded metal halide lamps only (IEC 60598 series)		Independent ballast IEC 60417 sheet No. 5138

CHAPTER 56 SAFETY SERVICES
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CHAPTER 56: SAFETY SERVICES

560.1 SCOPE

This chapter covers general requirements for safety services, selection and erection of electrical supply systems for safety services and electrical safety sources. Standby electrical supply systems are outside the scope.

This chapter does not apply to installations in hazardous areas (BE3), for which requirements are given in IEC 60079-14.

NOTE: Examples of safety services include (this list is not exhaustive):

- Emergency lighting
- Fire pumps
- Fire rescue service lifts
- Fire detection and alarm systems
- CO detection and alarm systems
- Fire evacuation systems
- Smoke ventilation systems
- Fire services communication systems
- Essential medical systems
- Industrial safety systems.

560.2 Not used

560.3 Not used

560.4 CLASSIFICATION

560.4.1 An electrical safety service supply is either:

(i) a non-automatic supply, the starting of which is initiated by an operator, or

(ii) an automatic supply, the starting of which is independent of an operator.

An automatic supply is classified as follows, according to the maximum changeover time:

(a) No-break: an automatic supply which produces a continuous supply within specified conditions during the period of transition, for example as regards variations in voltage and frequency

(b) Very short break: an automatic supply available within 0.15 s

(c) Short break: an automatic supply available within 0.5 s

(d) Normal break: an automatic supply available within 5 s

(e) Medium break: an automatic supply available within 15 s

(f) Long break: an automatic supply available in more than 15 s.

560.4.2 The essential equipment for safety services shall be compatible with the changeover time in order to maintain the specified operation.

560.5 GENERAL

560.5.1 Safety services may be required to operate at all relevant times including during mains and local supply failure and through fire conditions. To meet this requirement specific sources, equipment, circuits and wiring are necessary. Some applications also have particular requirements, as in Sections 560.5.2 and 560.5.3.

560.5.2 For safety services required to operate in fire conditions, the following two conditions shall be fulfilled:

(i) An electrical source for safety supply shall be so selected as to maintain a supply of adequate duration, and

(ii) all equipment of safety services shall be so provided, either by construction or by erection, with fire-resisting protection of adequate duration.

NOTE: The safety source is generally additional to the normal source. The normal source is, for example, the public supply network.

560.5.3 Where automatic disconnection of supply is used as a protective measure against electric shock, non-disconnection on the first fault is preferred. In IT systems, continuous insulation monitoring devices shall be provided which give an audible and visual indication in the event of a first fault.

560.5.4 A failure in the control or bus system of a normal installation shall not adversely affect the function of safety services.

560.6 ELECTRICAL SOURCES FOR SAFETY SERVICES

560.6.1 The following electrical sources for safety services are recognized:

(i) Storage batteries

(ii) Primary cells

(iii) Generator sets independent of the normal supply

(iv) A separate feeder of the supply network that is effectively independent of the normal feeder.

560.6.2 Safety sources for safety services shall be installed as fixed equipment and in such a manner that they cannot be adversely affected by failure of the normal source.

560.6.3 Safety sources shall be installed in a suitable location and be accessible only to skilled or instructed persons (BA5 or BA4).

560.6.4 The location of the safety source shall be properly and adequately ventilated so that exhaust gases, smoke or fumes from the safety source cannot penetrate areas occupied by one or more persons.

560.6.5 Separated independent feeders from a distributor's network shall not serve as electrical sources for safety services unless assurance can be obtained that the two supplies are unlikely to fail concurrently.

560.6.6 The safety source shall have sufficient capability to supply its related safety service.

560.6.7 A safety source may, in addition, be used for purposes other than safety services, provided that the availability for safety services is not thereby impaired. A fault occurring in a circuit for purposes other than safety services shall not cause the interruption of any circuit for safety services.

560.6.8 Special requirements for safety services having sources not capable of operation in parallel

560.6.8.1 Adequate precautions shall be taken to avoid the paralleling of sources.

NOTE: This may be achieved by mechanical interlocking.

560.6.8.2 Short-circuit protection and fault protection shall be provided for each source.

560.6.9 Special requirements for safety services having sources capable of operation in parallel

Short-circuit protection and fault protection shall be effective irrespective of whether the installation is supplied separately by either of the two sources or by both in parallel.

NOTE 1: The parallel operation of a private source with the public supply network is subject to authorization by the distribution network operator (DNO). This may require special devices, for example to prevent reverse power.

NOTE 2: Precautions may be necessary to limit current circulation in the connection between the neutral points of the sources, in particular the effect of triplen harmonics.

560.6.10 Central power supply sources

Batteries shall be of vented or valve-regulated maintenance-free type and shall be of heavy duty industrial design, for example cells complying with IEC 60623 or the appropriate part of the IEC 60896 series.

NOTE: The minimum design life of the batteries at 20 °C should be 10 years.

560.6.11 Low power supply sources

The power output of a low power supply system is limited to 500 W for 3-hour duration and 1500 W for a 1-hour duration. Batteries shall be of heavy duty industrial design, for example cells complying with IEC 60623 or the appropriate part of the IEC 60896 series are suitable.

NOTE: The minimum design life of the batteries at 20 °C should be 5 years.

560.6.12 Uninterruptible power supply sources (UPS)

Where an uninterruptible power supply is used, it shall:

(i) be able to operate distribution circuit protective devices, and

(ii) be able to start the safety devices when it is operating in the emergency condition from the inverter supplied by the battery, and

(iii) comply with the requirements of Section 560.6.10, and

(iv) comply with IEC 62040-1 and IEC 62040-3, as applicable.

560.6.13 Generator sets for safety services

Where a generating set is used as a safety source, it shall comply with ISO 8528-1:2018

560.6.14 Monitoring of safety sources

The condition of the source for safety services (ready for operation, under fault conditions, feeding from the source for safety services) shall be monitored.

560.7 CIRCUITS OF SAFETY SERVICES

560.7.1 Except where the recommendations of other safety standards apply, circuits of safety services shall be independent of other circuits.

NOTE: This means that any electrical fault or any intervention or modification in one system must not affect the correct functioning of the other. This may necessitate separation by fire-resistant materials or different routes or enclosures.

560.7.2 Circuits of safety services shall not pass through locations exposed to fire risk (BE2) unless they are fire-resistant. The circuits shall not, in any case, pass through zones exposed to explosion risk (BE3).

NOTE: Where practicable, the passage of circuits through locations presenting a fire risk should be avoided.

560.7.3 In accordance with Section 433.3.3, protection against overload may be omitted where the loss of supply may cause a greater hazard. Where protection against overload is omitted, the occurrence of an overload shall be monitored.

560.7.4 Overcurrent protective devices shall be selected and erected so as to avoid an overcurrent in one circuit impairing the correct operation of circuits of safety services.

560.7.5 Switchgear and controlgear shall be clearly identified and grouped in locations accessible only to skilled or instructed persons (BA5 or BA4).

560.7.6 In equipment supplied by two different circuits, a fault occurring in one circuit shall not impair the protection against electric shock or the correct operation of the other circuit. Such equipment shall be connected to the protective conductors of both circuits, if necessary.

560.7.7 Safety circuit cables, other than metallic screened, fire-resistant cables, shall be adequately and reliably separated by distance or by barriers from other circuit cables, including other safety circuit cables.

NOTE: For battery cables, special requirements may apply.

560.7.8 Circuits for safety services, with the exception of wiring for fire and rescue service lift supply cables and wiring for lifts with special requirements, shall not be installed in lift wells or other flue-like openings.

NOTE: While fire-resistant cables will survive most fires, if they are located in an unstopped vertical well the upward air draught in a fire can generate excessive temperatures above the capabilities of the cable so they should be avoided as a route for safety systems.

560.7.9 In addition to a general schematic diagram, full details of all electrical safety sources shall be given. The information shall be maintained adjacent to the distribution board. A single-line diagram is sufficient.

560.7.10 A drawing or drawings of the electrical safety installations shall be available showing the exact location of:

(i) all electrical equipment and distribution boards, with equipment designations

(ii) safety equipment with final circuit designation and particulars and purpose of the equipment

(iii) special switching and monitoring equipment for the safety power supply (e.g. area switches, visual or acoustic warning equipment).

560.7.11 A list of all the current-using equipment permanently connected to the safety power supply, indicating the nominal electrical power, rated nominal voltage, current and starting current, together with its duration, shall be available.

NOTE: This information may be included in the circuit diagrams.

560.7.12 Operating instructions for safety equipment and electrical safety services shall be available. They shall take into account all the particulars of the installation.

560.8 WIRING SYSTEMS

560.8.1 One or more of the following wiring systems shall be utilised for safety services required to operate in fire conditions:

(i) Mineral insulated cable systems complying with IEC 60702-1 and IEC 60702-2 and KS IEC 60332-1-2

(ii) Fire-resistant cables complying with IEC 60331-1, IEC 60331-2 or IEC 60331-3 and with KS IEC 60332-1-2

(iii) Fire-resistant cables complying with test requirements of IEC 50200, IEC 8434 or IEC 8491, appropriate for the cable size and with KS IEC 60332-1-2

(iv) A wiring system maintaining the necessary fire and mechanical protection.

The wiring system selected shall meet the requirements of the relevant code of practice appropriate to the application and shall be mounted and installed in such a way that the circuit integrity will not be impaired during a fire.

NOTE 1: IEC 5266, IEC 5839 and IEC 8519 specify cables to IEC 60702-1, IEC 7629-1 and IEC 7846 as being suitable when appropriately selected for the application.

NOTE 2: Examples of a system maintaining the necessary fire and mechanical protection could be:

(i) constructional enclosures to maintain fire and mechanical protection, or

(ii) wiring systems in separate fire compartments.

560.8.2 Wiring for control and bus systems of safety services shall be in accordance with the same requirements as the wiring which is to be used for the safety services. This does not apply to circuits that do not adversely affect the operation of the safety equipment.

560.8.3 *Reserved for future use*

560.8.4 Circuits for safety services which can be supplied by direct current shall be provided with two-pole overcurrent protection mechanisms.

560.8.5 Switchgear and controlgear used for both AC and DC supply sources shall be suitable for both AC and DC operation.

560.9 EMERGENCY LIGHTING SYSTEMS

Emergency lighting systems shall comply with the relevant parts of IEC 5266 series and IEC 1838.

560.10 FIRE DETECTION AND FIRE ALARM SYSTEMS

Fire detection and fire alarm systems shall comply with the relevant parts of IEC 5839 series.

560.11 LIFE SAFETY AND FIREFIGHTING APPLICATIONS

The selection and installation of power and control cable systems which are required to maintain their circuit
integrity for life safety and firefighting applications shall comply with the relevant parts of IEC 8519.

APPENDIX 1 (Informative)
STATUTORY SECTION S AND ASSOCIATED MEMORANDA

1. In Kenya the following classes of electrical installations are required to comply with the Statutory Sections indicated below. The Sections listed represent the principal legal requirements. Information concerning these Sections may be obtained from the appropriate authority also indicated below.

Provisions relating to electrical installations are also to be found in other legislation relating to particular activities.

SECTION TO BE UPDATED

APPENDIX 2 (Informative)
CURRENT-CARRYING CAPACITY AND VOLTAGE DROP FOR CABLES

CONTENTS

Tables:

4A1	Schedule of Installation Methods in relation to conductors and cables
4A2	Schedule of Installation Methods of cables (including Reference Methods) for determining current-carrying capacity
4A3	Schedule of cable specifications and current rating tables
4B1	Rating factors (Ca) for ambient air temperatures other than 30 °C
4B2	Rating factors (Ca) for ambient ground temperatures other than 20 °C
4B3	Rating factors (Cs) for soil resistivity, for cables buried direct or in underground conduit
4B4	Rating factors (Cd) for depths of laying other than 0.7 m for direct buried cables and cables in buried ducts
4B5	Rating factors for cables having more than 4 loaded cores
4C1	Rating factors (Cg) for one circuit or one multicore cable or for a group of circuits or multicore cables
4C2	Rating factors (Cg) for more than one circuit, cables buried directly in the ground
4C3	Rating factors (Cg) for more than one circuit, cables in ducts buried in the ground
4C4	Rating factors (Cg) for groups of more than one multicore cable on trays or cable ladders
4C5	Rating factors (Cg) for groups of one or more circuits of single-core cables on trays or cable ladders
4C6	Rating factors (Cg) for cables enclosed in infloor concrete troughs

4D1	Single-core non-armoured, with or without sheath	70 °C thermoplastic insulated cables	Copper conductors
4D2	Multicore non-armoured		
4D3	Single-core armoured (non-magnetic armour)		
4D4	Multicore armoured		
4D5	Flat cable with protective conductor		
4E1	Single-core non-armoured, with or without sheath	90 °C thermosetting	
4E2	Multicore non-armoured		
4E3	Single-core armoured (non-magnetic armour)		
4E4	Multicore armoured		
4F1	60 °C thermosetting insulated flexible cables	Flexible cables	
4F2	90 °C and 180 °C thermosetting insulated flexible cables		
4F3	Flexible cables		
4G1	Bare and exposed to touch, or having an overall thermoplastic covering	Mineral insulated cables	
4G2	Bare and neither exposed to touch nor in contact with combustible materials		
4H1	Single-core non-armoured, with or without sheath	70 °C thermoplastic insulated cables	Aluminium conductors
4H2	Multicore non-armoured		
4H3	Single-core armoured (non-magnetic armour)		
4H4	Multicore armoured		
4J1	Single-core non-armoured, with or without sheath	90 °C thermoplastic insulated cables	
4J2	Multicore non-armoured		
4J3	Single-core armoured (non-magnetic armour)		
4J4	Multicore armoured		

APPENDIX 2 (Informative)
CURRENT-CARRYING CAPACITY AND VOLTAGE DROP FOR CABLES

1 INTRODUCTION

The recommendations of this appendix are intended to provide for a satisfactory life of conductors and insulation subjected to the thermal effects of carrying current for prolonged periods of time in normal service. Other considerations affect the choice of cross-sectional area of conductors, such as the requirements for protection against electric shock (Chapter 41), protection against thermal effects (Chapter 42), overcurrent protection (Chapter 43), voltage drop (Section 525), and limiting temperatures for terminals of equipment to which the conductors are connected (Section 526).

This appendix applies to non-sheathed and sheathed cables having a nominal voltage rating not exceeding 1 kV AC or 1.5 kV DC.

The values in Tables 4D1A to 4J4A have been derived in accordance with the methods given in KS IEC 60287 using such dimensions as specified in the international standard IEC 60502-1 and conductor resistances given in IEC 60228. Known practical variations in cable construction (e.g. form of conductor) and manufacturing tolerances result in a spread of possible dimensions and hence current-carrying capacities for each conductor size. Tabulated current-carrying capacities have been selected in such a way as to take account of this spread of values with safety and to lie on a smooth curve when plotted against conductor cross-sectional area.

For multicore cables having conductors with a cross-sectional area of 25 mm^2 or larger, either circular or shaped conductors are permissible. Tabulated values have been derived from dimensions appropriate to shaped conductors.

All the current-carrying capacities given are based on the ambient temperature and conductor/sheath operating temperature stated in Tables 4D1A to 4F2A and 4G1A to 4J4A.

2 CIRCUIT PARAMETERS

2.1 Ambient Temperature

The current-carrying capacities in this appendix are based upon the following reference ambient temperatures:

(i) For non-sheathed and sheathed cables in air, irrespective of the Installation Method: 30 °C

(ii) For buried cables, either directly in the soil or in ducts in the ground: 20 °C.

Where the ambient temperature in the intended location of the non-sheathed or sheathed cables differs from the reference ambient temperature, the appropriate rating factors given in Tables 4B1 and 4B2 are to be applied to the values of current-carrying capacity set out in Tables 4D1A to 4J4A. For buried cables, further correction is not needed if the soil temperature exceeds the selected ambient temperature by an amount up to 5 °C for only a few weeks a year.

The rating factors in Tables 4B1 and 4B2 do not take account of the increase, if any, due to solar or other infrared radiation. Where non-sheathed or sheathed cables are subject to such radiation, the current-carrying capacity may be derived by the methods specified in KS IEC 60287.

2.2 Soil Thermal Resistivity

The current-carrying capacities tabulated in this appendix for cables in the ground are based upon a soil thermal resistivity of 2.5 K.m/W and are intended to be applied to cables laid in and around buildings. For other installations, where investigations establish more accurate values of soil thermal resistivity appropriate for the load to be carried, the values of current-carrying capacity may be derived by the methods of calculation given in KS IEC 60287 or obtained from the cable manufacturer.

In locations where the effective soil thermal resistivity is higher than 2.5 K.m/W, an appropriate reduction in current-carrying capacity should be made or the soil immediately around the cables should be replaced by a more suitable material. Such cases can usually be recognized by very dry ground conditions. Rating factors for soil thermal resistivities other than 2.5 K.m/W are given in Table 4B3.

2.3 Groups of cables containing more than one circuit

2.3.1 Methods of Installation A to D in Table 4A2

Current-carrying capacities given in Tables 4D1A to 4J4A apply to single circuits consisting of:

(i) two non-sheathed cables or two single-core cables, or one two-core cable

(ii) three non-sheathed cables or three single-core cables, or one three-core cable.

Where more non-sheathed cables, other than bare mineral insulated cables not exposed to touch, are installed in the same group, the group rating factors specified in Tables 4C1 to 4C3 need to be applied.

NOTE: The group rating factors have been calculated on the basis of prolonged steady-state operation at a 100 % load factor for all live conductors. Where the loading is less than 100 % as a result of the conditions of operation of the installation, the group rating factors may be higher.

2.3.2 Methods of Installation E and F in Table 4A2

The current-carrying capacities of Tables 4D1A to 4J4A apply to these Reference Methods.

For installations on perforated trays, cleats and similar, current-carrying capacities for both single circuits and groups are obtained by multiplying the capacities given for the relevant arrangements of non-sheathed or sheathed cables in free air, as indicated in Tables 4D1A to 4J4A, by the applicable group rating factors given in Tables 4C4 and 4C5. No group rating factors are required for bare mineral insulated cables not exposed to touch, Tables 4G1A and 4G2A refer.

NOTE 1: Group rating factors have been calculated as averages for the range of conductor sizes, cable types and installation condition considered. Attention is drawn to the notes under each table. In some instances, a more precise calculation may be required.

NOTE 2: Group rating factors have been calculated on the basis that the group consists of similar, equally loaded non-sheathed or sheathed cables. Where a group contains various sizes of non-sheathed or sheathed cables, caution should be exercised over the current loading of the smaller cables (see 2.3.3 below).

NOTE 3: A group of similar cables is taken to be a group where the current-carrying capacity of all the cables is based on the same maximum permissible conductor temperature and where the range of conductor sizes in the group spans not more than three adjacent standard sizes.

2.3.3 Groups of cables containing different sizes

Tabulated group rating factors are applicable to groups consisting of similar equally loaded cables. The calculation of rating factors for groups containing different sizes of equally loaded sheathed or non-sheathed cables is dependent on the total number in the group and the mix of sizes. Such factors cannot be tabulated but must be calculated for each group. The method of calculation of such factors is outside the scope of this appendix. Two specific examples of where such calculations may be advisable are given below.

2.3.3.1 Groups in conduit systems, cable trunking systems or cable ducting systems

For a group containing different sizes of non-sheathed or sheathed cables in conduit systems, cable trunking systems or cable ducting systems, a simple formula for calculation of the group rating factor is:

$$C_g = \frac{1}{\sqrt{n}}$$

where

C_g is the group rating factor

n is the number of circuits in the group.

The group rating factor obtained by this equation will reduce the danger of overloading the smaller sizes but may lead to under-utilization of the larger sizes. Such under-utilization can be avoided if large and small sizes of non-sheathed or sheathed cable are not mixed in the same group.

The use of a method of calculation specifically intended for groups containing different sizes of non-sheathed or sheathed cable in conduit will produce a more precise group rating factor.

2.3.3.2 Groups of cables on trays

Where a group contains different sizes of non-sheathed or sheathed cable, caution must be exercised over the current loading of the smaller sizes. It is preferable to use a method of calculation specifically intended for groups containing different sizes of non-sheathed or sheathed cables.

The group rating factor obtained in accordance with the formula in 2.3.3.1 will provide a value which may be safely applied, but which may result in under-utilisation.

2.4 Conductors

The current-carrying capacities and voltage drops tabulated in this appendix are based on cables having solid conductors (Class 1), or stranded conductors (Class 2), except for Tables 4F1A to 4F3B. To obtain the correct current-carrying capacity or voltage drop for cable types similar to those covered by Tables 4D1, 4D2,4E1 and 4E2 but with flexible conductors (Class 5), the tabulated values are multiplied by the following factors:

Cable size	Current-carrying capacity	Voltage drop
≤ 16 mm^2	0.95	1.10
≥ 25 mm^2	0.97	1.06

2.5 Other calculations

In addition to calculations related to current-carrying capacity, overload protection and voltage drop described in this appendix, other calculations are also required for the design of an electrical installation. These include calculations of fault current under various conditions. The equations given in IEC 60364-5-52 are recommended for calculating circuit impedances, fault currents and other parameters.

3 RELATIONSHIP OF CURRENT-CARRYING CAPACITY TO OTHER CIRCUIT PARAMETERS

The relevant symbols used in the Section s are as follows:

I_z the current-carrying capacity of a cable for continuous service, under the particular installation conditions concerned.

I_t the value of current tabulated in this appendix for the type of cable and installation method concerned, for a single circuit in the ambient temperature stated in the current-carrying capacity tables.

I_b the design current of the circuit, i.e. the current intended to be carried by the circuit in normal service.

I_n the rated current or current setting of the protective device.

I_2 the operating current (i.e. the fusing current or tripping current for the conventional operating time) of the device protecting the circuit against overload.

C a rating factor to be applied where the installation conditions differ from those for which values of current-carrying capacity are tabulated in this appendix. The various rating factors are identified as follows:

C_a for ambient temperature
C_c for circuits buried in the ground
C_d for depth of burial
C_f for semi-enclosed fuse to IEC 60269
C_g for grouping
C_i for thermal insulation
C_s for thermal resistivity of soil.

The rated current or current setting of the protective device (I_n) must not be less than the design current (I_b) of the circuit, and the rated current or current setting of the protective device (I_n) must not exceed the lowest of the current-carrying capacities (I_z) of any of the conductors of the circuit.

Where the overcurrent device is intended to afford protection against overload, I_2 must not exceed 1.45 I_z and I_n must not exceed I_z (see paragraph 4 below).

Where the overcurrent device is intended to afford fault current protection only, I_n can be greater than I_z and I_2 can be greater than 1.45 I_z. The protective device must be selected for compliance with Section 434.5.2.

4 OVERLOAD PROTECTION

Where overload protection is required, the type of protection does not affect the current-carrying capacity of a cable for continuous service (I_z) but it may affect the choice of conductor size. The operating conditions of a cable are influenced not only by the limiting conductor temperature for continuous service, but also by the conductor temperature which might be attained during the conventional operating time of the overload protective device, in the event of an overload.

This means that the operating current of the protective device must not exceed 1.45 I_z. Where the protective device is a fuse to IEC 60269 series, a circuit-breaker to IEC 60898 or IEC 60947-2 or a residual current circuit-breaker with integral overcurrent protection to IEC 61009-1 (RCBO), this requirement is satisfied by selecting a value of I_z not less than I_n.

In practice, because of the standard steps in ratings of fuses and circuit-breakers, it is often necessary to select a value of I_n exceeding I_b. In that case, because it is also necessary for I_z in turn to be not less than the selected value of I_n, the choice of conductor cross-sectional area may be dictated by the overload conditions and the current-carrying capacity (I_z) of the conductors will not always be fully utilised.

The size needed for a conductor protected against overload by a IEC 60269 semi-enclosed fuse can be obtained by the use of a rating factor, 1.45/2 = 0.725, which results in the same degree of protection as that afforded by other overload protective devices. This factor is to be applied to the nominal rating of the fuse as a divisor, thus indicating the minimum value of I_t required of the conductor to be protected. In this case also, the choice of conductor size is dictated by the overload conditions and the current-carrying capacity (I_z) of the conductors cannot be fully utilised.

The tabulated current-carrying capacities for cables direct in ground or in ducts in the ground, given in this appendix, are based an ambient temperature of 20 °C. The factor of 1.45 that is applied in Section 433.1.1 when considering overload protection assumes that the tabulated current-carrying capacities are based on an ambient temperature of 30 °C. To achieve the same degree of overload protection where a cable is “in a duct in the ground” or “buried direct” as compared with other installation methods a rating factor of 0.9 is applied as a multiplier to the tabulated current-carrying capacity.

5 DETERMINATION OF THE SIZE OF CABLE TO BE USED

Having established the design current (I_b) of the circuit under consideration, the appropriate procedure described in paragraphs 5.1 and 5.2 below will enable the designer to determine the size of the cable it will be necessary to use.

As a preliminary step it is useful to identify the length of the cable run and the permissible voltage drop for the equipment being supplied, as this may be an overriding consideration (see Section 525 and paragraph 6 of this appendix). The permissible voltage drop in mV, divided by I_b and by the length of run, will give the value of voltage drop in mV/A/m which can be tolerated. A voltage drop not exceeding that value is identified in the appropriate table and the corresponding cross-sectional area of conductor needed on this account can be read off directly before any other calculations are made.

The conductor size necessary from consideration of the conditions of normal load and overload is then determined. All rating factors affecting I_z (i.e. for factors for ambient temperature, grouping and thermal insulation) can, if desired, be applied to the values of I_t as multipliers. This involves a process of trial and error until a cross-sectional area is reached so that I_z is not less than I_b and not less than I_n of any protective device it is intended to select. In any event, if a rating factor for protection by a semi-enclosed fuse is necessary, this has to be applied to I_n as a divisor. It is therefore more convenient to apply all the rating factors to I_n as divisors.

This method is used in items 5.1 and 5.2 and produces a value of current and that value (or the next larger value) can be readily located in the appropriate table of current-carrying capacity and the corresponding cross-sectional area of conductor can be identified directly. It should be noted that the value of I_t appearing against the chosen cross-sectional area is not I_z. It is not necessary to know I_z where the size of conductor is chosen by this method.

5.1 Where overload protection is afforded by a device listed in Section 433.1.201 or a semi-enclosed fuse to IEC 60269

5.1.1 For single circuits

(i) Divide the rated current of the protective device (I_n) by any applicable rating factors for ambient temperature (C_a) , soil thermal resistivity (C_s) and depth of burial (C_d) given in Tables 4B1 to 4B4.

For cables installed above ground C_s and C_d = 1.

(ii) Then further divide by any applicable rating factor for thermal insulation (C_i).

(iii) Then further divide by the applicable rating factor for the type of protective device or installation condition (C_f, C_c):

$$I_t \geq \frac{I_n}{C_a\, C_s\, C_d\, C_i\, C_f\, C_c} \qquad \text{Equation 1}$$

(a) Where the protective device is a semi-enclosed fuse to IEC 60269, C_f = 0.725. Otherwise C_f = 1

(b) Where the cable installation method is 'in a duct in the ground' or 'buried direct', C_c = 0.9. For cables installed above ground C_c = 1.

The size of cable to be used is to be such that its tabulated current-carrying capacity (I_t) is not less than the value of rated current of the protective device adjusted as above.

5.1.2 For groups

(i) In addition to the factors given in 5.1.1, divide the rated current of the protective device (I_n) by the applicable rating factor for grouping (C_g) given in Tables 4C1 to 4C6:

$$I_t \geq \frac{I_n}{C_g\, C_a\, C_s\, C_d\, C_i\, C_f\, C_c} \qquad \text{Equation 2}$$

Alternatively, I_t may be obtained from the following formulae, provided that the circuits of the group are not liable to simultaneous overload:

$$I_t \geq \frac{I_b}{C_g\, C_a\, C_s\, C_d\, C_i\, C_f\, C_c} \qquad \text{Equation 3}$$

$$I_t \geq \frac{1}{C_a\, C_s\, C_d\, C_i}\sqrt{\left(\frac{I_n}{C_f\, C_c}\right)^2 + 0.48\, I_b^2\left(\frac{1-C_g^2}{C_g^2}\right)} \qquad \text{Equation 4}$$

The size of cable to be used is to be such that its tabulated single-circuit current-carrying capacity (I_t) is not less than the value of I_t calculated in accordance with equation 2 above or, where equations 3 and 4 are used, not less than the larger of the resulting two values of I_t.

5.2 Where overload protection is not required

Where Section 433.3.1 applies, and the cable under consideration is not required to be protected against overload, the design current of the circuit (I_b) is to be divided by any applicable rating factors, and the size of the cable to be used is to be such that its tabulated current-carrying capacity (I_t) for the installation method concerned is not less than the value of I_b adjusted as above, i.e.:

$$I_t \geq \frac{I_b}{C_g\, C_a\, C_s\, C_d\, C_i\, C_c} \qquad \text{Equation 5}$$

NOTE: Where overload protection is not required C_c = 1.

5.3 Other frequencies

Current ratings stated in the tables are for DC and 50/60 Hz AC. The current-carrying capacity of cables carrying, for example, balanced 400 Hz AC compared with the current-carrying capacity at 50 Hz, may be no more than 50 %. For small cables (e.g. as may be used to supply individual loads), the difference in the 50 Hz and the 400 Hz current-carrying capacities may be negligible. Current rating and voltage drop vary with frequency. Suitable ratings should be obtained from the manufacturer.

5.4 Effective current-carrying capacity

The current-carrying capacity of a cable corresponds to the maximum current that can be carried in specified conditions without the conductors exceeding the permissible limit of steady-state temperature for the type of insulation concerned.

The values of current tabulated represent the effective current-carrying capacity only where no rating factor is applicable. Otherwise, the current-carrying capacity corresponds to the tabulated value multiplied by the appropriate factor or factors for ambient temperature, grouping and thermal insulation as well as depth of burial and soil thermal resistivity, for buried cables, as applicable. Where harmonic currents are present further factors may need to be applied. See section 5.5 of this appendix.

Irrespective of the type of overcurrent protective device associated with the conductors concerned, the ambient temperature rating factors to be used when calculating current-carrying capacity (as opposed to those used when selecting cable sizes) are those given in Tables 4B1 and 4B2.

5.5 Rating factors for triple harmonic currents in four-core and five-core cables with four cores carrying current

5.5.1 Rating factors

Section 523.6.3 states that, where the neutral conductor carries current without a corresponding reduction in load of the line conductors, the neutral conductor shall be taken into account in ascertaining the current- carrying capacity of the circuit.

This section is intended to cover the situation where there is current flowing in the neutral of a balanced three-phase system. Such neutral currents are due to the line currents having a harmonic content which does not cancel in the neutral. The most significant harmonic which does not cancel in the neutral is usually the third harmonic. The magnitude of the neutral current due to the third harmonic may exceed the magnitude of the power frequency line current. In such a case the neutral current will have a significant effect on the current-carrying capacity of the cables of the circuit.

The rating factors given in this appendix apply to balanced three-phase circuits; it is recognized that the situation is more onerous if only two of the three phases are loaded. In this situation, the neutral conductor will carry the harmonic currents in addition to the unbalanced current. Such a situation can lead to overloading of the neutral conductor.

Equipment likely to cause significant harmonic currents includes, for example, variable-speed motor drives, fluorescent lighting banks and DC power supplies such as those found in computers. Further information on harmonic disturbances can be found in KS IEC 61000.

The rating factors given in the following table only apply to cables where the neutral conductor is within a four-core or five-core cable and is of the same material and cross-sectional area as the line conductors. These rating factors have been calculated on the basis of third harmonic currents measured with respect to the fundamental frequency of the line current. Where the total harmonic distortion is more than 15 %, due to the third harmonic or multiples thereof, e.g. 9th, 15th, etc. then lower rating factors are applicable. Where there is an imbalance between phases of more than 50 % then lower rating factors may be applicable.

The tabulated rating factors, when applied to the current-carrying capacity of a cable with three loaded conductors, will give the current-carrying capacity of a cable with four loaded conductors where the current in the fourth conductor is due to harmonics. The rating factors also take the heating effect of the harmonic current in the line conductors into account.

Where the neutral current is expected to be higher than the line current then the cable size should be selected on the basis of the neutral current.

Where the cable size selection is based on a neutral current which is not significantly higher than the line current it is necessary to reduce the tabulated current-carrying capacity for three loaded conductors.

If the neutral current is more than 135 % of the line current and the cable size is selected on the basis of the neutral current then the three line conductors will not be fully loaded. The reduction in heat generated by the line conductors offsets the heat generated by the neutral conductor to the extent that it is not necessary to apply any rating factor to the current-carrying capacity for three loaded conductors, to take account of the effect of four loaded conductors.

TABLE 4Aa – Rating factors for triple harmonic currents in four-core and five-core cables

Third harmonic content of line current* %	Rating factor	
	Size selection is based on line current	Size selection is based on neutral current
0 – 15	1.0	–
>15 – 33	0.86	–
>33 – 45	–	0.86
> 45	–	1.0

* **NOTE:** The third harmonic content expressed as total harmonic distortion.

5.5.2 Example of the application of rating factor for third harmonic currents

Consider a three-phase circuit with a design load (fundamental current) of 58 A is to be installed using a four-core 90 °C thermosetting insulated cable. The cable will be installed in a group with 3 other circuits on a perforated cable tray (method E or F) in an expected maximum ambient temperature of 35 °C. The cable will be protected at its origin using a circuit-breaker to IEC 60898-1.

Case 1: Load does not produce third harmonic currents

The design current, I_b, of the three-phase load is 58 A.

To satisfy Section 433.1.1, $I_n \geq I_b$, so the rated current of the circuit-breaker, I_n, is selected to be 63 A. The required tabulated current-carrying capacity, I_t, under the above operational conditions is to satisfy:

$I_t \geq \frac{I_n}{C_a C_g}$ (where circuits of the group are assumed to be liable to simultaneous overload)

From Table 4B1, $C_a = 0.96$ and from Table 4C1, $C_g = 0.77$

$$I_t = \frac{63}{0.96 \times 0.77} = 85.2 \text{ A}$$

From Table 4E4A, a 16 mm² cable with copper conductors and steel wire armour has a tabulated current-carrying capacity of 99 A and hence it is suitable if third harmonic currents are not present in the circuit.

