

Wide Area Communication Networks

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For any enquiries relating to the content of this document please contact the Standards Coordinator on 13 10 81.

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1 Purpose

To define the minimum technical standards for wide area and intra-substation communication systems in Endeavour Energy owned transmission, switching and zone substations.

2 Scope

This document covers communication systems for the purpose of SCADA, protection, corporate voice/data, security surveillance and the evolving smart grid associated with transmission, switching and zone substations, network apparatus and external customer connections operated or monitored by Endeavour Energy. It applies to greenfield sites and major augmentations. For minor augmentations, the extent of applicability of this standard is to be determined by the Telecommunications Manager.

The document includes:

- UHF radio systems.
- Inter-substation optical fibre for protection signalling and WAN communications.
- Inter-substation copper pilot cable systems for protection signalling.
- Intra-substation optical fibre systems for LAN communications.
- Intra-substation copper data cable systems.
- DC power systems for communication terminal equipment.

The relevant information from the Australian and International standards have been summarised in this document. In the event of inconsistencies and/or conflicts between the requirements outlined within this document and the Australian and/or International standards the requirements within this document shall take precedence.

3 References

Internal References
Company Policy 9.2.9 - Electrical Network Telecommunications
Company Policy 9.2.5 - (Network) Network Asset Design
Company Policy 9.7.1 - (Network) Network Asset Construction
Company Procedure GDS 0133 - Information & Communications Technology
Automation Design Instruction ADI 0001 - Radio communication site requirements
Earthing Design Instruction EDI 516 - Major substation earthing design, construction and commissioning
Equipment Technical Specification ETS0014 - Control panel fabrication and installation
Substation Design Instruction SDI 505 - Minimum design and construction requirements for transmission and zone substations and switching stations
Substation Design Instruction SDI 510 – Major Substation Building Design
Substation Design Instruction SDI 513 - Substation batteries and battery chargers
Substation Design Instruction SDI 520 - Lightning protection and insulation coordination
Substation Design Instruction SDI 526 - Design of Substation Secondary Systems
Substation Design Instruction SDI529 - Light and power
Substation Design Instruction SDI 531 - Installation of conduits in transmission/zone substations and switching stations

Substation Design Instruction SDI534 - Manuals, test reports and photographs
Substation Design Instruction SDI 537 – Electronic security systems in transmission/zone substations and switching stations
Substation Design Instruction SDI544 - Transmission feeder, structure and substation equipment numbering
Endeavour Energy Electrical Safety Rules

External References

Work Health and Safety Act 2011
AS 1768:2021 - Lightning protection
AS 2676.2:2020 - Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings, Part 2: Sealed cells
AS 3015:2022 Electrical Installations – Extra-low voltage power supplies and service earthing within telecommunications networks
AS 3835.1:2006 - Earth Potential Rise: - Protection of telecommunications network users, personnel and plant – Code of Practice
AS 3835.2:2006 - Earth Potential Rise: - Protection of telecommunications network users, personnel and plant – Application Guide
AS 3996:2019 - Access covers and grates
AS 4029.2:2000 - Stationary batteries Lead-acid Valve-regulated type
AS 4044:1992 - Battery chargers for stationary batteries
AS 11801.1:2019 – Information Technology – Generic cabling for customer premises – General Requirements
AS 11801.3:2019 – Information Technology – Generic cabling for customer premises – Industrial Premises
AS 14763.3:2017 - Telecommunications installations – Implementation and operation of customer premises cabling - Part 3: Testing of optical fibre cabling
AS/CA S002:2010 - Analogue interworking and non-interference requirements for Customer Equipment for connection to the PSTN
ARPANSA Radiation Protection Series S-1 (Rev.1) _ Standard for Limiting Exposure to Radiofrequency Fields – 100 kHz to 300 GHz
IEEE 525:2016 Standard - Guide for the Design and Installation of Cable Systems in Substations
IEEE C37.94:2017- for N Times 64 Kilobit per Second Optical Fibre Interfaces between Tele-protection and Multiplexer Equipment
IEEE 1588:2019 - IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems
ITU-T G.703:2016 - Physical/electrical characteristics of hierarchical digital interfaces
ACMA Publication - Radio communications Assignment and Licensing Instruction FX 16 on Point to Multipoint Services in 400 MHz and 900 MHz Bands.

