

Employer's Requirements

General Electrical

Project: Engineering, Procurement and Construction of Hybrid PV-Diesel-Battery Energy Storage System

Location: Pulau Tiga, Maluku, Indonesia

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1 Solar DC Cabling

1.1 General

This section covers DC cabling suitable for use on solar PV generation systems.

1.2 Standards

Solar DC cabling shall comply with all applicable international and Indonesia standards including but not limited to:

- TUV 2 Pfg 1169/08 PV1-F
- TUV 2 PfG 1169/08.07
- IEC 62930
- IEC 60228
- IEC 60216
- IEC 60332-1-2
- EN 50618
- EN 50267-2-1/-2
- EN 50396
- EN 50521
- EN 60811-3-1
- EN 60811-2-1
- EN 60068-2-78

1.3 Equipment

Provide high quality, robust, anti-corrosive and for outdoor applications solar DC cabling suitable for installation in hot, humid, tropical, saline environments with high exposure to sunlight (UV), salt, and tropical arid conditions. DC cable shall be:

- PV1-F or H1Z272-K certified.
- provided with a minimum size of 4 mm².
- UV resistant.
- Rated for use in wet and saline conditions.
- Minimum Rated value is 1500 Volt DC.
- Resistant to short-circuits up to 200°C
- Tinned fine copper strand according to VDE 0295/IEC 60228, class 5.
- Insulation and jacket: XLPO, flame-resistant according to IEC 60332, halogen free, electron-beam cross-linked, UV stable, ozone, double-insulated, high temperature, good notch and abrasion resistant, and hydrolysis and ammoniac resistant.
- RoHS and CE compliant
- Anticipated lifetime of at least 20 years

Solar DC cabling shall be provided with the following specifications:

- Maximum conductor temperature (TUV): 120°C
- Fixed installation ambient temperature: 40°C – 120°C
- Nominal voltage (TUV): 0.9/1.5 kVDC

- Insulation system: Halogen Free Two Layer Thermoset Copolymer

1.4 Colour Coding

The following colour coding should be utilized for the DC cabling:

Conductor	DC System
Positive	Red
Negative	Black or Blue
Isolated Ground	Green/Yellow Stripe

Add Wire markers, ID. A. cables wires shall be positively identified as per cable schedule.

1.5 Warranty

Solar DC cabling shall be provided with a minimum manufacturer's warranty of 5 years from date of installation.

1.6 Manufacturers recommendation

DC cables shall be from Phoenix Contact, Leoni, Lapp, Helukabel, or equivalent.

2 Solar DC Connectors

2.1 General

This section covers DC quick connectors suitable for use on solar PV generation systems.

2.2 Standards

Solar DC connectors shall comply with all applicable international and Indonesian standards including but not limited to:

- EN 50521
- IEC 62852

2.3 Equipment

Provide high quality solar DC quick connectors suitable for installation in hot, humid, tropical environments with high exposure to sunlight (UV) and arid conditions. The solar DC connectors shall:

- Be MC4 or equivalent and suitable for the solar DC cabling.
- be of exactly the same type as those provided on the solar PV modules.
- have a minimum ingress protection rating of IP67.
- have a minimum voltage rating of 1000 V_{DC}.
- have a minimum current rating of 25 A.
- Have a temperature range of 0°C - 85°C
- Solar DC quick connectors shall not be able to be opened without a special tool.

2.4 Warranty

Solar DC connectors shall be provided with a minimum manufacturer's warranty of 5 years from date of installation.

2.5 Manufacture

Solar DC quick connectors shall be of Staubli Group Multi Contact MC4, Tonglin, Hosiden, Amphenol, or equivalent manufacturer.

3 Solar DC Cable Management Systems

3.1 General

This section covers DC cable management suitable for use on solar PV generation systems.

3.2 Standards

- IEC 62930
- NEC 008/UL PV Wire
- EN50618

3.3 Equipment

Provide high quality solar DC cable management systems suitable for installation in hot, humid, tropical environments with high exposure to sunlight (UV) and arid conditions. The Solar DC cable management systems:

- Shall be UV resistant and or stabilized
- Shall be rated for use in wet conditions.
- Shall be flame retardant.
- consist of the following systems (or similar):
 - Stainless steel cable clips
 - **Epoxy coated stainless steel cable ties**
 - Galvanized steel cable tray/ladder complete with galvanized steel cover
 - HD and UV rated solar DC conduit for sun exposed sections of cabling **only** with higher risk of getting damaged (that cannot be buried)

3.4 Application and Installation

Cable management for DC cabling between modules in a string should be done with the use of epoxy coated stainless steel cable ties in a tidy manner. Minimize/avoid cable runs between different PV array tables. Fastening of cable ties shall be carried out so the electrical properties of the cables are not compromised. Sharp edges and corners should be avoided or other routing that could lead to cable sheath being punctured.

Galvanised steel cable tray/ladder complete with galvanised steel cover in all locations including risers and horizontal runs where practical and safe. In all other locations provide HD and UV rated solar DC conduit for cable sections that are not practical to be buried, e.g. between arrays next to each other. Cabling between arrays and powerhouse, or other longer exposed areas **MUST** be buried in conduit with the following minimum requirements:

- Depth 80 cm below ground level
- Minimum distance between the cable is 40 cm
- All cabling should be properly labelled

Tenderers should supply a tidy and neat installation of cabling and cable management and properly label cabling positive (+) and negative (-).

