Part of Energy Queensland

Substation Standard

Standard for Cables and Cable Installations (STNW3018)

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Abstract: The aim of this document is to establish a set of standard cables used in substations and to provide guidelines for cabling practices with the objective of providing safety to personnel and minimizing cable failures.

Keywords: Cables, cabling, screening, screen earthing, cable trays, cable ladders, fire stops, cable springs, double brass tape

Standard for Cables and Cable Installations (STNW3018)

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Standard for Cables and Cable Installations (STNW3018)

1 Overview

1.1 Purpose

This document establishes a set of standard cables and provides guidelines for design of cable systems and cabling installation practices in Energy Queensland (EQ) substations with the objective of:

- Complying with WH&S legislation, policies and requirements
- Minimising cable failures and their consequences
- Maximise the reliability of supply, minimise potential outage costs
- Be economical without detrimental effects on cable life
- Reduce EMF level.

1.2 Scope

This document is intended to apply to internal cabling within transmission substations and zone substations.

This document covers types of cables used in substations including:

- HV power cables
- LV power cables
- Control and instrumentation cables

It also covers practices to be incorporated in the design of cable systems and preferred Installation methods.

Communications cables and cabling are outside the scope of this document

Building wiring (light and power circuits) installed in accordance with AS/NZS 3000 are also excluded from the scope of this document.

2 References

2.1 Legislation, Regulations, Rules, and Codes

Document	Type
Electrical Safety Act 2002 (Qld)	Legislation
Electrical Safety Regulation 2013 (Qld)	Regulation
Electrical Safety Code of Practice – Works, 2020 (Queensland Government)	Code
Managing electrical risks in the workplace - Code of Practice 2021	Code of Practice
Queensland Heritage Act 1992 (Qld)	Legislation
Queensland WH&S Regulation 2011	Legislation

2.2 Controlled Documents

Document	Alternative Doc ID
Standard for Plant Rating Manual - 4179110	
Standard for AFLC Systems - 28183633	STNW3022
Standard for Clearances in Air - 3054141	STNW3013
Standard for Climate and Natural Hazard Resilience - 3057510	STNW3007
Standard for Communications Equipment Installations - 2920282	STMP004
Substation Construction Manual - 2915421	STNW3054
Standard for Electric and Magnetic Field Design - 3060782	STNW3042
Standard for HV Equipment Ratings - 26945507	STNW3015
Standard for Panel Wiring - 2938164	STNW3021
Standard for Substation AC Supplies - 39259289	STNW3023
Standard for Substation Design Requirements - 20468486	STNW3003
Standard for Substation Earthing - 39342177	STNW3028
Standard for Substation Fire and Explosion Protection - 3058013	STNW3035
Standard for Substation Signage - 2941554	STNW3037
Standard for Sub-Transmission and Distribution Planning - 11539388	STNW3467
STNW3393 Telecommunications Design Guide - 27590047	STNW3393

2.3 Other Documents

Underground Distribution Construction Manual (North/South)

Underground Distribution Construction Manual (South East)

TSD0217 Technical Instruction – HV Cable Terminations & Joints Compound Selection for up to 33 kV

BMS03930 – Standard Network Building Blocks Substations (circa 28/03/2011)

2.4 Other Sources

AS/CA S009:2020	Installation requirements for Customer Cabling (Wiring Rules)
AS/NZS 1429.1:2006 (R2017)	Electric cables – Polymeric insulated. Part 1: For working voltages 1.9/3.3 (3.6) kV up to and including 19/33 (36) kV
AS/NZS 1429.2:2009 (R2020)	Electric cables – Polymeric insulated. Part 2: For working voltages above 19/33 (36) kV up to and including 87/150 (170) kV

AS 2067:2016	Substation and high voltage installations exceeding 1 kV a.c,
AS/NZS 2373:2003 (R2017)	Electric cables – Twisted pair for control and protection circuits
AS/NZS 3000:2018 (Amd 1, 2, 3 and rule 1)	Electrical Installations “Wiring Rules”
AS/NZS 3008	(All parts) Electrical installations – Selection of cables
AS 3879:2011 (Amd 1, R2022)	Solvent cements and priming fluids for PVC (PVC-U and PVC-M) and ABS and ASA pipes and fittings
AS/NZS 5000.1:2005 (Amd 1, R2017)	Electric cables – Polymeric insulated. Part 1: For working voltages up to and including 0.6/1 (1.2) kV
AS/NZS 60840:2020	Power cables with extruded insulation and their accessories for rated voltages above 30 kV (Um=36 kV) up to 150 kV (Um=170 kV) – Test methods and requirements
AS/NZS 60898.1:2024	Electrical accessories – Circuit-breakers for overcurrent protection for household and similar installations- Part 1: Circuit-breakers for a.c. operation (IEC 60898-1:2015 (ED.2.1) MOD)
AS/NZS 60947.2:2015	Low-voltage switchgear and controlgear assemblies – Part 2: Circuit-breakers
AS 61386	(All parts) Conduits systems for cable management
AS/NZS 61439.1:2026	Low-voltage switchgear and controlgear assemblies – Part 1: General rules (IEC 61439-1:2020, MOD)
AS 62271.301:2022	High voltage switchgear and controlgear. Dimensional standardisation of terminals
IEC 60287	(All parts) Electric cables – Calculation of the current rating
IEC 60986:2008-11 Ed 2.1	Short-circuit temperature limits of electric cables with rated voltages from 6 kV (U_m=7,2 kV) up to 30 kV (U_m = 36 kV)
IEC 61443:2008-11 Ed 1.1	Short-circuit temperature limits of electric cables with rated voltages above 30 kV (U_m = 36 kV)
IEC 61537:2023-01 Ed 3.0	Cable management – Cable tray systems and cable ladder systems
IEC 61914:2021-10 Ed 3.0	Cable cleats for electrical installations
IEC 62271-209:2019 (Amd 1)	High-voltage switchgear and controlgear - Part 209: Cable connections for gas-insulated metal enclosed switchgear for rated voltages above 52kV – Fluid-filled and extruded insulation cables- Fluid-filled and dry-type cable terminations
IEEE 525-2025	IEEE Guide for the Design and Installation of Cable Systems in Substations
NEMA BI 50015-2017	Metal Cable Tray Systems

NEMA VE 2-2013	Cable Tray Installation Guidelines
EN 50180	Bushings above 1kV up to 52kV and from 250A to 3.15kA for Liquid Filled Transformers
EN 50181	Plug-in type bushings above 1kV up to 52kV and from 250A to 3.15kA for equipment other than liquid filled transformers
CIGRE 124	Guide on EMC in Power Plants and Substations
	High Voltage Cables (catalogue), Nexans

3 Definitions and Abbreviations

3.1 Definitions

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

Accessibility	As applied to cabling/wiring method: Capable of being removed or exposed without damaging the building structure or finish or not permanently closed in by the structure or finish
Bonded (bonding)	Connected to establish electrical continuity and conductivity
Cable fire break	Material, devices, or an assembly of parts installed in a cable system, other than at a cable penetration of a fire resistive barrier, to prevent the spread of fire along the cable system
Cable screen/shield	A non-magnetic material applied over the insulation of the conductor or conductors to confine the electric field of the cable to the insulation of the conductor/conductors for reducing electrostatic coupling between the screened conductors and others
Cable penetration	An assembly or a group of assemblies for electrical conductors to enter and continue through a fire-rated structural wall, floor, or floor-ceiling assembly
Cable penetration fire stop	Material, devices or an assembly of parts providing cable penetrations through fire-rated walls, floors or floor-ceiling assemblies and maintaining their required fire rating
Cable tray system	A section or assembly of sections, and associated fittings, forming a mechanical system used to support cables and raceways
Common-mode noise (longitudinal)	The noise voltage that appears equally and in phase from each signal conductor to earth. Common-mode noise may be caused by one or more of the following: Electrostatic induction. With equal capacitance between the signal wires and the surroundings, the noise voltage developed will be the same on both signal wires Electromagnetic induction. With the magnetic field linking the signal wires equally, the noise voltage developed will be the same on both signal wires

Common-mode to normal-mode conversation	In addition to the common-mode voltages which are developed in the single conductors by the general environmental sources of electrostatic and electromagnetic fields, differences in voltage exists between different earth points in a facility due to the flow of the earth currents. These voltage differences are considered common-mode when connection is made to them either intentionally or accidentally, and the current they produce are common-mode. These common-mode current can develop normal-mode noise voltage across unequal circuit impedance
Conduit	Parts of a closed wiring system enclosing cables in an electrical installation, which allow the cable to be drawn in or replaced. Conduits may have a circular or non-circular cross-section
Control cable	A cable used for control, measuring and protection circuits
Coupling	The mode of propagation of disturbing energy from a power system to a telecommunication system. There are three forms of coupling between the two systems. Magnetic (inductive) coupling, electric (capacitive) coupling, and conductive (resistive) coupling. In addition, coupling by electromagnetic radiation exists and is associated with propagation of radiation fields, e.g. radio frequency interference (RFI), electromagnetic pulse (EMP), and corona
Double Brass Tape	Overlapped helically applied
Earthed (earthing)	Connected (connecting) to earth or to a conductive body that extends the earth connection
Earthed, solidly	Connected to earth without inserting any resistor or impedance device
Emergency cyclic capacity (EEC)/Long term emergency rating (LTER)	Of a transformer: The maximum permissible peak daily emergency loading for a given load cycle that a transformer can operate at for at least six months without exceeding acceptable thermal limits and loss of transformer life
Fire resistive barrier	A wall, floor or floor-ceiling assembly erected to prevent the spread of fire
Fitting, cable tray	A component that is used to change the size or direction of a cable tray system
Halogen-free conduits and fittings	Conduits and fittings which, on combustion, produce low levels of halogen halide-acid gas emission
HFI-90-TP	Free Thermoplastic Insulation, suitable up to 90 °C, having characteristics of reduced smoke emission and reduced flame propagation properties in fire conditions
HFS-90-TP	Halogen Free Thermoplastic Sheath, suitable up to 90 °C, having characteristics of reduced smoke emission and reduced flame propagation properties in fire conditions
High voltage power cable	A cable designed to supply power to substation utilization devices rated higher than 1000 V

Instrumentation cable	A cable used for Supervisory Controls and Data Acquisition (SCADA) systems or event recorders, and thermocouple and resistance temperature detector
Ladder cable tray	A fabricated structure consisting of two longitudinal side rails connecting by individual transverse members (rungs)
Low voltage power cable	A cable designed to supply power to substation utilization devices rated 1000 V or less
Noise voltage	Extraneous disturbing voltage signal due to coupling
Non-flame propagating conduits and fittings	Conduits and fittings which may or may not ignite as a result of an applied flame and which do not propagate the flame
Normal-mode noise (transverse or differential)	The noise voltage that appears differentially between two signal wires and acts on the signal sensing circuit in the same manner as the desired signal. Normal-mode noise may be caused by one or more of the following: Electrostatic induction and difference in distributed capacitance between the signal wires and the surroundings, Electromagnetic induction and magnetic fields linking unequally with the signal wires, Junction of thermal voltages due to the use of dissimilar metals in the connection system, Common-mode to normal-mode noise conversion
Redundant cable systems	Two or more systems of cables serving the same objective. (They may be systems where personnel safety is involved, such as fire pumps, or systems provided with redundancy because of system reliability such as primary and backup protection that may utilise redundant cable system.)
Safe working load (SWL)	Of a cable tray/ladder: Maximum load that can be applied safely in normal use
Screen/shield	A metallic sheath (usually Cu or Al) applied over the insulation of a conductor or conductors for the purpose of providing means for reducing electrostatic coupling between the conductors so shielded and others which may be susceptible to or which may be generating (unwanted noise) electrostatic field

3.2 Abbreviations

This list does not include well-known unambiguous abbreviations, or abbreviations defined at their first occurrence within the text.

2HEC	Two-hour emergency capacity
Al	Aluminium
Comms	Communications

Cu	Copper
DBT	Double Brass Tape
ECC	Emergency cyclic capacity, also earth continuity conductor
EQL	Energy Queensland (includes Energex & Ergon Energy)
EMC	Electromagnetic compatibility
EMF	Electromagnetic field
EMI	Electromagnetic interference
F.S.L	Final Surface Level
FRC	Fibre Reinforced Composite
FRP	Fibre Reinforced Polymer
HDPE	High density polyethylene
HFI-90-TP	Halogen Free Thermoplastic Insulation, suitable up to 90°C
HFS-90-TP	Halogen Free Thermoplastic Sheath, suitable up to 90°C
LTER	Long term emergency rating
PVC	Polyvinyl chloride
SCADA	Supervisory controls and data acquisition
SST	Station service transformer
STP	Screened twisted pair
SWL	Safe working load
uPVC	Unplasticized Polyvinyl Chloride
UV	Ultraviolet

4 Operating Conditions

Refer to Standard for Climate and Natural Hazard Resilience - 3057510 and Standard for Plant Rating Manual - 4179110 for standard service conditions.