Case 2: Load produces an additional third harmonic content – THD-i = 20 %

For the second case it is assumed that the above load is expected to produce third harmonic distortion of 20 % in addition to the fundamental line current.

The fundamental line current of the above load is 58 A. Since the third harmonic content is between 15-33 %, the cable sizing is based upon the line current. Because the load has 20 % third harmonic the design current used for the selection of the protective device is given by:

$$I_{bh} = 58 \times \sqrt{1^2 + 0.2^2} = 59.1 \text{ A}$$

where: I_{bh} = design current including the effect of third harmonic currents

To satisfy Section 433.1.1, $I_n \geq I_b$, so the rated current of the circuit-breaker, I_n, is selected to be 63 A. In addition, to comply with the Section 431.2.3, overcurrent detection must be provided for the neutral conductor. Therefore, a 4-pole protective device with overcurrent protection of the neutral should be provided. The required tabulated current-carrying capacity, I_t, under the above operational conditions is to satisfy:

$I_t \geq \frac{I_n}{C_a C_g \times 0.86}$ (where circuits of the group are assumed to be liable to simultaneous overload)

The factor of 0.86 is taken from the above table.

Applying the above grouping and temperature rating factors, the required tabulated current-carrying capacity is found to be 99.1 A.

From Table 4E4A, a 16 mm² cable has a tabulated current-carrying capacity of 99 A, thus a rule-based system may select a 25 mm² cable whereas a designer may exercise judgement and select a 16 mm² cable.

Case 3: Load produces third harmonic content – THD-i = 42 %

The load is expected to produce third harmonic distortion of 42 % of the fundamental line current.

The fundamental line current of the above load is 58 A. Since the third harmonic content is between 33-45 %, the cable sizing is based upon the neutral current with a rating factor of 0.86 applied to the current-carrying capacity of the cable. In addition, to comply with Section 431.2.3, overcurrent detection must be provided for the neutral conductor. Therefore, a 4-pole protective device with overcurrent protection of the neutral should be provided.

The neutral current arising from third harmonics is given by

$$I_{bn} = \frac{3h}{100} I_{nL}$$

where: I_{bn} = neutral current due to third harmonic currents

I_{nL} = fundamental line current

h = third harmonic as a percentage of the fundamental line current.

Hence, the neutral current of the circuit is $I_{bn} = 3 \times 0.42 \times 58 = 73$ A.

Therefore, the design current of the circuit due to third harmonics is 73 A.

To satisfy Section 433.1.1, $I_n \geq I_b$, so the rated current of the circuit-breaker, I_n, is selected to be 80 A. The required tabulated current-carrying capacity, I_t, under the above operational conditions is to satisfy:

$I_t \geq \frac{I_n}{C_a C_g \times 0.86}$ (where circuits of the group are assumed to be liable to simultaneous overload)

Applying the above grouping and temperature rating factors, the required tabulated current-carrying capacity is found to be 125.8 A.

From Table 4E4A, a 25 mm^2 cable is necessary to compensate for the additional thermal effect due to third harmonic current.

All the above cable selections are based on the current-carrying capacity of the cable; voltage drop and other aspects of design have not been considered.

5.6 Harmonic currents in line conductors

Section 5.5 covers the effect of additive harmonic currents flowing in the neutral conductor. The rating factors given in section 5.5 take account of the heating effect of the third harmonic in the neutral as well as the heating effect of the third harmonic in each of the line conductors.

Where other harmonics are present, e.g. 5th, 7th etc, the heating effect of these harmonics in the line conductors has to be taken into account. For smaller sizes, less than 50 mm^2, the effect of harmonic currents can be taken into account by applying the following factor, C_h, to the fundamental design current.

$$C_h = \sqrt{\frac{I_f^{\,2} + \ldots + I_{hn}^{\,2}}{I_f^{\,2}}}$$

where: I_f = 50 Hz current

I_{hn} = nth harmonic current

For larger conductor sizes the increase in conductor resistance, due to skin and proximity effects, at higher frequencies has to be taken into account. The resistance at harmonic frequencies can be calculated using the equations given in IEC 60287-1-1.

6 TABLES OF VOLTAGE DROP

In the tables, values of voltage drop are given for a current of one ampere for a metre run, i.e. for a distance of 1 m along the route taken by the cables, and represent the result of the voltage drops in all the circuit conductors. The values of voltage drop assume that the conductors are at their maximum permitted normal operating temperature.

The values in the tables, for AC operation, apply to frequencies in the range 49 to 61 Hz and for single-core armoured cables the tabulated values apply where the armour is bonded to earth at both ends. The values of voltage drop for cables operating at higher frequencies may be substantially greater.

For a given run, to calculate the voltage drop (in mV) the tabulated value of voltage drop per ampere per metre for the cable concerned has to be multiplied by the length of the run in metres and by the current the cable is intended to carry, namely, the design current of the circuit (I_b) in amperes. For three-phase circuits the tabulated mV/A/m values relate to the line voltage and balanced conditions have been assumed.

For cables having conductors of 16 mm^2 or less cross-sectional area, their inductances can be ignored and $(mV/A/m)_r$ values only are tabulated. For cables having conductors greater than 16 mm^2 cross-sectional area the impedance values are given as $(mV/A/m)_z$, together with the resistive component $(mV/A/m)_r$ and the reactive component $(mV/A/m)_x$.

The direct use of the tabulated $(mV/A/m)_r$ or $(mV/A/m)_z$ values, as appropriate, may lead to pessimistically high calculated values of voltage drop or, in other words, to unnecessarily low values of permitted circuit lengths. For example, where the design current of a circuit is significantly less than the effective current-carrying capacity of the chosen cable, the actual voltage drop would be less than the calculated value because the conductor temperature (and hence their resistance) will be less than that on which the tabulated mV/A/m had been based.

As regards power factor in AC circuits, the use of the tabulated mV/A/m values (for the larger cable sizes, the tabulated $(mV/A/m)_z$ values) leads to a calculated value of the voltage drop higher than the actual value. In some cases it may be advantageous to take account of the load power factor when calculating voltage drop.

Where a more accurate assessment of the voltage drop is desirable the following methods may be used.

6.1 Correction for operating temperature

For cables having conductors of cross-sectional area 16 mm^2 or less, the design value of mV/A/m is obtained by multiplying the tabulated value by a factor C_t, given by:

$$C_t = \frac{230 + t_p - \left(C_a^2 C_g^2 C_s^2 C_d^2 - \frac{I_b^2}{I_t^2}\right)(t_p - 30)}{230 + t_p} \quad \text{Equation 6}$$

where t_p is the maximum permitted normal operating temperature (°C).

This equation applies only where the overcurrent protective device is other than a IEC 60269 fuse and where the actual ambient temperature is equal to or greater than 30 °C.

NOTE: For convenience, the above equation is based on the approximate resistance-temperature coefficient of 0.004 per °C at 20 °C for both copper and aluminium conductors.

For cables having conductors of cross-sectional area greater than 16 mm^2, only the resistive component of the voltage drop is affected by the temperature and the factor C_t is therefore applied only to the tabulated value of $(mV/A/m)_r$ and the design value of $(mV/A/m)_z$ is given by the vector sum of $C_t\,(mV/A/m)_r$ and $(mV/A/m)_x$.

For very large conductor sizes, where the resistive component of voltage drop is much less than the corresponding reactive part (i.e. when $x/r \geq 3$), this rating factor need not be considered.

6.2 Correction for load power factor

For cables having conductors of cross-sectional area 16 mm^2 or less, the design value of mV/A/m is obtained approximately by multiplying the tabulated value by the power factor of the load, cos Ø.

For cables having conductors of cross-sectional area greater than 16 mm^2, the design value of mV/A/m is given approximately by:

$$\cos Ø\,(\text{tabulated}(mV/A/m)_r) + \sin Ø\,(\text{tabulated}(mV/A/m)_x)$$

For single-core cables in flat formation the tabulated values apply to the outer cables and may underestimate for the voltage drop between an outer cable and the centre cable for cross-sectional areas above 240 mm^2, and power factors greater than 0.8.

6.3 Correction for both operating temperature and load power factor

For paragraphs 6.1 and 6.2 above, where it is considered appropriate to correct the tabulated mV/A/m values for both operating temperature and load power factor, the design figure for mV/A/m is given by:

(i) for cables having conductors of cross-sectional area 16 mm^2 or less

C_t cos Ø (tabulated mV/A/m)

(ii) for cables having conductors of cross-sectional area greater than 16 mm^2

C_t cos Ø (tabulated $(mV/A/m)_r$) + sin Ø (tabulated $(mV/A/m)_x$).

6.4 Voltage drop in consumers' installations

The voltage drop between the origin of an installation and any load point should not be greater than the values in the table below expressed with respect to the value of the nominal voltage of the installation.

The calculated voltage drop should include any effects due to harmonic currents.

TABLE 4Ab – Voltage drop

	Lighting	Other uses
(i) Low voltage installations supplied directly from a public low voltage distribution system	3 %	5 %
(ii) Low voltage installation supplied from private LV supply (*)	6 %	8 %

(*) The voltage drop within each final circuit should not exceed the values given in (i).

Where the wiring systems of the installation are longer than 100 m, the voltage drops indicated above may be increased by 0.005 % per metre of the wiring system beyond 100 m, without this increase being greater than 0.5 %.

The voltage drop is determined from the demand of the current-using equipment, applying diversity factors where applicable, or from the value of the design current of the circuit.

NOTE 1: A greater voltage drop may be acceptable for a motor circuit during starting and for other equipment with a high inrush current, provided that in both cases the voltage variations remain within the limits specified in the relevant equipment standard.

NOTE 2: The following temporary conditions are excluded:

- voltage transients
- voltage variations due to abnormal operation.

7 METHODS OF INSTALLATION

Table 4A2 lists the methods of installation for which this appendix provides guidance for the selection of the appropriate cable size. Table 4A3 lists the appropriate tables for selection of current ratings for specific cable constructions. The Reference Methods are those methods of installation for which the current-carrying capacities given in Tables 4D1A to 4J4A have been determined (see 7.1 below).

The use of other methods is not precluded and in that case the evaluation of current-carrying capacity may need to be based on experimental work.

7.1 Reference Methods

The Reference Methods are those methods of installation for which the current-carrying capacity has been determined by test or calculation.

NOTE 1: It is impractical to calculate and publish current ratings for every installation method, since many would result in the same current rating. Therefore a suitable (limited) number of current ratings have been calculated which cover all of the installation methods stated in Table 4A2 and have been called Reference Methods.

Reference Method A, for example, Installation Methods 1 and 2 of Table 4A2 (non-sheathed cables and multicore cables in conduit in a thermally insulated wall).

The wall consists of an outer weatherproof skin, thermal insulation and an inner skin of wood or wood-like material having a thermal conductance of at least 10 W/m^{2}K. The conduit is fixed such that it is close to, but not necessarily touching, the inner skin. Heat from the cables is assumed to escape through the inner skin only. The conduit can be metal or plastic.

Reference Method B, for example, Installation Method 4 of Table 4A2 (non-sheathed cables in conduit mounted on a wooden or masonry wall) and Installation Method 5 of Table 4A2 (multicore cable in conduit on a wooden or masonry wall).

The conduit is mounted on a wooden wall such that the gap between the conduit and the surface is less than 0.3 times the conduit diameter. The conduit can be metal or plastic. Where the conduit is fixed to a masonry wall the current-carrying capacity of the non-sheathed or sheathed cable may be higher.

Reference Method C (clipped direct), for example, Installation Method 20 of Table 4A2 (single-core or multicore cables on a wooden or masonry wall).

Cable mounted on a wooden wall so that the gap between the cable and the surface is less than 0.3 times the cable diameter. Where the cable is fixed to or embedded in a masonry wall the current-carrying capacity may be higher.

NOTE 2: The term 'masonry' is taken to include brickwork, concrete, plaster and similar (but excluding thermally insulating materials).

Reference Method D, for example, Installation Method 70 of Table 4A2 (multicore armoured cable in conduit or in cable ducting in the ground).

The cable is drawn into a 100 mm diameter plastic, earthenware or metallic duct laid in direct contact with soil having a thermal resistivity of 2.5 K.m/W and at a depth of 0.7 m. The values given for this method are those stated in this appendix and are based on conservative installation parameters. If the specific installation parameters are known (thermal resistance of the ground, ground ambient temperature, cable depth), reference can be made to the cable manufacturer or the ERA 69-30 series of publications, which may result in a smaller cable size being selected.

NOTE 3: The current-carrying capacity for cables laid in direct contact with soil having a thermal resistivity of 2.5 Km/W and at a depth of 0.7 m is approximately 10 % higher than the values tabulated for Reference Method D.

Reference Methods E, F and G, for example, Installation Methods 31 to 35 of Table 4A (single-core or multicore cables in free air).

The cable is supported such that the total heat dissipation is not impeded. Heating due to solar radiation and other sources is to be taken into account. Care is to be taken that natural air convection is not impeded. In practice, a clearance between a cable and any adjacent surface of at least 0.3 times the cable external diameter for multicore cables or 1.0 times the cable diameter for single-core cables is sufficient to permit the use of current-carrying capacities appropriate to free air conditions.

7.2 Other Methods

Cable on a floor: Reference Method C applies for current rating purposes.

Cable under a ceiling: This installation may appear similar to Reference Method C but because of the reduction in natural air convection, Reference Method B is to be used for the current rating.

Cable tray systems: A perforated cable tray has a regular pattern of holes that occupy at least 30 % of the area of the base of the tray. The current-carrying capacity for cables attached to perforated cable trays should be taken as Reference Method E or F. The current-carrying capacity for cables attached to unperforated cable trays (no holes or holes that occupy less than 30 % of the area of the base of the tray) is to be taken as Reference Method C.

Cable ladder system: This is a construction which offers a minimum of impedance to the air flow around the cables, i.e. supporting metalwork under the cables occupies less than 10 % of the plan area. The current-carrying capacity for cables on ladder systems should be taken as Reference Method E or F.

Cable cleats, cable ties and cable hangers: Cable supports hold the cable at intervals along its length and permit substantially complete free air flow around the cable. The current-carrying capacity for cable cleats, cable ties and cable hangers should be taken as Reference Method E or F.

Cable installed in a ceiling: This is similar to Reference Method A. It may be necessary to apply the rating factors due to higher ambient temperatures that may arise in junction boxes and similar mounted in the ceiling.

NOTE: Where a junction box in the ceiling is used for the supply to a luminaire, the heat dissipation from the luminaire may provide higher ambient temperatures than permitted in Tables 4D1A to 4J4A (see also Section 522.2.1). The temperature may be between 40 °C and 50 °C, and a rating factor according to Table 4B1 must be applied.

General notes to all tables in this appendix

NOTE 1: Current-carrying capacities are tabulated for methods of installation which are commonly used for fixed electrical installations. The tabulated capacities are for continuous steady-state operation (100 % load factor) for DC or AC of nominal frequency 50 Hz and take no account of harmonic content.

NOTE 2: Table 4A2 itemizes the reference methods of installation to which the tabulated current-carrying capacities refer.

TABLE 4A1 – Schedule of Installation Methods in relation to conductors and cables

Conductors and cables		Installation Method							
		Without fixings	Clipped direct	Conduit systems	Cable trunking systems*	Cable ducting systems	Cable ladder, cable tray, cable brackets	On insulators	Support wire
Bare conductors		np	np	np	np	np	np	P	np
Non-sheathed cable		np	np	P[1]	P[1 2]	P[1]	np[1]	P	np
Sheathed cables (including armoured and mineral insulated)	Multicore	P	P	P	P	P	P	N/A	P
	Single-core	N/A	P	P	P	P	P	N/A	P

P Permitted.

np Not permitted.

N/A Not applicable, or not normally used in practice.

* including skirting trunking and flush floor trunking

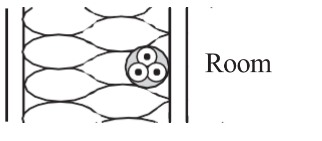
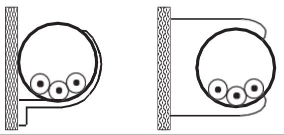
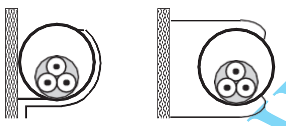
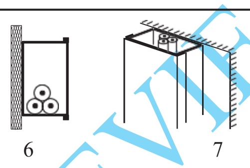
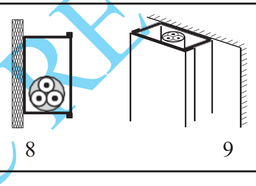
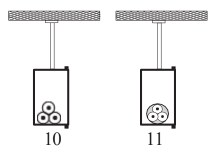
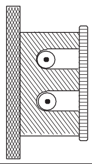
[1] Non-sheathed cables which are used as protective conductors or protective bonding conductors need not be laid in conduits or ducts

[2] Non-sheathed cables are acceptable if the trunking system provides at least the degree of protection IPXXD or IP4X and if the cover can only be removed by means of a tool or a deliberate action.

TABLE 4A2 - Schedule of Installation methods of cables (including Reference Methods) for determining current-carrying capacity

NOTE 1: The illustrations are not intended to depict actual product or installation practices but are indicative of the method described.

NOTE 2: The installation and reference methods stated are in line with IEC . However, not all methods have a corresponding rating for all cable types.

Installation Method			Reference Method to be used to determine current-carrying capacity
Number	**Examples**	**Description**	
1		Non-sheathed cables in conduit in a thermally insulated wall with an inner skin having a thermal conductance of not less than 10 W/m²K [c]	**A**
2		Multicore cable in conduit in a thermally insulated wall with an inner skin having a thermal conductance of not less than 10 W/m²K [c]	**A**
3		Multicore cable direct in a thermally insulated wall with an inner skin having a thermal conductance of not less than 10 W/m²K [c]	**A**
4		Non-sheathed cables in conduit on a wooden or masonry wall or spaced less than 0.3 × conduit diameter from it [c]	**B**
5		Multicore cable in conduit on a wooden or masonry wall or spaced less than 0.3 × conduit diameter from it [c]	**B**
6 **7**		Non-sheathed cables in cable trunking on a wooden or masonry wall 6 - run horizontally [b] 7 - run vertically [b, c]	**B**
8 **9**		Multicore cable in cable trunking on a wooden or masonry wall 8 - run horizontally [b] 9 - run vertically [b, c]	**B***
10		Non-sheathed cables in suspended cable trunking [b]	**B**
11		Multicore cable in suspended cable trunking [b]	**B**
12		Non-sheathed cables run in mouldings [c, e]	**A**

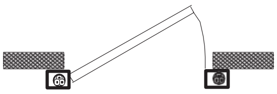
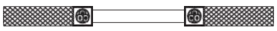
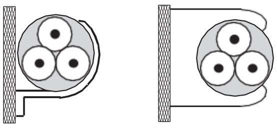
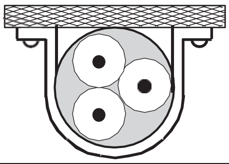
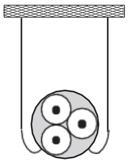
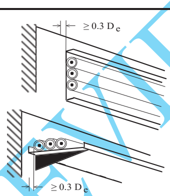
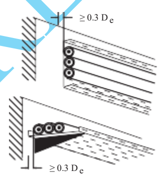
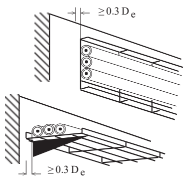
b Values given for Reference Method B in Appendix 2 are for a single circuit. Where there is more than one circuit in the trunking the group rating factor given in Table 4C1 is applicable, irrespective of the presence of an internal barrier or partition.

c Care is needed where the cable runs vertically and ventilation is restricted. The ambient temperature at the top of the vertical section can be much higher.

e The thermal resistivity of the enclosure is assumed to be poor because of the material of construction and possible air spaces. Where the construction is thermally equivalent to Installation Methods 6 or 7, Reference Method B may be used.

* Still under consideration in IEC .

TABLE 4A2 *(continued)*

Installation Method			Reference Method to be used to determine current-carrying capacity
Number	**Examples**	**Description**	
13 *14*		*Not used*	
15		Non-sheathed cables in conduit or single-core or multicore cable in architrave [c, f]	**A**
16		Non-sheathed cables in conduit or single-core or multicore cable in window frames [c, f]	**A**
20		Single-core or multicore cables: - fixed on (clipped direct), or spaced less than 0.3 × cable diameter from a wooden or masonry wall [c]	**C**
21		Single-core or multicore cables: - fixed directly under a wooden or masonry ceiling	**C** (Higher than standard ambient temperatures may occur with this installation method)
22		Single-core or multicore cables: - spaced from a ceiling	**E, F or G*** (Higher than standard ambient temperatures may occur with this installation method)
23		*Not used*	
30		Single-core or multicore cables: - on unperforated tray run horizontally or vertically [c, h]	**C** with item 2 of Table 4C1
31		Single-core or multicore cables: - on perforated tray run horizontally or vertically [c, h]	**E or F**
32		Single-core or multicore cables: - on brackets or on a wire mesh tray run horizontally or vertically [c, h]	**E or F**

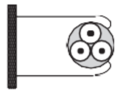
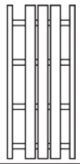
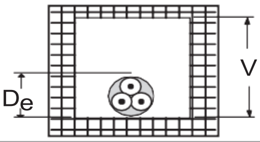
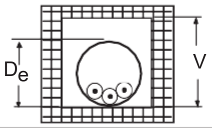
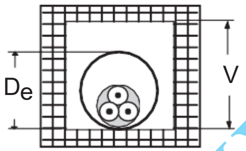
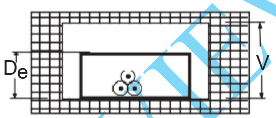
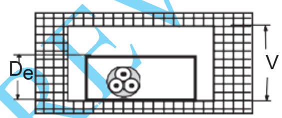
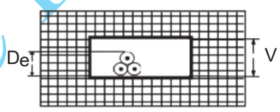
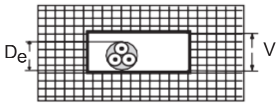
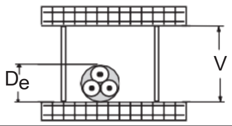
c Care is needed where the cable runs vertically and ventilation is restricted. The ambient temperature at the top of the vertical section can be much higher.

f The thermal resistivity of the enclosure is assumed to be poor because of the material of construction and possible air spaces. Where the construction is thermally equivalent to Installation Methods 6, 7, 8 or 9, Reference Method B may be used.

h D_e = the external diameter of a multicore cable:
- 2.2 × the cable diameter when three single-core cables are bound in trefoil, or
- 3 × the cable diameter when three single-core cables are laid in flat formation.

* Still under consideration in IEC .

TABLE 4A2 *(continued)*

Installation Method			Reference Method to be used to determine current-carrying capacity
Number	**Examples**	**Description**	
33		Single-core or multicore cables: - spaced more than 0.3 times the cable diameter from a wall	**E, F or G**[g]
34		Single-core or multicore cables: - on a ladder[c]	**E or F**
35		Single-core or multicore cable suspended from or incorporating a support wire or harness	**E or F**
36		Bare or non-sheathed cables on insulators	**G**
40		Single-core or multicore cable in a building void [c, h, i]	Where 1.5 $D_e \leq V < 20\ D_e$ use **B**
41		Non-sheathed cables in conduit in a building void in masonry having a thermal resistivity not greater than 2 K.m/W [c, i, j]	Where 1.5 $D_e \leq V$ use **B**
42		Single-core or multicore cable in conduit in a building void in masonry having a thermal resistivity not greater than 2 K.m/W [c, j]	Where 1.5 $D_e \leq V$ use **B**
43		Non-sheathed cables in cable ducting in a building void in masonry having a thermal resistivity not greater than 2 K.m/W [c, i, j]	Where 1.5 $D_e \leq V$ use **B**
44		Single-core or multicore cable in cable ducting in a building void in masonry having a thermal resistivity not greater than 2 K.m/W [c, i, j]	Where 1.5 $D_e \leq V$ use **B**
45		Non-sheathed cables in cable ducting in masonry having a thermal resistivity not greater than 2 K.m/W [c, h, i]	Where 1.5 $D_e \leq V < 50\ D_e$ use **B**
46		Single-core or multicore cable in cable ducting in masonry having a thermal resistivity not greater than 2 K.m/W [c, h, i]	Where 1.5 $D_e \leq V < 50\ D_e$ use **B**
47		Single-core or multicore cable: - in a ceiling void - in a suspended floor [h, i]	Where 1.5 $D_e \leq V < 50\ D_e$ use **B**

c Care is needed where the cable runs vertically and ventilation is restricted. The ambient temperature at the top of the vertical section can be much higher.

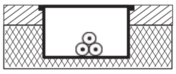
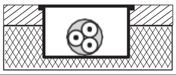
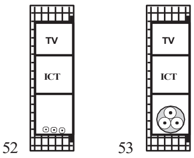
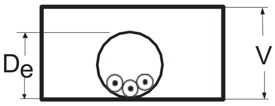
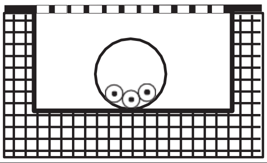
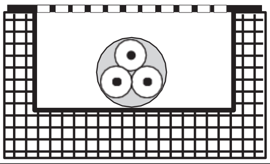
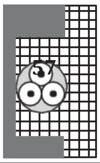
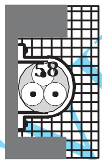
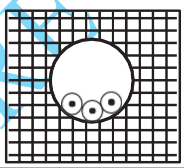
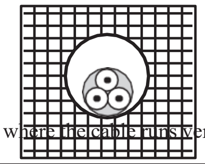
g The factors in Table 4C1 may also be used.

h D_e = the external diameter of a multicore cable:
- 2.2 × the cable diameter when three single-core cables are bound in trefoil, or
- 3 × the cable diameter when three single-core cables are laid in flat formation.

i V = the smaller dimension or diameter of a masonry duct or void, or the vertical depth of a rectangular duct, floor or ceiling void or channel.

j D_e = external diameter of conduit or vertical depth of cable ducting.

TABLE 4A2 *(continued)*

Installation Method			Reference Method to be used to determine current-carrying capacity
Number	**Examples**	**Description**	
50		Non-sheathed cables in flush cable trunking in the floor	**B**
51		Multicore cable in flush cable trunking in the floor	**B**
52		Non-sheathed cables in flush trunking[c]	**B**
53		Multicore cable in flush trunking [c]	**B**
54		Non-sheathed cables or single-core cables in conduit in an unventilated cable channel run horizontally or vertically [c, i, k, m]	Where 1.5 $D_e \leq V$ use **B**
55		Non-sheathed cables in conduit in an open or ventilated cable channel in the floor [l, m]	**B**
56		Sheathed single-core or multicore cable in an open or ventilated cable channel run horizontally or vertically [m]	**B**
		Single-core or multicore cable direct in masonry having a thermal resistivity not greater than 2 K.m/W - without added mechanical protection [n, o]	**C**
		Single-core or multicore cable direct in masonry having a thermal resistivity not greater than 2 K.m/W - with added mechanical protection [n, o] (e.g. capping)	**C**
5		Non-sheathed cables or single-core cables in conduit in masonry having a thermal resistivity not greater than 2 K.m/W [o]	**B**
6		Multicore cables in conduit in masonry having a thermal resistivity not greater than 2 K.m/W [o]	**B**

c Care is needed where the cable runs vertically and ventilation is restricted. The ambient temperature at the top of the vertical section can be much higher.

k D_e = external diameter of conduit.

i V = the smaller dimension or diameter of a masonry duct or void, or the vertical depth of a rectangular duct, floor or ceiling void or channel. The depth of the channel is more important than the width.

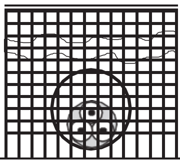
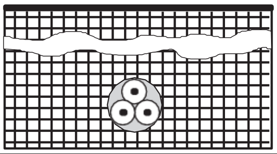
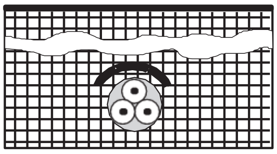
l For multicore cable installed as Method 55, use current-carrying capacity for Reference Method B.

m It is recommended that these Installation Methods are used only in areas where access is restricted to authorized persons so that the reduction in current-carrying capacity and the fire hazard due to the accumulation of debris can be prevented.

n For cables having conductors not greater than 16 mm², the current-carrying capacity may be higher.

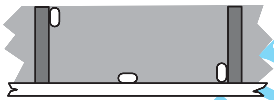
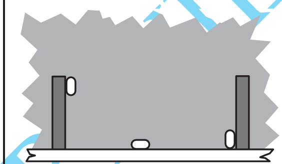
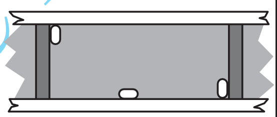
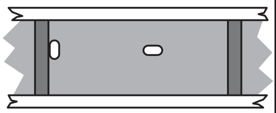
o Thermal resistivity of masonry is not greater than 2 K.m/W. The term masonry is taken to include brickwork, concrete, plaster and the like (excludes thermally insulating materials).

TABLE 4A2 *(continued)*

Installation Method			Reference Method to be used to determine current-carrying capacity
Number	**Examples**	**Description**	
70		Multicore armoured cable in conduit or in cable ducting in the ground	**D** **For multicore armoured cable only**
71		*Not used*	
72		Sheathed, armoured or multicore cables direct in the ground: - without added mechanical protection (see note)	**D**
73		Sheathed, armoured or multicore cables direct in the ground: - with added mechanical protection (e.g. cable covers) (see note)	**D**

NOTE: The inclusion of directly buried cables is satisfactory where the soil thermal resistivity is of the order of 2.5 K.m/W. For lower soil resistivities, the current-carrying capacity for directly buried cables is appreciably higher than for cables in ducts.

TABLE 4A2 *(continued - Installation methods for flat twin and earth cables in thermal insulation)*

Installation Method			Reference Method to be used to determine current-carrying capacity
Number	**Examples**	**Description**	
100		Installation methods for flat twin and earth cable clipped direct to a wooden joist, or touching the plasterboard ceiling surface, above a plasterboard ceiling with thermal insulation not exceeding 100 mm in thickness having a minimum U value of 0.1 W/m^{2}K	Table 4D5
101		Installation methods for flat twin and earth cable clipped direct to a wooden joist, or touching the plasterboard ceiling surface, above a plasterboard ceiling with thermal insulation exceeding 100 mm in thickness having a minimum U value of 0.1 W/m^{2}K	Table 4D5
102		Installation methods for flat twin and earth cable in a stud wall with thermal insulation with a minimum U value of 0.1 W/m^{2}K with the cable touching the inner wall surface, or touching the plasterboard ceiling surface, and the inner skin having a minimum U value of 10 W/m^{2}K	Table 4D5
103		Installation methods for flat twin and earth cable in a stud wall with thermal insulation with a minimum U value of 0.1 W/m^{2}K with the cable not touching the inner wall surface	Table 4D5

Wherever practicable, a cable is to be fixed in a position such that it will not be covered with thermal insulation.

TABLE 4A2 (*continued -*
Installation methods for cables enclosed in infloor concrete troughs)

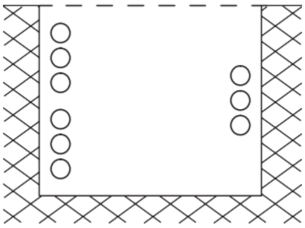
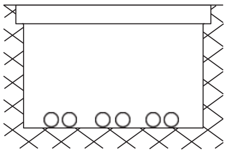
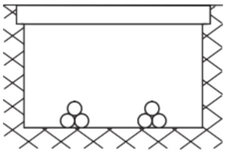
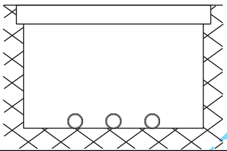
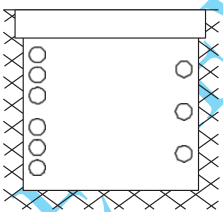
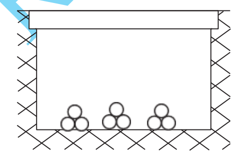
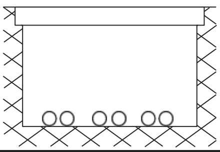
Installation Method			Reference Method to be used to determine current-carrying capacity
Number	**Examples**	**Description**	
117		Cables supported on the wall of an open or ventilated infloor concrete trough with spacing as follows: - Sheathed single-core cables in free air (any supporting metalwork under the cables occupying less than 10 % of plan area). - Two or three cables vertically one above the other, minimum distance between cable surfaces equal to the overall cable diameters, distance from the wall not less than ½ the cable diameter. - Two or three cables horizontally with spacing as above.	**E or F**
118		Cables in enclosed trench 450 mm wide by 300 mm deep (minimum dimensions) including 100 mm cover - Two to six single–core cables with surfaces separated by a minimum of one cable diameter	**E or F** **using rating factors in Table 4C6**
		- One or two groups of three single-core cables in trefoil formation	
		- One to four 2-core cables or one to three cables of 3 or 4 cores with all cables separated by a minimum of 50 mm	
119		Cables enclosed in an infloor concrete trough 450 mm wide by 600 mm deep (minimum dimensions) including 100 mm cover. Six to twelve single-core cables arranged in flat groups of two or three on the vertical trench wall with cables separated by one cable diameter and a minimum of 50 mm between groups.	**E or F** **using rating factors in Table 4C6**
		or two to four groups of three single-core cables in trefoil formation with a minimum of 50 mm between trefoil formations.	
		or four to eight 2-core cables or three to six cables of 3 or 4 cores with cables separated by a minimum of 75 mm. All cables spaced at least 25 mm from trench wall.	