3.5 Warranty



Solar DC cable management systems shall be provided with a minimum manufacturer's warranty of 5 years from date of installation.

4 Solar DC Isolators

This section covers solar DC isolators suitable for use on solar PV generation systems.

4.1 Standards

Solar DC isolators shall comply with all applicable international standards including but not limited to:

- EN 60947-3
- IEC 60364-7-712
- AS/NZS 5033

4.2 Equipment

Provide high quality solar DC isolators suitable for installation in hot, humid, tropical environments with high exposure to sunlight (UV) and arid conditions.

- Solar DC isolator enclosures shall be UV resistant.
- Solar DC isolator enclosures shall be rated for use in wet conditions.
- Solar DC isolator enclosures shall have a minimum ingress protection rating of IP67.
- Solar DC isolator enclosures shall be flame retardant.
- Solar DC isolators shall be lockable in the OFF position with a padlock.
- Solar DC isolators shall be able to switch both conductors (legs) simultaneously at full voltage rating to DC-218.
- Solar DC isolators shall not be polarised.
- Solar DC isolators shall achieve the following specifications:
 - Minimum DC-218 Voltage Rating: 1000 VDC per conductor (leg)
 - Minimum DC-218 Current Rating: 13 ADC @ 1000 VDC per conductor (leg)
 - Conductor connection size: 4-6 mm²
- Solar DC isolators should be able to handle over 15-20% (?) above V_{oc} of array and 20-25% over I_{sc}
- Solar DC isolators should be double pole

4.3 Warranty

Solar DC isolators shall be provided with a minimum manufacturer's warranty of 5 years from date of installation.

5 Earthing

5.1 Systems

Provide earthing systems as follows:

- Substations and main switchboards safety earths in accordance with requirements for MEN system and Supply Authority/Local requirements
- Lightning protection systems
- Technical (functional) earthing systems
- Bonding earthing system

Standards and guidelines:

- Earthing to distribution network in compliance with SPLN No. 3 :1978
- See recommendations from [Earthing and Lightning Overvoltage Protection for PV Plants](#)
- For DC system earthing, refer to AS/NZS5033:2012 - Installation and Safety Requirements for Photovoltaic (PV) Arrays
- If specific situations are not covered by the documents above, refer to
 - IEEE Std 80:2000 - Guide for Safety in AC Substation Grounding
 - NZECP35:1993 - Electrical Code of Practice for Power Systems Earthing
 - EEA Guide to Power System Earthing Practice
 - AS/NZS3835.1:2006 - Earth Potential Rise – Part 1: Code of Practice
 - AS/NZS4853:2012 - Electrical Hazards on Metallic Pipelines
 - AS/NZS3000: 2018 - Electrical Installations (known as the Australian/New Zealand Wiring Rules)

5.2 Equipment

The size of buried earthing conductor is determined by soil resistivity and the calculated EVGR across the site. However, the minimum cross-sectional area of the buried cable shall be 25mm² (bare plain annealed copper); where rods are used, they have to be a minimum of 12.5mm (half inch), 1.2m in length.

Protective earth conductor shall have a minimum cross sectional area of 25mm².

All underground connections are to be done using technology that fuses the copper together either by mechanical compression (crimps or shearlugs). Exothermic welding may be considered but installer qualifications and sample work will need to be approved by the engineer prior to commencement on site.

5.3 Design and installation

Contractor shall perform soil resistivity test in order to design earthing grid. For the installation, contractors **must**:

- Provide an insulated, isolated grounding conductor for branch circuits serving isolated ground and isolated ground surge suppressor type receptacles. Isolated grounding conductors shall be isolated from other grounding systems back to the system point of origin.

- Feeders and branch circuits shall be provided with an insulated grounding conductor run with the circuit conductors. This grounding conductor shall be in addition to the ground path provided by the continuously grounded metallic raceway system that encloses the phase and neutral conductors.
- Bare copper shall be installed with 0.5 - 1 meter depth from finished Ground Level
- Rods may be installed at a depth of 0.5 m
- Inspection pit is necessary in order to test earthing regularly.
- The measured resistance value of Earth termination systems should be the lowest possible (less than 5 Ω). This resistance should be measured on the earthing termination insulated from any other conductive component. If earth resistance more than 5 Ω , contractor shall responsible to provide extra rod and copper grid to comply with PUIL/SPLN local standard (less than 5 Ω).

5.4 Bonding Earth Conductors

Contractors must:

- Provide Bonding earth conductor may be a minimum of 6mm² for all equipment with exception for the Module array framing.
- Provide bonding earth conductors to all conductive array mounting and PV module framing in accordance with AS/NZS 5033. Minimum size 16 mm² along the entire run to the Main Earth Conductor.
- Metallic raceways, cable trays, cable armor, cable sheath, enclosures, equipment frames, fittings, and other metallic non-current carrying equipment parts and surfaces shall be effectively bonded to the earthing system.
- Receptacles and lighting fixtures shall be grounded to the outlet box by means of a bonding jumper between the outlet box and the receptacle or lighting fixture grounding terminal.
- Ensure any bonding straps shall be made of 25mm² stranded copper conductor.

5.5 Lightning protection

5.5.1 Lightning protection: air terminal/lightning rod

Copper rod shall be used as the lightning protection mechanism. Copper sized as required by structure class under provisions of UL 96A and NFPA 780 standards for lightning protection system installation except where specified in excess of herein. All materials should comply with EN 50164-2. Contractor shall provide Lightning event counter to monitor lightning strikes, with remote monitoring capability.