4 Definitions and Abbreviations

Abbreviation	Meaning
AC (or a.c)	alternating current
ACMA	Australian Communications and Media Authority
ADI	Automation Design Instruction
ADSS	all dielectric self-supporting optical fibre cable
DC (or d.c.)	direct current
DIN rail	Standardised 35mm wide metal rail having hat-shaped cross
FOBOT	Fibre Optic Breakout Terminal
FTP	Fibre Termination Point
IEC	International Electrotechnical Commission
IEEE	Institution of Electrical and Electronic Engineers
ISDN	integrated services digital network
ITU-T	International Telecommunication Union Telecommunication Standardization Sector
kN	Kilo Newton
LAN	local area network.
LC	A small form factor snap-in optical fibre connector with a 1.25mm diameter ferrule, having a packing density twice that of SC-PC.
MIB	management information base
MM	multi-mode
MPLS	multi-protocol label switching
National Electricity Rules (NER)	Rules that govern the operation of the National Electricity Market in Queensland, NSW, ACT, Victoria, Tasmania and South Australia.
OM3	Optical cable containing 50/125µm graded index multi-mode silica glass fibres, with maximum permissible attenuations of 3.5db/km and 1.5db/km at 850nm and 1300nm respectively
OPGW	optical ground wire
OS1	Optical cable containing 9/125µm step index single-mode silica glass fibre, with a maximum permissible attenuation of 1 db/km at 1300nm and 1500nm.
OTDR	optical time domain reflectometer

PVC	plasticised polyvinyl chloride
PIU	Process Interface Unit
RJ45	registered jack 45
rms	root mean square
RTU	remote terminal unit
SAS	substation automation system
SCADA	Supervisory Control and Data Acquisition
SC-PC	A snap-in optical fibre connector known as Subscriber Connector – Physical Contact, with a 2.5mm diameter ferrule.
SDI	Substation Design Instruction
SM	single-mode
ST	An optical fibre connector with a 2.5mm ferrule and a bayonet locking arrangement.
UHF	ultra high frequency
UPVC	plasticised polyvinyl chloride
VRLA	valve regulated lead acid battery
WAN	wide area network

5 Actions

5.1 Safety

5.1.1 General

The design, construction and commissioning of substation communication systems shall be carried out in accordance with Endeavour Energy's Health and Safety Management Systems and the Electrical Safety Rules. Systems shall be implemented and maintained to consider the range of human capacity, both physically and mentally, when designing substation communication systems.

5.1.2 Optical fibre safety

Optical fibre and associated terminal equipment shall be handled with due safety considerations, as set out in Safe Work Method Statement SWM 1.025.

5.1.3 Pilot cable, telephone and leased line safety

An insulated mat or platform, capable of withstanding a voltage of at least 15kV shall be placed on the floor and all work shall be performed whilst standing on the mat or platform when working on the pilot cable isolation cubical or line isolation devices.

Work on telephone and the associated isolation devices shall be conducted by ACMA registered telecommunication technicians in accordance with section 5.5.2 of this standard.

5.1.4 Radio safety

UHF Antenna: An Exclusion zone of at least 10cm in any direction shall be maintained from UHF antennas. Work on UHF installations with the antenna exposed to lightning (refer to Annexure B.2) shall cease and a clearance of at least 5m from the radio enclosure be maintained until 30 minutes after the last thunder is heard.

Substations with microwave radio links shall have a Radio Communications Site Management Book (RCSMB) documenting site safety information including Radio Frequency (RF) Electromagnetic Energy (EME) diagrams, access control and Radio Frequency (RF) signage. As part of this, Radio Frequency (RF) signage shall be installed warning the risk of exposure to electromagnetic radiation in all possible approaches to the antennas.

The Radio Frequency (RF) Electromagnetic Energy (EME) diagrams provide horizontal and vertical cross-sectional views of cumulative emission patterns from all the transmitting antennas. Staff without special training on managing exposure to radio frequency emissions shall always remain within the “White Zone” for general access.

5.2 System overview

Endeavour Energy owns and operates a communications network covering its franchise area to serve the requirements of SCADA, corporate voice/data and security surveillance.

This communications network consists of:

- a backbone sub-network with higher capacity (11Mb/s to 10Gb/s) consisting of optical fibre segments and microwave links. The backbone network encompasses strategically located mountain top microwave radio sites, most field service centres and selected substations; and,
- an access sub-network with lower capacity (9.6 to 256kbps) point to point and point to multipoint UHF radio systems extending SCADA communication from the backbone microwave sites to end devices, including substations, auto-reclosers and load-break switches.

5.3 UHF radio sub-systems

A UHF radio connection provides communications for substation SCADA RTU where establishing optical fibre and MPLS connectivity is not economically viable. The UHF radio connection to the substation is configured as a remote site in a point-to multipoint system operating in the 400MHz spectrum.

ADI 0001 sets out the installation requirements at base station sites. This section describes the requirements of the radio system installation requirements within the substation.

5.3.1 System assignments

The Telecommunications Manager or his delegate is responsible for assigning individual substations to appropriate point to multipoint radio systems.

The Telecommunications Manager is responsible for authorising any site specific variations to this standard.