TABLE 4A2 ***(continued - Installation methods for cables enclosed in floor concrete troughs)***

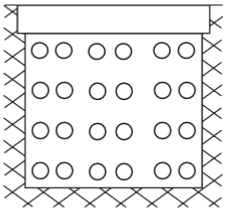
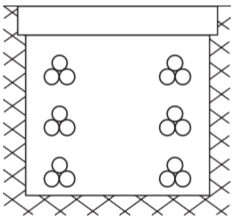
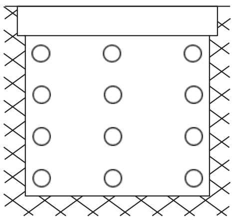
Installation Method			Reference Method to be used to determine current-carrying capacity
Number	**Examples**	**Description**	
120		Cables enclosed in an infloor concrete trough 600 mm wide by 760 mm deep (minimum dimensions) including 100 mm cover. Twelve to twenty-four single-core cables arranged in either flat formation of two or three cables in a group with cables separated by one cable diameter and each cable group separated by a minimum of 50 mm either horizontally or vertically	**E or F** **using rating factors in Table 4C6**
		or single-core cables in trefoil formation with each group or trefoil formation separated by a minimum of 50 mm either horizontally or vertically	
		or eight to sixteen 2-core cables or six to twelve cables of 3 or 4 cores with cables separated by a minimum of 75 mm either horizontally or vertically. All cables spaced at least 25 mm from trench wall.	

TABLE 4A3 – Schedule of cable specifications

Specification Number	Specification Title	Conductor Operating Temperature
KS IEC 60502-1	Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1.2 kV) up to 30 kV (Um = 36 kV) – Part 1: Cables for rated voltages of 1 kV (Um = 1.2 kV) and 3 kV (Um = 3.6 kV).	90 °C
IEC 60227 Series	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V – Part 3: Non-sheathed cables for fixed wiring.	70 °C
IEC 60227-6	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V – Part 6: Lift cables and cables for flexible connections.	70 °C
KS IEC 60502-1 (for Low Smoke Zero Halogen cables)	Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1.2 kV) up to 30 kV (Um = 36 kV) – Part 1: Cables for rated voltages of 1 kV (Um = 1.2 kV) and 3 kV (Um = 3.6 kV).	90 °C
KS IEC 60502-1 (for Low Smoke Zero Halogen, fire-resistant cables)	Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1.2 kV) up to 30 kV (Um = 36 kV) – Part 1: Cables for rated voltages of 1 kV (Um = 1.2 kV) and 3 kV (Um = 3.6 kV).	90 °C
IEC 60245 Series	Rubber insulated cables – Rated voltages up to and including 450/750 V.	60 °C to 90 °C, depending on the specific cable type.
IEC 60702-1	Mineral insulated cables and their terminations with a rated voltage not exceeding 750 V – Part 1: Cables.	Up to 105 °C under normal operating conditions.

TABLE 4B1 – Rating factors (C_a) for ambient air temperatures other than 30 °C

Ambient temperature[a] °C	Insulation				
	60 °C thermosetting	70 °C thermoplastic	90 °C thermosetting	Mineral[a]	
				Thermoplastic covered or bare and exposed to touch 70 °C	Bare and not exposed to touch 105 °C
25	1.04	1.03	1.02	1.07	1.04
30	1.00	1.00	1.00	1.00	1.00
35	0.91	0.94	0.96	0.93	0.96
40	0.82	0.87	0.91	0.85	0.92
45	0.71	0.79	0.87	0.78	0.88
50	0.58	0.71	0.82	0.67	0.84
55	0.41	0.61	0.76	0.57	0.80
60	–	0.50	0.71	0.45	0.75
65	–	–	0.65	–	0.70
70	–	–	0.58	–	0.65
75	–	–	0.50	–	0.60
80	–	–	0.41	–	0.54
85	–	–	–	–	0.47
90	–	–	–	–	0.40
95	–	–	–	–	0.32

a For higher ambient temperatures, consult manufacturer.

TABLE 4B2 – Rating factors (C_a) for ambient ground temperatures other than 20 °C

Ground temperature °C	Insulation	
	70 °C thermoplastic	90 °C thermosetting
10	1.10	1.07
15	1.05	1.04
20	1.00	1.00
25	0.95	0.96
30	0.89	0.93
35	0.84	0.89
40	0.77	0.85
45	0.71	0.80
50	0.63	0.76
55	0.55	0.71
60	0.45	0.65
65	–	0.60
70	–	0.53
75	–	0.46
80	–	0.38

TABLE 4B3 – Rating factors (C_s) for cables buried direct in the ground or in an underground conduit system to KS IEC 61386-24 for soil thermal resistivities other than 2.5 K.m/W to be applied to the current-carrying capacities for Reference Method D

Thermal resistivity, K.m/W	0.5	0.8	1	1.2	1.5	2	2.5	3
Rating factor for cables in buried ducts	1.28	1.20	1.18	1.13	1.1	1.05	1	0.96
Rating factor for direct buried cables	1.88	1.62	1.5	1.40	1.28	1.12	1	0.90

NOTE 1: The rating factors given have been averaged over the range of conductor sizes and types of installation included in the relevant tables in this appendix. The overall accuracy of rating factors is within ± 5 %.

NOTE 2: Where more precise values are required they may be calculated by methods given in KS IEC 60287 .

NOTE 3: The rating factors are applicable to ducts buried at depths of up to 0.8 m.

TABLE 4B4 – Rating factors (C_d) for depths of laying other than 0.7 m for direct buried cables and cables in buried ducts

Depth of laying, m	Buried direct	In buried ducts
0.5	1.03	1.02
0.7	1.00	1.00
1	0.97	0.98
1.25	0.95	0.96
1.5	0.94	0.95
1.75	0.93	0.94
2	0.92	0.93
2.5	0.90	0.92
3	0.89	0.91

TABLE 4B5 – Rating factors for cables having more than 4 loaded cores

Number of loaded cores	5	6	7	10	12	14	19
Rating factor	0.72	0.67	0.63	0.56	0.53	0.51	0.45
Number of loaded cores	24	27	30	37	44	46	48
Rating factor	0.42	0.40	0.39	0.36	0.34	0.33	0.33

NOTE 1: The current-carrying capacity for a cable in the size range 1.5 to 4 mm^2, having more than 4 loaded cores, is obtained by multiplying the current-carrying capacity of a 2-core, having the same insulation type, by the factor selected from this table. The current-carrying capacity for the 2-core cable is that for the installation condition to be used for the multicore cable.

NOTE 2: If, due to known operating conditions, a core is expected to carry not more than 30 % of its current-carrying capacity in the multicore cable it may be ignored for the purpose of determining the number of cores in the cable.

NOTE 3: If, due to known operating conditions, a core is expected to carry not more than 30 % of its rating, after applying the rating factor for the total number of current-carrying cores, it may be ignored for the purpose of obtaining the rating factor for the number of loaded cores.

For example, the current-carrying capacity of a cable having N loaded cores would normally be obtained by multiplying the current-carrying capacity of a 2-core, having the same insulation type, by the factor selected from this table for N cores. That is $I_{z1c} = I_{t2c} \times C_{gN}$

where:

I_{z1c} is the current-carrying capacity of the multicore cable after applying the rating factor for the total number of current-carrying cores

I_{t2c} is the tabulated current-carrying capacity of a 2-core cable, having the same insulation type as the multi-core cable

C_{gN} is the rating factor from Table 4B5 for the total number of current-carrying cores

However, if M cores in the cable carry loads which are not greater than $0.3 \times I_{t2c} \times C_{gN}$, the current-carrying capacity can be obtained by using the rating factor corresponding to (N-M) cores.

The 'not greater than $0.3 \times I_{t2c} \times C_{gN}$' calculation should be applied before the adjacent multicore cable grouping factor, if applicable, from Table 4C1. The 30 % rule should not be further applied to any adjacent cable grouping factor calculations.

I_{z1c} should be greater than or equal to I_n or I_b as appropriate, divided by the relevant rating factor(s) C, that is $I_{z1c} \geq I_n$ or I_b / C

TABLE 4C1 – Rating factors for one circuit or one multicore cable or for a group of circuits, or a group of multicore cables, to be used with current-carrying capacities of Tables 4D1A to 4J4A

Item	Arrangement (cables touching)	Number of circuits or multicore cables												To be used with current-carrying capacities, Reference Method
		1	2	3	4	5	6	7	8	9	12	16	20	
1.	Bunched in air, on a surface, embedded or enclosed	1.00	0.80	0.70	0.65	0.60	0.57	0.54	0.52	0.50	0.45	0.41	0.38	A to F
2.	Single layer on wall or floor	1.00	0.85	0.79	0.75	0.73	0.72	0.72	0.71	0.70	0.70	0.70	0.70	C
3.	Single layer multicore on a perforated horizontal or vertical cable tray system	1.00	0.88	0.82	0.77	0.75	0.73	0.73	0.72	0.72	0.72	0.72	0.72	E
4.	Single layer multicore on cable ladder system or cleats etc.	1.00	0.87	0.82	0.80	0.80	0.79	0.79	0.78	0.78	0.78	0.78	0.78	

NOTE 1: These factors are applicable to uniform groups of cables, equally loaded.

NOTE 2: Where horizontal clearances between adjacent cables exceed twice their overall diameter, no rating factor need be applied.

NOTE 3: The same factors are applied to:

- groups of two or three single-core cables;
- multicore cables.

NOTE 4: If a group consists of both two- and three-core cables, the total number of cables is taken as the number of circuits, and the corresponding factor is applied to the tables for two loaded conductors for the two-core cables, and to the Tables for three loaded conductors for the three-core cables.

NOTE 5: If a group consists of *n* single-core cables it may either be considered as *n*/2 circuits of two loaded conductors or *n*/3 circuits of three loaded conductors.

NOTE 6: The rating factors given have been averaged over the range of conductor sizes and types of installation included in Tables 4D1A to 4J4A and the overall accuracy of tabulated values is within 5 %.

NOTE 7: For some installations and for other methods not provided for in the above table, it may be appropriate to use factors calculated for specific cases, see for example Tables 4C4 and 4C5.

NOTE 8: Where cables having differing conductor operating temperature are grouped together, the current rating is to be based upon the lowest operating temperature of any cable in the group.

NOTE 9: If, due to known operating conditions, a cable is expected to carry not more than 30 % of its *grouped* rating, it may be ignored for the purpose of obtaining the rating factor for the rest of the group.

For example, a group of N loaded cables would normally require a group rating factor of C_g applied to the tabulated I_t.

However, if M cables in the group carry loads which are not greater than 0.3 C_gI_t amperes the other cables can be sized by using the group rating factor corresponding to (N-M) cables.

TABLE 4C2 – Rating factors for more than one circuit, cables buried directly in the ground – Reference Method D in Tables 4D4A to 4J4A multicore cables

Number of circuits	Cable-to-cable clearance (α)				
	Nil (cables touching)	One cable diameter	0.125 m	0.25 m	0.5 m
2	0.75	0.80	0.85	0.90	0.90
3	0.65	0.70	0.75	0.80	0.85
4	0.60	0.60	0.70	0.75	0.80
5	0.55	0.55	0.65	0.70	0.80
6	0.50	0.55	0.60	0.70	0.80

Multicore cables

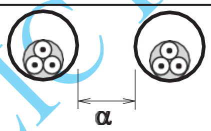
NOTE 1: Values given apply to an installation depth of 0.7 m and a soil thermal resistivity of 2.5 K.m/W. These are average values for the range of cable sizes and types quoted for Tables 4D4A to 4J4A. The process of averaging, together with rounding off, can result in some cases in errors of up to ±10 %. (Where more precise values are required they may be calculated by methods given in KS IEC 60287 .)

NOTE 2: In case of a thermal resistivity lower than 2.5 K.m/W the rating factors can, in general, be increased and can be calculated by the methods given in KS IEC 60287 .

TABLE 4C3 – Rating factors for more than one circuit, single cables in ducts buried in the ground – Reference Method D in Tables 4D4A to 4J4A (Multicore cables in single-way ducts)

Number of ducts	Duct-to-duct clearance (α)			
	Nil (ducts touching)	0.25 m	0.5 m	1.0 m
2	0.85	0.90	0.95	0.95
3	0.75	0.85	0.90	0.95
4	0.70	0.80	0.85	0.90
5	0.65	0.80	0.85	0.90
6	0.60	0.80	0.80	0.90

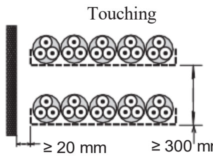
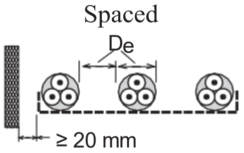
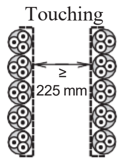
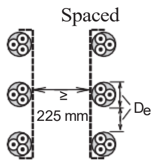
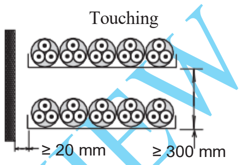
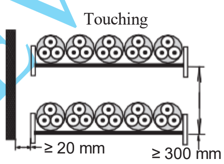
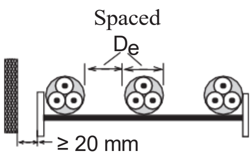
Multicore cables



NOTE 1: Values given apply to an installation depth of 0.7 m and a soil thermal resistivity of 2.5 K.m/W. They are average values for the range of cable sizes and types quoted for Tables 4D4A to 4J4A. The process of averaging, together with rounding off, can result in some cases in errors of up to ±10 %. (Where more precise values are required they may be calculated by methods given in KS IEC 60287 .)

NOTE 2: In case of a thermal resistivity lower than 2.5 K.m/W the rating factors can, in general, be increased and can be calculated by the methods given in KS IEC 60287 .

TABLE 4C4 – Rating factors for groups of more than one multicore cable, to be applied to reference current-carrying capacities for multicore cables in free air – Reference Method E in Tables 4D2A to 4J4A

Installation Method in Table 4A2			Number of trays or ladders	Number of cables per tray or ladder: 1	2	3	4	6	9
Perforated cable tray systems (Note 3)	31		1 2 3 6	See item 3 of Table 4C1 1.00 1.00 1.00	 0.87 0.86 0.84	 0.80 0.79 0.77	 0.77 0.76 0.73	 0.73 0.71 0.68	 0.68 0.66 0.64
			1 2 3	1.00 1.00 1.00	1.00 0.99 0.98	0.98 0.96 0.95	0.95 0.92 0.91	0.91 0.87 0.85	– – –
Vertical perforated cable tray systems (Note 4)	31		1 2	See item 3 of Table 4C1 1.00	 0.88	 0.81	 0.76	 0.71	 0.70
			1 2	1.00 1.00	0.91 0.91	0.89 0.88	0.88 0.87	0.87 0.85	– –
Unperforated cable tray systems	30		1 2 3 6	0.97 0.97 0.97 0.97	0.84 0.83 0.82 0.81	0.78 0.76 0.75 0.73	0.75 0.72 0.71 0.69	0.71 0.68 0.66 0.63	0.68 0.63 0.61 0.58
Cable ladder systems, cleats, wire mesh tray, etc. (Note 3)	32 33 34		1 2 3 6	See item 4 of Table 4C1 1.00 1.00 1.00	 0.86 0.85 0.84	 0.80 0.79 0.77	 0.78 0.76 0.73	 0.76 0.73 0.68	 0.73 0.70 0.64
			1 2 3	1.00 1.00 1.00	1.00 0.99 0.98	1.00 0.98 0.97	1.00 0.97 0.96	1.00 0.96 0.93	– – –

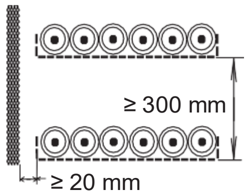
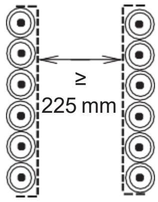
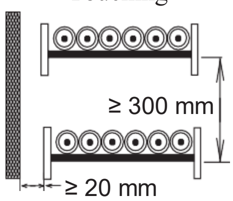
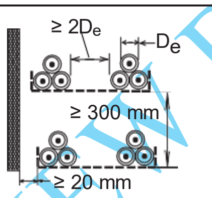
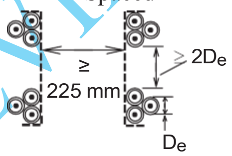
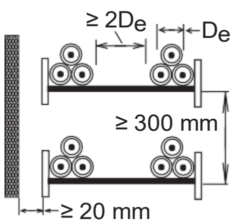
NOTE 1: Values given are averages for the cable types and range of conductor sizes considered in Tables 4D2A to 4J4A. The spread of values is generally less than 5 %.

NOTE 2: Factors apply to single layer groups of cables as shown above and do not apply when cables are installed in more than one layer touching each other. Values for such installations may be significantly lower and must be determined by an appropriate method.

NOTE 3: Values are given for vertical spacing between cable trays of 300 mm and at least 20 mm between cable trays and wall. For closer spacing the factors should be reduced.

NOTE 4: Values are given for horizontal spacing between cable trays of 225 mm with cable trays mounted back-to-back. For closer spacing the factors should be reduced.

TABLE 4C5 – Rating factors for groups of one or more circuits of single-core cables to be applied to reference current-carrying capacity for one circuit of single-core cables in free air – Reference Method F in Tables 4D1A to 4J3A

Installation Method in Table 4A2			Number of trays or ladders	Number of three-phase circuits per tray or ladder			Use as a multiplier to rating for
				1	2	3	
Perforated cable tray systems (Note 3)	31	Touching  	1 2 3	0.98 0.96 0.95	0.91 0.87 0.85	0.87 0.81 0.78	Three cables in horizontal formation
Vertical perforated cable tray systems (Note 4)	31	Touching  	1 2	0.96 0.95	0.86 0.84	– –	Three cables in vertical formation
Cable ladder systems, cleats, wire mesh tray, etc. (Note 3)	32 33 34	Touching  	1 2 3	1.00 0.98 0.97	0.97 0.93 0.90	0.96 0.89 0.86	Three cables in horizontal formation
Perforated systems (Note 3)	31	 	1 2 3	1.00 0.97 0.96	0.98 0.93 0.92	0.96 0.89 0.86	Three cables in trefoil formation
Vertical perforated cable tray systems (Note 4)	31	Spaced  	1 2	1.00 1.00	0.91 0.90	0.89 0.86	
Cable ladder systems, cleats, wire mesh tray, etc. (Note 3)	32 33 34	 	1 2 3	1.00 0.97 0.96	1.00 0.95 0.94	1.00 0.93 0.90	

NOTE 1: Values given are averages for the cable types and range of conductor sizes considered in Tables 4D1A to 4J3A. The spread of values is generally less than 5 %.

NOTE 2: Factors apply to single layer groups of cables (or trefoil groups) as shown above and do not apply when cables are installed in more than one layer touching each other. Values for such installations may be significantly lower and must be determined by an appropriate method.

NOTE 3: Values are given for vertical spacing between cable trays of 300 mm and at least 20 mm between cable trays and wall. For closer spacing the factors should be reduced.

NOTE 4: Values are given for horizontal spacing between cable trays of 225 mm with cable trays mounted back-to-back. For closer spacing the factors should be reduced.

NOTE 5: For circuits having more than one cable in parallel per phase, each three-phase set of conductors is to be considered as a circuit for the purpose of this table.

TABLE 4C6 – Rating factors for cables enclosed in floor concrete troughs (Installation Methods 118 to 120 of Table 4A2)

The rating factors tabulated below relate to the disposition of cables illustrated in items 118 to120 of Table 4A2 and are applicable to the current-carrying capacities for Reference Methods E and F as given in the relevant tables of this appendix.

Conductor cross-sectional area	Rating factor									
	Installation method 118				Installation method 119			Installation method 120		
	2 single-core cables, or 1 three- or four-core cables	3 single-core cables, or 2 two-core cables	4 single-core cables, or 2 three- or four-core cables	6 single-core cables, 4 two-core cables, or 3 three- or four-core cables	6 single-core cables, 4 two-core cables, or 3 three- or four-core cables	8 single-core cables, or 4 three- or four-core cables	12 single-core cables, 8 two-core cables, or 6 three- or four-core cables	12 single-core cables, 8 two-core cables, or 6 three- or four-core cables	18 single-core cables, 12 two-core cables, or 9 three- or four-core cables	24 single-core cables, 16 two-core cables, or 12 three- or four-core cables
1	2	3	4	5	6	7	8	9	10	11
(mm²)										
4	0.93	0.90	0.87	0.82	0.86	0.83	0.76	0.81	0.74	0.69
6	0.92	0.89	0.86	0.81	0.86	0.82	0.75	0.80	0.73	0.68
10	0.91	0.88	0.85	0.80	0.85	0.80	0.74	0.78	0.72	0.66
16	0.91	0.87	0.84	0.78	0.83	0.78	0.71	0.76	0.70	0.64
25	0.90	0.86	0.82	0.76	0.81	0.76	0.69	0.74	0.67	0.62
35	0.89	0.85	0.81	0.75	0.80	0.74	0.68	0.72	0.66	0.60
50	0.88	0.84	0.79	0.74	0.78	0.73	0.66	0.71	0.64	0.59
70	0.87	0.82	0.78	0.72	0.77	0.72	0.64	0.70	0.62	0.57
95	0.86	0.81	0.76	0.70	0.75	0.70	0.63	0.68	0.60	0.55
120	0.85	0.80	0.75	0.69	0.73	0.68	0.61	0.66	0.58	0.53
150	0.84	0.78	0.74	0.67	0.72	0.67	0.59	0.64	0.57	0.51
185	0.83	0.77	0.73	0.65	0.70	0.65	0.58	0.63	0.55	0.49
240	0.82	0.76	0.71	0.63	0.69	0.63	0.56	0.61	0.53	0.48
300	0.81	0.74	0.69	0.62	0.68	0.62	0.54	0.59	0.52	0.46
400	0.80	0.73	0.67	0.59	0.66	0.60	0.52	0.57	0.50	0.44
500	0.78	0.72	0.66	0.58	0.64	0.58	0.51	0.56	0.48	0.43
630	0.77	0.71	0.65	0.56	0.63	0.57	0.49	0.54	0.47	0.41

NOTES:

1. The factors in Table 4C6 are applicable to groups of cables all of one size. The value of current derived from application of the appropriate factors is the maximum current to be carried by any of the cables in the group.
2. If, due to known operating conditions, a cable is expected to carry not more than 30 % of its *grouped* rating, it may be ignored for the purpose of obtaining the rating factor for the rest of the group. |
3. Where cables having different conductor operating temperatures are grouped together the current rating should be based on the lowest operating temperature of any cable in the group.
4. When the number of cables used differs from those stated in the table, the rating factor for the next higher stated number of cables should be used.

COPPER CONDUCTORS

TABLE 4D1A – Single-core 70 °C thermoplastic insulated cables, non-armoured, with or without sheath (COPPER CONDUCTORS)

Ambient temperature: 30 °C
Conductor operating temperature: 70 °C

CURRENT-CARRYING CAPACITY (amperes):

Conductor cross-sectional area	Reference Method A (enclosed in conduit in thermally insulating wall etc.)		Reference Method B (enclosed in conduit on a wall or in trunking etc.)		Reference Method C (clipped direct)		Reference Method F (in free air or on a perforated cable tray horizontal or vertical)				
							Touching			Spaced by one diameter	
	2 cables, single-phase AC or DC	3 or 4 cables, three-phase AC	2 cables, single-phase AC or DC	3 or 4 cables, three-phase AC	2 cables, single-phase AC or DC flat and touching	3 or 4 cables, three-phase AC flat and touching or trefoil	2 cables, single-phase AC or DC flat	3 cables, three-phase AC flat	3 cables, three-phase AC trefoil	2 cables, single-phase AC or DC or 3 cables three-phase AC flat	
										Horizontal	Vertical
1	2	3	4	5	6	7	8	9	10	11	12
(mm²)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)
1	11	10.5	13.5	12	15.5	14	-	-	-	-	-
1.5	14.5	13.5	17.5	15.5	20	18	-	-	-	-	-
2.5	20	18	24	21	27	25	-	-	-	-	-
4	26	24	32	28	37	33	-	-	-	-	-
6	34	31	41	36	47	43	-	-	-	-	-
10	46	42	57	50	65	59	-	-	-	-	-
16	61	56	76	68	87	79	-	-	-	-	-
25	80	73	101	89	114	104	131	114	110	146	130
35	99	89	125	110	141	129	162	143	137	181	162
50	119	108	151	134	182	167	196	174	167	219	197
70	151	136	192	171	234	214	251	225	216	281	254
95	182	164	232	207	284	261	304	275	264	341	311
120	210	188	269	239	330	303	352	321	308	396	362
150	240	216	300	262	381	349	406	372	356	456	419
185	273	245	341	296	436	400	463	427	409	521	480
240	321	286	400	346	515	472	546	507	485	615	569
300	367	328	458	394	594	545	629	587	561	709	659
400	-	-	546	467	694	634	754	689	656	852	795
500	-	-	626	533	792	723	868	789	749	982	920
630	-	-	720	611	904	826	1005	905	855	1138	1070
800	-	-	-	-	1030	943	1086	1020	971	1265	1188
1000	-	-	-	-	1154	1058	1216	1149	1079	1420	1337

NOTE:

For cables having flexible conductors, see section 2.4 of this Appendix for adjustment factors for current-carrying capacity and voltage drop.

TABLE 4D1B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 70 °C

Conductor cross-sectional area	2 cables, DC	2 cables, single-phase AC									3 or 4 cables, three-phase AC											
		Reference Methods A & B (enclosed in conduit or trunking)			Reference Methods C & F (clipped direct, on tray or in free air)						Reference Methods A & B (enclosed in conduit or trunking)			Reference Methods C & F (clipped direct, on tray or in free air)								
					Cables touching			Cables spaced*						Cables touching, Trefoil			Cables touching, Flat			Cables spaced*, Flat		
1	2	3			4			5			6			7			8			9		
(mm^2)	(mV/A/m)	(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)		
1	44	44			44			44			38			38			38			38		
1.5	29	29			29			29			25			25			25			25		
2.5	18	18			18			18			15			15			15			15		
4	11	11			11			11			9.5			9.5			9.5			9.5		
6	7.3	7.3			7.3			7.3			6.4			6.4			6.4			6.4		
10	4.4	4.4			4.4			4.4			3.8			3.8			3.8			3.8		
16	2.8	2.8			2.8			2.8			2.4			2.4			2.4			2.4		
		r	x	z	r	x	z	r	x	z	r	x	z	r	x	z	r	x	z	r	x	z
25	1.75	1.80	0.33	1.80	1.75	0.20	1.75	1.75	0.29	1.80	1.50	0.29	1.55	1.50	0.175	1.50	1.50	0.25	1.55	1.50	0.32	1.55
35	1.25	1.30	0.31	1.30	1.25	0.195	1.25	1.25	0.28	1.30	1.10	0.27	1.10	1.10	0.170	1.10	1.10	0.24	1.10	1.10	0.32	1.15
50	0.93	0.95	0.30	1.00	0.93	0.190	0.95	0.93	0.28	0.97	0.81	0.26	0.85	0.80	0.165	0.82	0.80	0.24	0.84	0.80	0.32	0.86
70	0.63	0.65	0.29	0.72	0.63	0.185	0.66	0.63	0.27	0.69	0.56	0.25	0.61	0.55	0.160	0.57	0.55	0.24	0.60	0.55	0.31	0.63
95	0.46	0.49	0.28	0.56	0.47	0.180	0.50	0.47	0.27	0.54	0.42	0.24	0.48	0.41	0.155	0.43	0.41	0.23	0.47	0.40	0.31	0.51
120	0.36	0.39	0.27	0.47	0.37	0.175	0.41	0.37	0.26	0.45	0.33	0.23	0.41	0.32	0.150	0.36	0.32	0.23	0.40	0.32	0.30	0.44
150	0.29	0.31	0.27	0.41	0.30	0.175	0.34	0.29	0.26	0.39	0.27	0.23	0.36	0.26	0.150	0.30	0.26	0.23	0.34	0.26	0.30	0.40
185	0.23	0.25	0.27	0.37	0.24	0.170	0.29	0.24	0.26	0.35	0.22	0.23	0.32	0.21	0.145	0.26	0.21	0.22	0.31	0.21	0.30	0.36
240	0.180	0.195	0.26	0.33	0.185	0.165	0.25	0.185	0.25	0.31	0.17	0.23	0.29	0.160	0.145	0.22	0.160	0.22	0.27	0.160	0.29	0.34
300	0.145	0.160	0.26	0.31	0.150	0.165	0.22	0.150	0.25	0.29	0.14	0.23	0.27	0.130	0.140	0.190	0.130	0.22	0.25	0.130	0.29	0.32
400	0.105	0.130	0.26	0.29	0.120	0.160	0.20	0.115	0.25	0.27	0.12	0.22	0.25	0.105	0.140	0.175	0.105	0.21	0.24	0.100	0.29	0.31
500	0.086	0.110	0.26	0.28	0.098	0.155	0.185	0.093	0.24	0.26	0.10	0.22	0.25	0.086	0.135	0.160	0.086	0.21	0.23	0.081	0.29	0.30
630	0.068	0.094	0.25	0.27	0.081	0.155	0.175	0.076	0.24	0.25	0.08	0.22	0.24	0.072	0.135	0.150	0.072	0.21	0.22	0.066	0.28	0.29
800	0.053		-		0.068	0.150	0.165	0.061	0.24	0.25		-		0.060	0.130	0.145	0.060	0.21	0.22	0.053	0.28	0.29
1000	0.042		-		0.059	0.150	0.160	0.050	0.24	0.24		-		0.052	0.130	0.140	0.052	0.20	0.21	0.044	0.28	0.28

NOTE: * Spacings larger than one cable diameter will result in a larger voltage drop.

TABLE 4D2A – Multicore 70 °C thermoplastic insulated and thermoplastic sheathed cables, non-armoured (COPPER CONDUCTORS)

Ambient temperature: 30 °C

CURRENT-CARRYING CAPACITY (amperes): Conductor operating temperature: 70 °C

Conductor cross-sectional area	Reference Method A (enclosed in conduit in thermally insulating wall etc.)		Reference Method B (enclosed in conduit on a wall or in trunking etc.)		Reference Method C (clipped direct)		Reference Method E (in free air or on a perforated cable tray etc, horizontal or vertical)	
	1 two-core cable*, single-phase AC or DC	1 three-core cable* or 1 four-core cable, three-phase AC	1 two-core cable*, single-phase AC or DC	1 three-core cable* or 1 four-core cable, three-phase AC	1 two-core cable*, single-phase AC or DC	1 three-core cable* or 1 four-core cable, three-phase AC	1 two-core cable*, single-phase AC or DC	1 three-core cable* or 1 four-core cable, three-phase AC
1	2	3	4	5	6	7	8	9
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)
1	11	10	13	11.5	15	13.5	17	14.5
1.5	14	13	16.5	15	19.5	17.5	22	18.5
2.5	18.5	17.5	23	20	27	24	30	25
4	25	23	30	27	36	32	40	34
6	32	29	38	34	46	41	51	43
10	43	39	52	46	63	57	70	60
16	57	52	69	62	85	76	94	80
25	75	68	90	80	112	96	119	101
35	92	83	111	99	138	119	148	126
50	110	99	133	118	168	144	180	153
70	139	125	168	149	213	184	232	196
95	167	150	201	179	258	223	282	238
120	192	172	232	206	299	259	328	276
150	219	196	258	225	344	299	379	319
185	248	223	294	255	392	341	434	364
240	291	261	344	297	461	403	514	430
300	334	298	394	339	530	464	593	497
400	-	-	470	402	634	557	715	597

* with or without a protective conductor

NOTE:
For cables having flexible conductors, see section 2.4 of this Appendix for adjustment factors for current-carrying capacity and voltage drop.

TABLE 4D2B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 70 °C

Conductor cross-sectional area 1	Two-core cable, DC 2	Two-core cable, single-phase AC 3			Three- or four-core cable, three-phase AC 4		
(mm²)	(mV/A/m)	(mV/A/m)			(mV/A/m)		
1	44	44			38		
1.5	29	29			25		
2.5	18	18			15		
4	11	11			9.5		
6	7.3	7.3			6.4		
10	4.4	4.4			3.8		
16	2.8	2.8			2.4		
		r	x	z	r	x	z
25	1.75	1.75	0.170	1.75	1.50	0.145	1.50
35	1.25	1.25	0.165	1.25	1.10	0.145	1.10
50	0.93	0.93	0.165	0.94	0.80	0.140	0.81
70	0.63	0.63	0.160	0.65	0.55	0.140	0.57
95	0.46	0.47	0.155	0.50	0.41	0.135	0.43
120	0.36	0.38	0.155	0.41	0.33	0.135	0.35
150	0.29	0.30	0.155	0.34	0.26	0.130	0.29
185	0.23	0.25	0.150	0.29	0.21	0.130	0.25
240	0.180	0.190	0.150	0.24	0.165	0.130	0.21
300	0.145	0.155	0.145	0.21	0.135	0.130	0.185
400	0.105	0.115	0.145	0.185	0.100	0.125	0.160

TABLE 4D3A – Single-core armoured 70 °C thermoplastic insulated cables (non-magnetic armour) (COPPER CONDUCTORS)

Ambient temperature: 30 °C

CURRENT-CARRYING CAPACITY (amperes): Conductor operating temperature: 70 °C

Conductor cross-sectional area	Reference Method C (clipped direct)		Reference Method F (in free air or on a perforated cable tray, horizontal or vertical)								
	Touching		Touching			Spaced by one cable diameter					
	2 cables, single-phase AC or DC flat	3 or 4 cables, three-phase AC flat	2 cables, single-phase AC or DC flat	3 cables, three-phase AC flat	3 cables, three-phase AC trefoil	2 cables, DC		2 cables, single-phase AC		3 or 4 cables, three-phase AC	
						Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
1	2	3	4	5	6	7	8	9	10	11	12
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)
50	193	179	205	189	181	229	216	229	217	230	212
70	245	225	259	238	231	294	279	287	272	286	263
95	296	269	313	285	280	357	340	349	332	338	313
120	342	309	360	327	324	415	396	401	383	385	357
150	393	352	413	373	373	479	458	449	429	436	405
185	447	399	469	422	425	548	525	511	489	490	456
240	525	465	550	492	501	648	622	593	568	566	528
300	594	515	624	547	567	748	719	668	640	616	578
400	687	575	723	618	657	885	851	737	707	674	632
500	763	622	805	673	731	1035	997	810	777	721	676
630	843	669	891	728	809	1218	1174	893	856	771	723
800	919	710	976	777	886	1441	1390	943	905	824	772
1000	975	737	1041	808	945	1685	1627	1008	967	872	816

TABLE 4D3B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 70 °C

Conductor cross-sectional area	2 cables, DC	Reference Methods C & F (clipped direct, on tray or free air)														
		2 cables, single-phase AC						3 or 4 cables, three-phase AC								
		touching			spaced*			trefoil and touching			flat and touching			flat and spaced*		
1	2	3			4			5			6			7		
(mm²)	(mV/A/m)	(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)		
		r	x	z	r	x	z	r	x	z	r	x	z	r	x	z
50	0.93	0.93	0.22	0.95	0.92	0.30	0.97	0.80	0.190	0.82	0.79	0.26	0.84	0.79	0.34	0.86
70	0.63	0.64	0.21	0.68	0.66	0.29	0.72	0.56	0.180	0.58	0.57	0.25	0.62	0.59	0.32	0.68
95	0.46	0.48	0.20	0.52	0.51	0.28	0.58	0.42	0.175	0.45	0.44	0.25	0.50	0.47	0.31	0.57
120	0.36	0.39	0.195	0.43	0.42	0.28	0.50	0.33	0.170	0.37	0.36	0.24	0.43	0.40	0.30	0.50
150	0.29	0.31	0.190	0.37	0.34	0.27	0.44	0.27	0.165	0.32	0.30	0.24	0.38	0.34	0.30	0.45
185	0.23	0.26	0.190	0.32	0.29	0.27	0.39	0.22	0.160	0.27	0.25	0.23	0.34	0.29	0.29	0.41
240	0.180	0.20	0.180	0.27	0.23	0.26	0.35	0.175	0.160	0.23	0.20	0.23	0.30	0.24	0.28	0.37
300	0.145	0.160	0.180	0.24	0.190	0.26	0.32	0.140	0.155	0.21	0.165	0.22	0.28	0.20	0.28	0.34
400	0.105	0.140	0.175	0.22	0.180	0.24	0.30	0.120	0.130	0.195	0.160	0.21	0.26	0.21	0.25	0.32
500	0.086	0.120	0.170	0.21	0.165	0.23	0.29	0.105	0.145	0.180	0.145	0.20	0.25	0.190	0.24	0.30
630	0.068	0.105	0.165	0.195	0.150	0.22	0.27	0.091	0.145	0.170	0.135	0.195	0.23	0.175	0.22	0.28
800	0.053	0.095	0.160	0.185	0.145	0.21	0.25	0.082	0.140	0.160	0.125	0.180	0.22	0.170	0.195	0.26
1000	0.042	0.091	0.155	0.180	0.140	0.190	0.24	0.079	0.135	0.155	0.125	0.165	0.21	0.165	0.170	0.24

NOTE: * Spacings larger than one cable diameter will result in a larger voltage drop.