5.5.2 Lightning protection: down conductors

Bidders must ensure the following:

- Each air terminal shall be connected to at least one down conductors.
- The type of Down Conductor shall be Double Shielded cable to reduce lightning strike Induction.
- The size of Down conductor cable shall be minimum 50 mm².

- Down-conductors shall be mechanically fixed to the poles using appropriate mounts to provides adequate electrical isolation. (See “fixings” section below.)
- Connections to earth electrodes from down conductors formed by reinforcing steel or concrete clad steel frames will be made by the Contractor. They will comprise copper tape, not less than 20mm x 3mm, welded onto the steelworker bolted to a welded bracket.
- No aluminum conductor shall be buried in the ground.
- The down conductor should be installed in such a way that its path is as direct as possible. The routing of the down-conductor should be as straight as possible, following the shortest path, avoiding sharp bends or upward sections. The bend radii should not be less than 20 cm (see figure 4). For down-conductors, bends formed edgewise should preferably be used.
- The down-conductors should not be routed along or across electrical conduits.
- The down-conductor for the lightning protection system should be separate from the down conductors used for other grounding equipment. The down conductor for the lightning protection system should only connect to the grounding system, underground, at the grounding rods.

5.5.3 Lightning protection: joints

Regarding lightning protections joints, bidders must:

- Joints in conductors shall be kept to a minimum.
- Joints between conductors of the same metal, other than at test points, shall be made by an exothermic welding process or by using crimps or shear lugs. Overlap of conductors shall be not less than 100mm.
- Where an aluminum conductor is joined to a copper conductor, one of the following methods shall be used: a bi-metal connector formed by friction welding of high purity copper and aluminum; the copper conductor shall be completely sheathed for at least 100mm of its length with metal strip electrolytically compatible with copper and aluminum, and then clamped to the aluminum conductor. Bi-metal joints shall not be made at test points nor between the test point and earth electrode.
- Bonding connections to other metal parts shall be electrolytically compatible with those metal parts.

5.5.4 Lightning protection: earth electrodes

- Electrodes shall be installed in undisturbed ground. The distance between any two electrodes shall be not less than the sum of the lengths of the two electrodes. The minimum length of each Earth Electrode is 3 meter.
- Earth Electrode shall be installed with 0,5 meter depth from finished Ground Level as per SNI standard and separately from earthing equipment.
- A certain contact surface with the soil shall be assured in order to facilitate the lightning current dispersion in a short time.

5.5.5 Lightning protection: fixings

The maximum spacing of fixings shall not exceed 900mm. No fixings shall be made into joints in masonry. Saddles and holdfasts shall be of the following materials: for copper conductors: gunmetal, phosphor bronze or naval brass; for aluminum conductors: aluminum, aluminum alloy or stainless steel. Clips shall be either of metal, as above, or of outdoor grade polycarbonate or polypropylene with snap-on lids which cannot be inadvertently removed. Clips and saddles shall have rounded edges and countersunk screws. Brass components shall not be used.

5.5.6 Lightning protection: surge arresters

Surge arrester should be used to:

- Providing equipotential bonding to the services, reducing the risk of flashovers to/within the services when current from the LPS is injected into the ground and a portion of this current may flow out the service to remote ground points.
- Reducing transient energy entering into the facility from a direct or indirect flash to the service.
- Protecting internal electrical and electronic equipment.

In case an Air terminal is installed on the building, a class 1 SPD (Surge Protection Device) should be installed within the main electrical distribution panel as per SNI Standard.

The class 2 SPD Should be located within the Sub Electrical Distribution Panel.

The SPD should be located after the main disconnect/overcurrent device to allow the power to be isolated to the SPDs if maintenance is required. SPDs must provide a voltage protection level lower than the impulse voltage withstand than the equipment to be protected.

5.5.7 Installation and warranty

When installing the lightning protection system contractors should consider minimizing/avoiding any shading to the PV array. The lightning protection system should have a minimum manufacturers WARRANTY of minimum 3 years.

6 Switchboards

This section covers requirements and specifications for switchboards, distribution boards, load centres, control panels and the like.

6.1 Construction Material

Shall be sheet steel cubicle type suitable for accommodation in the cupboards or spaces provided, surface, floor or wall mounted or recessed in walls as shown on the drawings or schedules. Where appropriate ABS plastic enclosures may be used, provided that they hold the appropriate voltage, UV, temperature and fire rating certifications.

- **Standard**

Minimum Form 1 with shrouded incoming terminals.

- **Degree of Protection**

Provide enclosures offering IP65 minimum ingress protection. Where installed externally provide enclosures offering IP66 minimum ingress protection.

- **Manufacture**

Assemblies shall be supplied by an approved, experienced manufacturer and shall be similar to NHP MODG, IPD Evolution or PV Power as applicable.

- **Housing**

Powder coated folded sheet steel enclosures, fitted with hinged, removable escutcheon panels for access to wiring and equipment. Escutcheon panels shall be fitted with two "D" handles. Provide spare space within enclosure for future expansion.

- **Doors**

Doors shall be fitted, except where noted otherwise on drawings or schedules. Provide flush type lever handles to doors with three point locking on doors in excess of 800 mm high.