Factors that affect cable rating are mainly ambient temperature, ground soil temperature, soil thermal resistivity, backfill material, cable construction and load profile.

Table 1 provides common insulation & fault current ratings for standard HV cables used in most substations, note these are not suitable everywhere.

Table 1: Substation Cable Parameters

Voltage (kV)	Cable voltage rating	Conductor Fault Level (kA/s)	Effectively Earthed System – Screen fault Level (kA/s)	Non-Effectively Earthed System – Screen fault Level (kA/s)
LV	0.6/1	-	-	-
11	6.35/11 (12)[1]	25/1	10/1	6/1
22	12.7/22 (24)[1]	25/1	10/1	-
33	19.1/33 (36)	31.5/1	13.7/1 or 25/1	5/3
66	38/66 (72.5)	25/1	25/1	-
110/132	76/132 (145)	40/0.5	40/0.5	-

Note:

1. Single phase cable insulation is to be rated for the full phase-phase voltage where an 11kV or 22kV supply is connected to a transformer stabilising delta winding with one corner earthed i.e. 22/24kV cables are required for an 11kV earthed delta substation supply.
2. Installations supplied by an auto transformer, and galvanically connected to the common winding, where the neutral or a phase is not effectively earthed then equipment on the lower voltage winding shall be rated for the highest voltage on the primary winding. Refer AS 2067.
3. Screen fault levels are dependent on cable sizes and need to be checked against manufacturer data. Smaller gauge cables like 35mm^2 may only be rated for 3.3kA/1s.

5 Cable Construction

5.1 HV Power Cables (> 1kV)

HV cables from 6.35/11 kV (12 kV) up to 19/33kV (36kV) shall comply with AS/NZS 1429.1.

HV cables from 38/66kV (72kV) to 76/132 kV (145 kV) shall comply with either AS/NZS 1429.2 or AS/NZS 60840.

Single core cables shall have the following construction:

- Stranded, circular, annealed, high conductivity copper or aluminium wire conductors up to 630mm^2.
- Segmented (milliken) construction for cables 800mm^2 and above.
- Tree retardant TR-XLPE insulation for cables up to 36kV.
- Superclean XLPE for cables 66/72kV and above.
- Semi conducting water blocking tapes above and below XLPE insulation layer.
- Copper wire screen suitable for carrying expected earth fault current at 33kV and below, note in some cases this construction may extend to 66kV.

- Corrugated metal (copper, aluminium, stainless steel) sheath 66kV and above.
- Composite flame propagation resistant black inner sheath with insect protection by a nylon (polyamide 12) jacket and flame propagation resistant black outer sheath.
- Chemical insecticide shall not be accepted or used.
- For 33kV and 66kV cables with no full metal sheath, laminated aluminium tape (LAT) shall be installed during extrusion of outer jacket for additional moisture barrier.
- Marking as per Section 5.4, including printed meter marking and supplier details and cable type as per AS1429 Parts 1 or 2.

Note: Distribution cables that exit the substation will be purchased to the distribution cable standard, and as such may not have flame propagation resistant sheath.

5.2 LV Cables & Cable Installations

5.2.1 DBT Requirements for LV, Control and Instrumentation Cables.

In compliance with AS/NZS 5000.1, Double Brass Tape (DBT) is used to provide insect (vermin) and mechanical protection for cables, this layer acts as a screen for induced voltages as well. Earthed metallic screening also reduces induced voltages in cable cores.

- DBT shall have 2 layers laid in the same direction with a minimum thickness of 0.075 mm, applied helically over the bedding. A gap of up to 30% is required and the upper tape is to be positioned centrally over the gap of the underlying tape.
- Double Brass Tape screened cables shall be used in all multicore and sensitive power cables leaving the substation building.
- Where a metallic screen is required, it shall be a collective screen over all the cores, to provide 100% coverage of the conductors.

5.2.2 LV Power Cables (0.6/1 kV)

LV cables used on 230/400V circuits shall comply with AS/NZS 5000.1, and have the following construction:

- Control building AC power and lighting circuits shall comply with AS/NZS 3000.
- Stranded, circular, annealed, high conductivity copper wire conductors.
- Flame propagation resistant, 0.6/1.0 kV insulation, XLPE or HFI insulation.
- Flame propagation resistant outer sheath (preferably orange for AC circuit, black for DC circuits).a.c. power cable phase insulation is identified by colours of red, white and blue, with black neutral and green-yellow earth.
- d.c. power cables red and black only.
- 2% carbon black UV stabilised outer sheath for outdoor cables.
- Marking as per Section 5.4.

5.2.3 Control Cables

Control (multicore) cables shall be in accordance with AS/NZS 5000.1, and have the following construction:

- Stranded, circular, annealed, high conductivity copper wire conductors.
- Flame propagation resistant, 0.6/1.0 kV insulation, XLPE or HFI insulation, preferably in grey or white.
- Flame propagation resistant black outer sheath.
- be used in each tape, provided the following tape is approximately positioned centrally over the gap in the underlying tape.
- Individual cores shall be identified with numbers printed (or embossed) in words and numerals at intervals of not greater than 100 mm. Identification shall be with black characters on white insulation.
- 2% carbon black UV stabilised outer sheath for outdoor cables.
- Marking as per Section 5.4.

5.2.4 Instrumentation Cables

Instrumentation and specialty cables are used for transmitting special analogue or digital signals. Screened Twisted Pair (STP) instrumentation cables shall be in accordance with AS/NZS 2373 and a preference should be given to cables with the following construction

- Plain annealed copper wire conductors,
- PE insulation,
- PE collective insulation,
- Individually screened pairs, collective overall outer screen,
- Colour coded for each twisted pair,
- Flame propagation resistant HFS, 0.6/1.0 kV insulation,
- 2% carbon black UV stabilised outer sheath for outdoor cables,
- Suitable vermin and mechanical protection.

5.3 Communications Cables

Refer to the Standard for Communications Equipment Installations - 2920282 and STNW3393 Telecommunications Design Guide - 27590047.

5.4 Cable Markings

Markings shall be provided on all cable outer insulation, cable drums and/or packaging in accordance with AS/NZS 5000.1.

Additional requirements include:

- Meter marking,
- Number of cores and conductor size

- Conductor material,
- Insulation and sheath designation,
- Standard cables are constructed to i.e. AS/NZS 5000.1

6 Power Cable Ratings

The performance of a cable is largely determined by the insulation type, physical environment, system fault level, system voltage, method of earthing, method of installation and the number adjacent cables.

6.1 Voltage Rating

Refer to

Table 1 for typical cable voltages.

6.2 Environmental, System and Installation Conditions

Power cable size and accessories shall be selected to operate under the conditions specified in Section 4 and the Plant Rating Manual.

Consideration shall be given to the following when selecting cables:

- System voltage,
- Loading and load factors,
- Voltage drop limits (LV only),
- System earthing configuration,
- Fault levels and clearing times,
- Fault loop impedance (LV only),
- Screen & armour fault current ratings,
- Installation:
    - In air (shaded or unshaded), direct burial, in ducts, trenches and/or conduits,
    - Depth of bury,
    - Number of parallel cables per circuit,
    - Cable arrangement (flat/trefoil),
    - Adjacent cable distance and grouping,
- Surge and overvoltage protection or voltage limiting devices.

6.3 Continuous Current Ratings

6.3.1 General

Continuous current ratings are generally dictated by the maximum insulation operating temperature, installation conditions and cable configuration. Three options are available for determining continuous current rating:

- Manufacturer handbook ratings, including AS/NZS 3000 & 3008 (LV only), with adjustment factors – Refer Annex A for examples,
- Plant Rating Manual for selected cables and regions,
- Detailed cable modelling using industry accepted numerical or finite element analysis software.

6.3.2 LV Cables

Manufacturer handbook ratings or a combination of AS/NZS 3000 & AS/NZS 3008 are acceptable for LV, control and instrumentation cables, these provide a conservative approximation providing adjustment factors are applied correctly. Refer Annex A for examples.

6.3.3 HV Cables

Continuous current ratings for HV cables with a simple construction, double point bonded sheath/screen and similar adjacent cables may be calculated using the manufacturer's data sheet (Handbook) or IEC 60287 with appropriate environmental and installation adjustment factors.

Due to complexity of most modern HV cables and installations, industry accepted software such as Cymcap may be required. Refer to the Standard for Plant Rating Manual - 4179110 for details.

Note: Single point bonding generally requires computer simulation software. While single point bonding provides higher ratings by eliminating induced circulating current in the cable screen it may result in dangerously high standing voltages at the unbonded end.

6.4 Required Ratings of HV Power Cables in Substations

6.4.1 Power Transformer Cables

Cables supplying power transformers shall meet the requirements set out in the Plant Rating Manual for NCC, ECC and 2HEC.

Refer to the Standard for Plant Rating Manual - 4179110 for details.

6.4.2 Distribution Feeder Exit & Tie Cables

Distribution feeder exit and ties cables will be as per the project scope or in line with the Standard for Sub-Transmission and Distribution Planning - 11539388.

6.4.3 Capacitor Banks

Any cable providing a primary connection to capacitor banks shall be capable of carrying at least 143% of the bank rated current continuously. This is to compensate for harmonic currents at a system voltage of 1.1 p.u.

6.4.4 AFLC Systems & Local Supply Transformers

Refer to Standard for AFLC Systems - 28183633 & Standard for Substation AC Supplies - 39259289 for cable sizing.

Smaller gauge HV cables such as the standard 35mm^2 will have screen and fault ratings, these cables shall only be installed downstream of a HRC or fault limiting fuse. Total clearing time of the fuse shall be lower than the short time withstand capability of the cable/s and cable screens.

6.4.5 Bus Tie Cables

Bus sections generally don't have any overload capacity and unless stipulated in the project scope, and within reason, cables used for bus ties are to match the bus tie circuit breaker rating (preferable) or as a minimum 65% (2/3) the lower of the bus tie or transformer circuit breaker rating. Table 2 provides some guidance on potential scenarios and outcomes.

Substations with bus sections disproportionally larger than the connected transformer capacity may have bus tie cables rated to match the largest transformer 2HEC rating or 65% as a minimum, providing there are no plans for transformer augmentation.

An example of disproportionate would be 2 x 25MVA transformers connected to 2 x 60MVA 11kV bus sections with no future expansion. In this example it is uneconomical to install bus tie cables rated for ~3200A when the maximum theoretical N-1 current the transformer can supply is ~1300A.

Substations with double cable box transformers connected across 4 and 6 bus sections are normally operated in segmented sections as multiples of 2 and can be treated in the same manner as the equivalent bus sections in Table 2.

Table 2: Minimum Bus Tie Cable Ratings

Bus Sections	Transformers	Rating Criteria
1	1	N/A
2	2	65% of the lower rating between the bus tie CB & Tx CB
3	2	75% of the lower rating between the bus tie CB & Tx CB
3	3	65% of the lower rating between the bus tie CB & Tx CB

7 Cable Section & Installation Design

7.1 General Design Considerations

Unless otherwise specified in the project scope and where possible, all cable shall be installed in conduits, trenches, in cable trays or on cable ladders. All underground (UG) cables shall be in conduits or installed in trenches.

Refer to the Standard for Substation Construction Manual - 2915421 for cable preparation and construction.

The following should be considered while designing the cable system:

- Safety and accessibility,
- Mechanical and electrical protection of cables,
- Maintaining fire stops and fire breaks,
- Installation and ongoing maintenance,
  - Access,
  - Bending radius,
  - Pulling tension and stress limits,
  - Cable support and securing,
- Physical separation distances,
- Electrical segregation of cables for reducing electromagnetic interference (EMI),
- Screening/shielding,
- Circuits and equipment earthing.

7.1.1 Safety & Accessibility

Fundamentally, consideration shall be given to the safety of personal and their ability to perform work without obstruction. All parts that must be examined, adjusted or tested during installation and maintenance shall be arranged so as to be accessible to authorised persons by the provision of adequate working spaces, working facilities, clearances (exclusion zone), electrical switching, disconnection and reconnection.