TABLE 4D4A – Multicore armoured 70 °C thermoplastic insulated cables (COPPER CONDUCTORS)

Ambient temperature: 30 °C
Ground ambient temperature: 20 °C
Conductor operating temperature: 70 °C

CURRENT-CARRYING CAPACITY (amperes):

Conductor cross-sectional area	Reference Method C (clipped direct)		Reference Method E (in free air or on a perforated cable tray etc, horizontal or vertical)		Reference Method D (direct in ground or in ducting in ground, in or around buildings)	
	1 two-core cable, single-phase AC or DC	1 three- or four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or four-core cable, three-phase AC
1	2	3	4	5	6	7
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)
1.5	21	18	22	19	22	18
2.5	28	25	31	26	29	24
4	38	33	41	35	37	30
6	49	42	53	45	46	38
10	67	58	72	62	60	50
16	89	77	97	83	78	64
25	118	102	128	110	99	82
35	145	125	157	135	119	98
50	175	151	190	163	140	116
70	222	192	241	207	173	143
95	269	231	291	251	204	169
120	310	267	336	290	231	192
150	356	306	386	332	261	217
185	405	348	439	378	292	243
240	476	409	516	445	336	280
300	547	469	592	510	379	316
400	621	540	683	590	-	-

TABLE 4D4B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 70 °C

Conductor cross-sectional area 1	Two-core cable, DC 2	Two-core cable, single-phase AC 3			Three- or four-core cable, three-phase AC 4		
(mm^2)	(mV/A/m)	(mV/A/m)			(mV/A/m)		
1.5	29	29			25		
2.5	18	18			15		
4	11	11			9.5		
6	7.3	7.3			6.4		
10	4.4	4.4			3.8		
16	2.8	2.8			2.4		
		r	x	z	r	x	z
25	1.75	1.75	0.170	1.75	1.50	0.145	1.50
35	1.25	1.25	0.165	1.25	1.10	0.145	1.10
50	0.93	0.93	0.165	0.94	0.80	0.140	0.81
70	0.63	0.63	0.160	0.65	0.55	0.140	0.57
95	0.46	0.47	0.155	0.50	0.41	0.135	0.43
120	0.36	0.38	0.155	0.41	0.33	0.135	0.35
150	0.29	0.30	0.155	0.34	0.26	0.130	0.29
185	0.23	0.25	0.150	0.29	0.21	0.130	0.25
240	0.180	0.190	0.150	0.24	0.165	0.130	0.21
300	0.145	0.155	0.145	0.21	0.135	0.130	0.185
400	0.105	0.115	0.145	0.185	0.100	0.125	0.160

TABLE 4D5 – 70 °C thermoplastic insulated and sheathed flat cable with protective conductor (COPPER CONDUCTORS)

COPPER CONDUCTORS

Ambient temperature: 30 °C
Conductor operating temperature: 70 °C

CURRENT-CARRYING CAPACITY (amperes) and VOLTAGE DROP (per ampere per metre):

Conductor cross-sectional area	Method 100# (above a plasterboard ceiling covered by thermal insulation not exceeding 100 mm in thickness)	Method 101# (above a plasterboard ceiling covered by thermal insulation exceeding 100 mm in thickness)	Method 102# (in a stud wall with thermal insulation with cable touching the inner wall surface)	Method 103# (in a stud wall with thermal insulation with cable not touching the inner wall surface)	Reference Method C* (clipped direct)	Reference Method A* (enclosed in conduit in an insulated wall)	Voltage drop (per ampere per metre)
1	2	3	4	5	6	7	8
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)	(mV/A/m)
1	13	10.5	13	8	16	11.5	44
1.5	16	13	16	10	20	14.5	29
2.5	21	17	21	13.5	27	20	18
4	27	22	27	18.5	37	26	11
6	34	27	35	23.5	47	32	7.3
10	45	36	47	32	64	44	4.4
16	57	46	63	42.5	85	57	2.8

A* For full installation method refer to Table 4A2 Installation Method 2 but for flat twin and earth cable

C* For full installation method refer to Table 4A2 Installation Method 20 but for flat twin and earth cable

100# For full installation method refer to Table 4A2 Installation Method 100

101# For full installation method refer to Table 4A2 Installation Method 101

102# For full installation method refer to Table 4A2 Installation Method 102

103# For full installation method refer to Table 4A2 Installation Method 103

Wherever practicable, a cable is to be fixed in a position such that it will not be covered with thermal insulation.

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COPPER CONDUCTORS

TABLE 4E1A – Single-core 90 °C thermosetting insulated cables, non-armoured, with or without sheath (COPPER CONDUCTORS)

Ambient temperature: 30 °C

CURRENT-CARRYING CAPACITY (amperes):

Conductor operating temperature: 90 °C

Conductor cross-sectional area	Reference Method A (enclosed in conduit in thermally insulating wall etc.)		Reference Method B (enclosed in conduit on a wall or in trunking etc.)		Reference Method C (clipped direct)		Reference Method F (in free air or on a perforated cable tray etc horizontal or vertical etc) Touching			Reference Method G (in free air) Spaced by one cable diameter	
	2 cables, single-phase AC or DC	3 or 4 cables, three-phase AC	2 cables, single-phase AC or DC	3 or 4 cables, three-phase AC	2 cables, single-phase AC or DC flat and touching	3 or 4 cables, three-phase AC flat and touching or trefoil	2 cables, single-phase AC or DC flat	3 cables, three-phase AC flat	3 cables, three-phase AC trefoil	2 cables, single-phase AC or DC or 3 cables three-phase AC flat: Horizontal	2 cables, single-phase AC or DC or 3 cables three-phase AC flat: Vertical
1	2	3	4	5	6	7	8	9	10	11	12
(mm²)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)
1	14	13	17	15	19	17.5	-	-	-	-	-
1.5	19	17	23	20	25	23	-	-	-	-	-
2.5	26	23	31	28	34	31	-	-	-	-	-
4	35	31	42	37	46	41	-	-	-	-	-
6	45	40	54	48	59	54	-	-	-	-	-
10	61	54	75	66	81	74	-	-	-	-	-
16	81	73	100	88	109	99	-	-	-	-	-
25	106	95	133	117	143	130	161	141	135	182	161
35	131	117	164	144	176	161	200	176	169	226	201
50	158	141	198	175	228	209	242	216	207	275	246
70	200	179	253	222	293	268	310	279	268	353	318
95	241	216	306	269	355	326	377	342	328	430	389
120	278	249	354	312	413	379	437	400	383	500	454
150	318	285	393	342	476	436	504	464	444	577	527
185	362	324	449	384	545	500	575	533	510	661	605
240	424	380	528	450	644	590	679	634	607	781	719
300	486	435	603	514	743	681	783	736	703	902	833
400	-	-	683	584	868	793	940	868	823	1085	1008
500	-	-	783	666	990	904	1083	998	946	1253	1169
630	-	-	900	764	1130	1033	1254	1151	1088	1454	60269
800	-	-	-	-	1288	1179	1358	1275	1214	1581	1485
1000	-	-	-	-	1443	1323	1520	1436	1349	1775	1671

NOTES:

1. Where it is intended to connect the cables in this table to equipment or accessories designed to operate at a temperature lower than the maximum operating temperature of the cable, the cables should be rated at the maximum operating temperature of the equipment or accessory (see Section 512.1.5).
2. Where it is intended to group a cable in this table with other cables, the cable should be rated at the lowest of the maximum operating temperatures of any of the cables in the group (see Section 512.1.5).
3. For cables having flexible conductors see section 2.4 of this appendix for adjustment factors for current-carrying capacity and voltage drop.

TABLE 4E1B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 90°C

Conductor cross-sectional area	2 cables, DC	2 cables, single-phase AC									3 or 4 cables, three-phase AC											
		Reference Methods A & B (enclosed in conduit or trunking)			References Methods C, F & G (clipped direct, on tray or in free air)						Reference Methods A & B (enclosed in conduit or trunking)			Reference Methods C, F & G (clipped direct, on tray or in free air)								
					Cables touching			Cables spaced*						Cables touching, Trefoil			Cables touching, Flat			Cables spaced*, Flat		
1	2	3			4			5			6			7			8			9		
(mm²)	(mV/A/m)	(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)		
1	46		46			46			46			40			40			40			40	
1.5	31		31			31			31			27			27			27			27	
2.5	19		19			19			19			16			16			16			16	
4	12		12			12			12			10			10			10			10	
6	7.9		7.9			7.9			7.9			6.8			6.8			6.8			6.8	
10	4.7		4.7			4.7			4.7			4.0			4.0			4.0			4.0	
16	2.9		2.9			2.9			2.9			2.5			2.5			2.5			2.5	
		r	x	z	r	x	z	r	x	z	r	x	z	r	x	z	r	x	z	r	x	z
25	1.85	1.85	0.31	1.90	1.85	0.190	1.85	1.85	0.28	1.85	1.60	0.27	1.65	1.60	0.165	1.60	1.60	0.190	1.60	1.60	0.27	1.65
35	1.35	1.35	0.29	1.35	1.35	0.180	1.35	1.35	0.27	1.35	1.15	0.25	1.15	1.15	0.155	1.15	1.15	0.180	1.15	1.15	0.26	1.20
50	0.99	1.00	0.29	1.05	0.99	0.180	1.00	0.99	0.27	1.00	0.87	0.25	0.90	0.86	0.155	0.87	0.86	0.180	0.87	0.86	0.26	0.89
70	0.68	0.70	0.28	0.75	0.68	0.175	0.71	0.68	0.26	0.73	0.60	0.24	0.65	0.59	0.150	0.61	0.59	0.175	0.62	0.59	0.25	0.65
95	0.49	0.51	0.27	0.58	0.49	0.170	0.52	0.49	0.26	0.56	0.44	0.23	0.50	0.43	0.145	0.45	0.43	0.170	0.46	0.43	0.25	0.49
120	0.39	0.41	0.26	0.48	0.39	0.165	0.43	0.39	0.25	0.47	0.35	0.23	0.42	0.34	0.140	0.37	0.34	0.165	0.38	0.34	0.24	0.42
150	0.32	0.33	0.26	0.43	0.32	0.165	0.36	0.32	0.25	0.41	0.29	0.23	0.37	0.28	0.140	0.31	0.28	0.165	0.32	0.28	0.24	0.37
185	0.25	0.27	0.26	0.37	0.26	0.165	0.30	0.25	0.25	0.36	0.23	0.23	0.32	0.22	0.140	0.26	0.22	0.165	0.28	0.22	0.24	0.33
240	0.190	0.21	0.26	0.33	0.20	0.160	0.25	0.195	0.25	0.31	0.185	0.22	0.29	0.170	0.140	0.22	0.170	0.165	0.24	0.170	0.24	0.29
300	0.155	0.175	0.25	0.31	0.160	0.160	0.22	0.155	0.25	0.29	0.150	0.22	0.27	0.140	0.140	0.195	0.135	0.160	0.21	0.135	0.24	0.27
400	0.120	0.140	0.25	0.29	0.130	0.155	0.20	0.125	0.24	0.27	0.125	0.22	0.25	0.110	0.135	0.175	0.110	0.160	0.195	0.110	0.24	0.26
500	0.093	0.120	0.25	0.28	0.105	0.155	0.185	0.098	0.24	0.26	0.100	0.22	0.24	0.090	0.135	0.160	0.088	0.160	0.180	0.085	0.24	0.25
630	0.072	0.100	0.25	0.27	0.086	0.155	0.175	0.078	0.24	0.25	0.088	0.21	0.23	0.074	0.135	0.150	0.071	0.160	0.170	0.068	0.23	0.24
800	0.056		-		0.072	0.150	0.170	0.064	0.24	0.25		-		0.062	0.130	0.145	0.059	0.155	0.165	0.055	0.23	0.24
1000	0.045		-		0.063	0.150	0.165	0.054	0.24	0.24		-		0.055	0.130	0.140	0.050	0.155	0.165	0.047	0.23	0.24

NOTE: * Spacings larger than one cable diameter will result in a larger voltage drop.

TABLE 4E2A – Multicore 90 °C thermosetting insulated and thermoplastic sheathed cables, non-armoured (COPPER CONDUCTORS)

Ambient temperature: 30 °C
Conductor operating temperature: 90 °C

CURRENT-CARRYING CAPACITY (amperes):

Conductor cross-sectional area	Reference Method A (enclosed in conduit in thermally insulating wall etc.)		Reference Method B (enclosed in conduit on a wall or in trunking etc.)		Reference Method C (clipped direct)		Reference Method E (free air or on a perforated cable tray etc, horizontal or vertical)	
	1 two-core cable*, single-phase AC or DC	1 three- or four-core cable*, three-phase AC	1 two-core cable*, single-phase AC or DC	1 three- or four-core cable*, three-phase AC	1 two-core cable*, single-phase AC or DC	1 three- or four-core cable*, three-phase AC	1 two-core cable*, single-phase AC or DC	1 three- or four-core cable*, three-phase AC
1	2	3	4	5	6	7	8	9
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)
1	14.5	13	17	15	19	17	21	18
1.5	18.5	16.5	22	19.5	24	22	26	23
2.5	25	22	30	26	33	30	36	32
4	33	30	40	35	45	40	49	42
6	42	38	51	44	58	52	63	54
10	57	51	69	60	80	71	86	75
16	76	68	91	80	107	96	115	100
25	99	89	119	105	138	119	149	127
35	121	109	146	128	171	147	185	158
50	145	130	175	154	209	179	225	192
70	183	164	221	194	269	229	289	246
95	220	197	265	233	328	278	352	298
120	253	227	305	268	382	322	410	346
150	290	259	334	300	441	371	473	399
185	329	295	384	340	506	424	542	456
240	386	346	459	398	599	500	641	538
300	442	396	532	455	693	576	741	621
400	-	-	625	536	803	667	865	741

* with or without a protective conductor

NOTES:

1. Where it is intended to connect the cables in this table to equipment or accessories designed to operate at a temperature lower than the maximum operating temperature of the cable, the cables should be rated at the maximum operating temperature of the equipment or accessory (see Section 512.1.5).
2. Where it is intended to group a cable in this table with other cables, the cable should be rated at the lowest of the maximum operating temperatures of any of the cables in the group (see Section 512.1.5).
3. For cables having flexible conductors see section 2.4 of this appendix for adjustment factors for current-carrying capacity and voltage drop.

TABLE 4E2B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 90 °C

Conductor cross-sectional area	Two-core cable, DC	Two-core cable, single-phase AC			Three- or four-core cable, three-phase AC		
1	2	3			4		
(mm²)	(mV/A/m)	(mV/A/m)			(mV/A/m)		
1	46	46			40		
1.5	31	31			27		
2.5	19	19			16		
4	12	12			10		
6	7.9	7.9			6.8		
10	4.7	4.7			4.0		
16	2.9	2.9			2.5		
		r	x	z	r	x	z
25	1.85	1.85	0.160	1.90	1.60	0.140	1.65
35	1.35	1.35	0.155	1.35	1.15	0.135	1.15
50	0.98	0.99	0.155	1.00	0.86	0.135	0.87
70	0.67	0.67	0.150	0.69	0.59	0.130	0.60
95	0.49	0.50	0.150	0.52	0.43	0.130	0.45
120	0.39	0.40	0.145	0.42	0.34	0.130	0.37
150	0.31	0.32	0.145	0.35	0.28	0.125	0.30
185	0.25	0.26	0.145	0.29	0.22	0.125	0.26
240	0.195	0.200	0.140	0.24	0.175	0.125	0.21
300	0.155	0.160	0.140	0.21	0.140	0.120	0.185
400	0.120	0.130	0.140	0.190	0.115	0.120	0.165

TABLE 4E3A – Single-core armoured 90 °C thermosetting insulated cables (non-magnetic armour) (COPPER CONDUCTORS)

Ambient temperature: 30 °C

CURRENT-CARRYING CAPACITY (amperes): Conductor operating temperature: 90 °C

Conductor cross-sectional area	Reference Method C (clipped direct)		Reference Method F (in free air or on a perforated cable tray, horizontal or vertical)								
	Touching		Touching			Spaced by one cable diameter					
	2 cables, single-phase AC or DC flat	3 or 4 cables, three-phase AC flat	2 cables, single-phase AC or DC flat	3 cables, three-phase AC flat	3 cables, three-phase AC trefoil	2 cables, DC		2 cables, single-phase AC		3 or 4 cables, three-phase AC	
						Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
1	2	3	4	5	6	7	8	9	10	11	12
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)
50	237	220	253	232	222	284	270	282	266	288	266
70	303	277	322	293	285	356	349	357	337	358	331
95	367	333	389	352	346	446	426	436	412	425	393
120	425	383	449	405	402	519	497	504	477	485	449
150	488	437	516	462	463	600	575	566	539	549	510
185	557	496	587	524	529	688	660	643	614	618	574
240	656	579	689	612	625	815	782	749	714	715	666
300	755	662	792	700	720	943	906	842	805	810	755
400	853	717	899	767	815	1137	1094	929	889	848	797
500	962	791	1016	851	918	1314	1266	1032	989	923	871
630	1082	861	1146	935	1027	1528	1474	1139	1092	992	940
800	1170	904	1246	987	1119	1809	1744	1204	1155	1042	978
1000	1261	961	1345	1055	1214	2100	2026	1289	1238	1110	1041

NOTES:

1. Where it is intended to connect the cables in this table to equipment or accessories designed to operate at a temperature lower than the maximum operating temperature of the cable, the cables should be rated at the maximum operating temperature of the equipment or accessory (see Section 512.1.5).
2. Where it is intended to group a cable in this table with other cables, the cable should be rated at the lowest of the maximum operating temperatures of any of the cables in the group (see Section 512.1.5).

TABLE 4E3B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 90 °C

Conductor cross-sectional area	2 cables, DC	Reference Methods C & F (clipped direct, on tray or in free air)														
		2 cables, single-phase AC						3 or 4 cables, three-phase AC								
		touching			spaced*			trefoil and touching			flat and touching			flat and spaced*		
1	2	3			4			5			6			7		
(mm^2)	(mV/A/m)	(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)		
		r	x	z	r	x	z	r	x	z	r	x	z	r	x	z
50	0.98	0.99	0.21	1.00	0.98	0.29	1.00	0.86	0.180	0.87	0.84	0.25	0.88	0.84	0.33	0.90
70	0.67	0.68	0.200	0.71	0.69	0.29	0.75	0.59	0.170	0.62	0.60	0.25	0.65	0.62	0.32	0.70
95	0.49	0.51	0.195	0.55	0.53	0.28	0.60	0.44	0.170	0.47	0.46	0.24	0.52	0.49	0.31	0.58
120	0.39	0.41	0.190	0.45	0.43	0.27	0.51	0.35	0.165	0.39	0.38	0.24	0.44	0.41	0.30	0.51
150	0.31	0.33	0.185	0.38	0.36	0.27	0.45	0.29	0.160	0.33	0.31	0.23	0.39	0.34	0.29	0.45
185	0.25	0.27	0.185	0.33	0.30	0.26	0.40	0.23	0.160	0.28	0.26	0.23	0.34	0.29	0.29	0.41
240	0.195	0.21	0.180	0.28	0.24	0.26	0.35	0.180	0.155	0.24	0.21	0.22	0.30	0.24	0.28	0.37
300	0.155	0.170	0.175	0.25	0.195	0.25	0.32	0.145	0.150	0.21	0.170	0.22	0.28	0.20	0.27	0.34
400	0.115	0.145	0.170	0.22	0.180	0.24	0.30	0.125	0.150	0.195	0.160	0.21	0.27	0.20	0.27	0.33
500	0.093	0.125	0.170	0.21	0.165	0.24	0.29	0.105	0.145	0.180	0.145	0.20	0.25	0.190	0.24	0.31
630	0.073	0.105	0.165	0.195	0.150	0.23	0.27	0.092	0.145	0.170	0.135	0.195	0.24	0.175	0.23	0.29
800	0.056	0.090	0.160	0.190	0.145	0.23	0.27	0.086	0.140	0.165	0.130	0.180	0.23	0.175	0.195	0.26
1000	0.045	0.092	0.155	0.180	0.140	0.21	0.25	0.080	0.135	0.155	0.125	0.170	0.21	0.165	0.180	0.24

NOTE: * Spacings larger than one cable diameter will result in a larger voltage drop.

COPPER CONDUCTORS

TABLE 4E4A – Multicore armoured 90 °C thermosetting insulated cables (COPPER CONDUCTORS)

Air ambient temperature: 30 °C
Ground ambient temperature: 20 °C
Conductor operating temperature: 90 °C

CURRENT-CARRYING CAPACITY (amperes):

Conductor cross-sectional area	Reference Method C (clipped direct)		Reference Method E (in free air or on a perforated cable tray etc, horizontal or vertical)		Reference Method D (direct in ground or in ducting in ground, in or around buildings)	
	1 two-core cable, single-phase AC or DC	1 three- or 1 four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or 1 four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or 1 four-core cable, three-phase AC
1	2	3	4	5	6	7
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)
1.5	27	23	29	25	25	21
2.5	36	31	39	33	33	28
4	49	42	52	44	43	36
6	62	53	66	56	53	44
10	85	73	90	78	71	58
16	110	94	115	99	91	75
25	146	124	152	131	116	96
35	180	154	188	162	139	115
50	219	187	228	197	164	135
70	279	238	291	251	203	167
95	338	289	354	304	239	197
120	392	335	410	353	271	223
150	451	386	472	406	306	251
185	515	441	539	463	343	281
240	607	520	636	546	395	324
300	698	599	732	628	446	365
400	787	673	847	728	-	-

NOTES:

1. Where it is intended to connect the cables in this table to equipment or accessories designed to operate at a temperature lower than the maximum operating temperature of the cable, the cables should be rated at the maximum operating temperature of the equipment or accessory (see Section 512.1.5).
2. Where it is intended to group a cable in this table with other cables, the cable should be rated at the lowest of the maximum operating temperatures of any of the cables in the group (see Section 512.1.5).

TABLE 4E4B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 90 °C

Conductor cross-sectional area	Two-core cable, DC	Two-core cable, single-phase AC			Three- or four-core cable, three-phase AC		
1	2	3			4		
(mm^2)	(mV/A/m)	(mV/A/m)			(mV/A/m)		
1.5	31	31			27		
2.5	19	19			16		
4	12	12			10		
6	7.9	7.9			6.8		
10	4.7	4.7			4.0		
16	2.9	2.9			2.5		
		r	x	z	r	x	z
25	1.85	1.85	0.160	1.90	1.60	0.140	1.65
35	1.35	1.35	0.155	1.35	1.15	0.135	1.15
50	0.98	0.99	0.155	1.00	0.86	0.135	0.87
70	0.67	0.67	0.150	0.69	0.59	0.130	0.60
95	0.49	0.50	0.150	0.52	0.43	0.130	0.45
120	0.39	0.40	0.145	0.42	0.34	0.130	0.37
150	0.31	0.32	0.145	0.35	0.28	0.125	0.30
185	0.25	0.26	0.145	0.29	0.22	0.125	0.26
240	0.195	0.20	0.140	0.24	0.175	0.125	0.21
300	0.155	0.16	0.140	0.21	0.140	0.120	0.185
400	0.120	0.13	0.140	0.190	0.115	0.120	0.165

TABLE 4F1A – 60 °C thermosetting insulated flexible cables with sheath, non-armoured (COPPER CONDUCTORS)

CURRENT-CARRYING CAPACITY (amperes): Ambient temperature: 30 °C
Conductor operating temperature: 60 °C

Conductor cross-sectional area	Single-phase AC or DC	Three-phase AC	Single-phase AC or DC
	1 two-core cable, with or without protective conductor	1 three-core, four-core or five-core cable	2 single-core cables, touching
1	2	3	4
(mm^2)	(A)	(A)	(A)
4	30	26	-
6	39	34	-
10	51	47	-
16	73	63	-
25	97	83	-
35	-	102	140
50	-	124	175
70	-	158	216
95	-	192	258
120	-	222	302
150	-	255	347
185	-	291	394
240	-	343	471
300	-	394	541
400	-	-	644
500	-	-	738
630	-	-	861

NOTES:

1. The current ratings tabulated are for cables in free air but may also be used for cables resting on a surface. If the cable is to be wound on a drum on load the ratings should be reduced in accordance with NOTE 2 below and for cables which may be covered, NOTE 3 below.

2. *Flexible cables wound on reeling drums*

   The current ratings of cables used on reeling drums are to be reduced by the following factors:

   a) Radial type drum
   - ventilated: 85 %
   - unventilated: 75 %

   b) Ventilated cylindrical type drum
   - 1 layer of cable: 85 %
   - 2 layers of cable: 65 %
   - 3 layers of cable: 45 %
   - 4 layers of cable: 35 %

   A radial type drum is one where spiral layers of cable are accommodated between closely spaced flanges; if fitted with solid flanges the ratings given above should be reduced and the drum is described as non-ventilated. If the flanges have suitable apertures the drum is described as ventilated.

   A ventilated cylindrical cable drum is one where layers of cable are accommodated between widely spaced flanges and the drum and end flanges have suitable ventilating apertures.

3. Where cable may be covered over or coiled up whilst on load, or the air movement over the cable restricted, the current rating should be reduced.

   It is not possible to specify the amount of reduction but the table of rating factors for reeling drums can be used as a guide.

TABLE 4F1B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 60 °C

Conductor cross-sectional area	Two-core cable, DC	Two-core cable, single-phase AC			1 three-core, four-core or five-core cable, three-phase AC			2 single-core cables, touching: DC	2 single-core cables, touching: Single-phase AC*		
1	2		3			4		5		6	
(mm^2)	(mV/A/m)		(mV/A/m)			(mV/A/m)		(mV/A/m)		(mV/A/m)	
4	12		12			10		-		-	
6	7.8		7.8			6.7		-		-	
10	4.6		4.6			4.0		-		-	
16	2.9		2.9			2.5		-		-	
		r	x	z	r	x	z		r	x	z
25	1.80	1.80	0.175	1.85	1.55	0.150	1.55	-	-	-	-
35	-	-	-	-	1.10	0.150	1.15	1.31	1.31	0.21	1.32
50	-	-	-	-	0.83	0.145	0.84	0.91	0.91	0.21	0.93
70	-	-	-	-	0.57	0.140	0.58	0.64	0.64	0.20	0.67
95	-	-	-	-	0.42	0.135	0.44	0.49	0.49	0.195	0.53
120	-	-	-	-	0.33	0.135	0.36	0.38	0.38	0.190	0.43
150	-	-	-	-	0.27	0.130	0.30	0.31	0.31	0.190	0.36
185	-	-	-	-	0.22	0.130	0.26	0.25	0.25	0.190	0.32
240	-	-	-	-	0.170	0.130	0.21	0.190	0.195	0.185	0.27
300	-	-	-	-	0.135	0.125	0.185	0.150	0.155	0.180	0.24
400	-	-	-	-	-	-	-	0.115	0.120	0.175	0.21
500	-	-	-	-	-	-	-	0.090	0.099	0.170	0.20
630	-	-	-	-	-	-	-	0.068	0.079	0.170	0.185

NOTE: * A larger voltage drop will result if the cables are spaced.

TABLE 4F2A – 90 °C and 180 °C thermosetting insulated flexible cables with sheath, non-armoured (COPPER CONDUCTORS)

COPPER CONDUCTORS

CURRENT-CARRYING CAPACITY (amperes): Ambient temperature: 30 °C
Conductor operating temperature: 90 °C

Conductor cross-sectional area	Single-phase AC or DC	Three-phase AC	Single-phase AC or DC
	1 two-core cable, with or without protective conductor	1 three-core, four-core or five-core cable	2 single-core cables, touching
1	2	3	4
(mm^2)	(A)	(A)	(A)
4	42	37	-
6	55	49	-
10	76	66	-
16	103	89	-
25	136	119	-
35	-	146	200
50	-	177	250
70	-	225	310
95	-	273	369
120	-	316	432
150	-	363	497
185	-	414	564
240	-	487	673
300	-	560	773
400	-	-	924
500	-	-	1062
630	-	-	1242

RATING FACTOR FOR AMBIENT TEMPERATURE

90 °C thermosetting insulated cables:

Ambient temperature	35 °C	40 °C	45 °C	50 °C	55 °C	60 °C	65 °C	70 °C	75 °C	80 °C	85 °C
Rating factor	0.95	0.91	0.86	0.82	0.76	0.70	0.64	0.57	0.50	0.40	0.28

180 °C thermosetting insulated cables:

Ambient temperature	35 to 90 °C	95 °C	100 °C	105 °C	110 °C	115 °C	120 °C	125 °C	130 °C	135 °C	140 °C	145 °C
Rating factor	1.0	0.96	0.91	0.86	0.81	0.76	0.70	0.64	0.57	0.50	0.40	0.28

NOTES:

1. The current ratings tabulated are for cables in free air but may also be used for cables resting on a surface. If the cable is to be wound on a drum on load the ratings should be reduced in accordance with NOTE 2 below and for cables which may be covered, NOTE 3 below.

2. *Flexible cables wound on reeling drums*

The current ratings of cables used on reeling drums are to be reduced by the following factors:

a) Radial type drum
- ventilated: 85 %
- unventilated: 75 %

b) Ventilated cylindrical type drum
- 1 layer of cable: 85 %
- 2 layers of cable: 65 %
- 3 layers of cable: 45 %
- 4 layers of cable: 35 %

A radial type drum is one where spiral layers of cable are accommodated between closely spaced flanges; if fitted with solid flanges the ratings given above should be reduced and the drum is described as non-ventilated. If the flanges have suitable apertures the drum is described as ventilated.

A ventilated cylindrical cable drum is one where layers of cable are accommodated between widely spaced flanges and the drum and end flanges have suitable ventilating apertures.

3. Where cable may be covered over or coiled up whilst on load, or the air movement over the cable restricted, the current rating should be reduced. It is not possible to specify the amount of reduction but the table of rating factors for reeling drums can be used as a guide.
4. For 180 °C cables, the rating factors for ambient temperature allow a conductor operating temperature up to 150 °C. Consult the cable manufacturer for further information.
5. Where it is intended to connect the cables in this table to equipment or accessories designed to operate at a temperature lower than the maximum operating temperature of the cable, the cables should be rated at the maximum operating temperature of the equipment or accessory (see Section 512.1.5).
6. Where it is intended to group a cable in this table with other cables, the cable should be rated at the lowest of the maximum operating temperatures of any of the cables in the group (see Section 512.1.5).

TABLE 4F2B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 90 °C

Conductor cross-sectional area	1 two-core or 2 single-core cables, DC	Two-core cable, single-phase AC			1 three-core, four-core or five-core cable, three-phase AC			2 single-core cables touching Single-phase AC*		
1	2	3			4			5		
(mm^2)	(mV/A/m)	(mV/A/m)			(mV/A/m)			(mV/A/m)		
4	13.2	13.2			11.1			-		
6	8.5	8.5			7.4			-		
10	5.1	5.1			4.4			-		
16	3.2	3.2			2.7			-		
		r	x	z	r	x	z	r	x	z
25	2.03	2.03	0.175	2.04	1.73	0.15	1.73	-	-	-
35	1.42	-	-	-	1.22	0.15	1.23	1.44	0.21	1.46
50	1.00	-	-	-	0.91	0.145	0.93	1.00	0.21	1.02
70	0.71	-	-	-	0.62	0.14	0.64	0.71	0.20	0.73
95	0.54	-	-	-	0.47	0.135	0.49	0.54	0.195	0.57
120	0.42	-	-	-	0.37	0.135	0.39	0.42	0.190	0.46
150	0.34	-	-	-	0.29	0.130	0.32	0.34	0.190	0.39
185	0.27	-	-	-	0.24	0.130	0.27	0.27	0.190	0.33
240	0.21	-	-	-	0.188	0.130	0.23	0.21	0.185	0.28
300	0.167	-	-	-	0.147	0.125	0.195	0.173	0.180	0.25
400	0.127	-	-	-	-	-	-	0.132	0.175	0.22
500	0.100	-	-	-	-	-	-	0.107	0.170	0.20
630	0.074	-	-	-	-	-	-	0.085	0.170	0.190

NOTES:

1. The voltage drop figures given above are based on a conductor operating temperature of 90 °C and are therefore not accurate when the operating temperature is in excess of 90 °C. In the case of the 180 °C cables with a conductor temperature of 150 °C the above resistive values should be increased by a factor of 1.2.
2. *A larger voltage drop will result if the cables are spaced.