6.2 Equipment

- **Busbars**

Insulated, phase colour coded, copper busbars with stalks ready for connection of miniature air circuit breakers (MCBs) in all pole spaces. The busbar system shall permit interchangeable use of 1 or 3 phase circuit breakers. The busbar system shall be type tested to a minimum fault level of 25 kA for 0.2 sec.

- **Neutral/Earth Bars**

Provide neutral and earth bars sized to accommodate the total capacity of the chassis including isolated bars for RCDs.

- **Protective Devices**

Miniature moulded case air circuit breakers (MCBs) of approved manufacture and interchangeable 1, 2 or 3 pole type in ratings from G A to 80 A. Minimum fault capacity of 25 kA rms symmetrical at 400 V.

- **Manufacture**

Circuit breakers, where installed in existing switchboards or within an existing electrical installation shall be of the same manufacture as those existing.

6.3 Circuit Schedules and Labelling

- **General**

A typed Circuit Schedule shall be provided in a suitable holder either inside the switchboard door when doors are fitted or adjacent to the switchboard.

- **Information**

Circuit schedules shall identify equipment, number of items and relevant room identification codes. Neutral connections/terminals for each circuit shall be identified on the Circuit Schedule.

- **Submains Switches**

Where a switchboard has a circuit breaker controlling submains to another switchboard, that circuit breaker shall be identified with a label indicating the switchboard number and its location.

6.4 Design, installation, and warranty

All switchgear shall be free standing, air insulated, preferably metal clad and comply with AS/NZS 3439 for Form 3 fully segregated boards. They shall be continuously rated to operate under full load at the site conditions. The switchgear and switchboards shall have test certificates for arc fault containment. All cubicles shall be designed so that an internal fault with the maximum possible rate of energy release shall not open, nor force out of position, any of the front doors or panels of the cubicle and any hot gases or other products of the fault shall be directed away from any operator standing in front of the cubicle.

No hygroscopic insulating material shall be used. If the cubicles are to be fabricated using sheet steel, in no case shall sheet steel less than 1.6mm thick be used. The framework shall be constructed from folded steel or structural sections and shall provide satisfactory strength and rigidity. Eye bolts and/or a lifting beam shall be provided for each section to facilitate handling.

Each switchboard shall be constructed such that it may be broken down into sections not exceeding 5 metres in length for packaging and transport. The design shall allow easy re-assembly on site, and all nuts, bolts and other fittings required for re-assembly shall be provided. Width and depth of tiers shall be identical. General construction of each switchboard shall be such as to allow for extension at each end while preserving a neat, finished appearance.

No electrical equipment shall be installed within 150mm of ground level. The switchboards and motor control centres shall be designed such that no component requiring regular maintenance

or inspection is mounted less than 300mm or more than 2000mm above floor level. All equipment shall be accessible from the front of the switchboard.

All equipment necessary for setting and connection on site shall be provided.

All future or empty modules shall have all internal live parts permanently covered such that no live parts are exposed when the door is opened. This requirement applies whatever type of door fastener is supplied.

Insulated horizontal cable ways shall be provided for the full length at the top and bottom of each switchboard. Sheet steel work shall be finished to remove all sharp edges in these cable ways. In addition, each tier shall have a vertical cable space between the top and bottom cable ways of a minimum of 200mm.

All cable ways shall be separated from the busbar zones by adequate metal barriers to prevent cable damage under busbar short circuit conditions. All cable ways shall be fitted with facilities to cleat or tie wiring over their full length.

7 Switchgear, Control gear, breakers,

7.1 Cascade Protection and Discrimination

- **Requirement**

The entire distribution system shall incorporate circuit breakers of the same manufacture selected to achieve required prospective fault level both by inherent fault capacity and in the case of downstream equipment by applying the principles of cascade protection.

Discrimination: In addition, discrimination under overload and short circuit fault conditions shall be achieved throughout.

Switchgear shall operate to interrupt faults under all possible scenarios.

- **Selection and sizing**

The type, rating and trip unit settings of all circuit breakers shall be determined by the manufacturer. A schedule listing all equipment and associated characteristics shall be prepared and this shall be incorporated in the Operating and Maintenance Manual.

- **Warranty**

Provide a warranty that all equipment installed is in accordance with manufacturer's recommendations and provide a statement from manufacturer and signed by their manager certifying that the equipment selected as nominated in their schedule complies with the protection and discrimination principles outlined above.

- **Application**

The principles and requirements outlined above shall apply irrespective of other requirements included in this Specification.

7.2 Moulded Case Circuit Breakers (25 kA Fault Rating and Over)

- **Rated Short Circuit Breaking Capacity**

Not less than the switchboard fault level or circuit location where current limiters are fitted, or as required by manufacturer's selection table where cascade protection is used.

- **Status**

Status (ON/OFF/TRIPPED) shall be positively indicated.

- **Mounting**

Mount the circuit breakers so that the 'ON/OFF' and current rating indications are clearly visible with the cover or escutcheon in position, and so that arc discharges from the circuit breakers are directed away from live metal and insulation. Align operating toggles in the same plane.

7.3 Miniature Overcurrent Circuit Breakers (MCB)(10 kA and Under Fault Rating)

- **Rated Short Circuit Breaking Capacity**

Not less than the switchboard fault level and 10 kA minimum, or as required by manufacturer's selection table where cascade protection is used.

- **Status**

Status (ON/OFF/TRIPPED) shall be positively indicated.