Consideration is to be given to:

- Proximity of cables and components to arc vents,
- Manual handling,
- Provision of electrical isolation,
- Use of standardised tooling, equipment and procedures where possible,
- Eliminating or limiting confined space entry,
- Eliminating or limiting working at heights,
- Eliminating or limiting environmental impacts.

7.1.2 Installation & Maintenance

In addition to 7.1.1 location of UG cables shall be clearly indicated on substation drawings and cable records. Drawings are to detail cable size, cable types, installation cross sections, signage, terminations, joints, part numbers and location of basement louvers, pulling eyes and drum setup.

7.1.3 Earthing of Circuits and Equipment

Refer to the Standard for Substation Earthing - 39342177

All metallic parts including cable screens, sheaths, frames, cases, metallic ducts, metallic conduits, and metallic cable guards shall be earthed. Drawings are to clearly indicate location of earth attachments and earthing arrangements.

Ensure the screen wires at the unearthed end are insulated and sealed to prevent moisture ingress for all single point bonded cables.

7.1.4 EMF

Refer to the Standard for Electric and Magnetic Field Design - 3060782

7.2 HV Cables

7.2.1 Standard Cable Sizes

Where possible standard contract cables should be used.

7.2.2 General Layout

- Underground cables should be installed in dedicated conduits, refer to Section 9 for conduits and pipes.
- Bending radii are to be maintained, refer to Section 13.

- HV cable layouts should be designed to minimise mutual heating between adjacent circuits.
- A minimum of 300mm separation and a 90° angle between cables is required for cables crossings up to 33kV and 500mm separation for cables up to 132kV. Refer IEC 60287-3-3 for more information.
- Cable crossings of 45° or less shall be assumed to be in parallel with adjacent cables.
- Cable modelling should be conducted to and is preferred to determine appropriate separation between cables. Where cable modelling is not performed a minimum separation of 450mm is to be applied to circuits with cables grouped in trefoil. In limited cases a reduced separation may result in higher cable ratings.
- Foundations for sealing end structures to take account of potential excavation when installing cables.
- To maintain electrical clearance in air, sealing end structures shall be dimensioned to ensure bottom terminations, including the heatshrink and coldshrink components, are no lower than 2440mm above the final ground level.
- Decommissioned and disconnected cables that can be readily removed shall be.
- Decommissioned and disconnected cables that can't be removed shall;
    - Be capped at both ends with cores bonded to the sheath and earthed,
    - Have one end accessible, for future tracing and locating,
    - Be detailed on substation drawings, including type, route, and notes provided on earthing and cap arrangements.

7.2.3 Cable Joints

Cable joints shall be:

- Selected and constructed to suit the installed environment with an expected installation life of 50+ years and be maintenance free,
- Adequately supported to prevent sagging that can lead to premature failure,
- Accessible, not laid directly over or under other cables,
- Suitably rated to match or exceed the cable NCC, ECC and 2HEC ratings.

7.2.4 Cable Terminals, Terminations & Lugs

Termination lug size and material shall be suitable for both the cable and equipment palm, in all cases standard sizes and bolt patterns are preferred.

Palms shall be prepared according to the manufacturer's recommendations, AS 62271.301, or the Standard for Substation Construction Manual - 2915421. Bolt threads and interface surfaces shall be lubricated with grease.

Connection of dissimilar metals should be avoided where possible, following is the order of preference for connecting terminals and lugs:

- Avoid dissimilar metals where possible, i.e. use all aluminium or all copper cables, lugs and palms.
- Use tinned copper palms or lugs, ensure bare aluminium is installed above any bare copper where practical to avoid water-borne copper salts resting on the aluminium leading to electrolytic corrosion.
- Use bimetallic lugs, ensure bare aluminium is installed above any bare copper where practical to avoid water-borne copper salts resting on the aluminium leading to electrolytic corrosion.
- Use of direct bonded bare aluminium and copper – ensure surfaces are prepped and polished as per AS 62271.301, ensure bare aluminium is installed above any bare copper to avoid water-borne copper salts resting on the aluminium leading to electrolytic corrosion.

Terminals and terminations shall be selected, designed and construction in accordance with manufacturer instructions adhering to minimum clearances. Where the minimum clearances are not achievable the use of insulating boots, shrouds and compounds can be applied. Refer to the Standard for Clearances in Air - 3054141 for details.

For cable termination with a nominal voltage ≥66kV designs shall include additional clearances around air insulated cable terminations, this is to permit installation of temporary scaffolding similar to Figure 1.

Figure 1: Scaffolding Around 110kV Outdoor Termination

Table 3 provides a list of the most common connector standards and typical installation location. Note, with the exception of bare palms, a majority of HV cable terminations are manufactured to international standards.

Table 3: Termination Types

Voltage	Location	Type
HV ≤ 33kV	Air insulated	Heatshrink (preferred) or coldshrink, terminal palm to AS 62271.301
	Air insulated cable box – terminal palm	Heatshrink or coldshrink, terminal palm to AS 62271.301
	Air insulated cable box – DIN C2 bushing	Separable connector to suit DIN C2 profile
	GIS	Inner cone connector to EN 50181 to suit switchgear socket.
HV ≥ 66kV	Air insulated	Self supporting, insulated base, polymer insulator
	GIS	Plug/socket to IEC 62271-209 (110/132kV) or EN 50181 (66kV)

7.2.5 Air Insulated Cable Boxes

Most cable boxes are unfilled and air insulated, medium voltage switchgear may be more compact and won't have adequate spacing between phases to allow connections to be left un-insulated.

7.2.5.1 DIN Type Bushings

Bolted DIN Type C epoxy bushings compliant with CENELEC EN 50180/50181 are preferred for cable connections rated for 630A to 1250A. Push in DIN Type A (250A) and DIN Type B (400A) bushings with a contact ring and compliant to CENELEC EN 50180/50181 are preferred for cable connections below 630A.

Refer to Annex C for dimensions of DIN Type bushings.

Existing switchgear with DIN style bushings:

- ABB SafePlus
- Areva FBX
- Schneider RM6
- Siemens 8DJH
- Ormazabal / F&G 22kV RMU
- WTC skid transformers (11kV end)
- Tamco VH1F

NOTE	**ANSI bushings on early WTC skid mounted transformers look similar but have different dimensions, confirmation of the bushing is required prior to ordering accessories.**

7.2.5.2 Premoulded Connectors for DIN Style Bushings

Fully screened separable touch safe premoulded connectors and end caps with voltage stress control are required for din (or ANSI) type bushings. Unscreened connectors or screens that aren't earthed are to be treated as live when energised.

Advantages:

- Solid insulation removes arcing faults,
- Faults at the bushing interface are limited to phase to ground fault levels, transformer NERs/NEXs significantly reduce damage,
- Connections are water resistant and have a very low degree of water absorption,
- Excellent resistance to ozone that is produced during partial discharge,
- Connectors are stackable with tee connectors allowing 2 or more cables per bushing,
- Generally more compact for stacked tees and elbows.

Disadvantages:

- Separable connectors only support single core XLPE cables. Transitions and transition joints are required when connecting 3 core or Paper Lead (PLY) cables.
- Separate test bushings are inserted at the back of the elbow joint to allow HV testing, refer Figure 2. Suitable room at the back of the termination is required to attach test bushings.
- Accessories are manufacture specific and components may not be interchangeable.

Incorrect choice of lubricants has been shown to bond the accessory to the bushing. Ensure the correct components are used and manufacturer installation procedures followed including use of recommended compounds and grease/s, the connections may develop a vacuum seal between the back plug and the main body under normal service conditions.

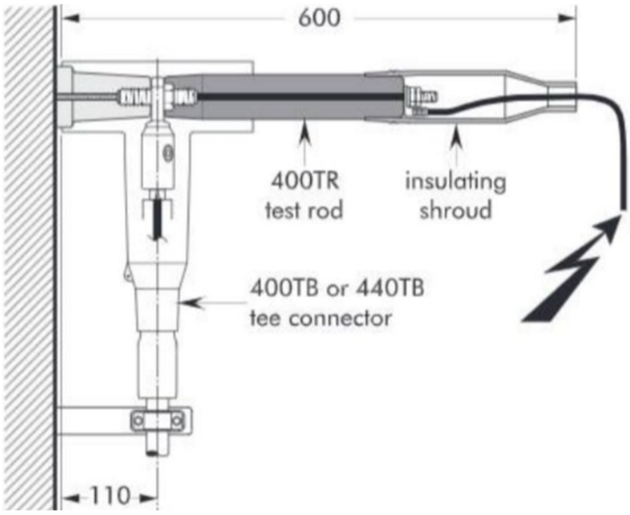


Figure 2: Test Bushing for Separable Connector

7.2.5.3 Three Core Cables

Three core cables (3 cores in 1 cable) installed in air insulated switchgear shall have:

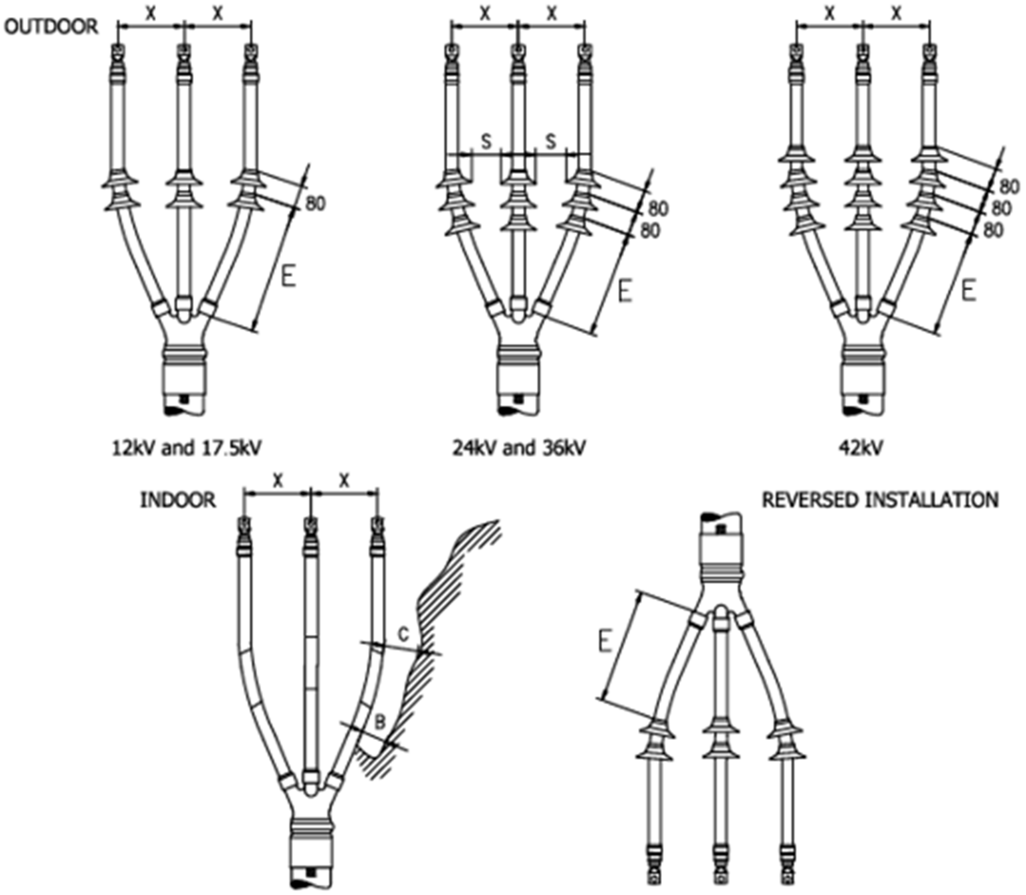
- A minimum of 700mm clearance from the bushing or palm to the bottom of the cable box, this is to allow for transposition of phases where required,
- Preferably three phase termination kits with stress control up to the lug, termination kits where the stress control stops at or just above the cable crutch should be avoided,
- Adequate clearance and strictly no touching between unscreened sections of the cables, touching will lead to partial discharge between cables. Refer to Figure 3 for recommendation from Nexan.

7.2.5.4 Clearances

For clearances in air refer to the Standard for Clearances in Air - 3054141

Where these clearances cannot be maintained, unscreened insulating boots may be used providing the minimum clearances can be maintained as per manufacturer's recommendations or Figure 3.