5.3.2 Radio link design

The UHF radio connection shall be designed by carrying out a desktop study to ascertain the initial viability of the radio link. If the desktop study reveals the radio propagation path to be fully obstructed, then a signal strength measurement shall be carried out at the site to confirm the viability (that the measured level is higher than -86dbm) prior to commencing any installation activity.

5.3.3 Radio configuration

The radio system used in Endeavour Energy's SCADA network shall comply with requirements set out in ACMA Publication - Radio communications Assignment and Licensing Instruction FX 16 on Point to Multipoint Services in 400 MHz and 900 MHz Bands.

Exact output power, channel spacing and operating frequencies shall be configured within the limits specified in the ACMA licence.

5.3.4 Radio location

The radio shall be installed in the most suitable location, typically inside the communication equipment cabinet (Figure 7-2; when antenna is protected from lightning) or in a separate insulated enclosure (Figure 7-1; when antenna is not protected from lightning), as set out in 7Annexure B.

5.3.5 Antenna

The antenna:

- height and gain shall be chosen to be within the licensed limits to achieve the designed receiver level;
- shall be polarised as specified in the licensing conditions; and,
- shall be earthed as set out in 7Annexure B.

5.3.6 Antenna cable

The antenna coaxial cable shall be LMR400 or similar with a 1.5m length of pigtail, similar to RG213, to make it more manageable close to the radio.

Where the coaxial cable needs to be deployed underground, it shall be routed through a white UPVC conduit having an internal diameter at least twice that of the cable or 50mm minimum. Radii of conduit bends shall be greater than the minimum allowable bending radius specified for the cable. SDI 531 provides detailed instructions on installing underground conduits inside the substation boundary.

Bird protection shall be installed in areas of high risk.

5.3.7 Radio towers

Where a separate structure is required for mounting the antenna, its height shall be chosen to achieve the designed receiver level.

5.3.8 Radio earthing and lightning protection

The radio installation shall be earthed and be protected against lightning as set out in Annexure B using suitable earthing points built as part of the design and construction of the substation.

5.4 Optical fibre sub-systems

Optical fibre cables are deployed both between the substations (inter-substation) and within substations (intra-substation). For the purpose of this Standard, inter-substation fibre cables also include cables that connect offices and field service centres.

5.4.1 Inter-substation optical fibre cables

Inter-substation optical fibre cables shall be single-mode and are commonly used to enable the following functions:

- Provide communication between protection relays in different substations; and
- Provide data communications between substations and the Company's offices. Communication services supported are SCADA, protection, corporate voice/data, security video surveillance and smart grid.

The inter-substation cables arrive from the remote substation(s) or offices in various forms (OPGW, underground, ADSS), carrying protection and communication signals.

Fibre cores of inter-substation single-mode optical cables shall terminate in a dedicated main fibre termination cabinet, individual inter-substation fibre cores shall be allocated to protection and communication functions, as set out in Annexure A.

5.4.2 Protection multiplexer cabinet

The protection multiplexer cabinet shall contain the multiplexer equipment allowing multiple protection relays to share fewer inter-substation fibres and associated FTPs for connecting to the main fibre termination cabinet and respective protection relay control panels.

5.4.3 Intra-substation fibre distribution

This section describes distribution of single mode fibre cables within the substation.

5.4.3.1 Main fibre termination cabinet

Terminated protection and communication fibre cores shall be patched to single-mode intra-substation distribution cables leading to respective protection relay control panels, the communication equipment cabinet and the protection multiplexer cabinet.

The main fibre termination cabinet contains fibre termination points (FTPs) for terminating fibre cables and ducting for managing fibre patch cords and cables.

The main fibre termination cabinet shall be accessible by authorised staff only. Work performed inside the main fibre cabinet by other staff shall be under the direct supervision of authorised protection and control or telecommunications staff. These steps are to ensure the integrity of protection schemes and communication systems by preventing inadvertent disturbance of protection optical fibres.

5.4.3.2 Communication equipment cabinet

The upper portion of the communication equipment cabinet contains communication equipment for connecting the WAN to the LAN within the substation. The lower portion of cabinet contains the SCADA RTU. Communication equipment includes MPLS routers, UHF radios, Ethernet switches and the station RTU. The Telecommunications Manager shall be responsible for authorising any site-specific variations to this standard.

5.4.4 Fibre cable installation

5.4.4.1 OPGW lead-in

OPGW cables consist of single-mode optical fibres embedded in an overhead earth wire. OPGW optical fibres shall terminate in an outdoor splice enclosure that is mounted on a:

- suitable structure inside the substation boundary chosen according to the earthing requirements set out in EDI 516; or,
- transmission tower/pole outside and adjacent to the substation boundary.