- **Mounting**

Mount the circuit breakers so that the 'ON/OFF' and current rating indications are clearly visible with the cover or escutcheon in position. Align operating toggles in the same plane.

7.4 Contactors

- **Type**

Block type, air break, electro-magnetic.

- **Mechanical Endurance**

To suit load and in any case 3 as a minimum to Standard

- **Minimum Size**

16 A at 400 VAC.

- **Utilisation Category**

Not less than AC-1 as applicable for resistive loads.

- **Auxiliary Contacts**

As required.

- **Mounting**

Mount the contactor with sufficient clearance to other equipment and to its enclosure to allow full access for maintenance, removal and replacement of coils and contacts, without the need to disconnect wiring or remove other equipment.

- **Interconnection**

Do not connect contactors in series or parallel to achieve the specified ratings.

- **Terminals**

Tunnel type clamp plate terminals.

8 Wires, cables and supports

This section covers AC- cabling, cable management, and supports for all other cabling apart from the solar DC cabling already described above.

8.1 Cable Selection

- **Selection**

Determine cable selection using the appropriate standard based on:

- Current-carrying capacity
- Voltage drop
- Short-circuit temperature rise
- AC or DC application.

- **Conductors**

Use multi-stranded copper conductors unless specified otherwise. Minimum size:

- 4 mm² for power and lighting circuits rated/protected at 20 A
- 2.5 mm² for power and lighting circuits rated/protected at 16 A
- 1.5 mm² for lighting circuits rated/protected at 10 A
- 1.5 mm² for control circuits

Otherwise to appropriate standard taking into consideration earth-fault loop impedance, voltage drop, bunching/grouping, depth of laying and temperature derating factors.

Increase cable sizes as required to account for derating factors due to installation conditions

- **Standards**

Cables to be fabricated in accordance with ASTM and IPCEA standard, or Indonesian equivalent.

- **Colour Coding**

Color Coding as per SNI 04-0225-2000:

Conductor	220 V Single Phase AC System
Phase	Brown or Black
Neutral	Blue
Isolated Ground(PE)	Green/Yellow Stripe

Conductor	380/400 V Three Phase AC System
Phase L1	Red

Phase L2	Yellow
Phase L3	Black
Neutral	Blue
Isolated Ground (PE)	Green/Yellow Stripe

- **Manufacture**

AC cables shall be from KMI, Sutrado, Sucaco manufacture or approved equivalent.

8.2 Cables General Requirements

- **Manufacturer's Recommendations**

Install, terminate and joint cables in accordance with the manufacturer's recommendations.

- **Classification**

Install wiring systems to WS classification for fire and/or mechanical protection where applicable.

- **Cable Routes and Supports**

Routes and support details shall be determined by the contractor with approval from the Employer. Cables, supports and enclosures shall be installed with all necessary bends, set ups/downs, etc., as required to coordinate with the building and other services without compromising the cables' electrical properties.

- **Handling Cables**

Ensure that cable serving or sheathing is not damaged prior to or during installation.

- **Joints**

Joints in cables are permitted at terminations only. Where joints are permitted other than at terminations, locate them as directed by the Employer.

- **Installation**

Cables shall be concealed unless noted otherwise. Proposed cable routes and installation methods are generally described in the specification. Where a more suitable route is found the approval of the Employer is required to utilise the alternative route.

- **Identification**

Submains cables installed in accessible locations on cable trays and ladders shall be labelled at 10 m intervals with a durable traffolyte engraved label to indicate function/purpose, origin and destination e.g. 'SUBMAIN TO DB 410 FROM MAIN SWITCHBOARD'

8.3 Cable Management

- **Requirement**

Provide a cable management system coordinated with all trades to provide a logical, coordinated reticulation system with trays and supports shared between trades where possible and allowed by codes and regulations to reduce clutter and improve manageability. Rationalise cable routes where possible.

- **Routes**

Cable routes shall be parallel to building axes and structural members.

- **Separation**

Maintain separation distances required by standards, applicable codes and regulations between power/lighting circuit cabling, communications cabling and other cabling and services.

- **Protection**

Wiring systems installed in situations where there is a risk of fire and/or mechanical damage shall be adequately protected in accordance with the WS classification as applicable.

- **Roof Penetrations**

Where cables penetrate the roof, use proprietary roof sealing system appropriate for the type of roofing material such as Dektites.

- **Concealment**

Cables, supports and enclosures shall be concealed unless shown otherwise. Utilise ceiling spaces, unoccupied rooms such as plant rooms and stores, wall cavities and underfloor void spaces to run cables and enclosures on the surface.

Inaccessible Locations: Enclose cables in conduits with accessible ends which allow installation and removal of cables when work is complete. Access to fixed plasterboard ceiling spaces may be obtained via manholes or by removal of luminaires.

- **Visible Enclosures**

Where concealment is impossible obtain approval to run cables in surface mounted cable ducts, trays, ladders or conduits as applicable. Plastic materials shall not be used in locations exposed to direct sunlight unless an appropriately certified for UV and temperature.

- **Supports**

Cables in false ceiling spaces shall be provided with the following support systems:

- Groups of 3 individual cables or more:
 - Cable trays fixed to soffit or slab over or roof structure.
 - Separate trays for power/lighting circuits and other cables.
 - Fixing to catenary wires (maximum number of circuits determined from bunching factor).
- One or two cables:
 - Where only one or two cables are to be run they shall be coordinated with other trades and where allowable shall share cable trays provided by other trades.