3. COMPLETION OF THE TERMINATION



TYPE	12TTG...	17TTG...	24TTG...	36TTG...	42TTG...
VOLTAGE Uo/U (kV)	6.3/11	8.7/15	12/20	19/33	20.8/36
N. SHEDS INDOOR TYPE	-	-	-	1	2
N. SHEDS OUTDOOR TYPE	2	2	3	3	4
E (mm)	300	300	440	780	780
OUTDOOR TYPE S min. (mm)	10	15	20	25	35
X (mm)	120	160	220	320	380
Y (mm)	40	60	90	160	220
B (mm)	10	15	25	35	45
C (mm)	15	20	40	50	60

X= min. distance between ph/ph in air
Y= min. distance between ph/ph with insulating boots

3.1 Slide and heatshrink the anti-tracking sheds one by one according to dimensions shown.
Different numbers of shed available upon request.

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Figure 3: Clearances for Insulated and Uninsulated Connections (Ref- Nexans)

7.2.6 Bitumen or Compound Filled Boxes

Refer to HV Cable Terminations & Joints Compound Selection for up to 33 kV - TSD0217 for details of bitumen or compound filled boxes.

7.3 LV Cables

For this section instrumentation cables refer to cables and cores carrying analogue signals from conventional Current Transformers (CTs) and Voltage Transformers (VTs). Analogues from non-conventional transformers or small signal analogue transducer outputs are considered to be data cables.

7.3.1 Segregation

- Control and instrumentation cables shall not be run beside HV power cables, in ducts or trenches.
- AS per AS/NZS 3000 50mm of separation or a durable barrier shall be installed between LV AC power, communications and data cables when installed in trenches, on cable trays or cables ladders.
- Adjacent circuits for the main and backup substation LV AC power supply shall be in separate conduits.
- LV power cables shall be installed in orange conduits, and control and instrumentation cables in white conduits refer Section 9.
- CT and VT circuits shall be cores of separate cables.
- DC supplies do not require segregation from DC control circuitry.
- Cabling for redundant main & backup or duplicated X & Y schemes shall be separated to ensure that no single event will prevent the adjacent scheme operating normally.
- Digital input cables should be segregated from digital output cable where possible.

7.3.2 Screening

As far as practical new installations of LV power, control and instrumentation cables in the switchyard shall be screened & electrically shielded, from the origins of transients, electromagnetic and electrostatic induction in substations. Like for like replacements are permitted for legacy installations where there is no exposure to aforementioned risks.

Sources of transients will include lightning strikes, switching, Earth Potential Rise (EPR) under fault conditions, internal resonance between capacitors and intermediate transformer (MHZ range) in Capacitor Voltage Transformers (CVT), some tap changes, and arcing faults.

Large earth grids with sufficiently high inductance may exhibit high voltage differences across the grid due to electromagnetic coupling and conduction.

Refer CIGRE 124, Guide on EMC in Power Plants and Substations for details of transients, induced voltages and currents.

Double Brass Tape screened cables are required for:

- External building LV, control and instrumentation cables.
- Substation security and transformer compound AC circuits.

- Where additional mechanical protection is required.
- Electrically noisy installations where high levels of electromagnetic or electrostatic induction may occur. Examples include:
  - High powered radio transmitters,
  - Industrial and medical scanning equipment (X-ray, CT, MRI etc),
  - Industrial arc/plasma furnaces,
  - Near air cored reactors,
  - Near capacitor banks,

Double Brass Tape screened cables are generally not required for:

- Internal building cabling.
- Power cables to general loads:
  - Yard lights,
  - Yard GPOs,
  - Heater circuits, or
  - Air conditioning

7.3.3 Screen Earthing

Control & instrumentation cable will be preferably single point bonded similar to Figure 4, this is to eliminate circulating currents in the screen. Voltage limiters or other mitigants are required where the voltage rise on the unbonded end will exceed 25V.

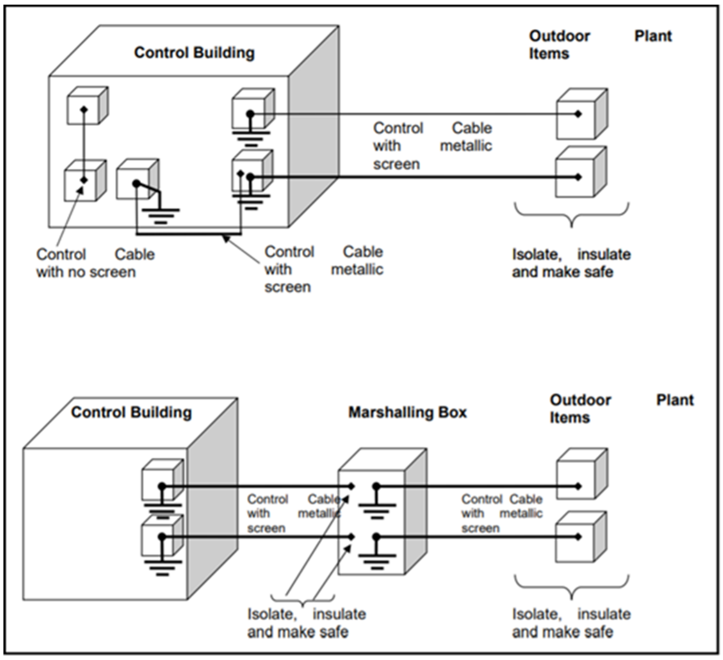


Figure 4: Earth Bonding of DBT

Constant force springs are acceptable for earthing control and instrumentation cable screens. Where these are utilised, they are to be installed as per the manufacturer's instructions or similar to Figure 5.

Earth tails for constant force springs are to be a minimum of 2.5mm^2 earth wire with green/yellow insulation.

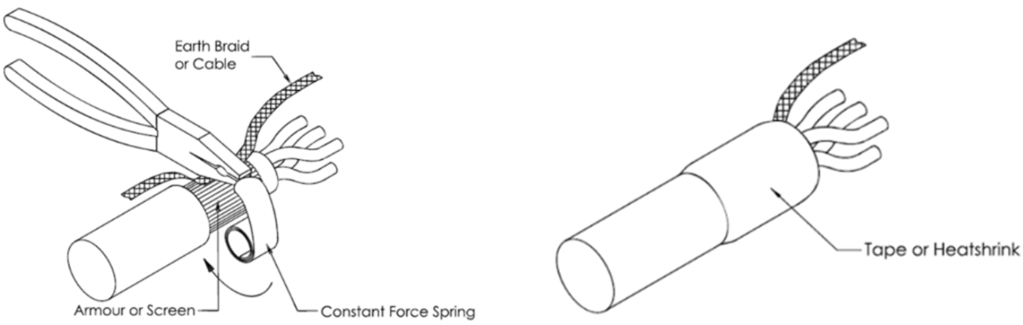


Figure 5: Constant Force Spring for DBT Earthing

7.3.4 General Guidelines

- Cables run vertically shall be secured regularly to minimise forces on terminals.
- Wherever possible, control and instrumentation cables should be routed perpendicular to HV buses. If unavoidable maximum separation distance must be maintained.
- To avoid a possible difference in EPR during earth faults, avoid routing of control and instrumentation cables through areas of high earth grid current e.g. transformers or earthing resistors/reactors.

- Refer to Table 9 for cable depth of bury, as per AS 2067 in restricted areas including substations other types of installations and mechanical protection may be used providing a risk assessment has been conducted.
- All cables from the same equipment should be grouped together.
- Cables connected to equipment having comparable sensitivities should be grouped together and then the maximum separation should be maintained between groups.
- Radial arrangement of control circuitry will reduce transient voltages.
- All supply and return conductors must be in a common cable to avoid possible large electromagnetic induction due to the very large flux linking loop that the loop arrangement provides.
- Circuits should be designed with all common wiring contained in common cables connected to switchyard equipment. Avoid circuits routed from one piece of equipment to another in the switchyard with the return conductor in another cable.
- Where interference may be an issue, use an earthing conductor in parallel with control cables to eliminate possible voltage difference in the earth grid. This conductor may also shield the control cables from transient/noise voltages. To be effective the conductor shall be as close as possible to the control cables.
- All secondary circuits from a CVT should be radial and shall be contained within a screened cable. The secondary cables should follow the earth conductor as closely as possible.

7.3.5 Conductor sizing

Refer to Section 6.4.4 or the Standard for Panel Wiring - 2938164

7.4 Communications, Data & Fibre Optic Cables

For ethernet, serial (RS232/485/422), voice and protection signalling refer to the Standard for Communications Equipment Installations - 2920282 and STNW3393 Telecommunications Design Guide - 27590047 for communication cables and circuits.

Refer to AS/CA S009:2020 Installation requirements for Customer Cabling (Wiring Rules) for physical separation requirements.

The following refers to cables for small signal equipment like non-conventional instrumentation transformers, transducer output, resistance temperature detector (RTD) and similar.

These circuits are subject to the following forms of noise or interference which can result in incorrect measurements:

- Common mode noise (longitudinal),
- Common mode to normal mode conversion,
- Crosstalk,
- Normal mode noise (transverse or differential).

To minimise noise pickup all instrumentation cables shall be twisted pair type with foil screening or shielding.

7.4.1 Segregation

- AS per AS/NZS 3000 50mm of separation or a durable barrier shall be installed between LV AC power, communications and data cables when co-located in trenches, on cable trays or cables ladders.
- Separation to other services and voltages are as per AS/CA S009:2020, select values reproduced in Table 4. Note fibre embedded in ADSS and UG cables are covered under a different standard.
- Circuits should be run in dedicated cables and conduits separate to LV AC power, AC and DC control and instrumentation cables and cores.
- Screened voice communications cable may be included in the trays with control and instrumentation cables.

Table 4: Minimum Separation Cables from Other Service (AS/CA S009:2020)

Cable Situation		ELV	LV	HV MC[5]	HV SC[5]
Metallic cores	Unenclosed	0	50[2]	300[6]	450
	In Conduit	0	150	150	450
Fibre Optics	Unenclosed	0	0	0	450
	In Conduit	0	0	0	450

Note 2: If the Cables are separated by a barrier of durable insulating material or metal or within a Conduit, no further separation is required unless the Cables are within 50mm of any securing face of Building structure that may be screwed or nailed.

Note 5: MC = Multi-Core SC=Single-Core

Note 6: This may be reduced to a minimum of 150mm if the Cables are separated by a permanent, rigidly fixed barrier of durable insulating material or earthed metal provided that a minimum clearance between the Cables through air anywhere around or over or under the barrier is at least 175mm.

7.4.2 Screening

Most cables should be Foil Twisted Pair (FTP) or Shielded Twisted Pair (STP). For DBT refer to Section 7.3.3.

8 Cable Support and Fixing

All cables are subject magnetic motive forces under through fault conditions, it is necessary to ensure cables are properly constrained to prevent damage to the cable, surrounding structures, personnel and equipment or bushings.

All HV cables and LV main power cables inside a substation shall be secured to supporting steelwork by a certified restraint system, saddles or cleats. Cable ties, rope or universal “spam” or “sardine” cleats are not acceptable for substations.

Designers are to ensure coordination of conduit placement and alignment with cable pulling eyelets and location for installation hardware.

All new, replacement and modified power cable installations inside a substation shall be brought up to the standard and meet the following criteria:

- RPEQ approval for all structures where cables are attached or supported. RPEQ to certify:
  - Structural support for the cable weight under static loading including changes from cable settling,
  - Structural support for dynamic forces under fault conditions,
  - Allowance for thermo-mechanical movement from changes in ambient temperature and/or cable heating.
- Only cable restraint systems or cleats designed and tested to IEC 61914:2021 shall be used,
- Rubber inserts shall be installed between the cables and clamps. Rubber inserts should also be used where necessary to achieve a tight clamp.

Nominal spacing:

- Supports or cleats for horizontal cable runs ≤1500mm
- Supports or cleats for vertical cable runs ≤900mm
- Where practical, centre to centre spacing between parallel and perpendicular cable bundles shall be at least 3 x the largest cable bundle diameter. Where this is not achievable it shall be 2 x the cable bundle diameter as an absolute minimum. Refer to Figure 6 and Table 5.

Horizontal cable constraints:

- 11kV & 22kV horizontal cable sections should be secured with two-hole cleats where practical. Single hole cleats may be used, if necessary, due to lack of space, or to accommodate change in direction.
- Two-hole cleats or IEC 61914 compliant constraint systems shall be used for all cables ≥33kV.
- Multi-rotational cable cleat adaptor bracket are acceptable for 11kV and 22kV cable, RPEQ approval is required for use with all cables ≥33kV.