Optical fibres within the OPGW shall be spliced to a nonconductive underground fibre cable conforming to ADI0003 as depicted in Annexure A.1. The underground cable is then routed directly into the main fibre termination cabinet using conduits or dedicated trays.

5.4.4.2 ADSS fibre cable lead-in

ADSS cables should land on a:

- suitable structure inside the substation boundary; or
- transmission tower/pole outside and adjacent to the substation boundary; or
- the substation control building.

ADSS cable shall then be routed directly into the main fibre termination cabinet using conduits or dedicated trays.

5.4.4.3 Underground fibre cable lead-in

Inter-substation underground optical fibre cables shall be directly routed into and terminated inside the main fibre termination cabinet, using conduits or dedicated trays.

5.4.4.4 Fibre cable diversity

Layout of inter-substation fibre cables within the substations shall be by physically diverse paths, eliminating any common points of failure affecting fibres associated with number 1 and number 2 protection schemes for individual feeders.

5.4.4.5 Conduits and trays

All fibre cables installed outdoors within substations shall be in white UPVC conduits dedicated for optical fibres having an internal diameter at least twice the sum of enclosed cable diameters or 50mm minimum. Pre-fabricated bends shall be used where appropriate to suit the largest minimum allowable bending radii of enclosed cables. SDI 531 provides detailed instructions on installing underground conduits inside the

substation boundary. Communication pits (covered under 5.8.5), may be installed in lieu of bends in strategic locations to facilitate hauling in additional optical fibre cables in the future.

All fibre cables installed indoors within substations (except patch cords) shall be in white conduits or specially marked trays dedicated for optical fibre cables only. Indoor conduits can be smaller than twice the sum of enclosed cable diameters where the cables are installed concurrently with the conduits.

Figure 7-1 depicts optical fibre cables being routed indoors using conduits:

- vertically on a cable ladder; and,
- into an equipment cabinet

5.4.4.6 Outdoor splice enclosures

Joining of optical fibre cables shall be in suitable splice enclosures capable of accommodating at least four (4) cable entries and be fully dust and moisture proof at a water head of at least 5m. Joints shall be located on poles or towers or pits or trenches, as set out below:

Overhead pole/tower mounted joints: Enclosures shall be UV stabilised and designed for this type of deployment, similar to *Coyote* fibre optic enclosure available from Preformed Line Products, or *OPTIXLINK* OFS-1080, available from Optical Fibre Systems.

Underground joints: Enclosure shall be designed for underground deployment similar to FOSC-400D, manufactured by *Raychem* (TYCO).

5.4.4.7 Spare fibre loops

An appropriately sized loop (diameter shall not be less than the minimum specified by the cable manufacturer) of optical fibre cable shall be coiled and secured neatly as set out below to allow future rearrangements:

Indoor: 3m to 5m long loops, preferably within the cabinet or under a raised floor; and

Outdoor: 40m long loops, attached to the tower or pole using a storage bracket similar to OFS-1080-18-02 (depicted in Annexure A.1), available from Optical Fibre Systems, where underground and overhead cables are joined. To discourage the thieves stealing copper cables, outdoor optical fibre cable loops shall be wrapped with a yellow marker tape carrying the text “optical fibre do not disturb”.

5.4.5 Fibre splicing

Optical fibre splicing shall only be carried out using a fusion splicer employing active alignment techniques (preferably active core alignment).

5.4.6 Fibre cable tests

After completion of installation and splicing on inter-substation optical fibre cables, the following tests shall be carried out on each fibre core using an Optical Time Domain Reflectometer (OTDR) [AS 14763-3: 2017 - fibre testing] to establish the integrity specifically of fusion splices and the overall installation:

- Fusion splices, measured using bi-directional OTDR testing, shall not exceed 0.25db per splice (those lower than 0.1db are preferred)
- Fusion splices along an individual fibre shall average to less than 0.1db per splice.
- OTDR testing shall
 - confirm continuity and polarity of each of fibre termination to ensure A End at Near End is B End at Far End, and vice versa.
 - include optical length of each fibre core.
 - include propagation delay on each fibre core.
 - Insertion loss of each fibre core at 1310 and 1550nm; the value measured shall not exceed the value calculated using cable manufacturer's attenuation data (if not available, use generic data in the table below) allowing not more than 0.1db per fusion splice.

For intra-substation single-mode or multi-mode fibre, a light source and a power meter may be used to verify the quality of splices and establish the continuity of fibres where the use of OTDR is not feasible.

Maximum permissible cable attenuation (db/km)						
	OM3 multi-mode intra substation		OS1 single-mode intra substation		OPGW/UG/ADSS inter-substation single-mode	
Wavelength	850	1310	1310	1550	1310	1550
Attenuation	3.5	1.5	1.0	1.0	0.4	0.3

5.4.7 Personnel qualifications

Only persons listed in an ACMA accredited registry shall carry out splicing, terminating and testing of optical fibres.