TABLE 4F3A - Flexible cables, non-armoured (COPPER CONDUCTORS)

CURRENT-CARRYING CAPACITY (amperes): and MASS SUPPORTABLE (kg):

Conductor cross-sectional area	Current-carrying capacity		Maximum mass supportable by twin flexible cable (see Regulations 522.7.2 and 559.5.2)
	Single-phase AC	Three-phase AC	
1	2	3	4
(mm^2)	(A)	(A)	(kg)
0.5	3	3	2
0.75	6	6	3
1	10	10	5
1.25	13	-	5
1.5	16	16	5
2.5	25	20	5
4	32	25	5

Where cable is on a reel see the notes to Table 4F1A.

RATING FACTOR FOR AMBIENT TEMPERATURE

60 °C thermoplastic or thermosetting insulated cable:

Ambient temperature	35 °C	40 °C	45 °C	50 °C	55 °C
Rating factor	0.91	0.82	0.71	0.58	0.41

90 °C thermoplastic or thermosetting insulated cable:

Ambient temperature	35 to 50 °C	55 °C	60 °C	65 °C	70 °C
Rating factor	1.0	0.96	0.83	0.67	0.47

110 °C flexible cable:

Ambient temperature	35 to 80 °C	85 °C	90 °C	95 °C	100 °C	105 °C
Rating factor	1.0	0.96	0.85	0.74	0.60	0.42

150 °C flexible cable:

Ambient temperature	35 to 120 °C	125 °C	130 °C	135 °C	140 °C	145 °C
Rating factor	1.0	0.96	0.85	0.74	0.60	0.42

Glass fibre flexible cable:

Ambient temperature	35 to 50 °C	155 °C	160 °C	165 °C	170 °C	175 °C
Rating factor	1.0	0.92	0.82	0.71	0.57	0.40

TABLE 4F3B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 60 °C

Conductor cross-sectional area	DC or single-phase AC	Three-phase AC
1	2	3
(mm^2)	(mV/A/m)	(mV/A/m)
0.5	93	80
0.75	62	54
1	46	40
1.25	37	-
1.5	32	27
2.5	19	16
4	12	10

NOTE: * The tabulated values above are for 60 °C thermoplastic or thermosetting insulated flexible cables and for other types of flexible cable they are to be multiplied by the following factors:

For	90 °C thermoplastic or thermosetting insulated	1.09
	110 °C	1.17
	150 °C	1.31
	185 °C glass fibre	1.43

TABLE 4G1A – Mineral insulated cables thermoplastic covered or bare and exposed to touch (COPPER CONDUCTORS AND SHEATH)

CURRENT-CARRYING CAPACITY (amperes):

Ambient temperature: 30 °C
Sheath operating temperature: 70 °C

Conductor cross-sectional area	Reference Method C (clipped direct)			Reference Methods E, F and G (in free air or on a perforated cable tray etc, horizontal or vertical)				
	Single-phase AC or DC	Three-phase AC		Single-phase AC or DC	Three-phase AC			
	2 single-core cables touching or 1 two-core cable	3 single-core cables in trefoil or 1 three-core or four-core cable	3 single-core cables flat and touching, horizontal or vertical	2 single-core cables touching or 1 two-core cable	3 single-core cables in trefoil or 1 three-core or four-core cable	3 single-core cables flat and touching	3 single-core cables flat and spaced by one cable diameter	
							vertical	horizontal
1	2	3	4	5	6	7	8	9
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)
Light duty 500 V								
1	18.5	15	17	19.5	16.5	18	20	23
1.5	23	19	21	25	21	23	26	29
2.5	31	26	29	33	28	31	34	39
4	40	35	38	44	37	41	45	51
Heavy duty 750 V								
1	19.5	16	18	21	17.5	20	22	25
1.5	25	21	23	26	22	26	28	32
2.5	34	28	31	36	30	34	37	43
4	45	37	41	47	40	45	49	56
6	57	48	52	60	51	57	62	71
10	77	65	70	82	69	77	84	95
16	102	86	92	109	92	102	110	125
25	133	112	120	142	120	132	142	162
35	163	137	147	174	147	161	173	197
50	202	169	181	215	182	198	213	242
70	247	207	221	264	223	241	259	294
95	296	249	264	317	267	289	309	351
120	340	286	303	364	308	331	353	402
150	388	327	346	416	352	377	400	454
185	440	371	392	472	399	426	446	507
240	514	434	457	552	466	496	497	565

NOTES:

1. For single-core cables, the sheaths of the circuit are assumed to be connected together at both ends.
2. For bare cables exposed to touch, the tabulated values should be multiplied by 0.9.

TABLE 4G1B

VOLTAGE DROP (per ampere per metre): Sheath operating temperature 70 °C

Conductor cross-sectional area	Single-phase AC or DC		Three-phase AC			
	2 single-core cables touching	1 two-core cable	1 three- or four-core cable	3 single-core cables in trefoil formation	3 single-core cables flat and touching	3 single-core cables flat and spaced by one cable diameter*
1	2	3	4	5	6	7
(mm^2)	(mV/A/m)	(mV/A/m)	(mV/A/m)	(mV/A/m)	(mV/A/m)	(mV/A/m)
1	42	42	36	36	36	36
1.5	28	28	24	24	24	24
2.5	17	17	14	14	14	14
4	10	10	9.1	9.1	9.1	9.1
6	7	7	6.0	6.0	6.0	6.0
10	4.2	4.2	3.6	3.6	3.6	3.6
16	2.6	2.6	2.3	2.3	2.3	2.3

1	2			3			4			5			6			7		
	r	x	z	r	x	z	r	x	z	r	x	z	r	x	z	r	x	z
25	1.65	0.200	1.65	1.65	0.145	1.65	1.45	0.125	1.45	1.45	0.170	1.45	1.45	0.25	1.45	1.45	0.32	1.50
35	1.20	0.195	1.20	-	-	-	-	-	-	1.05	0.165	1.05	1.05	0.24	1.10	1.05	0.31	1.10
50	0.89	0.185	0.91	-	-	-	-	-	-	0.78	0.160	0.80	0.79	0.24	0.83	0.82	0.31	0.87
70	0.62	0.180	0.64	-	-	-	-	-	-	0.54	0.155	0.56	0.55	0.23	0.60	0.58	0.30	0.65
95	0.46	0.175	0.49	-	-	-	-	-	-	0.40	0.150	0.43	0.41	0.22	0.47	0.44	0.29	0.53
120	0.37	0.170	0.41	-	-	-	-	-	-	0.32	0.150	0.36	0.33	0.22	0.40	0.36	0.28	0.46
150	0.30	0.170	0.34	-	-	-	-	-	-	0.26	0.145	0.30	0.29	0.21	0.36	0.32	0.27	0.42
185	0.25	0.165	0.29	-	-	-	-	-	-	0.21	0.140	0.26	0.25	0.21	0.32	0.28	0.26	0.39
240	0.190	0.160	0.25	-	-	-	-	-	-	0.165	0.140	0.22	0.21	0.20	0.29	0.26	0.25	0.36

NOTE: * Spacings larger than one cable diameter will result in a larger voltage drop.

TABLE 4G2A – Mineral insulated cables bare and neither exposed to touch nor in contact with combustible materials (COPPER CONDUCTORS AND SHEATH)

CURRENT-CARRYING CAPACITY (amperes):

Ambient temperature: 30 °C
Sheath operating temperature: 105 °C

Conductor cross-sectional area	Reference Method C (clipped direct)			Reference Methods E, F and G (in free air or on a perforated cable tray etc, horizontal or vertical)				
	Single-phase AC or DC	Three-phase AC		Single-phase AC or DC	Three-phase AC			
	2 single-core cables touching or 1 two-core cable	3 single-core cables in trefoil or 1 three-core or four-core cable	3 single-core cables flat and touching, horizontal or vertical	2 single-core cables touching or 1 two-core cable	3 single-core cables in trefoil or 1 three-core or four-core cable	3 single-core cables flat and touching	3 single-core cables flat and spaced by one cable diameter	
							vertical	horizontal
1	2	3	4	5	6	7	8	9
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)
Light duty 500 V								
1	22	19	21	24	21	23	26	29
1.5	28	24	27	31	26	29	33	37
2.5	38	33	36	41	35	39	43	49
4	51	44	47	54	46	51	56	64
Heavy duty 750 V								
1	24	20	24	26	22	25	28	32
1.5	31	26	30	33	28	32	35	40
2.5	42	35	41	45	38	43	47	54
4	55	47	53	60	50	56	61	70
6	70	59	67	76	64	71	78	89
10	96	81	91	104	87	96	105	120
16	127	107	119	137	115	127	137	157
25	166	140	154	179	150	164	178	204
35	203	171	187	220	184	200	216	248
50	251	212	230	272	228	247	266	304
70	307	260	280	333	279	300	323	370
95	369	312	334	400	335	359	385	441
120	424	359	383	460	385	411	441	505
150	485	410	435	526	441	469	498	565
185	550	465	492	596	500	530	557	629
240	643	544	572	697	584	617	624	704

NOTES:

1. For single-core cables, the sheaths of the circuit are assumed to be connected together at both ends.
2. No rating factor for grouping need be applied.
3. Where a conductor operates at a temperature exceeding 70 °C it should be ascertained that the equipment connected to the conductor is suitable for the conductor operating temperature (see Section 512.1.5).

TABLE 4G2B

VOLTAGE DROP (per ampere per metre): Sheath operating temperature 105 °C

Conductor cross-sectional area	Single-phase AC or DC						Three-phase AC											
	2 single-core cables touching			1 two-core cable			1 three- or four-core cable			3 single-core cables in trefoil formation			3 single-core cables flat and touching			3 single-core cables flat and spaced by one cable diameter*		
1	2			3			4			5			6			7		
(mm^2)	(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)		
1	47			47			40			40			40			40		
1.5	31			31			27			27			27			27		
2.5	19			19			16			16			16			16		
4	12			12			10			10			10			10		
6	7.8			7.8			6.8			6.8			6.8			6.8		
10	4.7			4.7			4.1			4.1			4.1			4.1		
16	3.0			3.0			2.6			2.6			2.6			2.6		
	r	x	z	r	x	z	r	x	z	r	x	z	r	x	z	r	x	z
25	1.85	0.180	1.85	1.85	0.145	1.85	1.60	0.125	1.60	1.60	0.160	1.65	1.60	0.23	1.65	1.60	0.31	1.65
35	1.35	0.175	1.35	-	-	-	-	-	-	1.15	0.155	1.20	1.15	0.23	1.20	1.20	0.30	1.25
50	1.00	0.170	1.00	-	-	-	-	-	-	0.87	0.150	0.88	0.88	0.22	0.91	0.90	0.29	0.95
70	0.69	0.165	0.71	-	-	-	-	-	-	0.60	0.145	0.62	0.61	0.22	0.65	0.63	0.29	0.70
95	0.51	0.160	0.54	-	-	-	-	-	-	0.45	0.140	0.47	0.46	0.21	0.50	0.48	0.28	0.56
120	0.41	0.160	0.44	-	-	-	-	-	-	0.36	0.135	0.38	0.37	0.21	0.42	0.39	0.28	0.48
150	0.33	0.155	0.36	-	-	-	-	-	-	0.29	0.135	0.32	0.31	0.20	0.37	0.34	0.27	0.43
185	0.27	0.150	0.31	-	-	-	-	-	-	0.23	0.130	0.27	0.26	0.20	0.33	0.29	0.26	0.39
240	0.21	0.150	0.26	-	-	-	-	-	-	0.180	0.130	0.22	0.22	0.195	0.29	0.26	0.25	0.36

NOTE: * Spacings larger than one cable diameter will result in a larger voltage drop.

ALUMINIUM CONDUCTORS

TABLE 4H1A – Single-core 70 °C thermoplastic insulated cables, non-armoured, with or without sheath (ALUMINIUM CONDUCTORS)

CURRENT-CARRYING CAPACITY (amperes):

Ambient temperature: 30 °C
Conductor operating temperature: 70 °C

Conductor cross-sectional area	Reference Method A (enclosed in conduit in thermally insulating wall etc.)		Reference Method B (enclosed in conduit on a wall or in trunking etc.)		Reference Method C (clipped direct)		Reference Method F (in free air on a perforated cable tray, horizontal or vertical)					
							Touching			Spaced by one diameter	
	2 cables, single-phase AC or DC	3 or 4 cables, three-phase AC	2 cables, single-phase AC or DC	3 or 4 cables, three-phase AC	2 cables, single-phase AC or DC flat and touching	3 or 4 cables, three-phase AC flat and touching or trefoil	2 cables, single-phase AC or DC flat	3 cables, three-phase AC flat	3 cables, three-phase AC trefoil	2 cables, single-phase AC or DC or 3 cables three-phase AC flat	
										Horizontal	Vertical
1	2	3	4	5	6	7	8	9	10	11	12
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)
50	93	84	118	104	125	110	149	133	128	169	152
70	118	107	150	133	160	140	192	173	166	217	196
95	142	129	181	161	195	170	235	212	203	265	241
120	164	149	210	186	226	197	273	247	237	308	282
150	189	170	234	204	261	227	316	287	274	356	327
185	215	194	266	230	298	259	363	330	316	407	376
240	252	227	312	269	352	305	430	392	375	482	447
300	289	261	358	306	406	351	497	455	434	557	519
380	-	-	413	352	511	472	543	502	507	625	584
480	-	-	477	405	591	546	629	582	590	726	680
600	-	-	545	462	679	626	722	669	680	837	787
740	-	-	-	-	771	709	820	761	776	956	902
960	-	-	-	-	900	823	953	886	907	1125	1066
1200	-	-	-	-	1022	926	1073	999	1026	1293	1229

TABLE 4H1B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 70 °C

Conductor cross-sectional area	2 cables, DC	2 cables, single-phase AC									3 or 4 cables, three-phase AC											
		Reference Methods A & B (enclosed in conduit or trunking)			Reference Methods C & F (clipped direct, on tray or in free air)						Reference Methods A & B (enclosed in conduit or trunking)			Reference Methods C & F (clipped direct, on tray or in free air)								
					Cables touching			Cables spaced*						Cables touching, Trefoil			Cables touching, Flat			Cables spaced*, Flat		
1	2	3			4			5			6			7			8			9		
(mm^2)	(mV/A/m)	(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)		
		r	x	z	r	x	z	r	x	z	r	x	z	r	x	z	r	x	z	r	x	z
50	1.55	1.60	0.30	1.60	1.55	0.190	1.55	1.55	0.28	1.55	1.35	0.26	1.40	1.35	0.165	1.35	1.35	0.24	1.35	1.35	0.32	1.40
70	1.05	1.10	0.30	1.15	1.05	0.185	1.05	1.05	0.27	1.10	0.94	0.26	0.97	0.91	0.160	0.92	0.91	0.24	0.94	0.91	0.31	0.96
95	0.77	0.81	0.29	0.86	0.77	0.185	0.79	0.77	0.27	0.82	0.70	0.25	0.74	0.67	0.160	0.69	0.67	0.23	0.71	0.67	0.31	0.74
120	0.61	0.64	0.29	0.70	0.61	0.180	0.64	0.61	0.27	0.67	0.55	0.25	0.61	0.53	0.155	0.55	0.53	0.23	0.58	0.53	0.31	0.61
150	0.49	0.51	0.28	0.59	0.49	0.175	0.52	0.49	0.26	0.55	0.45	0.24	0.51	0.42	0.155	0.45	0.42	0.23	0.48	0.42	0.30	0.52
185	0.39	0.42	0.28	0.50	0.40	0.175	0.43	0.39	0.26	0.47	0.36	0.24	0.44	0.34	0.150	0.37	0.34	0.23	0.41	0.34	0.30	0.46
240	0.30	0.32	0.27	0.42	0.30	0.170	0.35	0.30	0.26	0.40	0.28	0.24	0.37	0.26	0.150	0.30	0.26	0.22	0.35	0.26	0.30	0.40
300	0.24	0.26	0.27	0.37	0.24	0.170	0.30	0.24	0.26	0.35	0.23	0.23	0.32	0.21	0.145	0.26	0.21	0.22	0.31	0.21	0.30	0.36
380	0.190	0.22	0.27	0.35	0.195	0.165	0.26	0.195	0.25	0.32	0.190	0.23	0.30	0.170	0.145	0.22	0.170	0.22	0.28	0.170	0.29	0.34
480	0.150	0.18	0.26	0.32	0.155	0.165	0.23	0.155	0.25	0.29	0.155	0.23	0.27	0.140	0.140	0.195	0.140	0.22	0.26	0.135	0.29	0.32
600	0.120	0.150	0.26	0.30	0.130	0.160	0.21	0.125	0.25	0.28	0.125	0.22	0.26	0.110	0.140	0.180	0.110	0.22	0.24	0.110	0.29	0.31
740	0.099	-	-	-	0.105	0.160	0.190	0.100	0.25	0.27	-	-	-	0.094	0.135	0.165	0.094	0.21	0.23	0.089	0.29	0.30
960	0.075	-	-	-	0.086	0.155	0.180	0.082	0.24	0.26	-	-	-	0.077	0.135	0.155	0.077	0.21	0.22	0.071	0.29	0.29
1200	0.060	-	-	-	0.074	0.155	0.170	0.068	0.24	0.25	-	-	-	0.066	0.135	0.150	0.066	0.21	0.22	0.059	0.28	0.29

TABLE 4H2A – Multicore 70 °C thermoplastic insulated and thermoplastic sheathed cables, non-armoured (ALUMINIUM CONDUCTORS)

CURRENT-CARRYING CAPACITY (amperes):

Ambient temperature: 30 °C
Conductor operating temperature: 70 °C

Conductor cross-sectional area	Reference Method A (enclosed in conduit in thermally insulating wall etc.)		Reference Method B (enclosed in conduit on a wall or in trunking etc.)		Reference Method C (clipped direct)		Reference Method E (in free air or on a perforated cable tray etc, horizontal or vertical)	
	1 two-core cable, single-phase AC or DC	1 three- or four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or four-core cable, three-phase AC
1	2	3	4	5	6	7	8	9
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)
16	44	41	54	48	66	59	73	61
25	58	53	71	62	83	73	89	78
35	71	65	86	77	103	90	111	96
50	86	78	104	92	125	110	135	117
70	108	98	131	116	160	140	173	150
95	130	118	157	139	195	170	210	183
120	-	135	-	160	-	197	-	212
150	-	155	-	176	-	227	-	245
185	-	176	-	199	-	259	-	280
240	-	207	-	232	-	305	-	330
300	-	237	-	265	-	351	-	381

TABLE 4H2B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 70 °C

Conductor cross-sectional area	Two-core cable, DC	Two-core cable, single-phase AC			Three- or four-core cable, three-phase AC		
1	2	3			4		
(mm^2)	(mV/A/m)	(mV/A/m)			(mV/A/m)		
16	4.5	4.5			3.9		
		r	x	z	r	x	z
25	2.9	2.9	0.175	2.9	2.5	0.150	2.5
35	2.1	2.1	0.170	2.1	1.80	0.150	1.80
50	1.55	1.55	0.170	1.55	1.35	0.145	1.35
70	1.05	1.05	0.165	1.05	0.90	0.140	0.92
95	0.77	0.77	0.160	0.79	0.67	0.140	0.68
120	-	-	-	-	0.53	0.135	0.55
150	-	-	-	-	0.42	0.135	0.44
185	-	-	-	-	0.34	0.135	0.37
240	-	-	-	-	0.26	0.130	0.30
300	-	-	-	-	0.21	0.130	0.25

TABLE 4H3A – Single-core armoured 70 °C thermoplastic insulated cables (non-magnetic armour) (ALUMINIUM CONDUCTORS)

CURRENT-CARRYING CAPACITY (amperes):

Ambient temperature: 30 °C
Conductor operating temperature: 70 °C

Conductor cross-sectional area	Reference Method C (clipped direct)		Reference Method F (in free air or on a perforated cable tray, horizontal or vertical)								
	Touching		Touching			Spaced by one cable diameter					
	2 cables, single-phase AC or DC flat	3 or 4 cables, three-phase AC flat	2 cables, single-phase AC or DC flat	3 cables, three-phase AC flat	3 cables, three-phase AC trefoil	2 cables, DC		2 cables, single-phase AC		3 or 4 cables, three-phase AC	
						Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
1	2	3	4	5	6	7	8	9	10	11	12
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)
50	143	133	152	141	131	167	157	168	159	169	155
70	183	168	194	178	168	214	202	212	200	213	196
95	221	202	234	214	205	261	247	259	245	255	236
120	255	233	270	246	238	303	288	299	285	293	272
150	294	267	310	282	275	349	333	340	323	335	312
185	334	303	352	319	315	400	382	389	371	379	354
240	393	354	413	374	372	472	452	457	437	443	415
300	452	405	474	427	430	545	523	520	498	505	475
380	518	452	543	479	497	638	613	583	559	551	518
480	586	501	616	534	568	742	715	655	629	604	568
600	658	550	692	589	642	859	828	724	696	656	618
740	728	596	769	642	715	986	952	802	770	707	666
960	819	651	868	706	808	1171	1133	866	832	770	726
1200	893	692	952	756	880	1360	1317	938	902	822	774

TABLE 4H3B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 70 °C

Conductor cross-sectional area	2 cables, DC	Reference Methods C & F (clipped direct, on tray or in free air)														
		2 cables, single-phase AC						3 or 4 cables, three-phase AC								
		touching			spaced*			trefoil and touching			flat and touching			flat and spaced*		
1	2	3			4			5			6			7		
(mm^2)	(mV/ A/m)	(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)		
		r	x	z	r	x	z	r	x	z	r	x	z	r	x	z
50	1.55	1.55	0.23	1.55	1.55	0.31	1.55	1.35	0.195	1.35	1.35	0.27	1.35	1.30	0.34	1.35
70	1.05	1.05	0.22	1.10	1.05	0.30	1.10	0.92	0.190	0.93	0.93	0.26	0.96	0.95	0.33	1.00
95	0.77	0.78	0.21	0.81	0.81	0.29	0.86	0.68	0.185	0.70	0.70	0.25	0.75	0.73	0.32	0.80
120	0.61	0.62	0.21	0.66	0.65	0.29	0.71	0.54	0.180	0.57	0.57	0.25	0.62	0.60	0.32	0.68
150	0.49	0.50	0.20	0.54	0.53	0.28	0.60	0.44	0.175	0.47	0.46	0.24	0.52	0.50	0.31	0.58
185	0.39	0.41	0.195	0.45	0.44	0.28	0.52	0.35	0.170	0.39	0.38	0.24	0.45	0.42	0.30	0.51
240	0.30	0.32	0.190	0.37	0.34	0.27	0.44	0.28	0.165	0.32	0.30	0.23	0.38	0.33	0.29	0.44
300	0.24	0.26	0.185	0.32	0.28	0.26	0.39	0.22	0.160	0.27	0.24	0.23	0.34	0.28	0.29	0.40
380	0.190	0.22	0.185	0.28	0.26	0.25	0.36	0.185	0.155	0.24	0.22	0.22	0.32	0.27	0.26	0.38
480	0.150	0.180	0.180	0.25	0.22	0.25	0.33	0.155	0.155	0.22	0.195	0.22	0.29	0.24	0.25	0.35
600	0.120	0.150	0.175	0.23	0.195	0.24	0.31	0.130	0.150	0.200	0.170	0.21	0.27	0.21	0.24	0.32
740	0.097	0.135	0.170	0.22	0.180	0.23	0.29	0.115	0.145	0.185	0.160	0.20	0.26	0.200	0.22	0.30
960	0.075	0.115	0.160	0.200	0.165	0.21	0.27	0.100	0.140	0.175	0.150	0.185	0.24	0.190	0.195	0.27
1200	0.060	0.110	0.155	0.190	0.160	0.180	0.24	0.094	0.140	0.170	0.145	0.160	0.22	0.185	0.165	0.25

ALUMINIUM CONDUCTORS

TABLE 4H4A – Multicore armoured 70 °C thermoplastic insulated cables (ALUMINIUM CONDUCTORS)

Air Ambient temperature: 30 °C
Ground Ambient temperature: 20 °C
Conductor operating temperature: 70 °C

CURRENT-CARRYING CAPACITY (amperes):

Conductor cross-sectional area	Reference Method C (clipped direct)		Reference Method E (in free air or on a perforated cable tray etc, horizontal or vertical)		Reference Method D (direct in ground or in ducting in ground, in or around buildings)	
	1 two-core cable, single-phase AC or DC	1 three- or 1 four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or 1 four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or 1 four-core cable, three-phase AC
1	2	3	4	5	6	7
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)
16	68	58	71	61		
25	89	76	94	80	77	64
35	109	94	115	99	93	77
50	131	113	139	119	109	91
70	165	143	175	151	135	112
95	199	174	211	186	159	132
120	-	202	-	216	-	150
150	-	232	-	250	-	169
185	-	265	-	287	-	190
240	-	312	-	342	-	218
300	-	360	-	399	-	247

TABLE 4H4B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 70 °C

Conductor cross-sectional area	Two-core cable, DC	Two-core cable, single-phase AC			Three- or four-core cable, three-phase AC		
1	2	3			4		
(mm^2)	(mV/A/m)	(mV/A/m)			(mV/A/m)		
16	4.5	4.5			3.9		
		r	x	z	r	x	z
25	2.9	2.9	0.175	2.9	2.5	0.150	2.5
35	2.1	2.1	0.170	2.1	1.80	0.150	1.80
50	1.55	1.55	0.170	1.55	1.35	0.145	1.35
70	1.05	1.05	0.165	1.05	0.90	0.140	0.92
95	0.77	0.77	0.160	0.79	0.67	0.140	0.68
120	-	-	-	-	0.53	0.135	0.55
150	-	-	-	-	0.42	0.135	0.44
185	-	-	-	-	0.34	0.135	0.37
240	-	-	-	-	0.26	0.130	0.30
300	-	-	-	-	0.21	0.130	0.25

TABLE 4J1A – Single-core 90 °C thermosetting insulated cables, non-armoured, with or without sheath (ALUMINIUM CONDUCTORS)

CURRENT-CARRYING CAPACITY (amperes):

Ambient temperature: 30 °C
Conductor operating temperature: 90 °C

Conductor cross-sectional area	Reference Method A (enclosed in conduit in thermally insulating wall etc.)		Reference Method B (enclosed in conduit on a wall or in trunking etc.)		Reference Method C (clipped direct)		Reference Method F (in free air or on a perforated cable tray horizontal or vertical etc.) Touching			Reference Method G (in free air) Spaced by one cable diameter	
	2 cables, single-phase AC or DC	3 or 4 cables, three-phase AC	2 cables, single-phase AC or DC	3 or 4 cables, three-phase AC	2 cables, single-phase AC or DC flat and touching	3 or 4 cables, three-phase AC flat and touching or trefoil	2 cables, single-phase AC or DC flat	3 cables, three-phase AC flat	3 cables, three-phase AC trefoil	2 cables, single-phase AC or DC or 3 cables three-phase AC flat Horizontal	Vertical
1	2	3	4	5	6	7	8	9	10	11	12
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)
50	125	113	157	140	154	136	184	165	159	210	188
70	158	142	200	179	198	174	237	215	206	271	244
95	191	171	242	217	241	211	289	264	253	332	300
120	220	197	281	251	280	245	337	308	296	387	351
150	253	226	307	267	324	283	389	358	343	448	408
185	288	256	351	300	371	323	447	413	395	515	470
240	338	300	412	351	439	382	530	492	471	611	561
300	387	344	471	402	508	440	613	571	544	708	652
380	-	-	-	-	658	594	679	628	638	798	742
480	-	-	-	-	765	692	786	728	743	927	865
600	-	-	-	-	871	791	903	836	849	1058	990
740	-	-	-	-	1001	911	1025	60364	979	1218	1143
960	-	-	-	-	1176	1072	1191	1108	1151	1440	1355
1200	-	-	-	-	1333	1217	1341	1249	1307	1643	1550

NOTES:

1. Where it is intended to connect the cables in this table to equipment or accessories designed to operate at a temperature lower than the maximum operating temperature of the cable, the cables should be rated at the maximum operating temperature of the equipment or accessory (see Section 512.1.5).
2. Where it is intended to group a cable in this table with other cables, the cable should be rated at the lowest of the maximum operating temperatures of any of the cables in the group (see Section 512.1.5).

TABLE 4J1B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 90 °C

Conductor cross-sectional area	2 cables, DC	2 cables, single-phase AC									3 or 4 cables, three-phase AC											
		Reference Methods A & B (enclosed in conduit or trunking)			References Methods C, F & G (clipped direct, on tray or in free air)						Reference Methods A & B (enclosed in conduit or trunking)			Reference Methods C, F & G (clipped direct, on tray or in free air)								
					Cables touching			Cables spaced*						Cables touching, Trefoil			Cables touching, Flat			Cables spaced*, Flat		
1	2	3			4			5			6			7			8			9		
(mm²)	(mV/A/m)	(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)		
		r	x	z	r	x	z	r	x	z	r	x	z	r	x	z	r	x	z	r	x	z
50	1.65	1.70	0.30	1.72	1.65	0.190	1.66	1.65	0.28	1.68	1.44	0.26	1.46	1.44	0.165	1.45	1.44	0.24	1.46	1.44	0.32	1.48
70	1.13	1.17	0.30	1.21	1.12	0.185	1.14	1.12	0.27	1.15	1.00	0.26	1.04	0.97	0.160	0.98	0.97	0.24	1.00	0.97	0.31	1.02
95	0.82	0.86	0.29	0.91	0.82	0.185	0.84	0.82	0.27	0.94	0.75	0.25	0.79	0.71	0.160	0.73	0.71	0.23	0.75	0.71	0.31	0.78
120	0.65	0.68	0.29	0.74	0.65	0.180	0.67	0.65	0.27	0.70	0.59	0.25	0.64	0.57	0.155	0.59	0.57	0.23	0.61	0.57	0.31	0.64
150	0.53	0.54	0.28	0.61	0.52	0.175	0.55	0.52	0.26	0.58	0.48	0.24	0.54	0.45	0.155	0.47	0.45	0.23	0.50	0.45	0.30	0.54
185	0.42	0.45	0.28	0.53	0.43	0.175	0.46	0.42	0.26	0.49	0.38	0.24	0.45	0.36	0.150	0.39	0.36	0.23	0.43	0.36	0.30	0.47
240	0.32	0.34	0.27	0.43	0.32	0.170	0.36	0.32	0.26	0.41	0.30	0.24	0.38	0.28	0.150	0.32	0.28	0.22	0.35	0.28	0.30	0.41
300	0.26	0.28	0.27	0.38	0.26	0.170	0.31	0.26	0.26	0.36	0.25	0.23	0.34	0.22	0.145	0.27	0.22	0.22	0.31	0.22	0.30	0.37
380	0.20	-	-	-	0.21	0.165	0.27	0.21	0.25	0.33	0.20	0.23	0.31	0.180	0.145	0.23	0.180	0.22	0.28	0.180	0.29	0.34
480	0.160	-	-	-	0.170	0.165	0.23	0.165	0.25	0.30	0.165	0.23	0.28	0.150	0.140	0.20	0.150	0.22	0.27	0.145	0.29	0.32
600	0.130	-	-	-	0.140	0.160	0.21	0.135	0.25	0.28	0.135	0.22	0.26	0.120	0.140	0.185	0.120	0.22	0.25	0.120	0.29	0.31
740	0.105	-	-	-	0.115	0.160	0.19	0.110	0.25	0.27	-	-	-	0.100	0.135	0.170	0.100	0.21	0.23	0.095	0.29	0.30
960	0.080	-	-	-	0.092	0.155	0.18	0.087	0.24	0.26	-	-	-	0.082	0.135	0.160	0.082	0.21	0.23	0.076	0.29	0.30
1200	0.064	-	-	-	0.079	0.155	0.17	0.073	0.24	0.25	-	-	-	0.070	0.135	0.150	0.070	0.21	0.22	0.063	0.28	0.29

TABLE 4J2A – Multicore 90 °C thermosetting insulated and thermoplastic sheathed cables, non-armoured (ALUMINIUM CONDUCTORS)

Ambient temperature: 30 °C

CURRENT-CARRYING CAPACITY (amperes) Conductor operating temperature: 90 °C

Conductor cross-sectional area	Reference Method A (enclosed in conduit in thermally insulating wall etc.)		Reference Method B (enclosed in conduit on a wall or in trunking etc.)		Reference Method C (clipped direct)		Reference Method E (in free air or on a perforated cable tray etc, horizontal or vertical)	
	1 two-core cable, single-phase AC or DC	1 three- or four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or four-core cable, three-phase AC
1	2	3	4	5	6	7	8	9
(mm²)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)
16	60	55	72	64	84	76	91	77
25	78	71	94	84	101	90	108	97
35	96	87	115	103	126	112	135	120
50	115	104	138	124	154	136	164	146
70	145	131	175	156	198	174	211	187
95	175	157	210	188	241	211	257	227
120	-	180	-	216	-	245	-	263
150	-	206	-	240	-	283	-	304
185	-	233	-	272	-	323	-	347
240	-	273	-	318	-	382	-	409
300	-	313	-	364	-	440	-	471

NOTES:

1. Where it is intended to connect the cables in this table to equipment or accessories designed to operate at a temperature lower than the maximum operating temperature of the cable, the cables should be rated at the maximum operating temperature of the equipment or accessory (see Section 512.1.5).
2. Where it is intended to group a cable in this table with other cables, the cable should be rated at the lowest of the maximum operating temperatures of any of the cables in the group (see Section 512.1.5).