Horizontal to vertical transitions:

- Cables shall be supported at least twice below the cable termination with two-hole mount cleats or a certified support system, refer Figure 7 a),
- Cables shall be supported either side of the set radius with two-hole mount cleats or a certified support system, refer Figure 7 b),
- Cables ≥110kV shall be supported at the extents of the bend with two-hole mount cleats or certified support system, refer Figure 7 b).
- Cables transitioning from horizontal to vertical that are backfilled shall be supported on the transition with stabilised sandbags. Refer Figure 7 c).

Vertical cable constraints:

- Vertical cable sections are to be secured with two-hole mount cleats, single-hole mount cleats may be used but require RPEQ design review and approval.
- Single core cables in trefoil should be separated and secured individually with single core cleats, except when required to fit through a small cable penetration or at the discretion of the RPEQ design engineer.
- Transformer cables to have one end connected with flexible cables (usually at air insulated transformer cable box) to allow for expansion/contraction. Refer Figure 7 d).
- Cables to be supported or cleated as close as possible to the cable box base to prevent stress onto equipment bushings.

Triplex Cables:

- When cleating triplex cables in the trefoil arrangement, rated inserts shall be used to accommodate the twist in the cables, to avoid applying twisting forces to the cable supports (Figure 4). The only exception to this is for 95sqmm Al triplex cables, for which a sufficiently small insert is not available.

Earthing:

- Refer to the Standard for Substation Earthing - 39342177 mainly section 8.10.2

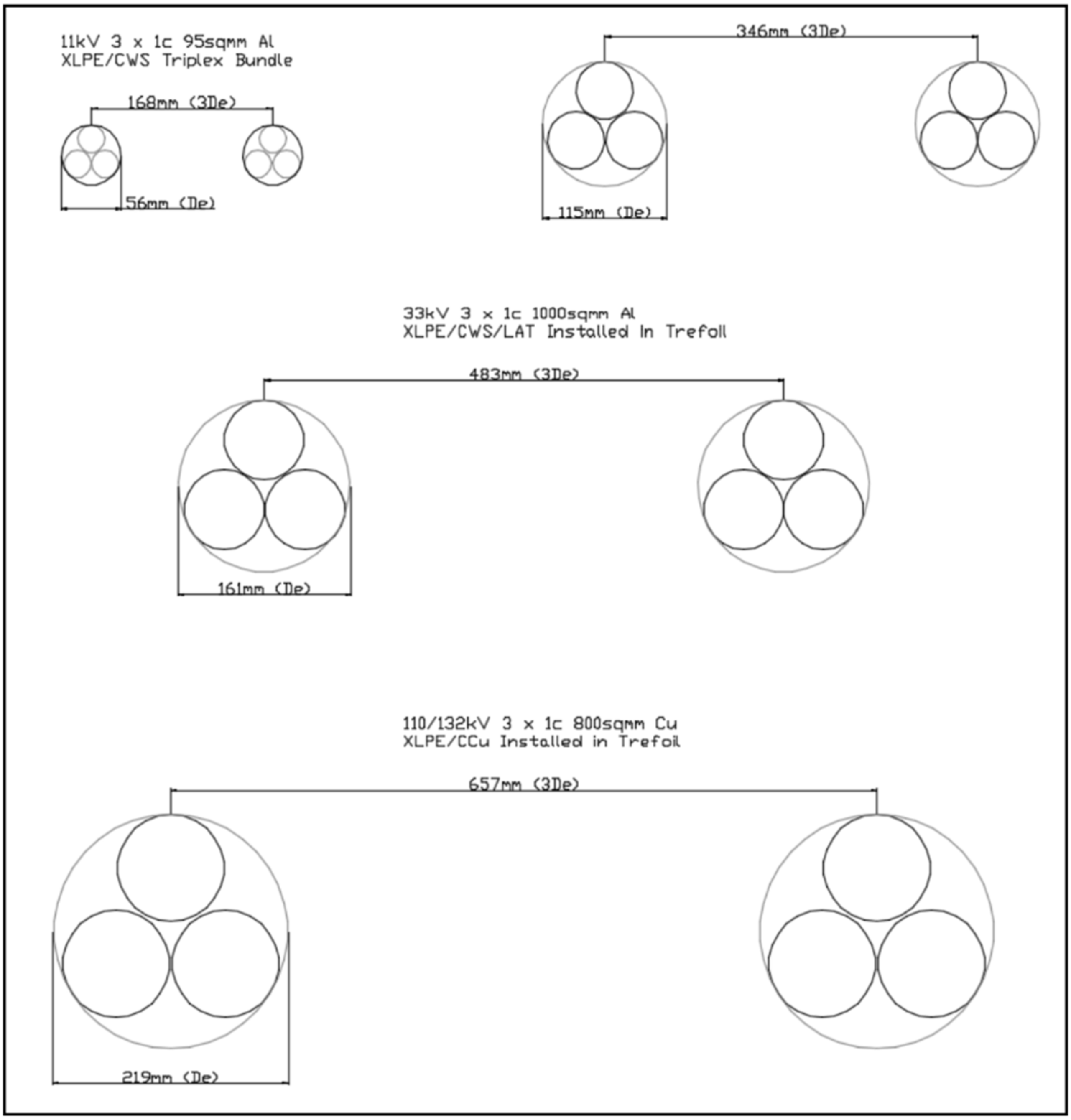
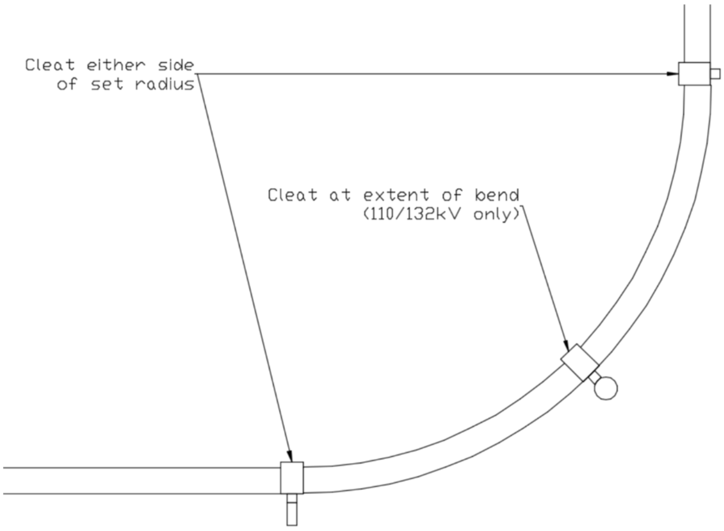


Figure 6: Cable Bundle Spacing

Table 5: Cable and Bundle Diameters

Cable	Single cable diameter (mm)	Trefoil bundle diameter (mm)
11kV		
95mm2 3x1c Al XLPE/CWS Triplex	26	56
240mm2 3x1c Cu XLPE/CWS Triplex	40	85
400mm2 3x1c Al XLPE/CWS Triplex	45	96
630mm2 1c Cu XLPE/CWS	54	116
800mm2 1c Cu XLPE/CWS	58	125
33 kV		
185mm2 1c Cu XLPE/CWS/CCu	57	123
630mm2 1c Cu XLPE/CWS/LAT	65	141
800mm2 1c Cu XLPE/CWS/LAT	69	149
1000mm2 1c Cu XLPE/CWS/LAT	75	161
110/132 kV		
400mm2 1c Cu XLPE/CCu	89	192
800mm2 1c Cu XLPE/CCu	102	219
1600mm2 1c Cu XLPE/CCu	117	253

a)



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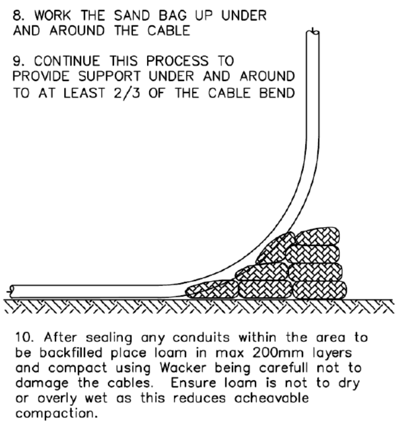


c)

d)

Figure 7: Horizontal to Vertical Power Cable Transition

9 Pipes & Conduits

9.1 General

- Conduits shall comply with AS 61386.1 and relevant parts of AS 61386. Mechanical protection and marker tape shall be provided.
- Rigid conduits shall be Unplasticized Polyvinyl Chloride (uPVC) or Fibre Reinforced Composite/Polymer (FRC/P) for extreme environmental conditions. Corflo conduits are not acceptable for any installation.
- All solvent cements used shall comply with AS/NZS 3879.
- Selection of the appropriate conduit/duct shall be based on the internal diameter to suit cable size, cable pulling tension, jamming ratios, and conduit wall thickness to prevent conduit deformation during installation.
- Conduits entering the building and cable ramps shall be as per ZSS control building drawings and Energex LOSTD drawing standards.
- Conduits are to have their invert levels a maximum of 50 mm above the finished floor level of the basement and sealed.
- The new foundations of switchyard equipment, where required, shall have conduits/ducts cast into the concrete. Cables shall be drawn through these conduits/ducts which shall connect to cable trenches.
- Conduit bends must have a minimum 1m from end of bend to the conductor connection on the cable, to ensure cables can be installed straight and without tension on the bushing. If this dimension can't be maintained, then a pit should be used instead of conduit bends.
- All conduits are to be proven clear by a mandrel, and a draw rope included by the installer.
- Conduits shall be laid true to levels, grades and alignment as shown on the civil conduit plans. When conduits are laid in two or more layers, the joints of each conduit in each layer shall be staggered with respect to the joints in the next layer of conduits.
- Bell-mouths shall be installed for all conduit penetrations into basements and pits and sealed with an approved product to prevent moisture seeping through the concrete interface.
- Conduit and duct system are to be designed consider the maximum pulling lengths of cable according to the manufacturer's recommendations. Refer Section 13 for details.
- All conduit systems should have suitable pull points to avoid over-tensioning of the cable during installation. Pull point or manholes should be installed wherever calculations show the expected pulling tensions exceed the allowable tension limit or side wall pressure.
- Bending radius of the conduit shall not be less than the conductor allowable minimum bending radius. Refer Section 13 for details.
- Conduit/duct runs shall be parallel or perpendicular to the foundations without diagonals.

- Conduits containing one phase of a three-phase power circuit or one leg of a single phase of a power circuit should not be supported by reinforcing steel or brackets of magnetic material forming closed loops around individual conduits.
- Reinforcing steel in the manhole wall should not form closed loops around individual non-metallic conduit entering the manhole. Non-metallic spacers should be used.
- Protection should be provided where non-metallic conduits emerge out of a floor.
- Concrete-encased duct banks should be adequately reinforced under roads and in areas where heavy equipment may be moved over the duct bank.
- Conduits in duct banks should be sloped downward toward manholes or drain points.
- Ensure all spare conduits are sealed with a plumber's plug to prevent moisture ingress. Water that enters through power cable conduits creates a damp atmosphere that can promote partial discharge issues and rusting of supporting steelwork.
- All conduits with power cables shall be sealed after cable installation with an approved conduit seal. This can be a mechanical seal, gas filled sealing bags or a rubber mastic seal that is capable of withstanding at least 1m head of water. Expanding foam to seal cables in conduits is **not recommended**.

Typical sizes for conduits are as shown in Table below:

Table 6: Conduit Particulars

Application	Conduit diameter (mm NB)	Conduit & bends wall thickness	Conduit Bend Radius (mm)
Telecoms	80 (white)	Light Duty	600
Low voltage, control	125	Heavy duty	1830
11 – 33kV	125	Heavy duty	1830
110/132 kV up to $800mm^2$	150	Heavy Duty	2000-3000
110/132 kV greater than $800mm^2$	200	Heavy Duty	3000

Note: 33/110/132kV feeders require 2 x 80mm conduits for ECC/fibre optic cables for each feeder.

Maximum conduit fill shall be as follows:

Table 7: Conduit Fill Factor (AS/NZS 3000)

Number of conductors	% fill for all conductor types
1	50
2	33
Over 2	40

Supports shall be provided for PVC rigid conduits as per the following table:

Table 8: Distance Between Supports for Conduits

Conduit size (mm)	Maximum distance between supports (m)
35 – 53	1.5
63 – 78	1.8
91 – 129	2.1
150 and over	2.5

9.2 Conduit Ground Cover in Substations

Minimum ground cover shall be as per Table 9, depth of cover is measured from F.S.L excluding any gravel or crusher dust layers. Reduced depths shall only be used following advice and approval from suitably qualified Civil and Electrical Engineers.