5.4.8 Fibre termination points (FTPs)

Fibre termination points (FTPs) are used to terminate the individual cores in fibre cables onto sockets. These sockets are readily accessible to allow patching using patch cords. The FTPs are installed inside the *main fibre termination cabinet, communication equipment cabinet, SCADA HMI cabinet, protection and control panels.*

5.4.8.1 Rack mounted FTPs

The fibre termination points used inside the main fibre termination cabinet and communication equipment cabinet shall be:

- 19-inch rack mountable.
- Have either SC-PC or LC connector sockets on angle adapter panels.
- Have a socket density not exceeding 24 per rack unit (RU) for terminating cables having less than 48 fibre cores.
- Have a socket density that allows conservation of rack space for terminating cables with up to 144 fibre cores (usually inter-substation underground or ADSS).

Separate FTPs shall be used for single-mode and multi-mode terminations and each cable shall be terminated in a single FTP. All the fibres of inter-substation cables shall be terminated. Spares are not to be left unterminated due to complexities and costs of terminating unterminated fibres in an FTP containing live fibres.

5.4.8.2 Panel mounted FTPs

Panel mounted FTPs shall have angled SC-PC or LC sockets for terminating at least 12 fibres. Preference shall be given to FTPs capable of being DIN rail or flat panel mounted.

5.4.9 Fibre patch cords

For each Single-mode and multi-mode patch cords shall have the optical specifications, jacket colours and FTP side connectors set out in the table below.

Label Prefix*	Application	Optical specification	Jacket colour	FTP side connector
P	Protection signalling between substations (For example OPGW)	single-mode OS1 9/125µm	Red	Blue connector matching FTP socket (SC-PC or LC connector)
C	Telecommunications single-mode applications other than protection	single-mode OS1 9/125µm	Yellow	Blue connector matching FTP socket (SC-PC or LC connector)
P	Protection relay to a protection multiplexer (within the substation)	multi-mode OM3 or OM4 50/125µm	Salmon Pink	Aqua connector matching FTP socket (SC-PC or LC connector)

* Note: The label prefix is used in the labelling of patch cords according to requirements set out in 5.8.3 and Annexure C.6.

Connectors on the equipment side for both single-mode and multi-mode patch cords shall be chosen to suit the respective equipment, LC connectors are preferred where possible.

Patch cord jackets should be two (2) mm in diameter and be made of PVC. Duplex patch cords shall be used for all duplex applications. Simplex patch cords shall be used for simplex applications only.

5.4.10 Patch cord management

Raceway ducts and flexible tubing shall be used as outlined below when managing fibre optic patch cords to eliminate the risks of sharp bends and pressure points.

5.4.10.1 Management in racks

When managing horizontally run fibre optic patch cords at the 19-inch rack level, 19-inch rack mountable cable management rails (similar to Rittal 7159.035) should be used.

5.4.10.2 Securing patch cords

Cable ties used for electrical cabling shall not be used with fibre optic patch cords. Materials similar to *Velcro*™, which eliminate the risk of pressure points, should be used instead.

5.5 Copper communication sub-systems

5.5.1 Inter-substation copper pilot cables

There are many substations interconnected with copper pilot cables to carry protection signalling, load control signals and communications services.

Endeavour Energy will continue to operate and maintain these cables until they are phased out and replaced with optical fibre cables. Hardex is no longer to be used and all asset relocations involving Hardex are to be in consultation with the Telecommunications Manager for alternative solutions.

5.5.1.1 Pilot cable isolation cubicle

An isolation cubicle shall be installed for terminating the copper pilot cables in the substation control room. It shall be constructed from a suitable insulating material and all fittings and metal work within the cubicle shall be isolated from the substation earth to withstand a voltage of at least 15kV.

Copper cable cores shall terminate on isolating links capable of withstanding a voltage of at least 15kV. Termination is typically achieved by soldering onto a tag, which is then covered with a snap-on insulation shroud.

Where the cable cores are used for communications, signal isolation transformers capable of withstanding a voltage of at least 15kV shall be installed inside the cabinet, interposed between the isolating links and the communications equipment.

No exposed earths are permitted within one (1) metre of the enclosure.

5.5.2 Substation telephone

This section sets out technical requirements for the external telephone service described in SDI510.

Work on telephone and the associated isolation devices shall be conducted by ACMA registered telecommunication technicians in conformity with the relevant telecommunications industry standards, specifically AS/CA S009: 2020 and AS 3835: 2006.

A voice over IP telephone may be used in substation where two inter-substation fibres are available. The power to the phone shall be battery backed by the 48V system in 5.7.2.