TABLE 4J2B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 90 °C

Conductor cross-sectional area	Two-core cable, DC	Two-core cable, single-phase AC			Three- or four-core cable, three-phase AC		
1	2	3			4		
(mm^2)	(mV/A/m)	(mV/A/m)			(mV/A/m)		
16	4.8	4.8			4.2		
		r	x	z	r	x	z
25	3.1	3.1	0.165	3.1	2.7	0.140	2.7
35	2.2	2.2	0.160	2.2	1.90	0.140	1.95
50	1.60	1.65	0.160	1.65	1.40	0.135	1.45
70	1.10	1.10	0.155	1.15	0.96	0.135	0.97
95	0.82	0.82	0.150	0.84	0.71	0.130	0.72
120	-	-	-	-	0.56	0.130	0.58
150	-	-	-	-	0.45	0.130	0.47
185	-	-	-	-	0.37	0.130	0.39
240	-	-	-	-	0.28	0.125	0.31
300	-	-	-	-	0.23	0.125	0.26

TABLE 4J3A – Single-core armoured 90 °C thermosetting insulated cables (non-magnetic armour) ALUMINIUM CONDUCTOR

Ambient temperature: 30 °C
CURRENT-CARRYING CAPACITY (amperes): Conductor operating temperature: 90 °C

Conductor cross-sectional area	Reference Method C (clipped direct)		Reference Method F (in free air or on a perforated cable tray, horizontal or vertical)									
	Touching		Touching			Spaced by one cable diameter						
	2 cables, single-phase AC or DC flat	3 or 4 cables, three-phase AC flat	2 cables, single-phase AC or DC flat	3 cables, three-phase AC flat	3 cables, three-phase AC trefoil	2 cables, DC		2 cables, single-phase AC		3 or 4 cables, three-phase AC		
						Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	
1	2	3	4	5	6	7	8	9	10	11	12	
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	
50	179	165	192	176	162	216	197	212	199	215	192	
70	228	209	244	222	207	275	253	269	254	270	244	
95	276	252	294	267	252	332	307	328	310	324	296	
120	320	291	340	308	292	384	357	378	358	372	343	
150	368	333	390	352	337	441	411	429	409	424	394	
185	419	378	444	400	391	511	480	490	467	477	447	
240	494	443	521	468	465	605	572	576	549	554	523	
300	568	508	597	536	540	701	666	654	624	626	595	
380	655	573	688	608	625	812	780	735	704	693	649	
480	747	642	786	685	714	942	906	825	790	765	717	
600	836	706	880	757	801	1076	1036	909	872	832	780	
740	934	764	988	824	897	1250	1205	989	950	890	835	
960	1056	838	1121	911	1014	1488	1435	1094	1052	970	911	
1200	1163	903	1236	990	1118	1715	1658	1187	1141	1043	980	

NOTES:

1. Where it is intended to connect the cables in this table to equipment or accessories designed to operate at a temperature lower than the maximum operating temperature of the cable, the cables should be rated at the maximum operating temperature of the equipment or accessory (see Section 512.1.5).
2. Where it is intended to group a cable in this table with other cables, the cable should be rated at the lowest of the maximum operating temperatures of any of the cables in the group (see Section 512.1.5).

TABLE 4J3B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 90 °C

Conductor cross-sectional area	2 cables, DC	Reference Method C & F (clipped direct, on tray or in free air)														
		2 cables, single-phase AC						3 or 4 cables, three-phase AC								
		touching			spaced*			trefoil and touching			flat and touching			flat and spaced*		
1	2	3			4			5			6			7		
(mm^2)	(mV/A/m)	(mV/A/m)			(mV/A/m)			4 (mV/A/m)			(mV/A/m)			(mV/A/m)		
		r	x	z	r	x	z	r	x	z	r	x	z	r	x	z
50	1.60	1.60	0.22	1.60	1.60	0.30	1.60	1.40	0.185	1.40	1.40	0.26	1.40	1.35	0.34	1.40
70	1.10	1.10	0.21	1.15	1.10	0.29	1.15	0.96	0.180	0.98	0.97	0.25	1.00	0.99	0.33	1.05
95	0.82	0.83	0.20	0.85	0.85	0.29	0.90	0.71	0.175	0.74	0.74	0.25	0.78	0.76	0.32	0.83
120	0.66	0.66	0.20	0.69	0.69	0.28	0.74	0.57	0.170	0.60	0.60	0.24	0.64	0.63	0.31	0.70
150	0.52	0.53	0.195	0.57	0.56	0.28	0.62	0.46	0.170	0.49	0.49	0.24	0.54	0.52	0.30	0.60
185	0.42	0.43	0.190	0.47	0.46	0.27	0.54	0.38	0.165	0.41	0.40	0.24	0.47	0.44	0.30	0.53
240	0.32	0.34	0.185	0.39	0.37	0.27	0.45	0.29	0.160	0.34	0.32	0.23	0.39	0.35	0.29	0.46
300	0.26	0.27	0.185	0.33	0.30	0.26	0.40	0.24	0.160	0.29	0.26	0.23	0.34	0.29	0.29	0.41
380	0.21	0.23	0.180	0.29	0.26	0.25	0.36	0.195	0.155	0.25	0.23	0.22	0.32	0.27	0.27	0.38
480	0.160	0.185	0.175	0.25	0.23	0.25	0.34	0.160	0.155	0.22	0.20	0.21	0.29	0.24	0.26	0.35
600	0.130	0.160	0.175	0.24	0.20	0.24	0.31	0.135	0.150	0.20	0.175	0.21	0.27	0.22	0.25	0.33
740	0.105	0.140	0.170	0.22	0.190	0.22	0.29	0.120	0.145	0.190	0.165	0.195	0.26	0.21	0.22	0.30
960	0.080	0.120	0.160	0.20	0.170	0.21	0.27	0.105	0.140	0.175	0.150	0.180	0.24	0.195	0.195	0.28
1200	0.064	0.105	0.160	0.190	0.155	0.20	0.25	0.093	0.135	0.165	0.140	0.175	0.22	0.180	0.185	0.26

NOTE: * Spacings larger than one cable diameter will result in a larger voltage drop.

ALUMINIUM CONDUCTORS

TABLE 4J4A – Multicore armoured 90 °C thermosetting insulated cables (ALUMINIUM CONDUCTORS)

Air Ambient temperature: 30 °C
Ground Ambient temperate: 20 °C
Conductor operating temperature: 90 °C

CURRENT-CARRYING CAPACITY (amperes):

Conductor cross-sectional area	Reference Method C (clipped direct)		Reference Method E (in free air or on a perforated cable tray etc, horizontal or vertical)		Reference Method D (direct in ground or in ducting in ground, in or around buildings)	
	1 two-core cable, single-phase AC or DC	1 three- or 1 four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or 1 four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or 1 four-core cable, three-phase AC
1	2	3	4	5	6	7
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)
16	82	71	85	74	71	59
25	108	92	112	98	90	75
35	132	113	138	120	108	90
50	159	137	166	145	128	106
70	201	174	211	185	158	130
95	242	214	254	224	186	154
120	-	249	-	264	-	174
150	-	284	-	305	-	197
185	-	328	-	350	-	220
240	-	386	-	418	-	253
300	-	441	-	488	-	286

NOTES:

1. Where it is intended to connect the cables in this table to equipment or accessories designed to operate at a temperature lower than the maximum operating temperature of the cable, the cables should be rated at the maximum operating temperature of the equipment or accessory (see Section 512.1.5).
2. Where it is intended to group a cable in this table with other cables, the cable should be rated at the lowest of the maximum operating temperatures of any of the cables in the group (see Section 512.1.5).

TABLE 4J4B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 90 °C

Conductor cross-sectional area	Two-core cable, DC	Two-core cable, single-phase AC			Three- or four-core cable, three-phase AC		
1	2	3			4		
(mm^2)	(mV/A/m)	(mV/A/m)			(mV/A/m)		
16	4.8	4.8			4.2		
		r	x	z	r	x	z
25	3.1	3.1	0.165	3.1	2.7	0.140	2.7
35	2.2	2.2	0.160	2.2	1.90	0.140	1.95
50	1.60	1.65	0.160	1.65	1.40	0.135	1.45
70	1.10	1.10	0.155	1.15	0.96	0.135	0.97
95	0.82	0.82	0.150	0.84	0.71	0.130	0.72
120	-	-	-	-	0.56	0.130	0.58
150	-	-	-	-	0.45	0.130	0.47
185	-	-	-	-	0.37	0.130	0.39
240	-	-	-	-	0.28	0.125	0.31
300	-	-	-	-	0.23	0.125	0.26

APPENDIX 3 (Informative)
CLASSIFICATION OF EXTERNAL INFLUENCES

This appendix gives the classification and codification of external influences.

NOTE 1: The appendix is an extract from HD 60364-5-51.

Each condition of external influence is designated by a code comprising a group of two capital letters and a number, as follows:

The first letter relates to the general category of external influence:

A Environment
B Utilization
C Construction of buildings

The second letter relates to the nature of the external influence:

. . . **A**
. . . **B**
. . . **C**

The number relates to the class within each external influence:

. . . . . . **1**
. . . . . . **2**
. . . . . . **3**

For example, the code **AA4** signifies:

A = Environment
AA = Environment - Ambient temperature
AA4 = Environment - Ambient temperature in the range of –5 °C to +40 °C .

NOTE 2: The codification given in this appendix is not intended to be used for marking equipment.

The following key is for use when referencing the list of external influences:

[a] May necessitate certain supplementary precautions (e.g. special lubrication).

[b] This means that ordinary equipment will operate safely under the described external influences.

[c] This means that special arrangements should be made, for example, between the designer of the installation and the equipment manufacturer, e.g. for specially designed equipment.

CONCISE LIST OF EXTERNAL INFLUENCES

Environment

A	**AA**	***Ambient (°C)***		**AF**	***Corrosion***	**AM8**	**Radiated magnetic fields**
	AA1	-60 °C	+5 °C	AF1	Negligible	AM9	Electric fields
	AA2	-40 °C	+5 °C	AF2	Atmospheric	AM21	High-frequency etc. . .
	AA3	-25 °C	+5 °C	AF3	Intermittent	AM22	Conducted. . .nano. . .
	AA4	-5 °C	+40 °C	AF4	Continuous	AM23	Conducted. . .micro. . .
	AA5	+5 °C	+40 °C			AM24	Conducted oscillatory
	AA6	+5 °C	+60 °C	**AG**	***Impact***	AM25	Radiated HF
	AA7	-25 °C	+55 °C	AG1	Low	AM31	Electrostatic discharges
	AA8	-50 °C	+40 °C	AG2	Medium	AM41	Ionization
				AG3	High		
	AB	***Temperature and Humidity***				**AN**	***Solar***
				AH	***Vibration***	AN1	Low
	AC	***Altitude (metres)***		AH1	Low	AN2	Medium
	AC1	≤ 2000 metres		AH2	Medium	AN3	High
	AC2	> 2000 metres		AH3	High		
						AP	***Seismic***
	AD	***Water***		**AJ**	***Other mechanical stresses***	AP1	Negligible
	AD1	Negligible				AP2	Low
	AD2	Drops		**AK**	**Flora**	AP3	Medium
	AD3	Sprays		AK1	No hazard	AP4	High
	AD4	Splashes		AK2	Hazard		
	AD5	Jets				**AQ**	**Lightning**
	AD6	Waves		**AL**	**Fauna**	AQ1	Negligible
	AD7	Immersion		AL1	No hazard	AQ2	Indirect
	AD8	Submersion		AL2	Hazard	AQ3	Direct
	AE	***Foreign Bodies***		**AM**	***Electromagnetic. . .***	**AR**	***Movement of air***
	AE1	Negligible		AM1	Level	AR1	Low
	AE2	Small		AM2	Signalling voltages	AR2	Medium
	AE3	Very small		AM3	Voltage amplitude variations	AR3	High
	AE4	Light dust		AM4	Voltage unbalance		
	AE5	Moderate dust		AM5	Power frequency variations	**AS**	***Wind***
	AE6	Heavy dust		AM6	Induced low-frequency voltage	AS1	Low
				AM7	DC current in AC voltage	AS2	Medium
						AS3	High

Utilization

B	**BA**	***Capability***	**BC**	***Contact with Earth***	**BE**	***Materials***
	BA1	Ordinary	BC1	None	BE1	No risk
	BA2	Children	BC2	Low	BE2	Fire risk
	BA3	Handicapped	BC3	Frequent	BE3	Explosion risk
	BA4	Instructed	BC4	Continuous	BE4	Contamination risk
	BA5	Skilled				
			BD	***Evacuation***		
	BB	***Resistance***	BD1	Normal		
			BD2	Difficult		
			BD3	Crowded		
			BD4	Difficult and crowded		

Buildings

C	**CA**	***Materials***	**CB**	***Structure***
	CA1	Non-combustible	CB1	Negligible
	CA2	Combustible	CB2	Fire propagation
			CB3	Structural movement
			CB4	Flexible

A ENVIRONMENT:

Code	External influences	Characteristics required for selection and erection of equipment	Reference for information only
A	*Environmental conditions*		
AA	*Ambient temperature* The ambient temperature is that of the ambient air where the equipment is to be installed It is assumed that the ambient temperature includes the effects of other equipment installed in the same location The ambient temperature to be considered for the equipment is the temperature at the place where the equipment is to be installed resulting from the influence of all other equipment in the same location, when operating, not taking into account the thermal contribution of the equipment to be installed.		
AA1	–60 °C +5 °C		Includes temperature range of IEC 60721-3-3, class 3K8, with high air temperature restricted to +5 °C. Part of temperature range of IEC 60721-3-4, class 4K4, with low air temperature restricted to –60 °C and high air temperature restricted to +5 °C
AA2	–40 °C +5 °C	Specially designed equipment or appropriate arrangements[a]	Part of temperature range of IEC 60721-3-3, class 3K7, with high air temperature restricted to +5 °C. Includes part of temperature range of IEC 60721-3-4, class 4K3, with high air temperature restricted to +5 °C
AA3	–25 °C +5 °C		Part of temperature range of IEC 60721-3-3, class 3K6, with high air temperature restricted to +5 °C. Includes temperature range of IEC 60721-3-4, class 4K1, with high air temperature restricted to +5 °C
AA4	–5 °C +40 °C	Normal (in certain cases special precautions may be necessary)	Part of temperature range of IEC 60721-3-3, class 3K5, with high air temperature restricted to +40 °C
AA5	+5 °C +40 °C	Normal[b]	Identical to temperature range of IEC 60721-3-3, class 3K3

A ENVIRONMENT ***(cont.)***

Code	External influences						Characteristics required for selection and erection of equipment	Reference for information only
AA6	+5 °C +60 °C						Specially designed equipment or appropriate arrangements[a]	Part of temperature range of IEC 60721-3-3, class 3K7, with low air temperature restricted to +5 °C and high air temperature restricted to +60 °C. Includes temperature range of IEC 60721-3-4, class 4K4 with low air temperature restricted to +5 °C
AA7	-25 °C +55 °C -50 °C +40 °C						Specially designed equipment or appropriate arrangements[a]	– Identical to temperature range of IEC 60721-3-3, class 3K6
AA8	Ambient temperature classes are applicable only where humidity has no influence The average temperature over a 24 h period must not exceed 5 °C below the upper limits Combination of two ranges to define some environments may be necessary. Installations subject to temperatures outside the ranges require special consideration							– Identical to temperature range of IEC 60721-3-4, class 4K3
AB	*Atmospheric humidity*							
	Air temperature °C		**Relative humidity** %		**Absolute humidity** g/m³			
	a) low	**b) high**	**c) low**	**d) high**	**e) low**	**f) high**		
AB1	–60	+5	3	100	0.003	7	Indoor and outdoor locations with extremely low ambient temperatures Appropriate arrangements should be made[c]	Includes temperature range of IEC 60721-3-3, class 3K8, with high air temperature restricted to +5°C. Part of temperature range of IEC 60721-3-4, class 4K4, with low air temperature restricted to – 60°C and high air temperature restricted to +5°C
AB2	–40	+5	10	100	0.1	7	Indoor and outdoor locations with low ambient temperatures Appropriate arrangements should be made[c]	Part of temperature range of IEC 60721-3-3, class 3K7, with high temperature restricted to +5°C. Part of temperature range of IEC 60721-3-4, class 4K4, with low air temperature restricted to – 40°C and high air temperature restricted to +5°C

A ENVIRONMENT ***(cont.)***

Code	External influences						Characteristics required for selection and erection of equipment	Reference for information only
	Air temperature °C		Relative humidity %		Absolute humidity g/m³			
	a) low	b) high	c) low	d) high	e) low	f) high		
AB3	–25	+5	10	100	0.5	7	Indoor and outdoor locations with low ambient temperatures Appropriate arrangements should be made[c]	Part of temperature range of IEC 60721-3-3, class 3K6, with high air temperature restricted to +5°C. Includes temperature range of IEC 60721-3-4, class 4K1, with high air temperature range restricted to +5°C
AB4	–5	+40	5	95	1	29	Weather protected locations having neither temperature nor humidity control. Heating may be used to raise low ambient temperatures Normal[b]	Identical with temperature range of IEC 60721-3-3, class 3K5. The high air temperature restricted to +40°C
AB5	+5	+40	5	85	1	25	Weather protected locations with temperature control Normal[b]	Identical with temperature range of IEC 60721-3-3, class 3K3
AB6	+5	+60	10	100	1	35	Indoor and outdoor locations with extremely high ambient temperatures, influence of cold ambient temperatures is prevented. Occurrence of solar and heat radiation Appropriate arrangements should be made[c]	Part of temperature range of IEC 60721-3-3, class 3K7, with low air temperature restricted to +5°C and high air temperature restricted to +60°C. Includes temperature range of IEC 60721-3-4, class 4K4, with low air temperature restricted to +5°C
AB7	–25	+55	10	100	0.5	29	Indoor weather protected locations having neither temperature nor humidity control, the locations may have openings directly to the open air and be subjected to solar radiation Appropriate arrangements must be made[c]	Identical to temperature range of IEC 60721-3-3, class 3K6
AB8	–50	+40	15	100	0.04	36	Outdoor and non-weather protected locations, with low and high temperatures Appropriate arrangements should be made[c]	Identical to temperature range of IEC 60721-3-4, class 4K3

A ENVIRONMENT *(cont.)*

Code	External influences	Characteristics required for selection and erection of equipment	Reference for information only
AC AC1 AC2	*Altitude* ≤2 000 m >2 000 m	Normal[b] May necessitate special precautions such as the application of derating factors **NOTE:** For some equipment special arrangements may be necessary at altitudes of 1 000 m and above	
AD	*Presence of water*		
AD1	Negligible	IPX0 Probability of presence of water is negligible. Location in which the walls do not generally show traces of water but may do so for short periods, for example in the form of vapour which good ventilation dries rapidly	KS IEC 60529 IEC 60721-3-4, class 4Z6
AD2	Free-falling drops	IPX1 or IPX2 Possibility of vertically falling drops Location in which water vapour occasionally condenses as drops or where steam may occasionally be present	KS IEC 60529 IEC 60721-3-3, class 3Z7
AD3	Sprays	IPX3 Possibility of water falling as a spray at an angle up to 60° from the vertical Locations in which sprayed water forms a continuous film on floors and/or walls	KS IEC 60529 IEC 60721-3-3, class 3Z8 IEC 60721-3-4, class 4Z7 KS
AD4	Splashes	IPX4 Possibility of splashes from any direction Locations where equipment may be subjected to splashed water; this applies, for example, to certain external luminaires, construction site equipment	IEC 60529 IEC 60721-3-3, class 3Z9 IEC 60721-3-4, class 4Z7
AD5	Jets	IPX5 Possibility of jets of water from any direction Locations where hose water is used regularly (yards, car-washing bays)	KS IEC 60529 IEC 60721-3-3, class 3Z10 IEC 60721-3-4, class 4Z8 KS
AD6	Waves	IPX6 Possibility of water waves Seashore locations such as piers, beaches, quays, etc	IEC 60529 IEC 60721-3-4, class 4Z9
AD7	Immersion	IPX7 Locations which may be flooded and/ or where the equipment is immersed as follows: • Equipment with a height of less than 850 mm is located in such a way that its lowest point is not more than 1 000 mm below the surface of the water • Equipment with a height equal to or greater than 850 mm is located in such a way that its highest point is not more than 150 mm below the surface of the water	
AD8	Submersion	IPX8 Possibility of permanent and total covering by water Locations such as swimming pools where electrical equipment is permanently and totally covered with water	

A ENVIRONMENT *(cont.)*

Code	External influences	Characteristics required for selection and erection of equipment	Reference for information only
AE	*Presence of foreign solid bodies*	IPXX see also Section 416	
AE1	Negligible	IP0X The quantity or size of dust or foreign solid bodies is not significant	KS IEC 60529 IEC 60721-3-3, class 3S1 IEC 60721-3-4, class 4S1
AE2	Small objects (2.5 mm)	IP3X Presence of foreign solid bodies where the smallest dimension is not less than 2.5 mm Tools and small objects are examples of foreign solid bodies of which the smallest dimension is at least 2.5 mm	KS IEC 60529 IEC 60721-3-3, class 3S2 IEC 60721-3-4, class 4S2
AE3	Very small objects (1 mm)	IP4X Presence of foreign solid bodies where the smallest dimension is not less than 1 mm Wires are examples of foreign solid bodies of which the smallest dimension is not less than 1 mm	KS IEC 60529 IEC 60721-3-3, class 3S3 IEC 60721-3-4, class 4S3
AE4	Light dust	IP5X Presence of dust if dust penetration is not harmful to the functioning of the equipment	KS IEC 60529 IEC 60721-3-3, class 3S2 IEC 60721-3-4, class 4S2
AE5	Moderate dust	IP6X Presence of dust if dust penetration is harmful to the functioning of the equipment	KS IEC 60529 IEC 60721-3-4, class 3S3 IEC 60721-3-3, class 4S3
AE6	Heavy dust	IP6X Presence of dust Dust must not penetrate equipment	IEC 60721-3-3, class 3S4 IEC 60721-3-4, class 4S4
AF	*Presence of corrosive of polluting substances*		
AF1	Negligible	Normal[b]	IEC 60721-3-3, class 3C1 IEC 60721-3-4, class 4C1
AF2	Atmospheric	The presence of corrosive or polluting substances of atmospheric origin is significant. Installations situated by the sea or near industrial zones producing serious atmospheric pollution, such as chemical works, cement works; this type of pollution arises especially in the production of abrasive, insulating or conductive dusts According to the nature of substances (for example, satisfaction of salt mist test according to IEC 60068-2-11)	IEC 60721-3-3, class 3C2 IEC 60721-3-4, class 4C2
AF3	Intermittent or accidental	Intermittent or accidental subjection to corrosive or polluting chemical substances being used or produced Locations where some chemical products are handled in small quantities and where these products may come only accidentally into contact with electrical equipment; such conditions are found in factory laboratories, other laboratories or in locations where hydrocarbons are used (boiler-rooms, garages, etc.) Protection against corrosion according to equipment specification	IEC 60721-3-3, class 3C3 IEC 60721-3-4, class 4C3

Code	External influences	Characteristics required for selection and erection of equipment	Reference for information only
AF4	Continuous	Continuously subject to corrosive or polluting chemical substances in substantial quantity, e.g. chemical works Equipment specially designed according to the nature of substances	IEC 60721-3-3, class 3C4 IEC 60721-3-4, class 4C4
AG	*Mechanical stress:* *Impact*		
AG1	Low severity	Normal, e.g. household and similar equipment	IEC 60721-3-3, classes 3M1/3M2/3M3 IEC 60721-3-4, classes 4M1/4M2/4M3
AG2	Medium severity	Standard industrial equipment, where applicable, or reinforced protection	IEC 60721-3-3, classes 3M4/3M5/3M6 IEC 60721-3-4, classes 4M4/4M5/4M6
AG3	High severity	Reinforced protection	IEC 60721-3-3, classes 3M7/3M8 IEC 60721-3-4, classes 4M7/4M8

A ENVIRONMENT *(cont.)*

Code	External influences	Characteristics required for selection and erection of equipment	Reference for information only
AH	*Vibration*		
AH1	Low severity	Household and similar conditions where the effects of vibration are generally negligible Normal	IEC 60721-3-3, classes 3M1/3M/3M3 IEC 60721-3-4, classes 4M1/4M2/4M3
AH2	Medium severity	Usual industrial conditions Specially designed equipment or special arrangements	IEC 60721-3-3, classes 3M4/3M5/3M6 IEC 60721-3-4, classes 4M4/4M5/4M6
AH3	High severity	Industrial installations subject to severe conditions Specially designed equipment or special arrangements	IEC 60721-3-3, classes 3M7/3M8 IEC 60721-3-4, classes 4M7/4M8
AJ	*Other mechanical stresses*	Under consideration	
AK	*Presence of flora and/or mould growth*		
AK1	No hazard	No harmful hazard from flora and/or mould growth Normal[b]	IEC 60721-3-3, class 3B1 IEC 60721-3-4, class 4B1
AK2	Hazard	Harmful hazard from flora and/or mould growth The hazard depends on local conditions and the nature of flora. Distinction should be made between harmful growth of vegetation or conditions for promotion of mould growth Special protection, such as: – increased degree of protection (see AE) – special materials or protective coating of enclosures – arrangements to exclude flora from location	IEC 60721-3-3, class 3B2 IEC 60721-3-4, class 4B2
AL	*Presence of fauna*		
AL1	No hazard	No harmful hazard from fauna Normal[b]	IEC 60721-3-3, class 3B1 IEC 60721-3-4, class 4B1

Code	External influences	Characteristics required for selection and erection of equipment	Reference for information only
AL2	Hazard	Harmful hazard from fauna (insects, birds, small animals) The hazard depends on the nature of the fauna. Distinction should be made between: – presence of insects in harmful quantity or of an aggressive nature; – presence of small animals or birds in harmful quantity or of an aggressive nature Protection may include: – an appropriate degree of protection against penetration of foreign solid bodies (see AE) – sufficient mechanical resistance (see AG) – precautions to exclude fauna from the location (such as cleanliness, use of pesticides) – special equipment or protective coating of enclosures	IEC 60721-3-3, class 3B2 IEC 60721-3-4, class 4B2

A ENVIRONMENT *(cont.)*

Code	External influences	Characteristics required for selection and erection of equipment	Reference for information only
AM	*Electromagnetic, electrostatic, or ionizing influences* *Low-frequency electromagnetic phenomena (conducted or radiated)* *Harmonics, interharmonics*		
AM-1-1	Controlled level	Care should be taken that the controlled situation is not impaired	Lower than table 1 of IEC 61000-2-2
AM-1-2	Normal level	Special measures in the design of the installation, e.g. filters	Complying with table 1 of IEC 61000-2-2
AM-1-3	High level	Special measures in the design of the installation, e.g. filters	Locally higher than table 1 of IEC 61000-2-2
	Signalling voltages		
AM-2-1	Controlled level	Possibly: blocking circuits	Lower than specified below
AM-2-2	Medium level	No additional requirement	IEC/TR 61000-2-1 and IEC 61000-2-2
AM-2-3	High level	Appropriate measures	
	Voltage amplitude variations		
AM-3-1	Controlled level	e.g. controlled by UPS	
AM-3-2	Normal level	Compliance with KS 662-4 Chapter 44	
AM-4	*Voltage unbalance*		Compliance with IEC 61000-2-2
AM-5	*Power frequency variations*		±1 Hz according to IEC 61000-2-2
AM-6	*Induced low-frequency voltages* No classification	Refer to KS 662-4 Chapter 44 High withstand of signal and control systems of switchgear and controlgear	ITU-T (International Telecommunication Union)
AM-7	*Direct current in AC networks (321.10.1.7)* No classification	Measures to limit their presence in level and time in the current-using equipment or their vicinity	
	Radiated magnetic fields		
AM-8-1	Medium level	Normal[b]	Level 2 of IEC 61000-4-8
AM-8-2	High level	Protection by appropriate measures e.g. screening and/or separation	Level 4 of IEC 61000-4-8

A ENVIRONMENT *(cont.)*

Code	External influences	Characteristics required for selection and erection of equipment	Reference for information only
	Electric fields		
AM-9-1	Negligible level	Normal[b]	
AM-9-2	Medium level		IEC TR 61000-2-5
AM-9-3	High level		IEC TR 61000-2-5
AM-9-4	Very high level		IEC TR 61000-2-5
	High-frequency electromagnetic phenomena conducted, induced or radiated (continuous or transient)		
AM-21	*Induced oscillatory voltages or currents*		
	No classification	Normal[b]	IEC 61000-4-6
	Conducted unidirectional transients of the nanosecond time scale		IEC 61000-4-4
AM-22-1	Negligible level	Protective measures are necessary	Level 1
AM-22-2	Medium level	Protective measures are necessary	Level 2
AM-22-3	High level	Normal equipment	Level 3
AM-22-4	Very high level	High immunity equipment	Level 4
	Conducted unidirectional transients of microsecond to millisecond time scale		
AM-23-1	Controlled level	Impulse withstand of equipment and overvoltage protective means chosen taking into account the nominal supply voltage and the impulse withstand category according to KS 662-4 Chapter 44	KS 662-4 Chapter 44
AM-23-2	Medium level		KS 662-4 Chapter 44
AM-23-3	High level		
	Conducted oscillatory transients		
AM-24-1	Medium level	Refer to IEC 61000-4-12	IEC 61000-4-12
AM-24-2	High level	Refer to IEC 60255-26	IEC 60255-26:2013
	Radiated high-frequency phenomena		IEC 61000-4-3
AM-25-1	Negligible level		Level 1
AM-25-2	Medium level	Normal[b]	Level 2
AM-25-3	High level	Reinforced level	Level 3
	Electrostatic discharges		IEC 61000-4-2
AM-31-1	Small level	Normal[b]	Level 1
AM-31-2	Medium level	Normal[b]	Level 2
AM-31-3	High level	Normal[b]	Level 3
AM-31-4	Very high level	Reinforced	Level 4
AM-41-1	*Ionization* No classification	Special protection such as: – Spacings from source – Interposition of screens, enclosure by special materials	

A ENVIRONMENT *(cont.)*

Code	External influences	Characteristics required for selection and erection of equipment	Reference for information only
AN	*Solar radiation*		
AN1	Low	Intensity ≤ 500 W/m^2 Normal[b]	IEC 60721-3-3 class 3K1
AN2	Medium	500 W/m^2 < intensity ≤ 700 Wm^2 Appropriate arrangements must be made[c]	IEC 60721-3-3 Classes 3K2 to 3K5
AN3	High	700 W/m^2 < intensity ≤ 1120 W/m^2 Appropriate arrangements must be made[c] Such arrangements could be: – material resistant to ultraviolet radiation – special colour coating – interposition of screens	IEC 60721-3-3 Higher than class 3K5 IEC 60721-3-4
AP	*Seismic effects*		
AP1	Negligible	Acceleration ≤ 30 Gal (1 Gal = 1 cm/s^2) Normal[b]	
AP2	Low severity	30 Gal < acceleration ≤ 300 Gal Under consideration	
AP3	Medium severity	300 Gal < acceleration ≤ 600 Gal Under consideration	
AP4	High severity	600 Gal < acceleration Under consideration Vibration which may cause the destruction of the building is outside the classification Frequency is not taken into account in the classification; however, if the seismic wave resonates with the building, seismic effects must be specially considered. In general, the frequency of seismic acceleration is between 0 Hz and 10 Hz	
AQ	*Lightning*		
AQ1	Negligible	Normal[b]	
AQ2	Indirect exposure	In accordance with Section 443	
AQ3	Direct exposure	KS IEC 62305-1	
AR	*Movement of air*		
AR1	Low	Speed ≤ 1 m/s Normal[b]	
AR2	Medium	1 m/s < speed ≤ 5 m/s Appropriate arrangements should be made[c]	
AR3	High	5 m/s < speed ≤ 10 m/s Appropriate arrangements should be made[c]	
AS	*Wind*		
AS1	Low	Speed ≤ 20 m/s Normal[b]	
AS2	Medium	20 m/s < speed ≤ 30 m/s Appropriate arrangements should be made[c]	
AS3	High	30 m/s < speed ≤ 50 m/s Appropriate arrangements should be made[c]	

B UTILIZATION:

Code	External influences	Characteristics required for selection and erection of equipment	Reference for information only
BA	**Capability of persons**		
BA1	Ordinary	Uninstructed persons Normal[b]	Inaccessibility of electrical equipment. Limitation of temperature of accessible surfaces
BA2	Children	Locations intended for presence of children e.g. nurseries, infant schools, etc.Equipment of degrees of protection equal to or greater than IP2XC. Inaccessibility of equipment with external surface temperature exceeding 60 °C	
BA3	Handicapped	Persons not in command of all their physical and/or intellectual abilities (sick persons, old persons) According to the nature of the handicap	
BA4	Instructed	Persons adequately advised or supervised by skilled persons to enable them to avoid dangers which electricity may create (operating and maintenance staff) Electrical operating areas	
BA5	Skilled	Equipment not having basic protection against direct contact with live parts admitted solely in locations which are accessible only to duly authorized persons with technical knowledge or sufficient experience to enable them to avoid danger which electricity may create (engineers and technicians) Closed electrical operating areas	
BB	**Electrical resistance of the human body** Under consideration		
BC	**Contact of persons with Earth potential**		
		Class of equipment according to KS IEC 61140 I II III	
BC1	None	Persons in non-conducting situations A A A	
BC2	Occasional	Persons who do not in usual conditions make contact with extraneous-conductive-parts or stand on conducting surfaces A A A	
BC3	Frequent	Persons who are frequently in touch with extraneous-conductive-parts or stands on conducting services Locations with extraneous-conductive-parts, either numerous or of a large area Class of equipment according to KS IEC61140 0-01 I II III X A A A A Equipment permitted X Equipment prohibited Y Permitted if used as class 0	
BC4	Continuous	Persons who are immersed in water or in long term permanent contact with metallic surroundings and for whom the possibility of interrupting contact is limited Metallic surroundings such as boilers and tanks	Under consideration
BD	**Conditions of evacuation in an emergency**		
BD1	Low density / easy exit	Normal[b] Low density occupation, easy conditions of evacuation Buildings of normal or low height used for habitation	
BD2	Low density / difficult exit	Low density occupation, difficult conditions of evacuation High-rise buildings	
BD3	High density / easy exit	High density occupation, easy conditions of evacuation Locations open to the public (theatres, cinemas, departments stores, etc.)	
BD4	High density / difficult exit	High density occupation, difficult conditions of evacuation High-rise buildings open to the public (hotels, hospitals, etc.)	