Table 9: Preferred Cable Buried Depth

Voltage	Preferred Depth
HV Cables – Restricted substations (AS 2067) *	500mm to 1000mm
66/110/132kV Power Cables	≥ 900mm
33kV Power Cables	750mm
22 & 11kV Power Cables	750mm
LV Cables – Public areas, no surface cover or <75mm Cat B system (AS/NZS 3000)	≥ 500mm
All other LV Cables including 125V (nominal) control cables	As per AS/NZS 3000 & 2067
Earthing Grid Cables	500mm
Control Cables <120V DC nominal	350mm

* Ergon and Energex substations where access is restricted from the general public

9.3 Backfill

- Only tested and approved thermal backfill shall be used.
- Thermal fill is to be solidly packed, and hand rammed around conduits.
- Thermal fill shall extend 300mm above the top of the uppermost conduit.
- Approved filling and bedding material shall comprise stone free friable loam.
- Flowable fill is NOT to be installed within substation yards.

The thermal properties for typical backfill material:

Table 10: Thermal Resistivity of Thermal Backfill

Material	Thermal Resistivity (°C-m/W)	Application
Standard	0.99-1.17	Control, LV
Blended	0.94-0.98	11, 33 kV
Premium	0.75-0.87	66/110/132kV, high-capacity transformer cables

9.4 Earthing

Refer to the Standard for Substation Earthing - 39342177

10 Cable Pits & Trenches

- Cable trenches shall be installed in all new outdoor switchyards to permit cabling between the control room and outdoor primary plant.
- Without exception, new and replacement installations of cables for control, protection and instrumentation within an outdoor switchyard shall be installed in conduits between trenches or pits and marshalling box/equipment.
- Cable pits and trenches should be precast concrete or moulded polymer, alternative materials may be used however they shall have a design life of 50+ years, contain no hazardous or controlled materials, non-conductive, non-flammable, fit for purpose and have sufficient strength to allow typical mobile plant to traverse over them. All civil designs are to be RPEQ approved.
- Cable pits and trenches shall be box sections with removable lids.
- Cable pits and trenches shall be placed so that the top of the lid is 50mm above the finished switchyard level.
- Drainage, drainage sumps and drainage lines shall be provided and installed in all pits and trenches. Cable ducts, conduits and trenches shall not be used for ad hoc site drainage.
- Pits and trenches shall be excavated such that there is a fall from end to end which permits rainwater to drain.
- Heavy duty pit/trench covers rated for gross vehicle weight shall be installed in trafficable areas. Pits and trench walls shall be rated to support the lid and vehicle weight.
- All exposed metal shall be bonded to the main earth grid.
- Consideration should be given to the following:
    - Eliminate or limit confined spaces,
    - Provide a horizontal working clearance of at least 900 mm,
    - Orientate pits to minimise bends in the duct banks,

- Provide cable pulling facility where possible,
- Provide pit openings to accommodate full cable bending radii,
- Provision for a corrosion resistant and fixed ladder for ingress/egress.

11 Cable Trays & Ladders

Cable trays, ladders, channel and accessories shall be designed and tested to either NEMA BI 50015-2017 (previously NEMA V1), IEC 61537 or equivalent international standard.

11.1 General requirements for Installation Design

- All cable trays/ladders shall be installed in accordance with NEMA VE 2 or as recommended by the manufacturer.
- Cable trays/ladders shall be wide enough to meet separation requirements and maintain spare capacity of at least 25% width. As a minimum the cable trays/ladders shall be 300 mm wide x 112 mm deep.
- The cable trays/ladders shall be designed for straight lines parallel or at a right angle to walls and floors.
- Cable tray/ladder routes shall not obstruct access to other plant and shall be clear of pipes, valves and arc chutes.
- Where cable trays/ladders are installed in plant rooms or across walkways clearance between the final floor level and tray/ladder underside shall be ≥ 2.1 m.
- A minimum of 300mm shall be maintained between vertically stacked cable tray/ladder systems.
- In a stacked cable tray system where cables are arched down into a room, panel or switchboard, the cables shall be arranged with power cables positioned above control and instrumentation cables to provide additional space for bending cables down into a panel or switchboard.
- In a stacked cable tray system where cables are arched up into a room, panel or switchboard, the cables shall be arranged with power cables positioned below control and instrumentation cables to provide additional space for bending cables up into a panel or switchboard.
- Cable trays/ladders shall have a load rating capacity equivalent to NEMA Class B (112 kg/m) with a safety factor of 1.5. i.e. total design weight ≤ 75 kg/m.

11.2 Standard Dimensions

Standard dimensions based on NEMA BI 50015 are detailed in Table 11.

Table 11: NEMA BI 50015-2017 Tray and Ladder Typical Dimensions

Description	Value
NEMA Standards Lengths (mm)	3000 (10 ft) ± 5 mm

Description	Value
	3660 (12 ft) ± 5 mm 6000 (20 ft) ± 9 mm 7320 (24 ft) ± 9 mm
NEMA Standards Widths (mm)[1]	50 (2 in) 75 (3 in) 100 (4 in) 150 (6 in) 225 (9 in) 300 (12 in) 450 (18 in) 600 (24 in) 750 (30 in) 900 (36 in)
NEMA Standards Fill Depths (mm)	75 (3 in) 100 (4 in) 125 (5 in) 150 (6 in)
NEMA Standards Rung Spacing (mm)	150 (6 in) 225 (9 in) 300 (12 in)
NEMA Standards Inside Radius (mm)	300 (12 in) 600 (24 in) 900 (36 in)
NEMA Standards Arc Angles for Elbows (°)	30 45 60 90

Note 1: Width includes ladder, solid, slotted, trough and channel. Refer to NEMA B1 50015 or manufacturer data for standard wire mesh tray.

11.3 Galvanised Steel Cable Tray/Ladder

Cable tray/ladder are to be fabricated from steel with horizontal rungs at 300mm spacing welded to vertical side rails. Slots shall be provided in the horizontal rungs for cable fastening. All cable trays/ladders and fittings shall be hot dip galvanised after fabrication.

Aluminium cable tray/ladder can be used as an alternative – it also can be utilised for basement earthing conductor provided it has sufficient short time rated earth fault current carrying capacity.

“Side-rail out” is the preferred structure.

11.4 Fittings

Factory fabricated bends, risers, tees and crosses shall be used for all connections and changes of direction. All fittings shall maintain the specified minimum bending radius for the largest cable to be installed on the tray/ladder run.

11.5 Brackets

Support brackets shall be installed at the required spacing to suit the load capacity of the cable tray/ladder. Support brackets shall be provided at all connections or changes of direction in accordance with the recommendations of NEMA BI 50015-2017 (or IEC 61537).

Support brackets shall be fabricated from Unistrut channel with suitable accessories or as per manufacturer's recommendations. Cable tray/ladder shall be firmly attached to each support bracket with weight rated hold-down clamps.

Where centre support brackets can't be used, suitably rated cantilever support brackets shall be used to provide unobstructed access to the opposite side.

11.6 Covers

A continuous cover shall be fitted over cable trays and ladders in areas exposed to direct sunlight or where cables may be vulnerable to physical or chemical damage. Covers shall be peaked to provide rigidity and allow additional air circulation around cables.

Outdoor covers shall be wind rated and securely attached with approved clamps or hook bolts to allow easy removal and replacement. Covers should be made from the same material as the cable tray to avoid electrolytic corrosion.

11.7 Earthing

Refer to the Standard for Substation Earthing - 39342177

12 Cable Penetration Fire Stops and Fire Breaks

Refer to the Standard for Substation Fire and Explosion Protection - 3058013

Power cable insulation, jackets and sheaths are a high fuel source in a substation or substation basement.

Protection from fire can be improved by:

- Spacing cables further apart,
- Avoid cables and joints resting on each other at cable crossing,
- Apply fire-retardant intumescent paint that ceramifies under heat and prevents propagation,
- Fire performance and rating shall be re-instated when making new cable penetrations through existing fire stops, fire breaks or fire rated wall, ceilings and floors.
- Installing a fire suppression system such as a sprinkler or inert gas system. Refer to the Standard for Substation Fire and Explosion Protection - 3058013.

13 Installation design limits

13.1 Bending Radius

The safe bending radius for a cable is limited by the insulation flexibility and sheathing material. High elongation due to severe bending will impair the performance and delaminate the semi-conductive screening. HDPE sheathing and nylon termite barriers are hard but brittle and both have to be treated with caution.

When installed in conduits the cables must be pulled around several curves in different directions and subject to dynamic stresses that could cause damage. Consequently, the bending radius around which a cable may be pulled is greater than that at which it can be set into its final position.

Fire retardant and halogen free sheathing materials, some being soft materials that could be damaged during the pulling operation. This should be taken into account in the design.

The following recommended minimum bending radii are expressed as a function of the cable diameter and refer to the inside of the curve, and a bending radius factor. Some common cables are listed in Table 13.

Table 12: Recommended Bending Radius Factors for Cables [57]

Cable type	Voltage	Minimum bending radius factor (F)	
		During installation	Set
All XLPE cables (other than HDPE sheathed or nylon covered)	HV	18	12
XLPE HDPE sheathed		25	15
XLPE Nylon covered & Steel Wire Armoured (SWA)		30	20
Oil-filled		40	25
Unarmoured sheathed cables (AS/NZS 3000)	LV	9	6
Armoured sheathed cables (AS/NZS 3000)		18	12
Other cables	As per manufacturer's recommendations		

Equation 1: Minimum Bending Radius (in mm)

$$R = F \times D$$

$R = Bending\ radius\ (mm)$

$F = Bending\ radius\ factor$ (Table 14)

$D = Overall\ cable\ outside\ diameter\ (mm)$

Table 13: Common Cable Bending Radii

Cable	Pulling Radius (mm)	Setting Radius (mm)
11kV		
95mm2 3x1c Al XLPE/CWS Triplex	850	600
240mm2 3x1c Cu XLPE/CWS Triplex	1200	800
400mm2 3x1c Al XLPE/CWS Triplex	1350	900
630mm2 1c Cu XLPE/CWS	1300	800
800mm2 1c Cu XLPE/CWS	1400	850
33 kV		
185mm2 1c Cu XLPE/CWS/CCu	1400	850
630mm2 1c Cu XLPE/CWS/LAT	1550 (Nylon – 1950)	950 (Nylon – 1300)
800mm2 1c Cu XLPE/CWS/LAT	1650 (Nylon – 2050)	1000 (Nylon – 1350)
1000mm2 1c Cu XLPE/CWS/LAT	1800 (Nylon – 2200)	1100 (Nylon – 1500)
110/132 kV		
400mm2 1c Cu XLPE/CCu	1710	1300
800mm2 1c Cu XLPE/CCu	1930	1450
1600mm2 1c Cu XLPE/CCu	2240	1700

13.2 Pulling Tension Limits and Stress Limits

The maximum tension which may be used is limited by the tensile strength of the conductors or armour wires or by the gripping capability of the cable stocking, depending on the method used.

Manufacturers will provide information specific to a cable’s maximum pulling tension and maximum allowable sidewall pressure in their cable datasheets.

In the calculating pulling tension, it is not usual to allow for the tensile strength of the insulating and sheathing materials, which can be considerable in the case of XLPE. Reliance on these materials, which have high elongation factors, may result in some elongation of the conductors and a consequent increase in conductor resistance.

Table 14: Maximum Safe Tensile Stress, S of Conductors and Armour shall be as follows [57]

Material	Maximum safe tensile stress, S (N/mm^2)
Stranded copper conductor	70
Stranded aluminium conductor	50
Solid aluminium conductor	30
Galvanised steel armour	130
Hard drawn aluminium wire armour	60

Maximum pulling tensions are calculated using the value of S from Table. For pulling by conductor the maximum pulling tension, Tc shall be calculated as below:

Equation 2: Maximum Pulling Tension

$$T_c = N \times A_c \times S$$

$T_c = Maximum\ pulling\ tension\ (N)$

$N = Number\ of\ conductors$

$A_c = Cross\ sectional\ area\ of\ one\ conductor\ (mm^2)$

$S = Maximum\ safe\ tensile\ stress\ (N/mm^2)$

13.3 Sidewall Pressure

Sidewall pressure is the pressure applied at bends to the installation. Excessive sidewall pressure can cause deformation of the insulation and lead to premature failure.

Sidewall pressure is calculated as follows:

Equation 3: Sidewall Pressure

$$SWP = \frac{T}{r}$$

$SWP = Sidewall\ pressure\ (kN/m)$

$T = Maximum\ pulling\ tension\ (kN)$

$r = Radius\ at\ bend\ (m)$

13.4 Jamming Ratio

Jamming is the effect of wedging cables in a conduit when three cables lie side by side in the same plane. Jamming and it’s measure, jam or jamming ratio, is a concern because jamming could cause damage to one or more cables, the possibility of jamming is greater when the cables change direction through bends.