5.5.2.1 Telephone instrument

The substation telephone shall be installed as set out in SDI510. The telephone instrument shall conform to AS/CA S002:2010 for connection to an analogue public switched network.

5.5.2.2 Line isolation device

A *line isolation device* providing at least 15kV isolation shall be interposed between the telephone instrument and the copper wires leading in from the exchange. No *line isolation device* is required if the connection to the carrier is via fibre and NBN. The *line isolation device* shall be installed in the control room close to the main instrument described in SDI 510. The *line isolation device* shall conform to AS 3835: 2006 for isolation requirements and AS/CA S002:2010 for connection to an analogue public switched network.

The isolation device shall:

- use optical fibre isolation techniques described in AS3835: 2006 part 2, section 7.5.2.2.4, with a line powered exchange side and a locally powered customer equipment (telephone instrument) side.
- The customer equipment side shall incorporate 24-hour battery back-up, provided through a replaceable battery;
- be supplied from an adjacent general power outlet wired according to SDI 529; and
- have 15kV isolating links on the telephone exchange side.

5.5.2.3 Ethernet cables

Copper cabling used for the transport of Ethernet signals having rates of up to 100Mb/s shall be Category 6, consisting of unshielded twisted pairs. These cables shall be no more than 5m in length and be restricted to within the equipment cabinets. Shielded twisted pairs shall be used where there is a risk of electromagnetic interference.

5.5.2.4 Copper communication (non-protection) cable terminations

Copper communication cable terminations shall be insulation displacement contact (IDC), similar to high band disconnect module (part number 6468 5 061-00) from ADC Krone, capable of being mounted on a 19 inch rack. Termination shall be achieved by using the correct punch down tool.

5.6 SCADA WAN Communications

WAN links for substation Master Station communications shall be terminated directly from the WAN equipment to the SCADA RTU, protocol gateway or other monitoring device (e.g. DC Monitor). All devices requiring WAN connectivity shall use a dedicated interface, unmanaged switches may not be used to provide access to multiple devices.

Routable WAN links providing remote connectivity must not be connected to the substation SCADA LAN, station bus or process bus networks.

Protection IED ethernet connections must remain isolated from all WAN networks other than those dedicated for inter-site protection schemes.

WAN connections to SCADA equipment shall utilise multi-mode 1310nm 100Base-FX by default unless specified otherwise by the Endeavour Energy Communications team. Where SFP modules are required for SCADA WAN connectivity, only manufacturer approved and tested devices may be used.

5.7 DC power supply requirements

5.7.1 12V DC Power

A 12V DC power supply is required for the UHF radio installed in the substation communications equipment cabinet.

The 12V DC power supply consists of a 12V battery charged by a 12V rectifier. Where 48V DC telecommunication batteries are available, the radio 12V DC power may be supplied using a 48VDC/12V converter (refer to 5.7.4 for details).

5.7.1.1 12V Rectifiers

The rectifier shall have the ability to disconnect the power feed to the radio when the battery reaches a low voltage threshold adjustable between 11V and 12V.

The rectifier supplying the battery shall have a 10A fuse (on 12V DC) with the ability to provide a DC fail alarm contact for the SCADA system.

5.7.2 48V DC Power

The 48V DC power system is used for supplying substation fibre optic communication equipment. The 48V DC power system shall conform to the general requirements set out in SDI 513 and the specific requirements set out in this Standard.

5.7.2.1 48V system architecture

The 48V DC power system shall consist of two (2) independent positive earthed busbar pairs (designated A and B), feeding the load through circuit breakers to the load.

Busbars shall be supplied by independent and identically sized battery strings, which in turn are being charged by dedicated rectifiers tuned to the parameters of the associated string.

Where the use of a dedicated communications battery is not feasible, suitable 120V DC to 48V DC converters connected to the 120V station batteries may be used subject to approval from Manager Primary Systems.

5.7.2.2 48V Rectifiers

The rectifiers shall:

- Be 19 inch rack mountable;
- Be capable of supplying sensitive telecommunications equipment with a maximum allowable ripple voltage of 0.2% rms at the nominal float voltage without the battery connected [AS 4044:1992];
- Consist of multiple plug-in modules providing N-1 redundancy by being able to recharge a fully discharged battery bank within 24 hours whilst one plug-in module is out of service;
- Be able to limit the charging current to the maximum value specified for the battery (nominally total battery capacity in Ampere-hours divided by 10);
- Be able to simultaneously supply 150% of the maximum initial load current and the maximum charging current;
- Have the ability to disconnect the battery on reaching a low voltage threshold adjustable between 36V and 48V;
- Have an integrated DC distribution board with circuit breakers on all load circuits and the outputs to the batteries (for isolation purposes);
- Provide a display of system voltages, battery currents and load currents; and,
- Operate from a single phase 240 VAC power supply.