Code	External influences	Characteristics required for selection and erection of equipment	Reference for information only
BE	**Nature of processed or stored materials**		
BE1	No significant risk	Normal[b]	
BE2	Fire risks	Manufacture, processing or storage of flammable materials including presence of dust Barns, wood-working shops, paper factories Equipment made of material retarding the spread of flame Arrangements such that a significant temperature rise or a spark within electrical equipment cannot initiate an external fire	Chapter 42 Chapter 52
BE3	Explosion risks	Processing or storage of explosive or low-flash-point materials including presence of explosive dusts Oil refineries, hydrocarbon stores Requirements for electrical apparatus for explosive atmospheres (see KS IEC 60079),	Under consideration
BE4	Contamination risks	Presence of unprotected foodstuffs, pharmaceutics, and similar products without protection Foodstuff industries, kitchens: Certain precautions may be necessary, in the event of fault, to prevent processed materials being contaminated by electrical equipment, e.g. by broken lamps Appropriate arrangements, such as: protection against falling debris from broken lamps and other fragile objects screens against harmful radiation such as infrared or ultraviolet	Under consideration

C CONSTRUCTION OF BUILDINGS:

Code	External influences	Characteristics required for selection and erection of equipment	Reference for information only
CA	**Construction materials**		
CA1	Non-combustible	Normal	
CA2	Combustible	Buildings mainly constructed of combustible materials Wooden buildings Under consideration	HD 60364-4-42
CB	**Building design**		
CB1	Negligible risks	Normal	
CB2	Propagation of fire	Buildings of which the shape and dimensions facilitate the spread of fire (e.g. chimney effect) High-rise buildings. Forced ventilation systems Equipment made of material retarding the propagation of fire including fires not originating from the electrical installation. Fire barriers	HD 60364-4-42 HD 60364-5-52
CB3	Movement	Risk due to structural movement (e.g. displacement) Buildings of considerable length or erected on unstable ground Contraction or expansion joints in electrical wiring	Contraction or expansion joints (under consideration) HD 60364-5-52
CB4	Flexible or unstable	Structures which are weak or subject to movement (e.g. oscillation) Tents, air-support structures, false ceilings, removable partitions. Installations to be structurally self-supporting Under consideration	Flexible wiring HD 60364-5-52

APPENDIX 4 (Informative)
CURRENT-CARRYING CAPACITY AND VOLTAGE DROP FOR BUSBAR TRUNKING AND POWERTRACK SYSTEMS

1 Basis of current-carrying capacity

The current-carrying capacity (I_{nA}) of a busbar trunking or powertrack system relates to continuous loading and is declared by the manufacturer based on tests to KS IEC 61439-6 (busbar trunking) or IEC 61534 series of standards (Powertrack). The current-carrying capacity is designed to provide for satisfactory life of the system, subject to the thermal effects of carrying current for sustained periods in normal service.

Considerations affecting the choice of size of a busbar trunking or powertrack system include the requirements for protection against electric shock (see Chapter 41), protection against thermal effects (see Chapter 42), overcurrent protection (see Chapter 43 and sec 4 below) and voltage drop (see sec 5 below).

2 Rating factors for current-carrying capacity

The current-carrying capacity (I_{nA}) can be affected by the ambient temperature and the mounting conditions (for example the orientation of the conductors).

I_{nA} for Powertrack according to IEC 61534 is defined as 'The rated current value assigned to a Powertrack system by the manufacturer and to which operation and performance characteristics are referred.'

I_{nA} for a busbar trunking system according to KS IEC 61439-6 is defined as 'The rated current value declared by the manufacturer which can be carried without the temperature rise of various parts of the busbar trunking system exceeding specified limits under specified conditions.'

I_{nC} for a busbar trunking system according to KS IEC 61439-6 is the value of the current that can be carried by a circuit loaded alone, undernormal service conditions without the temperature rise of the various parts of the ASSEMBLY exceeding the limits specified.

Installation ambient temperature

For a busbar trunking system, if the ambient temperature exceeds 35 °C the rating factor k_{1A} to be applied is obtained from the manufacturer of the busbar trunking system (k_{1A} = 1 for 35 °C).

The effective current-carrying capacity (I_{nA}) at the new temperature is $k_{1A} \times I_{nA}$.

Mounting attitude

For a busbar trunking system the mounting factor k_{2C} to be applied is obtained from the manufacturer of the busbar trunking system.

The effective current-carrying capacity (I'_{nC}) under the new mounting conditions is $k_{2C} \times I_{nC}$.

In a typical installation, both factors may have to be taken into account and the effective current-carrying capacity (I'_{nC}) then becomes $k_{1C} \times k_{2C} \times I_{nC}$

where:

k_{1C} is a temperature factor , equal to 1 at an ambient air temperature of 35 °C

k_{2C} is a mounting factor, equal to 1 in the reference mounting conditions.

NOTE: For a powertrack system the effective current-carrying capacity is the rated current I_{nA} declared by the manufacturer in accordance with IEC 61534 series under all normal conditions.

3 Effective current-carrying capacity

I_z must be not less than I_b, such that: $I_z \geq I_b$

where:

I_z is the effective current-carrying capacity of the busbar trunking (I'_{nC}) or powertrack system (I_{nA}) for continuous service under the particular installation conditions, and

I_b is the design current of the circuit.

4 Protection against overload current

The minimum operating current of the protective device should not exceed 1.45 I_z. Where the protective device is a fuse to IEC 60269 series or a circuit-breaker to either IEC 60947-2 or IEC 60898, this requirement is satisfied by selecting a value of I_z not less than I_n, where I_n is the rated current or current setting of the device protecting the circuit against overcurrent.

5 Voltage drop

The voltage drop (V_d) for the busbar trunking or powertrack system is obtained from the manufacturer. It is usually expressed as mV/ampere/metre, tabulated according to the value of the load-circuit power factor. The voltage drop given is calculated on the basis of a single load at the end of the run and, in this case, the total voltage drop = $V_d \times I_b \times L / 1000$ volts, where L is the length of run in metres.

In the case of an evenly distributed load (tapped off at intervals along the busbar trunking or powertrack system) then the voltage drop at the furthest tap-off point may be taken as 0.5 V_d, and is calculated by the above method.

In the case of an unevenly distributed load it will be necessary to calculate the voltage drop for each section between tap-off points and add them together to find the voltage drop at the furthest tap-off point.

APPENDIX 5 (Informative)
DEFINITIONS – MULTIPLE SOURCE, DC AND OTHER SYSTEMS

Fig 9 – Explanation of symbols used within Appendix 5

	Neutral conductor (N); midpoint conductor (M)
	Protective conductor (PE)
	Combined protective and neutral conductor (PEN)

NOTE 1: The dotted lines indicate the parts of the system that are not covered by the scope of the Standard, whereas the solid lines indicate the part that is covered by the Standard.

NOTE 2: For private systems, the source and/or the distribution system may be considered as part of the installation within the meaning of this Standard. For this case, the figures may be completely shown in solid lines.

Fig 9A – TN-C-S multiple source system with separate protective conductor and neutral conductor to current-using equipment

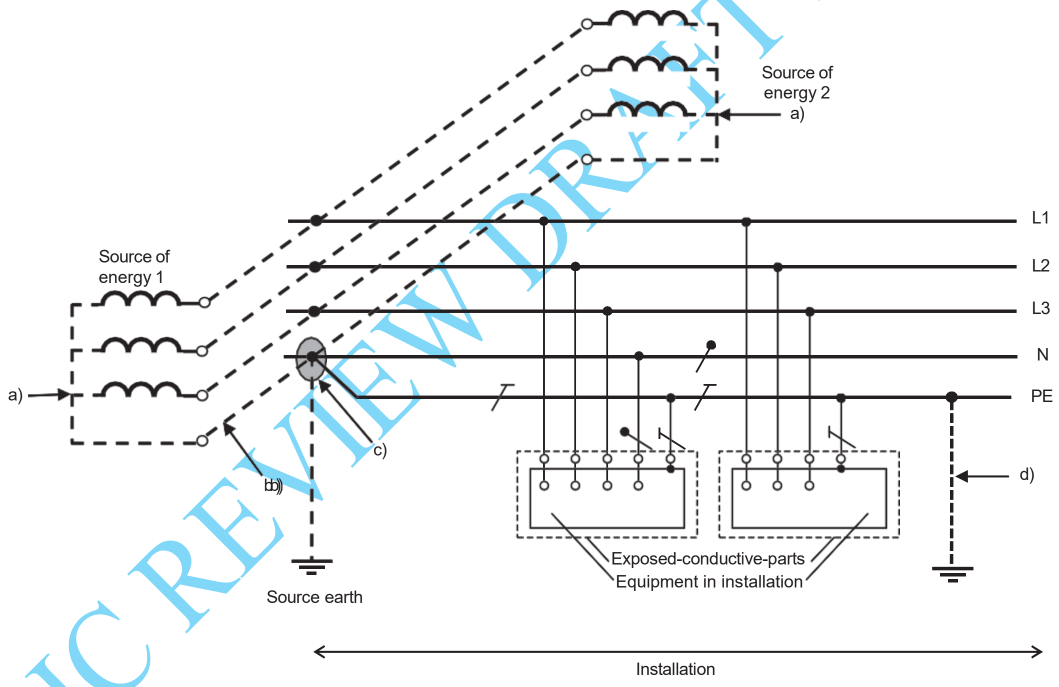
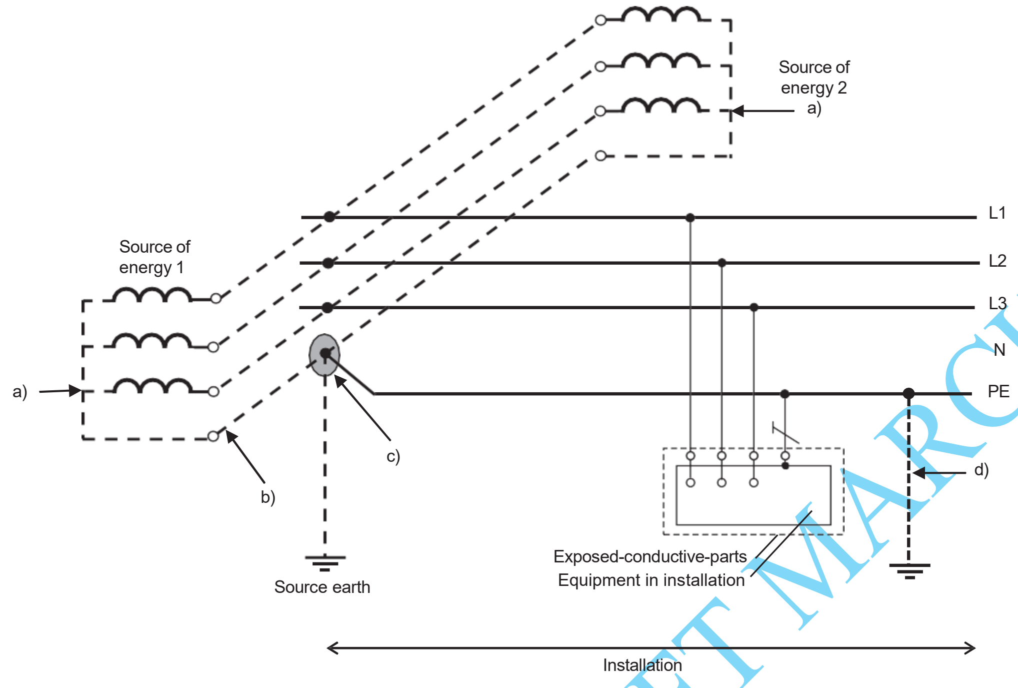


Fig 9B – TN multiple source system with protective conductor and no neutral conductor throughout the system for 2- or 3-phase load



NOTES to Figures 9A and 9B

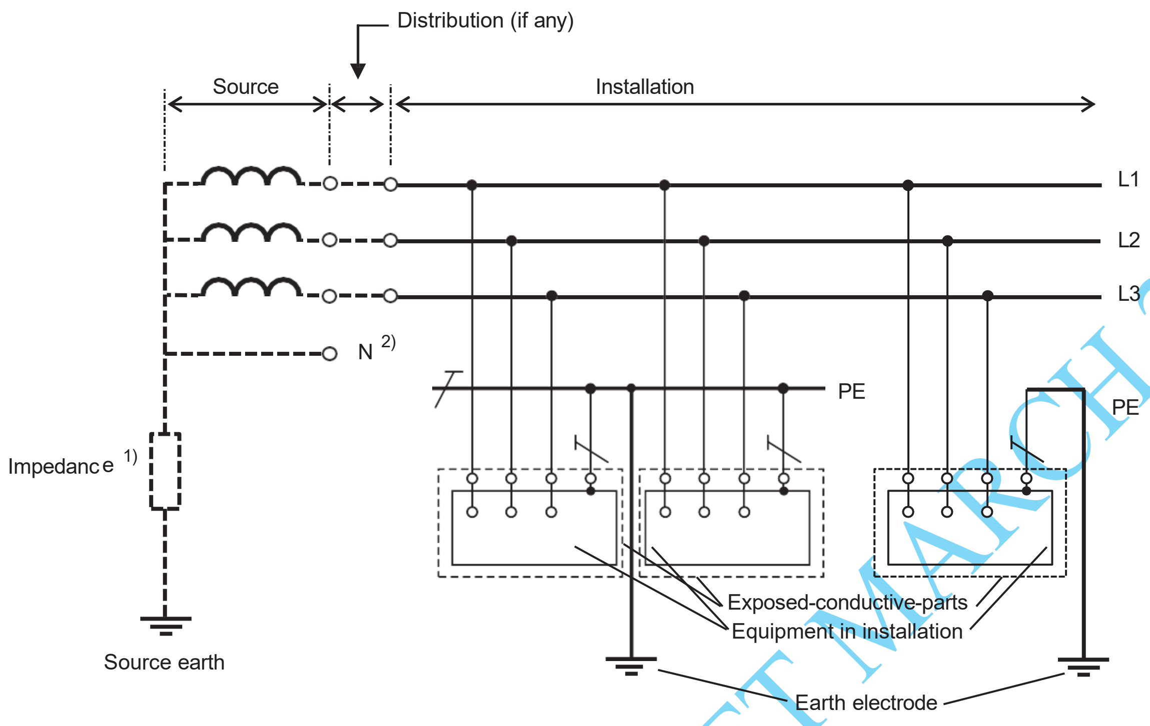
(1) No direct connection from either the transformer neutral point or the generator star point to Earth is permitted.

(2) The interconnection conductor between either the neutral points of the transformers or the generator star points is to be insulated. The function of this conductor is similar to a PEN; however, it must not be connected to current-using equipment.

(3) Only one connection between the interconnected neutral points of the sources and the PE is to be provided. This connection is to be located inside the main switchgear assembly.

(4) Additional earthing of the PE in the installation may be provided.

Fig 9C – IT system with exposed-conductive-parts earthed in groups or individually



NOTES

Additional earthing of the PE in the installation may be provided.

(1) The system may be connected to Earth via a sufficiently high impedance.

(2) The neutral conductor may or may not be distributed.

Fig 9D – TN-S DC system with earthed line conductor L− separated from the protective conductor throughout the installation

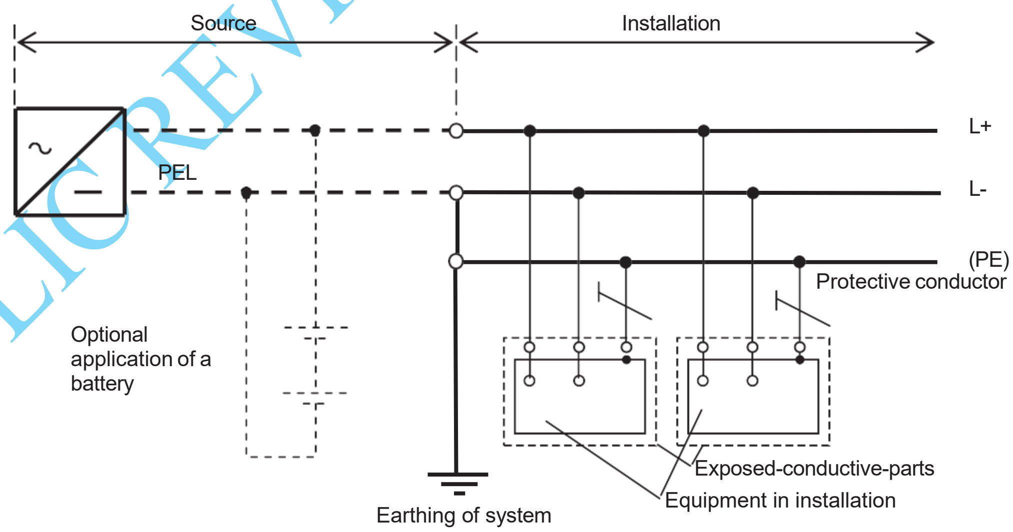
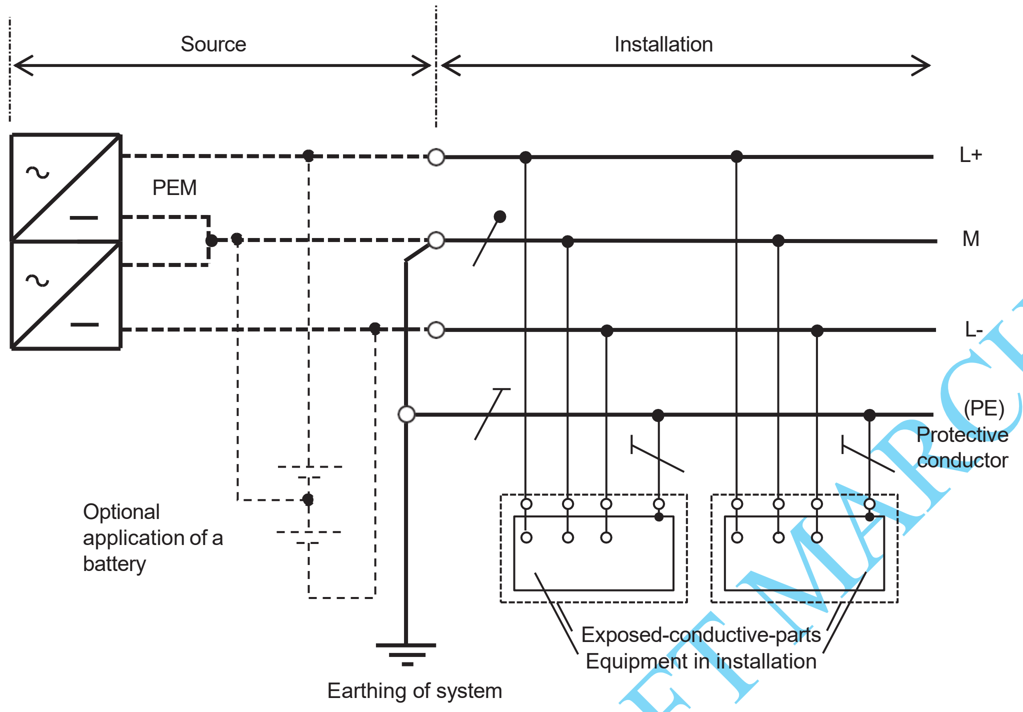


Fig 9E – TN-S DC system with earthed midpoint conductor M separated from the protective conductor throughout the installation



NOTE to Figures 9D and 9E

Additional earthing of the PE in the installation may be provided.

Fig 9F – TN-C DC system with earthed line conductor L– and protective conductor combined in one single conductor PEL throughout the installation

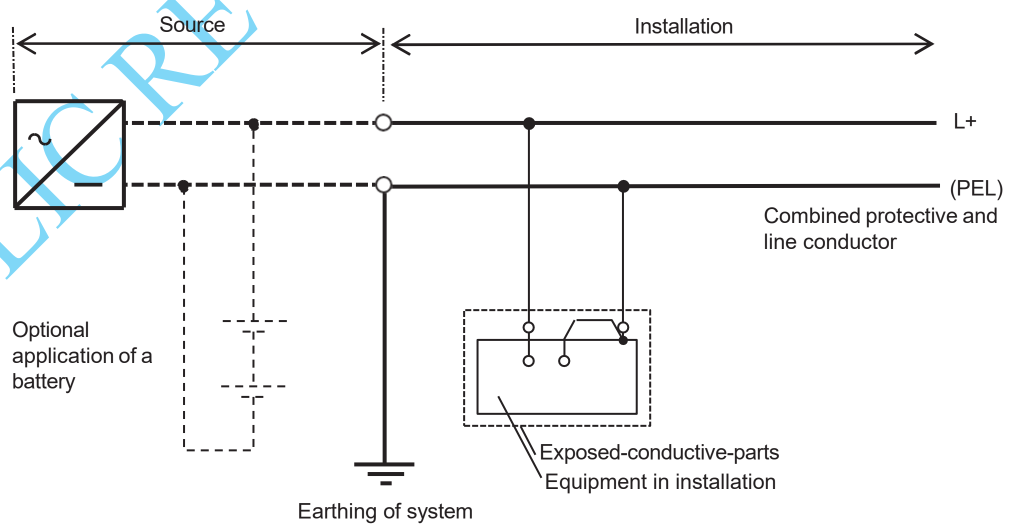
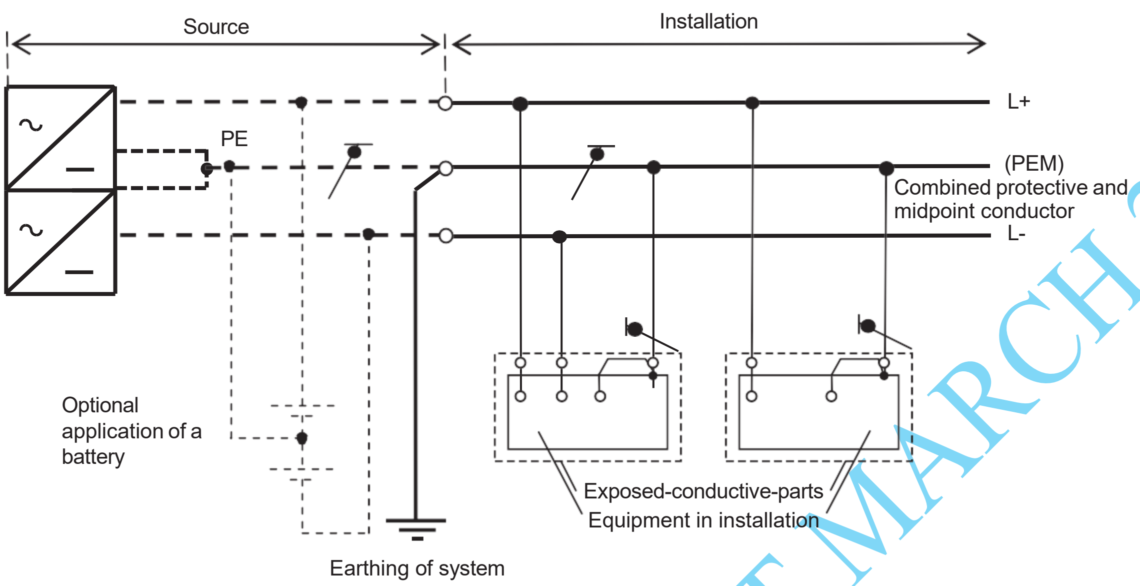


Fig 9G – TN-C DC system with earthed midpoint conductor M and protective conductor combined in one single conductor PEM throughout the installation



NOTE to Figures 9F and 9G

Additional earthing of the PEL or PEM in the installation may be provided.

Fig 9H – TN-C-S DC system with earthed line conductor L – and protective conductor combined in one single conductor PEL in a part of the installation

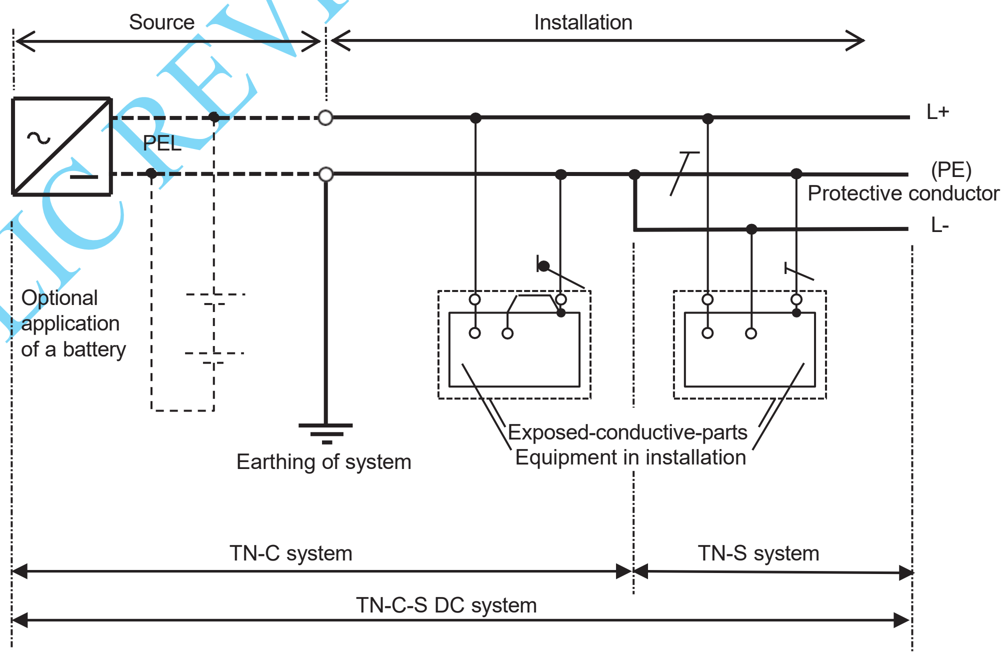
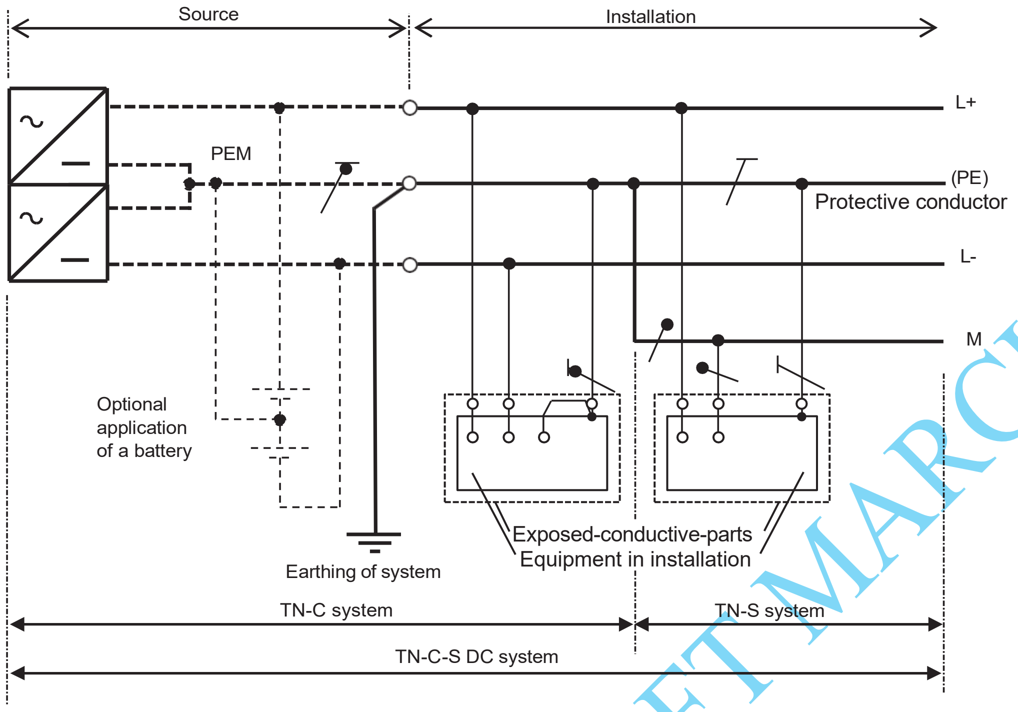


Fig 9I – TN-C-S DC system with earthed midpoint conductor M and protective conductor combined in one single conductor PEM in a part of the installation



NOTES to Figures 9H and 9I

Additional earthing of the PE in the installation may be provided.

Fig 9J – TT DC system

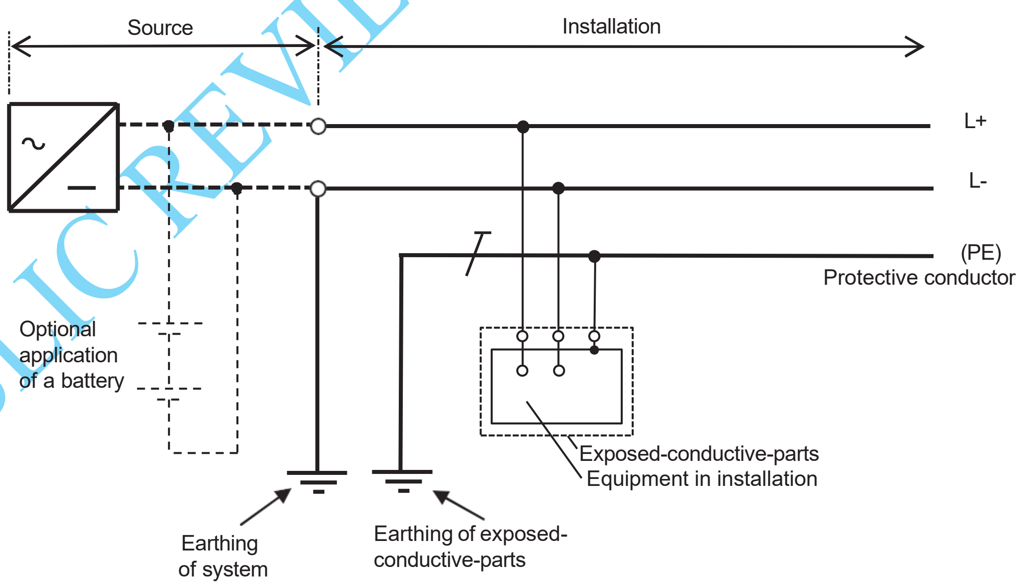
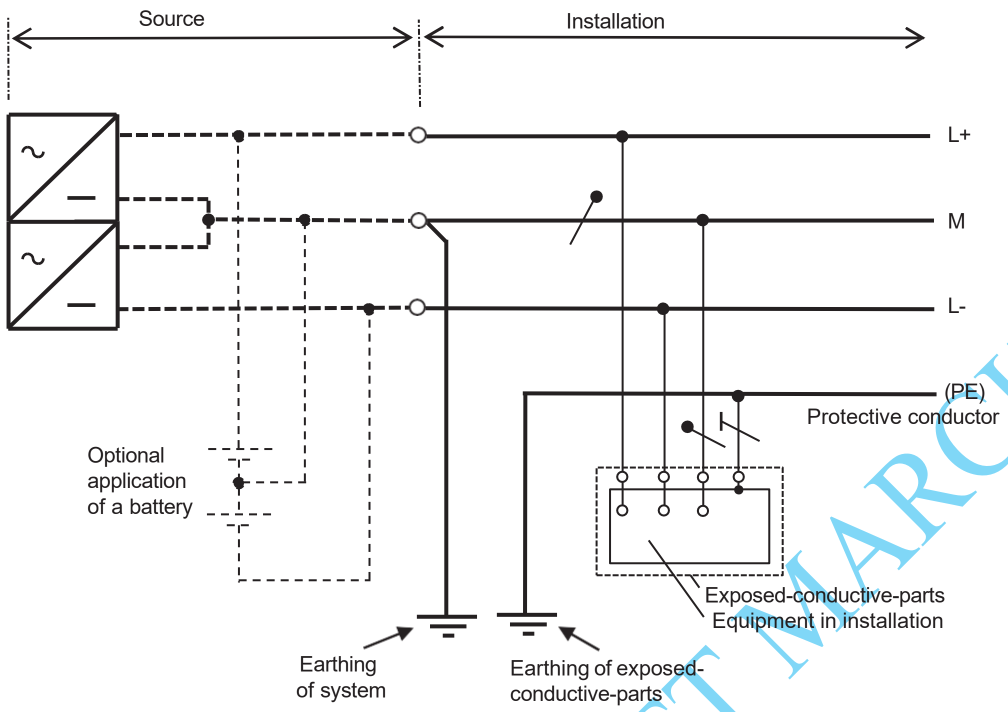


Fig 9K – TT DC system



NOTE to Figures 9J and 9K

Additional earthing of the PE in the installation may be provided.