- Only where there are no trays within the vicinity shall the following methods be used:
 - Fixing with nylon ties to slab or roof structure at maximum intervals of 1500 mm.
 - Fixing to catenary wires.
- No cables shall rest on the ceiling, or be supported by ceiling hanger or the support systems for pipes or ventilation ducts
- **Tagging**

Identify different cable types and function by stamped, non-ferrous tags clipped around each cable or common group at each end, at major branches and junctions, at crowded intermediate points and at 20 m centres.

8.4 Cable Installation

- **Manufacturer's Recommendations**

Install, terminate and joint cables in accordance with manufacturers' recommendations unless otherwise specified.

- **Handling Cables**

Handle cables so as to avoid damage to insulation, serving or sheathing. Report all damage and replace or repair damaged cable as directed.

- **Straight-through Joints**

Run cables for their entire route length without intermediate straight-through joints. Where cable joints are unavoidable due to length or difficult installation conditions locate approved joints as directed.

- **Conductors**

Insulation colour: For fixed wiring colour the conductor insulation to the wiring rules or, if this is not practicable, slide not less than 150 mm of close fitting coloured sleeving to each conductor at the termination points.

- **Tagging**

Identify multicore cables and trefoil groups at each end and at crowded intermediate points by means of stamped, non-ferrous tags, clipped around each cable, or trefoil group.

- **Multiphase Circuits**

Single core cables of 3 phase circuits shall be installed in trefoil (RWB) or quadrefoil (RWNB) groups. On long runs transpose phases periodically to reduce system impedance.

- **Other Systems**

Communications: For cable type see sub-section "COMMUNICATIONS CABLING SYSTEM". Support and enclosure generally as for power sub-circuits.

Communications cabling shall be installed by licensed communications cablers.

Cabling shall be installed in accordance with relevant IEC standards

8.5 Sheathed TPS Cables

- **Type**

0.6/1 kV range, 75° temperature rated cable except where XLPE or fire rated wiring system is specified. Deliver to site in the original packages.

- **TPS Installation**

Install TPS cables as follows:

- Not in routes where cables cannot be withdrawn for rewiring on completion of building construction.
- With bushes or glanding where passing through metallic holes.
- Horizontally or vertically only in stud partitions and cavity walls.
- Grouped in trefoil where single core cables are installed.
- Protected in accordance with the wiring rules.

8.6 Single Insulated TPI Wiring in Conduit

- **Requirement**

Complete and permanently fix the conduit run before installing the wiring. Clean and dry conduits before installing wiring. Use draw wires to pull in the conductor groups from outlet to outlet.

- **Junction Boxes**

Do not make conductor joints in through-runs of cables unless approved. Install boxes containing joints in accessible locations.

- **Vertical Runs**

For vertical conduit runs in excess of 15 m make adequate provision for supporting the weight of the wiring to avoid insulation damage.

- **Damaged Insulation**

Replace all wiring in conduits containing conductors with insulation damaged during installation, after determining and removing the cause of damage.

8.7 Copper Conductor Terminations

- **Requirement**

Unless otherwise approved, terminate copper conductors to equipment, other than small accessory and luminaire terminals, by means of compression-type lugs of the correct size for the conductor, compressed only using the correct tool.

- **Within Switchboards and Equipment**

Loom and lace together, with PVC straps or string, all conductors from within the same cable or conduit from the point of cable sheath or conduit termination to the terminal block. Neatly bend each conductor to enter directly into the terminal tunnel or terminal stud section, allowing sufficient slack for easy disconnection and reconnection.

- **Insulated DIN rail mounting type with clamp plates to secure conductors.**

Provide in switchboards and control panels for all interconnecting control wiring. Fit clear insulating labeled cover for extra low voltage wiring terminations.

8.8 Conduits Generally

- **Minimum Sizes**

Metallic and non-metallic conduits: 20 mm with minimum size of 25 mm when embedded in concrete slabs and columns.

- **Support**

Unless otherwise specified, fix conduit saddles at a maximum of 1 m intervals in horizontal runs and 2m intervals in vertical runs. Ensure that installed conduits are fully supported during construction.

- **Protection in Roof Space**

Protect uPVC conduits installed in accessible roof spaces and the like with double depth timber battens.

- **Inspection Fittings**

Inspection fittings shall be accessible.

- **Draw-in Boxes**

Provide draw-in boxes at suitable intervals not exceeding 30 m in straight runs, and at intervals not exceeding 25 m in other runs including directional changes.

8.9 Conduit Installation above Ground

- **Route**

Run conduits concealed in wall chases, between facing panels of stud walls, embedded in floor slabs and installed in inaccessible locations, direct between points of termination with a minimum number of bends and sets. Where conduit runs cannot be concealed from view obtain prior approval to route. Do not conceal conduit fittings.

- **Location**

Locate conduit run in concrete slabs entirely within the structural slab. Do not run conduits in the concrete topping screed unless approved by structural engineer.

- **Steel Conduit**

Hot dipped galvanised steel conduit shall be used if run in concrete slabs.

- **Fixing**

Route conduits in slabs so as to avoid crossovers and to keep the number of conduits in any one location to a minimum. Space conduits horizontally minimum 75 mm apart in slabs. Fix conduits directly to the reinforcing where the conduits pass above a single layer of reinforcing, or fix midway between double layers of reinforcing. Route conduit runs away from runs of

pipework and ductwork that are to be hung off the slab to minimize the risk of cables/conduits being damaged by the fixings for these other services.