5.7.2.3 48V positive earthing

The positive busbars of the two 48V DC systems shall be bonded to the communication cabinet earth bar. A 35mm² copper cable with red insulation shall be used for bonding the positive busbar to the earth bar.

5.7.3 Batteries

The 12V and 48V batteries shall be of valve regulated lead acid (VRLA) type conforming to SDI513.

The 12V battery for the radio shall have a minimum capacity of 100Ahr.

Batteries constituting each 48V banks shall be sized for supplying 150% (allowing for load growth and decline in performance), of the initial load requirement over a minimum 24 hour normal discharge period.

5.7.4 DC/DC converters

120VDC/ 48VDC and 48V DC/12V converters shall:

- Be 19 inch rack mountable;
- Have N-1 redundant configuration with hot swappable plug in units;
- Have at least 1kV DC galvanic isolation between the primary (120V DC or 48V DC) input and the secondary output (48V DC or 12V DC);
- Be capable of output current limiting; and,
- Be supplied through dedicated circuit breakers in the 120V DC or 48V DC distribution systems feeding the converters.

The maximum current for the converter shall be 150% of the initial load current.

5.7.5 Rectifier/converter remote monitoring

The rectifier system and the DC/DC converters shall have Simple Network Management Protocol (SNMP) logical interface (operating over Internet Protocol) for connecting to Endeavour Energy's Network Monitoring System (NMS) through a 10/100/1000Mb/s RJ45 Ethernet socket. Management Information Base (MIB) defining the SNMP messages shall be obtained at the time of procuring rectifiers and converters.

5.7.6 Rectifier/converter environmental requirements

Rectifiers and DC/DC converters shall be capable of operating within the following environmental parameters:

- Inlet air temperatures in the range of 0 deg C to 55 deg C.
- Altitudes not exceeding 1000m.
- Relative humidity of up to 95% (without condensation).

5.7.7 DC cable colour code

DC cables shall have insulation sheaths colour coded as below:

- Red for positive 48V conductor.
- Blue for negative 48V conductor.

5.7.8 Protection coordination

Circuit breakers for AC feeds to the rectifiers and 12V/48V DC feeds shall be chosen to provide sufficient level of grading to ensure fault discrimination.

- All AC/DC cables and the circuit breakers shall be rated at 150% of the maximum or initial load current, whichever is greater;
- In addition, 48V battery cables shall be rated to carry the 1s short-circuit battery current. The 48V battery cables shall also be protected against the 1s short-circuit current by purpose built circuit breakers/fuses installed on both poles as close to the battery as possible. The 1s short circuit current value shall be obtained from the battery manufacturer [AS 2676.2:2020].

5.8 Miscellaneous requirements

5.8.1 Cabinet construction

Main fibre termination and communication equipment cabinets shall have:

- Enclosed metal frame panel construction.
- 19 inch frames at least 45 Rack Units (RU) high at the front to allow mounting of communication terminal equipment, fibre termination points, and patch cord management accessories. Position of the 19 inch frame within the cabinet shall allow a clearance of at least 100mm for communication terminal equipment, FTPs and accessories from the face of the closed front door.

- Rear access to facilitate intra cabinet wiring and installation of cables being led into the cabinet. Where rear access is not feasible, 19 inch swing frame shall be provided.
- Provision for cables to enter from the bottom and be directed upwards to the respective termination points through a gland plate. Where bottom entry is not possible, a top entry option can be used.
- Cable entry points sealed with a fireproof sealant to protect the cabinet against ingress of moisture, dust, fire, and vermin.
- A minimum 25mm wide x 6mm thick tinned copper main earth bar (conforming to ETS 0014), with provisions for accepting at least two earth cables (for bonding to the substation earth underneath in accordance with EDI 516), shall be located on the inside rear panel near the base.
- Basic equipotential bonding between doors, side panels, cabinet frame and main earth bar by using 16mm² braided copper earthing cables.

5.8.1.1 Main fibre termination cabinet

Main fibre termination cabinet shall:

- have ingress protection level of at least IP5X (against dust); and,
- be lockable to restrict access to unauthorised persons.