Fig 9L – IT DC system with earthed line conductor L− and protective conductor

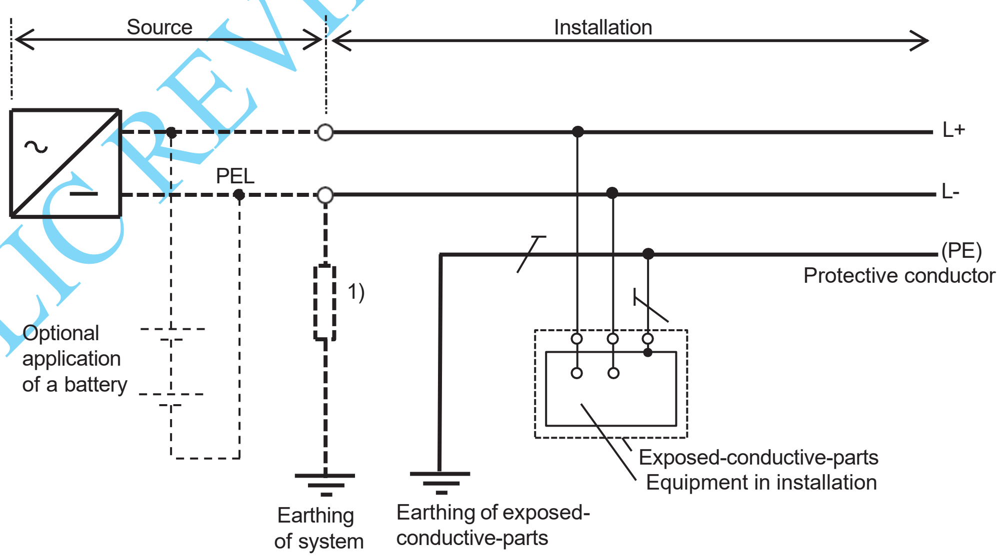
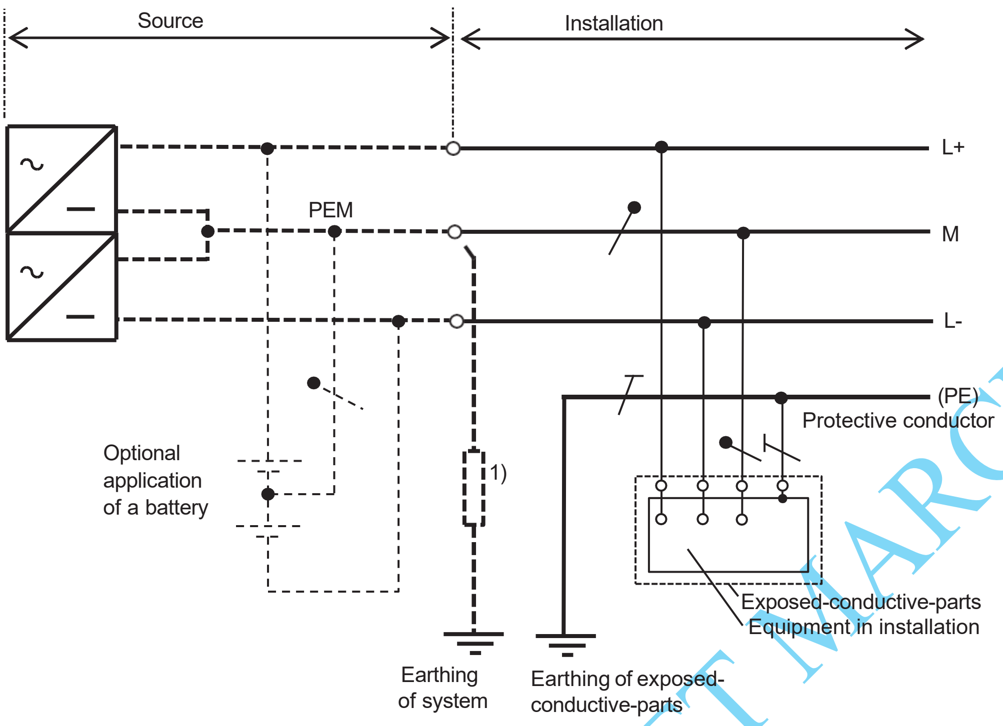


Fig 9M – IT DC system with earthed midpoint conductor M and protective conductor



NOTES to Figures 9L and 9M

Additional earthing of the PE in the installation may be provided.

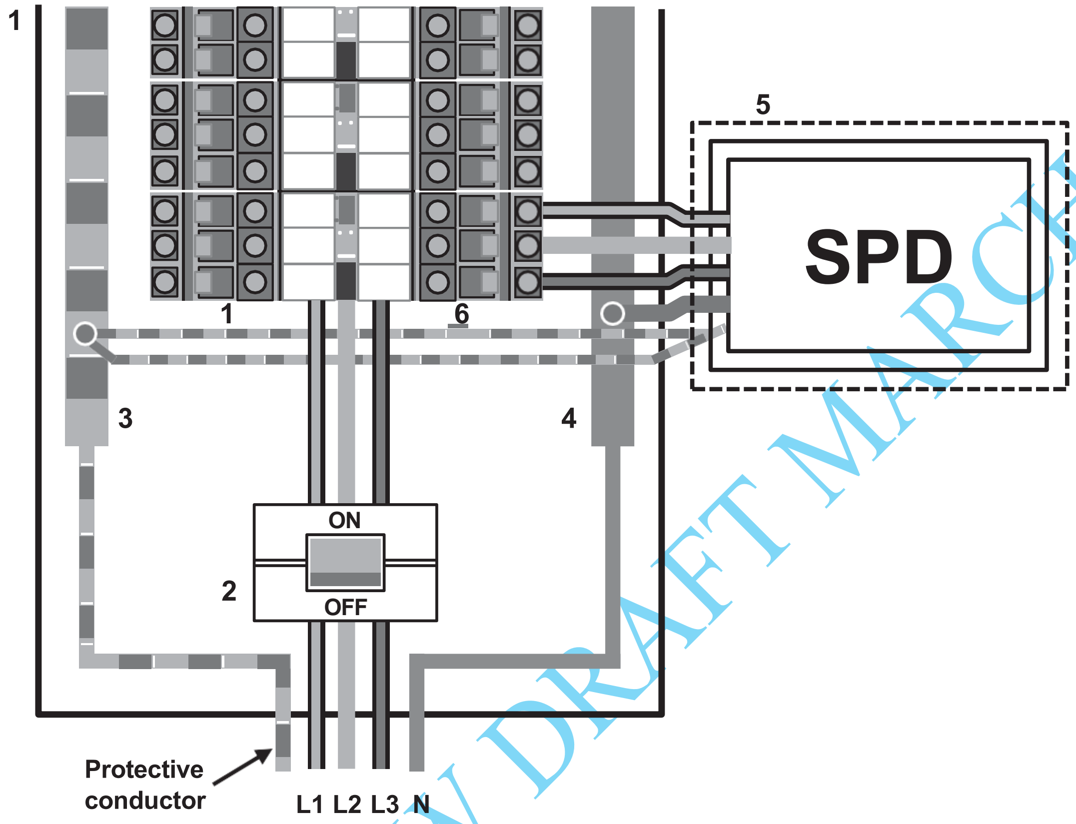
(1) The system may be connected to Earth via a sufficiently high impedance.

APPENDIX 6 (Informative)

Devices for protection against Overvoltage

Typical installation of a surge protective device (SPD) in a power distribution board for a TN-S system.

Fig 16A1 – SPD connected to the first overcurrent protective device (OCPD) to the incoming supply



Key :

1 Distribution board

2 Main switch

3 Earthing bar

4 Neutral bar

5 Enclosure for SPD

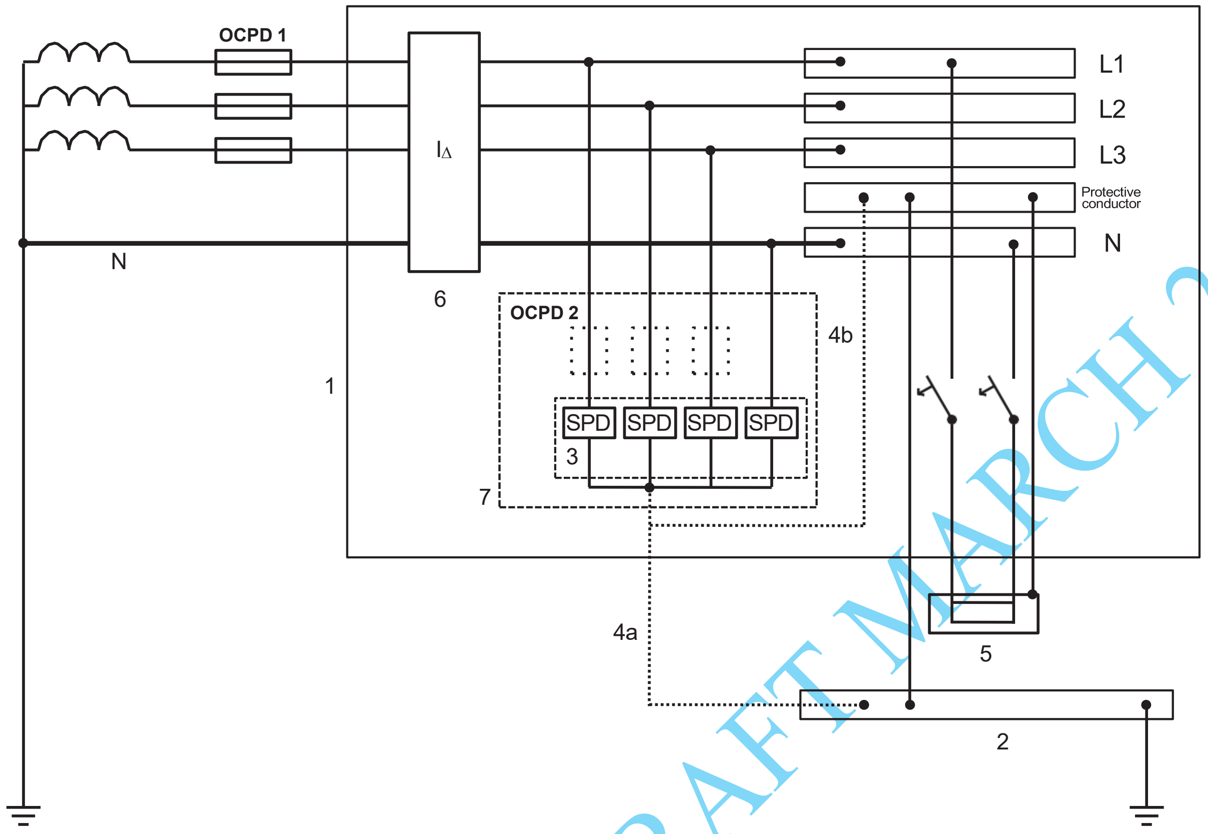
6 First OCPD

7 Alternative first OCPD

NOTE: The OCPD provides a convenient means to protect the SPD and a means of isolation. As there is insufficient room within the distribution board the SPD is mounted in a separate enclosure for electrical safety. This enclosure is mounted directly alongside the distribution board so that the connecting leads are kept short. An additional local bonding connection is made to further minimize voltage drop on the connecting leads.

Installation of surge protective devices in TT systems, Connection Type 1 (CT 1)

Fig 16A2 – SPDs on the load side of an RCD [according to Section 534.4.6(a)]



Key

1 Distribution board

2 Main earthing terminal or bar

3 Surge protective devices ensuring a protection level in accordance with overvoltage Category II

4a, 4b Earthing connection of surge protective devices, either 4a or 4b, whichever is the shorter route

5 Current-using equipment

6 Residual current protective device (RCD)

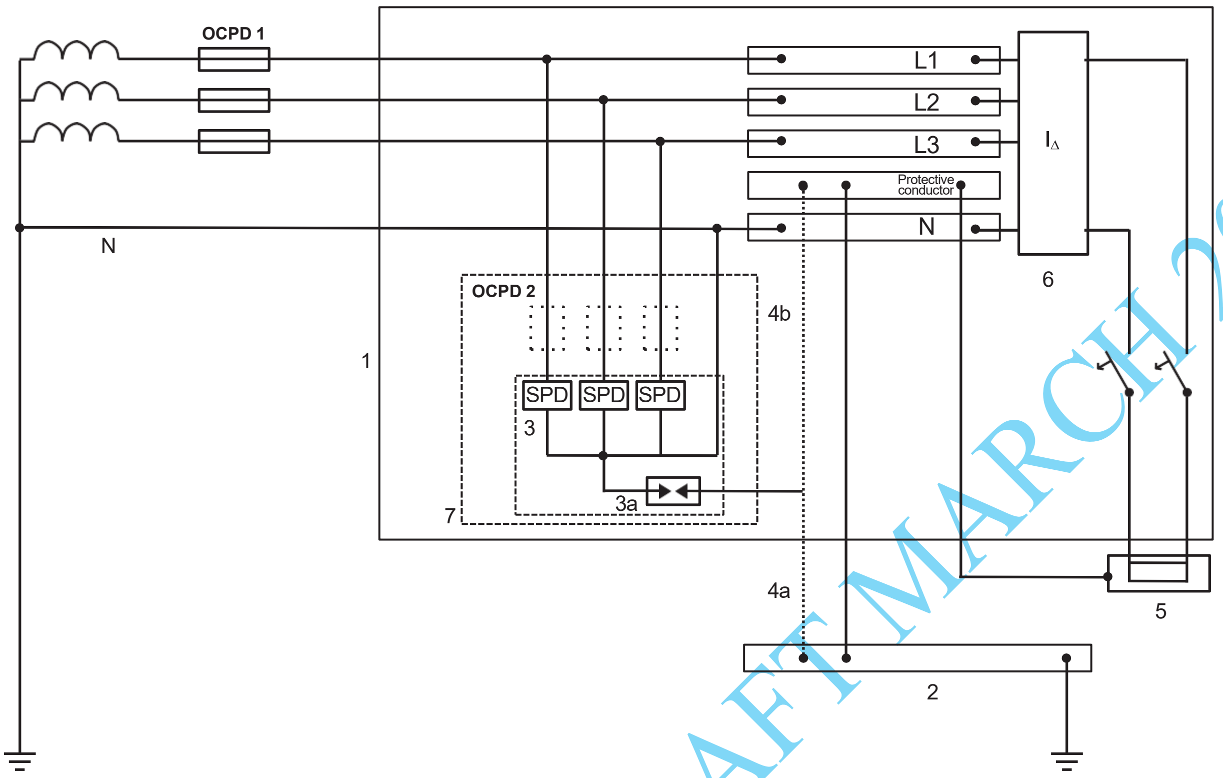
7 SPD assembly

OCPD 1 Overcurrent protective devices at the origin of the installation

OCPD 2 Overcurrent protective devices

Installation of surge protective devices in TT systems, Connection Type 2 (CT 2)

Fig 16A3 – SPDs on the supply side of an RCD [according to Section 534.4.6(b)]



Key

1 Distribution board

2 Main earthing terminal or bar

3 Surge protective devices

3a Surge protective device (SPDs 3 and 3a in series ensuring a protection level in accordance with overvoltage Category II)

4a, 4b Earthing connection of surge protective devices, either 4a or 4b, whichever is the shorter route

5 Current-using equipment

6 Residual current protective device (RCD) installed downstream of the surge protective devices

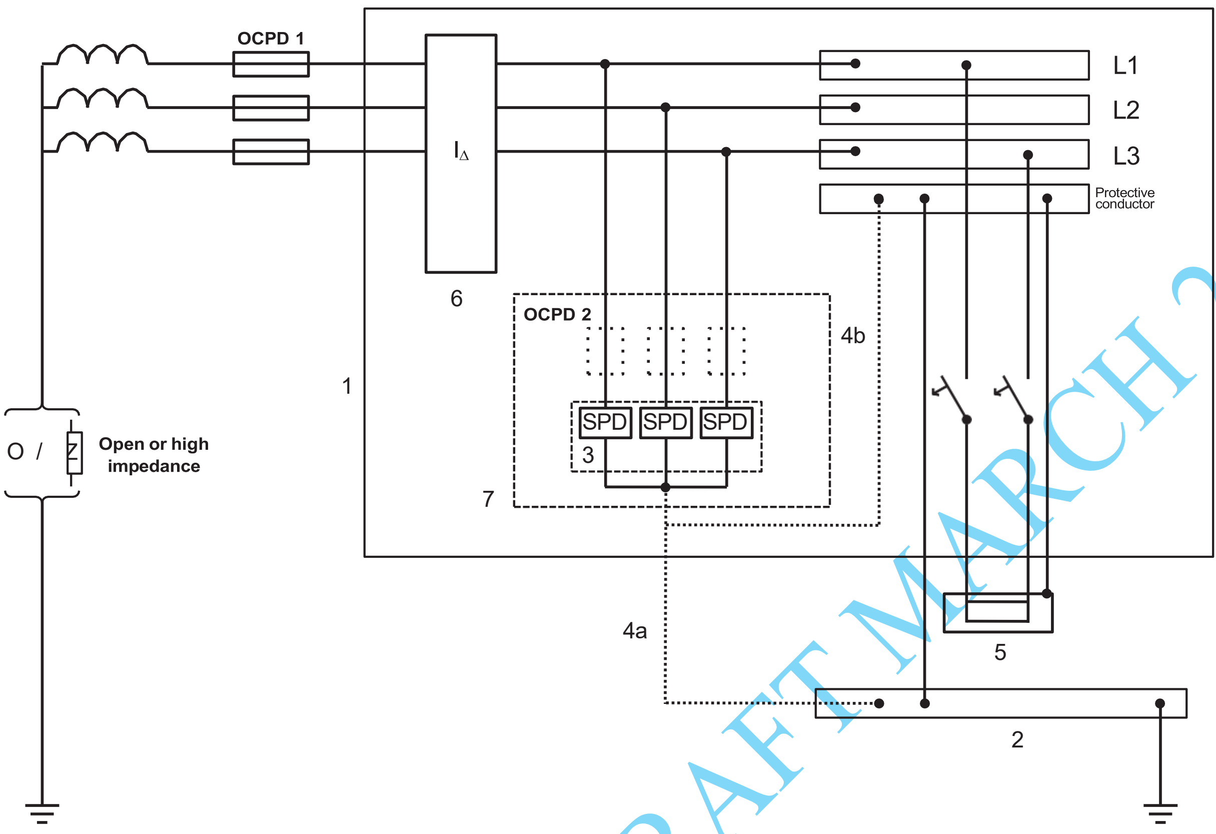
7 SPD assembly

OCPD 1 Overcurrent protective devices at the origin of the installation

OCPD 2 Overcurrent protective devices

Installation of surge protective devices in IT systems

Fig 16A4 – SPDs on the load side of an RCD

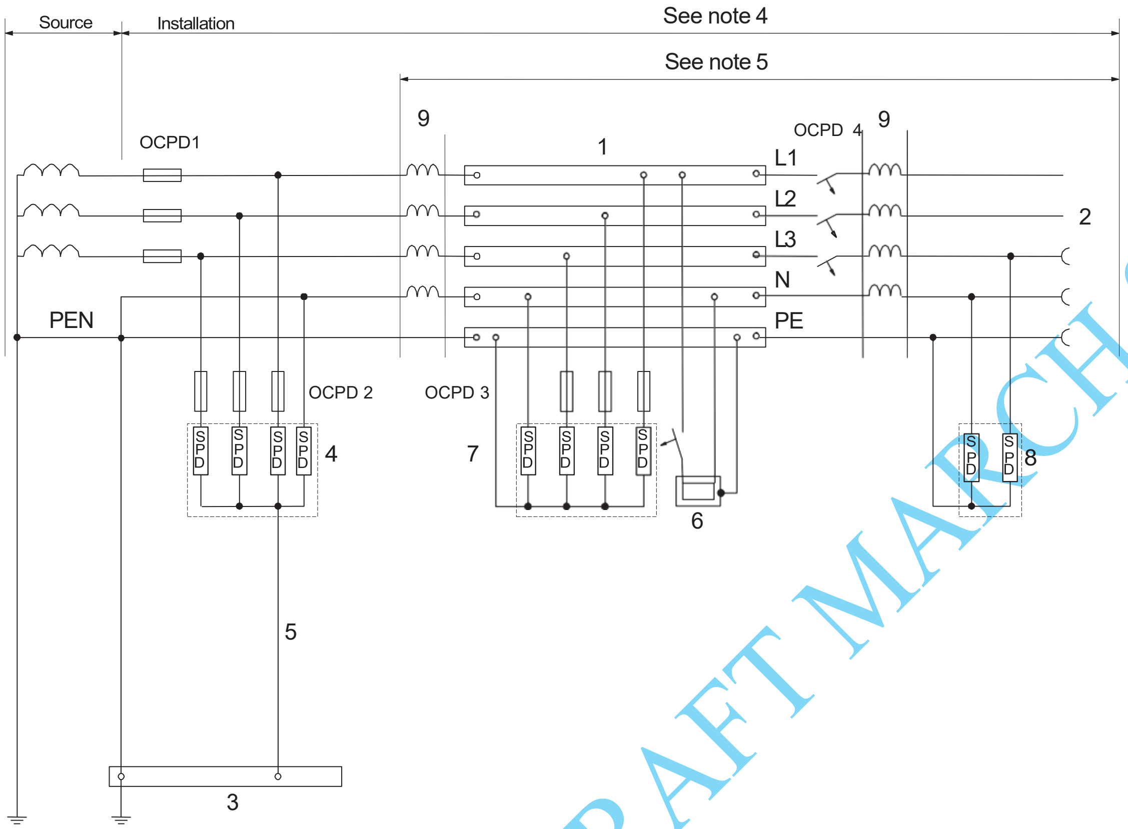


Key

1	Distribution board
2	Main earthing terminal or bar
3	Surge protective devices ensuring a protection level in accordance with overvoltage Category II
4a, 4b	Earthing connection of surge protective devices, either 4a or 4b, whichever is the shorter route
5	Current-using equipment
6	Residual current protective device (RCD) installed upstream of the surge protective devices
7	SPD assembly
OCPD 1	Overcurrent protective devices at the origin of the installation
OCPD 2	Overcurrent protective devices

Installation of Types 1, 2 and 3 SPDs, for example in TN-C-S systems

Fig 16A5 – Installation example of Types 1, 2 and 3 coordinated SPDs



Key

1 Distribution board

2 Distribution outlet

3 Main earthing terminal or bar

4 Surge protective device, Type 1

5 Earthing connection (earthing conductor) of surge protective device

6 Fixed equipment to be protected

7 Surge protective device, Type 2

8 Surge protective device, Type 2 or Type 3

9 Decoupling element or line length

NOTE: If the cable length between the SPD types is short (refer to manufacturers' data), a decoupling element is employed to provide inductance for correct SPD co-ordination.

OCPD 1, 2, 3,4 Overcurrent protective devices

NOTE 1: For further information reference should be made to KS IEC 61643-12.

NOTE 2: SPDs 4 and 7 (or 7 and 8) can be combined in a single SPD.

NOTE 3: SPDs may require additional modes of protection for sensitive equipment.

NOTE 4: KS IEC 62305-4 covers the protection of electrical and electronic systems within structures against lightning.

NOTE 5: Section 443 of KS 662 deals with the protection of electrical installations against transient overvoltages of atmospheric origin, transmitted by the supply distribution system, and against switching overvoltages generated by the equipment within the installation.

Typically, Type 1 SPDs are used at the origin of the installation, Type 2 SPDs are used at distribution boards and Type 3 SPDs are used near terminal equipment. Combined Type SPDs are classified with more than one Type, e.g. Type 1+2, Type 2+3. Type 1 SPDs are only used where there is a risk of direct lightning current.

The most important aspect in selecting an SPD is its limiting voltage performance (protection level U_p) during the expected surge event, and not the energy withstand (e.g. I_{imp}) which it can handle. An SPD with a low protection level will provide adequate protection of the equipment, while an SPD with a high energy withstand may only result in a longer operating life.

TABLE 16A – Information on SPD classification

SPD according to KS IEC 62305	SPD according to IEC 61643-11
SPD tested with I_{imp}	Type 1
SPD tested with I_n	Type 2
SPD tested with a combination wave	Type 3

SPD tested with Iimp (KS IEC 62305-4)

SPDs which withstand the partial lightning current (with a typical waveform 10/350 µs) require a corresponding impulse test current I_{imp}.

NOTE 1: For power lines, a suitable test current I_{imp} is defined in the Class I test procedure of IEC 61643-11.

SPD tested with In (KS IEC 62305-4)

SPDs which withstand induced surge currents with a typical waveform 8/20 µs require a corresponding impulse test current I_{nspd}.

NOTE 2: For power lines a suitable test current I_{nspd} is defined in the Class II test procedure of IEC 61643-11.

SPD tested with a combination wave (KS IEC 62305-4)

SPDs that withstand induced surge currents with a typical waveform 8/20 µs and require a corresponding impulse test current I_{sc}.

NOTE 3: For power lines a suitable combination wave test is defined in the Class III test procedure of IEC 61643-11, defining the open-circuit voltage U_{oc} 1.2/50 µs and the short-circuit current I_{sc} 8/20 µs of a 2 Ω combination wave generator.

APPENDIX 7 (Informative)
ENERGY EFFICIENCY

17.1 Scope

This appendix provides recommendations for the design and erection of electrical installations, including installations having local production and storage of energy, for optimizing the overall efficient use of electricity.

NOTE: On-site renewable energy sources and other local production sources do not of themselves increase the efficiency of an electrical installation. However, they do reduce the overall public electricity network losses as the consumption of the installation from the public supply is reduced. This may be considered an indirect energy efficiency measure. For installation of solar photovoltaic (PV) power supply systems, see Section 712 of this Standard.

The recommendations within the scope of this appendix apply for new electrical installations and modification of existing installations. Much of this appendix will not apply to domestic and similar installations.

It is intended that this appendix will be developed into Part 8 of KS 662 in a future amendment.

17.2 Availability of electrical energy and user decision

Energy efficiency management should be so designed that it does not reduce electrical supply availability and/or services or operation below the level desired by the user. The user of the electrical installation must be able to take the final decision over whether or not to operate a service at nominal value, or optimized value or not to operate it for a certain time.

NOTE: Examples are when someone is ill, the user may decide to heat the room at a higher temperature, even during peak consumption; when a company receives an urgent delivery order, the workshop may need to work at an unexpected hour.

17.3 Design requirements and recommendations

The designer should take into account the following without losing the quality of service and the performance of the electrical installation:

(i) Load energy profile (active and passive)

(ii) Availability of local generation (solar, wind, generator, etc.)

(iii) Reduction of energy losses in the electrical installation

(iv) The tariff structure offered by the supplier of electrical energy.

17.4 Design requirements and recommendations

Determination of load profile

The main load demands within the installation have to be determined. The loads, together with their durations of operation, and/or an estimate of the annual load consumption of the main load demands (in kWh) should be identified.

Voltage drop

Consideration should be given to limiting the voltage drop within an installation to a level below that required by Section 525.202, to reduce the energy losses in the wiring systems.

Cross-sectional areas of conductors

Increasing the cross-sectional area of conductors will reduce the energy losses but will increase initial installation costs. The decision as to whether to do this should be made by assessing both the savings within a time scale and the additional cost due to the increased size. Practical constraints, such as size of terminations, will also affect the sizing of conductors.

NOTE: In some applications (particularly industrial), the most economical cross-sectional area of conductor may be several sizes larger than that required for thermal reasons.

Power factor correction

Consideration should be given to improving the load power factor to reduce thermal losses in the wiring and tariff penalties.

Power factor correction can be made at the load level or centrally, depending on the type of application. The complexity of the issue leads to careful consideration of each individual application.

17.5 Determination of zones

The installation should be divided into zones for the purpose of energy efficiency analysis. A zone represents a floor area in square metres (m^2) or a location where the electricity is used.

NOTE: Zones may correspond, for example, to:
- an industrial workshop
- a floor in building
- a space near windows or a space far from windows
- a room in a dwelling
- highway road lighting
- a hotel kitchen.

17.6 Determining the usages within the identified zones

The use of a particular circuit or zone should be clearly identified to enable accurate measurement and analysis of its energy consumption.

NOTE: Examples of different usages are:
- hot water production
- HVAC (cooling and heating)
- lighting
- motors
- appliances.

17.7 Energy efficiency and load management system

Requirements from the user

Requirements from the user are the first input to take into consideration. These requirements will be the key input to design the energy efficiency management system.

Requirements on the loads

The designer and installer must take into account the user decisions on selection of energy efficient appliances.

The user may give priority to the usage of the different loads as an input of the load optimization process (e.g. load shedding).

17.8 Inputs from loads, sensors and forecasts

Requirements on accuracy and measuring range

Provision must be made to allow the measurement and recording of energy consumption throughout the major parts of the installation, to provide for the management of that consumption. Accuracy of measurement should at least comply with the following:

- the meter at the origin of the loads must be accurate for billing purposes and can be used for the measurement of the efficiency of the whole installation
- at a lower level it may be necessary to provide measurement with an accuracy allowing sub-billing within the same entity. For example, a company such as a hotel may wish to charge the department for catering separately from the department in charge of entertainment
- at the lowest level of the final circuit directly powering loads it can be enough to provide information for following trends without precise needs for current to power conversion.

Measurement is a key parameter to determine the efficiency of the installation giving the user an awareness of his or her consumption. Consequently, device accuracy and measuring range must be adapted to the intended use, as close as possible to the loads.

17.9 Loads

Loads should be classified regarding their user's acceptance of load shedding. Some loads, such as information technology equipment systems, computers and TV sets, are not suitable for load shedding. Others, such as heaters, refrigerators and electric vehicles, can accept a load shedding for up to a certain length of time without any impact on their service.

For each type of load, an acceptable duration of shedding in normal conditions should be determined.

NOTE 1: Examples of acceptable durations of shedding are 50 ms for a lamp and 15 minutes for a refrigerator or heater.

NOTE 2: Information on the ability of loads to accept, or not, load shedding and the corresponding duration(s) is useful.

Energy sensors

Energy-sensing devices should be of at least the same class as the energy performance and monitoring devices defined in Annex D of IEC 61557-12.

Forecasts

Forecasts can be used as inputs to the energy efficiency management system, such as weather and occupancy forecasts.

Data logging

Historical data, where available, can be an input for making energy demand forecasts.

To achieve a design capable of delivering a high level of energy efficiency, all available energy consumption data should be taken into account.

17.10 Inputs from the supplies: energy availability and pricing, smart metering

The user should consider information concerning the energy availability and pricing which may vary with time.

Where the supply is a local source, the user should consider the minimum and/or the maximum available power and define the price of the corresponding energy based on the total cost of ownership including fixed and variable costs.

17.11 Information for the user: monitoring the electrical installation

The installation should be designed to enable the measurement of its total consumption in kWh for every hour of each day. This data, and the related cost of energy information, should be logged and stored for a minimum of one year and be accessible to the user.

NOTE: Multiple years of data can be useful for effective trend analysis.

In addition, by the use of sub-metering for example, the installation should be designed to enable the recording and saving of data for the consumption of individual or grouped loads totalling 97 % of the total load.

An energy efficiency management system comprises monitors for the whole electrical installation, including loads, local production and storage. It can manually (easiest cases) or automatically (most situations) monitor the electrical installation so as to allow optimization of the overall consumption of the system, taking into account the user requirements and the input parameters coming from the public electricity supply network, local electricity production and storage, the loads, sensors, and forecasts etc.

17.12 Efficiency measures for equipment

Motors and controls

An AC induction motor will consume more energy than it actually needs when operated at less than full-load conditions. This excess consumption of energy is dissipated by the motor in the form of heat. A better choice of motor and motor control will improve the global energy efficiency of the electric motor system.

Motors with a rated output of 0.75 kW – 375 kW must meet either the IE3 efficiency level or the IE2 level and be equipped with a variable speed drive. The energy efficiency classes are as follows:

- IE2 (High efficiency)
- IE3 (Premium efficiency)
- IE4 (Super premium efficiency).

NOTE 1: Commission Section (EC) No 640/2009, as amended, implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for electric motors. Reference may also be made to IEC 60034-30-1 Rotating electrical machines: Efficiency classes of line operated AC motors (IE code).

As about 95 % of the operating cost of a motor comes from its electrical energy consumption, adopting a higher energy efficiency class according to IEC 60034-30-1, especially for high-duty applications, saves significant energy.

Consideration should be given to the use of motor starters, or other motor control devices such as variable speed drives, to achieve higher energy efficiency, particularly for efficient management of energy for intensive consumption applications (e.g. flow control of fans, pumps, air compressors).

Examples of aspects to be considered are:

- reducing electrical energy consumption
- optimizing the rated power
- reducing the inrush current
- reducing noise and vibration, in this way avoiding mechanical damage and failures within the air conditioning or heating system
- better control and better accuracy in achieving required flow and pressure.

NOTE 2: In industry, it is understood that 60 % of consumed electricity is used to turn motors and 63 % of this energy is used for applications such as pumps and fans.

Lighting

Lighting can represent a large amount of energy consumption in an electrical installation, depending upon the type of lamps and luminaires selected for each application. Lighting control is one of the easiest ways to improve energy efficiency. Therefore, careful consideration should be given to lighting control. The type of lamp, ballast switchgear and controlgear should be taken into consideration when applying lighting control. Building Section s have specific requirements on the selection of luminaire types for locations, the minimum required energy performance of luminaires and energy consumption per square metre (m^2) of the installation.

NOTE: Solutions for lighting control can improve the energy efficiency by more than 50 %. These systems should be flexible and designed for the comfort of the users. The solutions can range from very small and local, such as with timer and occupancy sensors, up to sophisticated customized and centralized solutions that are part of complete building automation systems.

To operate lighting only when and where needed, permanent control of lighting may be implemented by using, for example:

- movement detectors
- dimming controls
- timed switches
- light-sensitive switches
- constant brightness controls.

Heating, ventilation and air conditioning (HVAC)

Consideration should be given to:

- the choice of HVAC equipment depending on the installation structure and usage
- the appropriate control system to optimize environment control (e.g. temperature, humidity, etc.) depending on the usage and occupancy of individual spaces.

NOTE: An example is a heating system controlled by a timer and thermostat monitoring the temperature threshold according to the expected occupancy.

17.13 Distribution system

Wiring systems

The cross-sectional areas of conductors may be optimized to reduce losses.

The electrical infrastructure may be optimized by locating the power source at an appropriate position to minimize circuit lengths.

The impact of thermal losses, off-load consumption and on-load energy consumption of equipment connected in the wiring system, e.g. switchgear and controlgear, power monitors and relays included in an electrical circuit, is negligible compared to the energy used in the load and in the energy transportation.

Power factor correction

Reduction of reactive current improves electrical energy efficiency by, for example, reducing thermal losses in wiring systems.

Where a reduction of reactive current is required, the optimized level of reactive current should be determined. This level generally depends on the public electricity supply contract.

In order to reduce reactive current, the following may be implemented:

- selection of current-using equipment with low reactive current component
- systems for compensation of reactive energy by using capacitors.

NOTE: Harmonic distortion rate and voltage impulse are important considerations for selecting capacitor banks. The provision of harmonic filters may need to be considered.

Energy

It is of prime importance, in terms of electrical energy efficiency, to ascertain by either calculation or measurement, the energy consumption of each item of current-using equipment.

Load profile

Measurement of the energy used is necessary to give a load profile. This should be over a period of a minimum of 24 h to give a reasonable estimate of load profile.

NOTE: The time period of measurement is typically from every 10 mins to 1 hour. The time period varies depending on the usage, zone and the sector of activity, and also the season (especially for lighting and HVAC).

Voltage drop

Voltage drop reduces energy efficiency of the electrical installation.

Where the voltage drop measurement is required, voltage measurements should be made on the current-using equipment and at the origin of the circuit serving the current-using equipment.