Jamming ratio is defined for three cables of equal diameter as the ratio of the conduit inside diameter (D) to the cable outside diameter (d) at each bend.

Equation 4: Jamming Ratio

$$JR = \frac{D}{d}$$

$$Jamming\ is\ probable\ when;\ 2.8 \leq JR \leq 3.0$$

$JR = Jamming\ ratio$

$D = Conduit\ inside\ diameter\ (mm)$

$d = Cable\ outside\ diameter\ (mm)$

13.5 Cable Pulling Tension Calculator

Lines Standards provide a calculator for calculating pulling tension of a number of power cables. The calculator can be accessed from Substation Standards Design Tools.

14 Documentation

Documentation on the design of HV cable systems shall take the form of a design report to be submitted for approval and stored in the EQL drawing management system. The report is to include, but not be limited to the following:

- Values for the critical design factors, the initial temperature and maximum permissible final temperature, and the methods used and assumptions made in ascertaining these values.
- Details on how compliance is achieved with clause 6.1 and.
- Methodology and determination of power cable ratings.
- Details of EMF reduction, EMC considerations, fire spreading prevention.
- Determination of pulling tension, cable fill.
- A drawing or a series of drawings showing the location of cable pits, trenches, conduits, ducts and underground services in the substation site.
- A series of drawings detailing cable schedule, cable routing, depth of burial, conduit/duct arrangement, cross sections of cable arrangement in trays/on ladders, separation between cable groups, separation between cable trays/ladders, protection against mechanical damage, required signage, cable tray/ladder installation, cable supports, cable restraints, cable terminations, cable screen earthing, tray/ladder earthing, resistance minimisation at tray/ladder joints, pit and trench details, fire barriers, notes for installation and construction, etc.
- All as constructed drawings and records.

Annex A

Informative

Cable Calculations

A.1 Manufacturer Standard Conditions

Generally, the nominal current rating for cables is provided by the manufacturer via data sheets and should be calculated in accordance with IEC 60287-3-1 for Australian conditions as detailed in Table 15. AS/NZS 3000 in conjunction with AS/NZS 3008 provide a series of simplified calculations and look up tables for LV cables as an alternative.

Note: cables rating provided by international manufacturers may differ and need to be checked.

Table 15: Standard Cable Laying Conditions (Typical)

Environmental Component	Value
Ambient air temperature Summer	40°C
Ambient soil temperature Summer	25°C
Soil thermal resistivity	1.2°K.m/W
XLPE Maximum conductor temperature	90°C for continuous current rating
XLPE Maximum conductor temperature	105°C for emergency rating
Depth of bury HV Cables	
LV	0.5 m
≥ 11kV	0.8 m
≥ 33kV	1.0 m

A.2 LV Power Cable

A2.1 Current Ratings

Current ratings of LV power cables are to be determined using either relevant tables in AS/NZS 3008-1.1 or manufacturer data sheets (Handbook). Deviations from the standard conditions in Table 15 will require adjustment factors to ensure cables are suitably rated.

Example: Consider an underground 3 phase, solid stranded cable installed in trefoil and in conduit supplying a 400V distribution board with an anticipated load of 40kW. Assuming no other cables are installed in parallel and no other de-rating or adjustment factors are applicable.

$$I_{FLA} = \frac{40\times10^3}{1.73\times400} = 57\text{A}$$

$$\text{From Table 8 Column 24 } AS\ /\ NZS\ 3008.1.2 \text{ a } 10\text{mm}^2 \text{ cable is required}$$

$Cable\ type =\ Cu\ conductor, XLPE/PVC$

$Cable\ run =\ Enlosed\ in\ conduit$

A2.2 Simplified Voltage Drop

AS/NZS 3000 Annex C provides a simplified method for calculating the required cable size based on allowable voltage drop, alternatively AS/NZS 3008.1.2 provides detail for calculating voltage drop based on the selected cable.

Using the second method from AS/NZS 3008.1.2 Table 41, the following example is based on a 10mm^2 cable with 57A of full load current:

$$V_d = V_c \times I_{FLA} \times l$$

$$V_d = \frac{4.05 \times 57 \times 40}{1000} = 9.234V$$

$$V_d = \frac{9.234V}{400V} \times 100 = 2.31\%$$

$V_c = 4.05mV/A.m$

$l = Cable\ length\ 40m$

Allowable voltage drop limit is 5% so 2.31% is acceptable.

Note: as per note 1 on table 41 of AS 3008.1.2, V_c is multiplied by 1.155 (2/√3) for single phase cables to compensate for current in the neutral conductor.

A2.3 Overcurrent/Overload Protection

Based on AS/NZS 3000 the maximum circuit breaker size for overload protection can be determined using the following relationship in Equation 5.

Equation 5: Overload/Overcurrent Circuit Breaker Rating

$$I_B \leq I_N \leq I_Z$$

$I_B =\ Load\ current\ (A)$

$I_N =\ Nominal\ current\ of\ protective\ device\ (A)$

$I_Z =\ Continuous\ current\ rating\ of\ cable/s\ (A)$

Note: Refer AS/NZS 3000 for fuse requirements

Example: Using AS/NZS 61439.1 as a reference for standard circuit breaker values, an MCB with a nominal rating of 63A is required, this assumes a 10mm^2 cable rated for 72A and 57A of load current based on previous examples.

$$57 \leq I_N \leq 72$$

$$I_N = 63A$$

A2.4 Short Circuit Rating

To ensure cable insulation is not damaged the upstream protection should will need to limit the conductor temperature below the maximum permissible temperature. The maximum permissible fault clearing time can be determined based on AS/NZS 3000 section 2.5.4 and AS/NZS 3008.1.2:

Equation 6: Short Circuit Rating

$$t = \frac{K^2 A^2}{Isc^2}$$

$t = Fault\ clearing\ time\ (s)$

$A = Cable\ cross\ section\ area\ (mm^2)$

$I_{sc} = Short\ circuit\ current\ at\ main\ board\ (A)$

$K = Constant\ for\ XLPE\ cables\ at\ 90°C/250°C\ (AS\ /\ NZS\ 3008.1.2\ Table\ 52)$

Example: Assuming the distribution board has a 3kA fault level the required clearing time to protect the cable and insulation is 0.227s:

$$t = \frac{143^2 10^2}{3000^2} = 0.227s$$

Protection by a 63A MCB Class B breaker to AS/NZS 60947.2 the fault clearing time at 3kA will be 0.01s.

A2.5 Maximum Earth Loop Resistivity

Earth loop impedance needs to be low enough to allow sufficient fault current to flow and guarantee correct protection operation. Equation 7 may be applied as a general rule of thumb though AS/NZS 3000 Annex B lists it's limitations and provides potentially better methods:

Equation 7: Max Earth Loop Resistivity

$$Lmax = \frac{0.8U_o SphSpe}{I\ \rho\ (Sph + Spe)}$$

$L_{max} = Maximum\ cable\ length\ (m)$

$U_o = Nominal\ phase\ voltage\ (230V)$

$S_{ph} = Cross\ sectional\ area\ of\ active\ conductor\ (mm^2)$

$S_{pe} = Cross\ sectional\ area\ of\ protective\ earth\ conductor\ (mm^2)$

$P = Resistvity\ of\ copper\ (22.5 \times 10^{-3}\ \Omega\ \mathrm{mm}^2/\mathrm{m})$

$I = Mean\ trip\ current\ for\ instantaneous\ element\ or\ fuse\ operating\ current$

Example: Applying the "rule of thumb" method in Equation 7 and assuming a 230V/400V supply via 40m of $10mm^2$ Cu cable with a $6mm^2$ Cu earth lead and Class B 63A MCB with a magnetic trip between 3xIn and 5xIn as per AS/NZS 60898.1. In this case 40m is less than 97m so is acceptable.

$I_{min} = 3 \times 63A = 189A$

$I_{max} = 5 \times 63A = 315A$

$$L_{min} = \frac{0.8 \times 230 \times 10 \times 6}{189 \times 22.5 \times 10^{-3} \ (10+6)} = 162m$$

$$L_{max} = \frac{0.8 \times 230 \times 10 \times 6}{315 \times 22.5 \times 10^{-3} \ (10+6)} = 97m$$

A.3 HV Power Cable Current Ratings (Handbook)

The preferred method for calculating current ratings of HV power cables is using numerical or finite element software like Cymecap. Alternatively, ratings may be determined from manufacturer data sheets with adjustments or handbook calculations.

When using manufacturer data sheets, the current ratings must be adjusted for any deviations from the standard conditions, this may be done by applying the adjustment factors for the following variables:

- Ambient temperature
- Ambient ground temperature
- Depth of burial
- Ground thermal resistivity (usually with various sizes and types of cables, single or three core and methods of laying, direct in ground or in duct),
- Screen bonding / earthing
- Grouping of cables derating

Example: Calculating current ratings utilising manufacturer data sheet:

A 3-phase circuit comprising 2 parallel single-core XLPE, 6.35/11 kV, 630 mm^2, Cu cables with a 10 kA screen cables laid in conduit buried at a depth of 1000 mm, in two horizontal touching trefoil groups, 0.60 m apart, solidly bonded screen (double point bonded), with a ground thermal resistivity of 1.5°K.m/W.

Table 16: Manufacturer Information

Single-core 6.35/11 kV, XLPE, 630 mm^2, Cu cable current rating in underground ducts in touching trefoil and standards conditions	**625 A**
Ground temperature adjustment factor for 35^{o}C (Summer – Ergon regional)	0.92
Ground temperature adjustment factor for 29^{o}C (Summer – Energex)	0.97
Ground temperature adjustment factor for 20^{o}C (Winter)	1.04
Depth of burial adjustment factor at 1000 mm	0.98
Ground TR adjustment factor at 1.5 K.m/W for single core 630 mm^2 cables laid in single way conduits	0.94
Derating factor for 2 groups of cables in touching trefoil single way conduits, horizontal formation at 0.60 m apart	0.90

Regional Areas Summer Rating:

$$I_{summer} = 2 \times (625 \times \mathbf{0.92} \times 0.98 \times 0.94 \times 0.9) = 953A$$

South East Summer Rating:

$$I_{summer} = 2 \times (625 \times \mathbf{0.97} \times 0.98 \times 0.94 \times 0.9) = 1005A$$

Winter Rating:

$$I_{winter} = 2 \times (625 \times \mathbf{1.04} \times 0.98 \times 0.94 \times 0.9) = 1077A$$

A3.1 Simplified Short Circuit Current Ratings

The maximum short circuit current under adiabatic conditions may be calculated using Equation 8 or IEC 60949. Table 17 and Table 18 provide maximum permissible temperature rise limits for common insulation materials, refer to IEC 60986 and IEC 61443 for further details.

Note: this is a simplified calculation method and assumes adiabatic conditions i.e. no heat is lost to the surrounding atmosphere.

For common XLPE insulated cables the initial operating temperature is assumed to be 90°C with a maximum permissible temperature of 250°C under fault conditions. Cable screen initial temperature will be lower starting at 80°C and will have a maximum permissible temperature of 150°C for typical MD/HD Polyethylene (PE).

Equation 8: Short circuit rating

$$I_{sc} = \frac{1}{1000} \times \sqrt{\frac{K^2 S^2}{t} \times \ln\frac{\theta_f + \beta}{\theta_i + \beta}}$$

$I_{sc} = Short\ circuit\ current\ (kA)$

$K = Constant\ for\ material$

$\beta = Reciprocal\ of\ temperature\ coefficient\ of\ resistance\ at\ 0°C$

$\theta_f = Permissible\ or\ final\ short\ circuit\ temperature\ (°C)$

$\theta_i = Initial\ temperature\ before\ short\ circuit\ (°C)$

$S = Cross\ sectionla\ area\ of\ sheath\ or\ screen\ (mm^2)$

$t = \ Rated\ short\ circuit\ duration\ (s)$

Table 17: Material constants

Material	K	β
Aluminium	148	228
Bronze	180	313
Copper	226	234.5
Steel	78	202
Lead or lead alloy	41	230

Table 18: Short Circuit Temperature Limits for Insulation Materials

Material 1)		Temperature °C
Paper: – MIND (mass-impregnated non-draining)	≤20 kV	170
	>20 kV	150
– oil/resin	≤20 kV	170
	>20 kV	150
– oil-filled		250
Polyvinyl chloride	(PVC/B)	
– conductor cross-section ≤300 mm^2		160
– conductor cross-section >300 mm^2		140
Cross-linked polyethylene	(XLPE)	250
Ethylene propylene rubber	(EPR and HEPR)	250
1) Materials and designations according to IEC 60055, IEC 60141 and IEC 60502-2.		