- **Attendance at Pours**

Ensure that conduits are not displaced, broken, or damaged during concrete pours. Replace if broken or damaged.

- **Draw Cords**

Polypropylene draw cords shall be installed in all spare conduits and in all conduits, including sub- mains conduits with spare capacity, which may be used in future.

8.10 Non-Metallic Conduits and Fittings

- **Type**

Rigid conduit shall be used generally but corrugated type may be used where convenient with approval.

- **Arrangement**

Provide separate conduits for light, power, communications cables and other systems where required.

- **Material**

Conduits, fittings and adhesive cement shall be from the same manufacturer where possible.

- **Joints**

Adopt the manufacturer's recommended procedures for making joints.

- **Wall Boxes**

Wall boxes shall be of the same material as the conduit.

- **Fittings**

Use inspection type fittings where conduits are exposed. Use large radii bends, formed with correctly sized springs. Conduits manipulated or bent shall maintain true effective diameter and shape and shall not show evidence of kinks, or having been heated.

- **Flexible Couplings**

Install flexible couplings wherever expansion or contraction joints occur in a building. Install expansion fittings in straight runs of rigid uPVC conduit except those embedded in concrete or in wall chases.

Space expansion fittings, at 4 m or less. Install conduit clips close to expansion fittings to allow the conduit to move freely while expanding or contracting.

- **Mechanical Damage**

In situations where the conduit is exposed to mechanical damage and external to buildings, provide mechanical protection to uPVC conduit for a height of not less than 3 m above ground or platform level.

- **UV Damage**

In situations where the conduit is exposed to direct sunlight, the conduit and conduit fittings shall be black UV Resistant HFT type.

8.11 Cable Ladders and Trays

- **Requirement**

Utilise existing cable ladders and trays only where sufficient spare capacity exists for a neat and compliant installation. Provide cable ladders and trays to support cable runs as required. Ladders and trays shall be sized with at least 30% spare capacity for future additions.

- **Type**

Ladders and trays shall be of corrosion resistant finish, pressed and folded zincalume finish or galvanised sheet steel. The design shall comprise a ventilated rib with side rail and folded edges. Standard perforated cable trays is not acceptable except for switchboard work.

Light Duty: For support of smaller cables and where supports are closely spaced.

Heavy Duty: For support of groups of larger cables or where supports are more widely spaced, heavy duty steel cable ladder or equal shall be used.

- **Installation**

Install in accordance with manufacturer's instructions with a maximum deflection/span ratio of 1:200. Install complete with all necessary splice plates, bends, etc.

- **Support**

Provide substantial supports comprising plain or angle mounting brackets of galvanised steel, Unistrut or similar, fixed to walls or floors or suspended from structure where applicable.

- **Access**

Position the support system to give adequate access for inspecting, replacing, or adding cable.

- **Cable Installation**

Install cables neatly, generally to one side leaving as much free space on other side as possible for future additions.

- **Cable Fixing**

Fix cable generally to the support system by proprietary stainless-steel straps or saddles, at 1000 mm centres for vertical runs and 2000 mm centres for horizontal runs. Single conductors of multi-phase circuits shall be adequately secured to prevent separation under short circuit conditions.

Large Conductors: Large conductors shall be fixed by proprietary cable cleats of appropriate size. For long straight runs the cleats shall be arranged to fasten cables firmly at 5000 mm

to 7000 mm intervals. Intermediate fixings shall provide clearance to allow cable movement for thermal expansion and contraction.

- **Covers**

Where ladders and trays are exposed to sunlight or in public areas and where shown or specified, provide removable covers consisting of folded zincanneal finish sheet steel. Edges of covers shall be folded and fixed to supports or to adjacent wall or ceiling to completely conceal cables and cable supports from view but to permit free movement of air around cables. Cover fixings shall be by threaded bolt to permit easy removal.

- **Fire Rating**

Where cable trays/ladders are used to support wiring systems that are required to have a fire rating, the cable tray/ladders and their associated support system shall also have an equivalent fire rating together with appropriate test certificate.

8.12 Cable Ducts

The following table details key specifications for cable ducts:

Fabrication	Cable ducts shall be fabricated of sheet steel except where rigid PVC ducts are specified.
Accessories	Ducts shall be complete with all necessary matching bends, tees, risers, end stops and other accessories.
Size	Ducts shall be adequately sized for the installation of 30% additional cables.
Barriers	Where separate services are accommodated in one duct a continuous internal barrier shall be provided for segregation.
Conduits	Conduits shall be locknuttet to ducts and ends bushed. Where shown or specified, ducts shall be provided with conduit knockouts at regular intervals.
Installation	Ducts shall be installed neat and square with building lines.

8.13 Steel Ducts

Construction	Ducts and lids shall be galvabond or zincanneal (where painted) sheet steel of thickness as shown below. Grade of coating shall be as specified in Clause "Finishes".
Lids	Lids shall be provided unless specified otherwise and all ducts with lids shall be electrically continuous and lids and top edges of ducts shall have a 10 mm to 15 mm return edge for fastening and stiffening purposes.