Table 19: Temperature Limits for Oversheath Materials

Material 1)		Temperature 2), 3) °C
Polyvinyl chloride	(ST_1 and ST_2)	200
Polyethylene	(ST_3)	150
	(ST_7)	180
Polychloroprene, chlorosulphonated polyethylene or similar polymers	(SE_1)	200
Polyethylene bonded to aluminium or copper foil		150
Polyvinyl chloride bonded to aluminium or copper foil		160

1) Materials and designations according to IEC 60502-2.

2) Higher temperatures may be allowed, provided experimental data are available to demonstrate their use.

3) For cables in trefoil formation, these temperatures should be used with care due to possible high temperatures in the centre.

Example: By way of an example and consider the 33kV 630mm^2 XLPE/LY/MDPE cable from Figure 8, the cable screen calculated short circuit rating is 3.7kA for 3s based on Equation 8 and assuming the PE layer is in direct contact with the lead screen.

$$I_{sc} = \frac{1}{1000} \times \sqrt{\frac{41^2 349^2}{3} \times \ln \frac{150 + 230}{80 + 230}} = 3.7\ kA$$

$K = 41$, $\beta = 230$, $\theta_f = 150°C$, $\theta_i = 80°C$, $S = 349mm^2$, $t = 3s$

Material selection is important, copper has a much lower resistance and a CWS or Copper Wire Screen (instead of lead), with the same cross sectional area, results in a fault rating of 20.4kA for 3s. This also means the screen and overall cable diameter could be reduced if required:

$$I_{sc} = \frac{1}{1000} \times \sqrt{\frac{226^2 349^2}{3} \times \ln \frac{150 + 230}{80 + 230}} = 20.4\ kA$$

$K = 226$, $\beta = 234.5$, $\theta_f = 150°C$, $\theta_i = 80°C$, $S = 349mm^2$, $t = 3s$

Similarly, the short circuit rating of the core can be calculated by substituting relevant values for copper and XLPE from Figure 8 and Table 17:

$$I_{sc} = \frac{1}{1000} \times \sqrt{\frac{226^2 728^2}{3} \times \ln \frac{250 + 234.5}{90 + 234.5}} = 28.8\ kA$$

$K = 226$, $\beta = 234.5$, $\theta_f = 250°C$, $\theta_i = 90°C$, $S = 728mm^2$ $(stranding\ 61/3.9mm)$, $t = 3s$

Construction	Type of material		Thickness(mm)			Diameter	Direc	Maximum	Unit	Weight
	Material	Size or code	Nom.	Min. avg.	Min.	(mm)	-tion	pitch (mm)		(Kg/Km)
Conductor	SCR	Φ8.0mm				3.9			61	5,735.9
Stranding	WOA	#61/3.9				30.5	S		1	
Binding(1)	Swellable tape	0.4t	0.4	Overlap		31.3	Z		1	19.4
Binding(2)	Semi-con. tape	0.13t	0.13	Overlap		31.7	S		1	14.2
Con. Screen	Semi-XLPE	SI-2	0.7		0.3	33.1			1	81.2
Insulation	X L P E	EI-1	8.2	8.0	7.1	49.5			1	979.6
Ins. Screen	Semi-XLPE	SO-2	0.8		0.6	51.1			1	146.6
W/B Layer	Swellable tape	0.4t	1.2	Overlap		53.5	S		3	97.1
Metallic sheath	Lead alloy	E alloy	2.0		1.8	57.5			1	3,939.8
Outer sheath	HDPE(Black)	ES-5C	2.9	2.8	2.04	63.3			1	522.7
Conducting layer	Graphite	CPA-B3	0.01			63.3			1	2.1
									Total	11,538.7

*. Water Blocking tape
 -. Conductor : Material should be semi-conducting swellable tape.
 -. Under metallic sheath : Material should be semi-conducting swellable tape. (Min. 1 layer)

*. Cable Marking
 -. Interval : Max. 500mm
 -. Height of characters : Min. 9mm ~ Max. 13mm

*. Meter marking
 Length shall be marked with number at one meter intervals on the sheath.

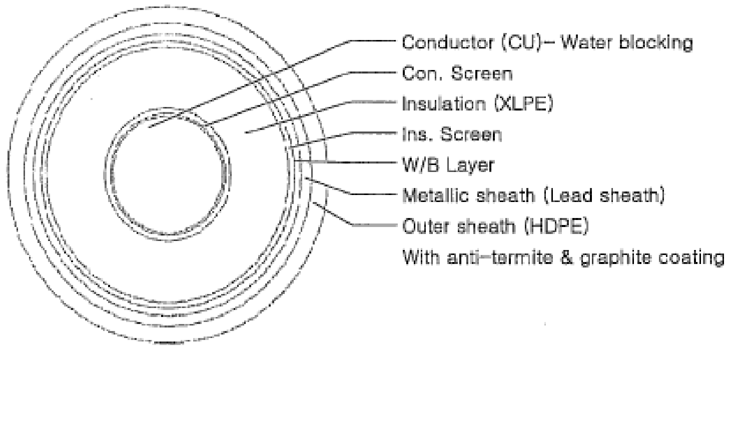
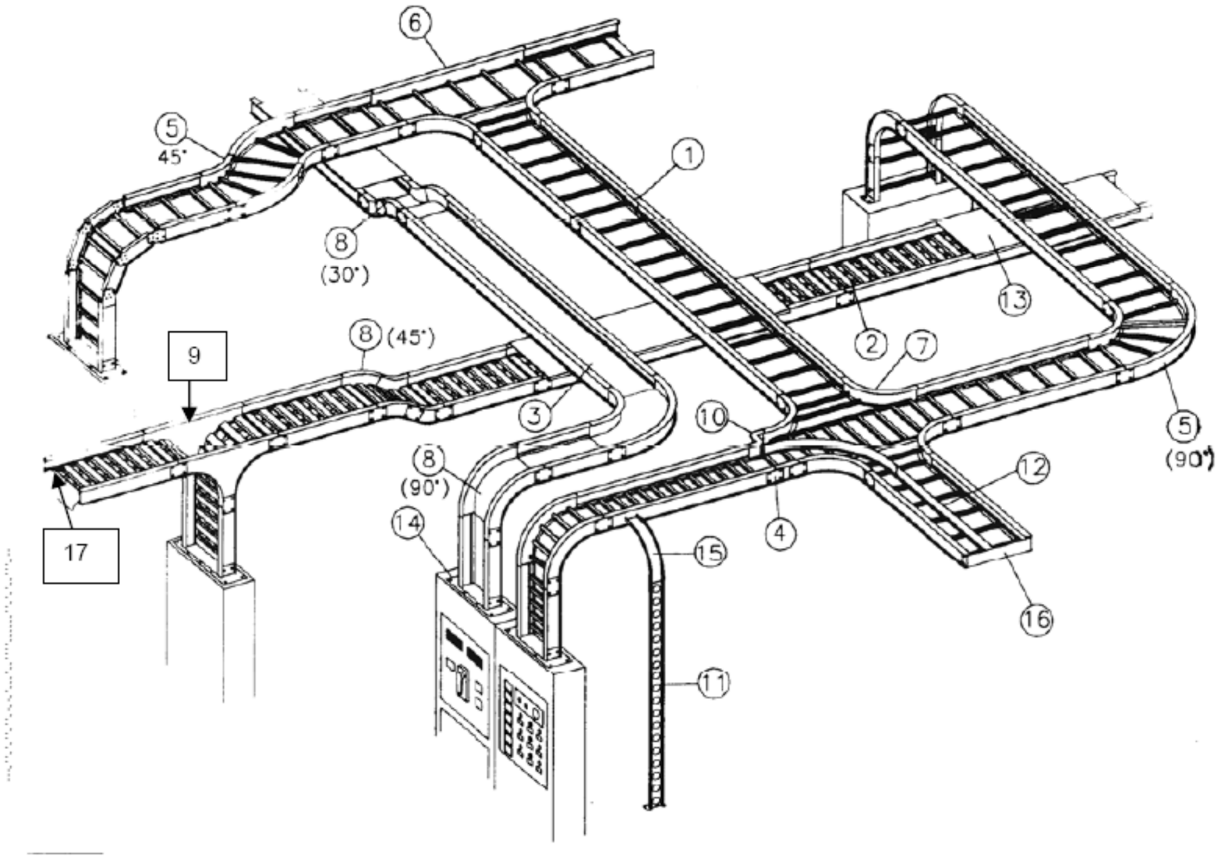


Figure 8: 33kV Cable Design Table

Annex B

Informative

Example of a Cable Tray System

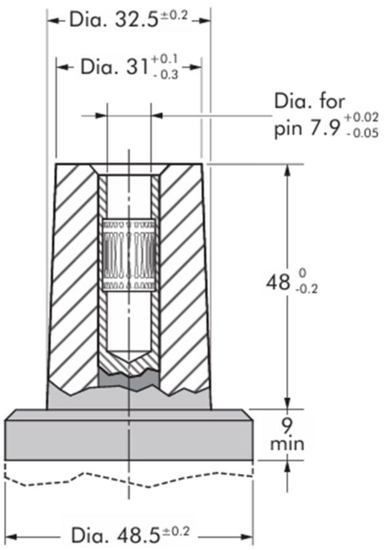


Legend:
1 = Ladder cable tray
2 = Ventilated cable tray
3 = Solid-bottom cable tray
4 = Rigid connector
5 = Horizontal elbow
6 = Horizontal tee
7 = Horizontal cross
8 = Vertical elbow
9 = Vertical tee
10 = Reducer
11 = Channel cable tray
12 = Divider
13 = Cover
14 = Tray-to-box connector
15 = Channel vertical elbow
16 = Blind end
17 = Dropout

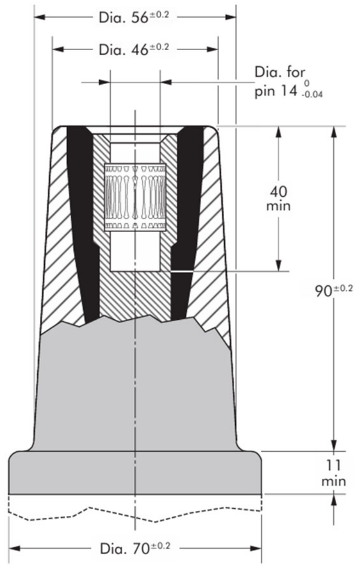
Annex C

Informative

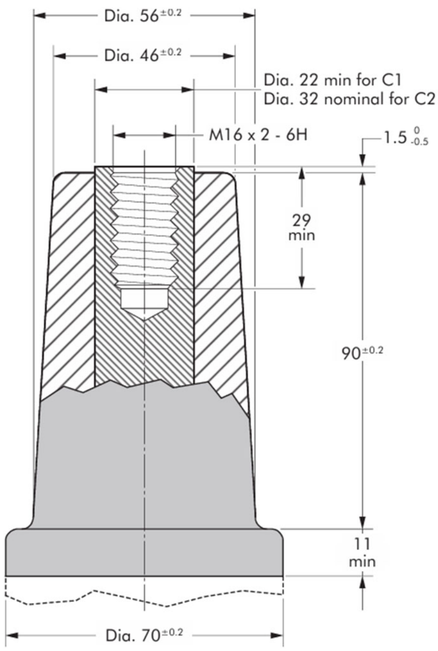
Terminations



DIN Type A (A1) 250A



DIN Type B (B1 & B2) 400A



DIN Type C (C1 & C2) 630A - 1250A

Annex D

Revision History

Revision Date	Version Number	Author	Description of Change / revision
August 2026	5	D. Fink	Updated sections: 7.1 General design considerations for conduits and trenches. 7.1.2 Updated with more design considerations for basement installations. 7.3.1 Clarified the need for separation of LV supplies and CT and VT circuits in multicore cables. 7.3.2 Clarified the need for screening cables and added conditional exemptions for legacy cables. 8.3 Additional requirements for conduit lays to align with cable pulling hardware. 10. Clarified cable positioning into panels. 13. EDMS changed to EQL drawing system and need for “as constructed” drawings. Part of TSD0188 have been migrated to this standard.
Sept 2026	6	D Fink	Minor changes to references