Fixings	Lids shall be fastened at ends and at maximum 1500 mm intervals between with galvanised steel gutter bolts and captive nuts. No mixing of materials between bolts, nuts, ducts and sheets.
Retaining	Lids shall be held by retaining chains or nylon cords properly anchored and approx. 300 long.
Labelling	Duct and lid shall be identified in accordance with "Labelling and Identification" Clause.
Accessories	Fish plates shall be provided at all joints. Bolt duct with galvanised round head metal thread screws at each joint using spring washers to provide electrical continuity.
Holes	Holes for cable entering or leaving ducts shall be bushed.
Installation	Vertical runs of duct shall be provided with an approved means of supporting the vertical runs of cable at intervals of 5000 mm maximum. This may be accomplished by provision of support bars with cleats or saddles within the duct or for smaller cables by an arrangement of steel pegs sleeved with PVC which form a matrix through which the cables weave and are supported by friction.
Size	Sheet steel thickness for ducts shall be not less than the following: <ul style="list-style-type: none"> • Duct up to and including 50 mm wide: 0.8 mm • Duct above 50 mm, up to and including 100 mm wide: 1.0 mm • Duct above 100 mm wide: 1.2 mm

8.14 Cable Duct Installation

Installation	Installation shall be true and straight and parallel with the main lines of the building unless otherwise approved or indicated and shall provide continuous support or enclosure.
Earthing	Metal ducts shall be earthed.
Accessibility	Ducts shall be accessible throughout for cable installation or removal. Lids shall be cut either side of walls or floors.
Joints	Joints shall be effected with fishplates bolted each side, and also at the bottom for ducts more than 75 mm wide.
Splice Plates	Where duct crosses an expansion joint provide sliding splice plates in duct and lid where applicable to allow 30 mm movement. Provide flexible earth bonding strap across sliding joint.
Expansion	Overlapping joint with elongated fixing holes shall be installed at not more than 20 m intervals on straight runs to allow at least 15 mm thermal expansion/contraction. Joints shall be bridged with a flexible bonding strap.
Fire Barriers	Where duct passes through fire barriers the duct shall be sealed after cable installation.
Supports	Supports shall be of fabricated galvanised steel, angle brackets for wall supports and brackets attached to single leg hangers for overhead supports to allow cables to be installed without threading through supports. Where

single leg supports would deflect due to width of duct and cable weight, provide a removable suspension rod on "open" side to support free edge of bracket.

9 Communications cabling

The Contractor shall supply and install a communications cabling, conduits and catenary support system in accordance with this Specification.

9.1 System

The Contractor shall use only proprietary systems and components. All elements of the cabling infrastructure shall be provided with a written, contractually enforceable warranty or guarantee both from the installation contractor and all cabling product manufacturers and vendors. This warranty and/or guarantee shall cover a minimum fifteen continuous years from practical completion of the project. The system shall match the existing installation or as specified by the Employer.

The Contractor shall provide patch and fly leads as required to connect all provided equipment. All patch and fly leads shall be the same manufacture as the remainder of the cabling system.

9.2 Design Submissions

The Contractor shall submit the following information:

- system design parameters - performance.
- voice and/or data transfer rate.
- cable type and characteristics.
- segregation requirements for EMI/EMR.
- maximum length of cables.
- telecommunications outlets.
- cross-connect type and characteristics.
- cross-connect layout.
- system warranty conditions and terms.
- Certify compliance with AS/NZS 3080.

9.3 Cables and Accessories

9.3.1 Modular Connector Patch Panels

Terminations	Terminate directly to the modular connector.
Patch cords	Terminate cord ends with appropriate registered jacks. Colour code voice, data and Building systems patch leads.
Records	<p>Record Book: Provide a record book at each cross-connect.</p> <p>Records in Pencil: Complete the records in pencil for each termination and jumper, providing origin and destination and type of service.</p> <p>Location: Secure log books in each distribution frame records holder. Identification, labelling, and record documentation.</p> <p>Telecommunications Outlets: Outlets are to be coloured to match adjacent outlets and equipment.</p>

9.4 Cable Separation

Voltage separation: Separate telecommunications cables not enclosed in conduits or ducts from low voltage services by at least 150 mm.

Electromagnetic interference (EMI): Provide clearance to minimise the effect of EMI where communications cables are installed parallel and adjacent to power cables carrying loads in excess of 200 A.

Fluorescent luminaries: Maintain a clearance s 300 mm.

External Cables: To ACIF C524.

9.4.1 Installation

- Crossover: Install cables neatly and without crossovers between cables.
- Loom size: Loom cables into groups not exceeding 50 cables, and hold looms in place using reusable cable ties at least 20 mm wide. Do not exert compressive force on the cables when installing cable straps.

Outlets and Pinouts

- Outlets: Provide RJ45 8 way modular jacks.
- Pinouts: The pinouts vary with the application. The Contractor shall determine required pinouts before making cable terminations.

Labels

- Cables: To indicate the origin and destination of the cable.
- **Outlets:** To show the origin of the cross-connect, the workstation or outlet number and the port designation.

9.5 Completion

Verification: The Contractor shall verify the system operation with the power system energised, and the telecommunications cabling system in use. The Contractor shall provide all testing data for each cable in the Operations and Maintenance Manuals. Submit manufacture warranty for data cabling before practical completion.

Commissioning: The Contractor shall test the installation in accordance with the requirements of AS 3087. The Contractor shall install patch leads and fly leads and test the permanent links and submit test results in hard copy and electronic format.