Communication equipment cabinet

The communication equipment cabinet shall be located where it is not likely to be exposed to external heat sources. The communication equipment cabinet shall have:

- Ingress protection level of at least IP4X (against solid foreign objects with a diameter of 1.0 mm and greater);
- 15 x 5mm vertically mounted copper earth bus bar (similar to Rittal DK 7546.000), bonded to the main cabinet earth bar with a 16mm² yellow/green earth cable, to allow rack mounted shelves to be earthed. In cabinets equipped with a swing frame, the vertical earthing bus shall be mounted on the inner – hinge side (of the swing frame). Earthing of the shelf mounted equipment shall be achieved using 6mm² yellow/green stranded earth conductors;
- Two heavy duty shelves capable of holding four (4) 60kg batteries where floor space does not exist for separate battery cabinets;
- Two power distribution boards capable of 20A installed according to SDI 529, each on its own circuit breaker;

5.8.2 Communication equipment building

Whenever possible, communication equipment cabinet and the associated 48V DC batteries shall be housed within the substation control building. However, if this is not possible due to space restrictions or other practical reasons, then the communications equipment cabinet and the associated 48V batteries may be housed in a specially constructed shelter. Where the construction of a permanent building within the substation property is not economically viable then a portable communications shelter may be erected.

5.8.3 Labelling

All optical fibre cables, patch cords, FTPs, copper signal cables, communication equipment, rectifiers, power distribution circuit breakers and power cables shall be clearly labelled as follows:

- Each end of a cable shall be labelled within 300mm of the end of the jacket with a label similar to Panduit M300X050Y7C.
- Where patch lead length exceeds five (5) meters or is installed in raceway ducts or tubing, each end of the patch cord shall be labelled within 100mm of the end of the connector boot with a label similar to Panduit S100X220VAC/ NWSLC-7Y label/sleeve combination.
- Labels on the FTPs/connector sockets and circuit breakers shall be on the face plate in a way that clearly identifies the individual socket/circuit breaker. The labels should be similar to Panduit ULS8BW.
- Labels on the equipment should preferably be attached on the front face plate. Where labels cannot practicably be placed on the front face plate, alternate locations such as blanking plates shall be chosen to maximise the accessibility and visibility.

- To maximise legibility, labels should be printed or generated by a mechanical device. The text on labels for communication devices (including routers), FTPs and patch cords (optical or Category 6 copper) shall be derived according to the naming convention set out in Annexure C.

5.8.4 Record keeping

Cabling system records in a combination of printed and soft copy format shall be maintained as specified in SDI 534. The records should include the following [HB29]

- Description of pathways and cable routing.
- Length of cable segments, and transmission mode and wavelength.
- Optical fibre test results.
- Description of configuration including as-built drawings.
- Rack layout diagrams.

5.8.5 Communication cable pits

Underground preformed concrete polymer pits (typically 1000mm long x 500mm wide x 600mm deep), with covers conforming to or exceeding AS 3996:2019 Class B or C or D (see note below) requirements shall be used for housing enclosures for splicing underground communication cables. An example is type 95 pit and galvanised steel cover from ACO CABLEMATE.

Note: Pit covers are classified in AS 3996:2019 according to the load bearing capacity. Load capacities applicable for Class B, C and D are listed below.

Class	Typical use	Nominal wheel loading (kg)	Serviceability design load (kN)	Ultimate limit state design load (kN)
B	Areas (including footways and light tractor paths) accessible to vehicles (excluding commercial vehicles) or livestock (light duty)	2 670	53	80
C	Malls and areas open to slow moving commercial vehicles (medium duty)	5 000	100	150
D	Carriageways of roads and areas open to commercial vehicles (heavy duty)	8 000	160	240

5.8.6 Terminal equipment interfaces

The preferred interface for connecting communications equipment to substation equipment is the 100Mb/s *Ethernet* using 1310nm optics employing multi-mode optical fibre with SC or ST or LC termination (100Base-FX).

For applications confined to the communication equipment cabinet, electrical *Ethernet* interface with RJ45 termination may be used. Electrical connections leaving the communications cabinet should be avoided.

For special applications where the *Ethernet* interface is not feasible, the following alternatives are available:

- For WAN connections slower than 2Mb/s, IEEE C37.94 optical interface.
- For 2 Mb/s WAN connections, ITU-T G703 interface.
- For WAN connections slower than 2Mb/s, ITU-T G703 co-directional or RS232 or RS485 interface

6 Authorities and Responsibilities

Chief Data People & Sustainability Officer has the authority and the responsibility for approving this Standard, including any variations.

Telecommunications Manager has the responsibility for:

- Coordinating the content of this document.
- Keeping this instruction up to date.
- Ensuring that the requirements of this instruction are adhered to in the design and construction of substation communication systems.

Endeavour Energy employee and/or contractors have the responsibility for:

- Ensuring that the requirements of this instruction are met.
- Working in accordance with local and statutory requirements.
- Ensuring that public safety is not compromised.
- Working in accordance with Endeavour Energy's Electrical Safety Rules.

Regional Transmission Managers have the responsibility for ensuring that Endeavour Energy personnel and/or contractors engaged to perform the work have appropriate authorisations.

7 Document Control

Documentation Content Coordinator: Telecommunications Manager

Documentation Distribution Coordinator: Branch Process Coordinator

ANNEXURE A INTER-SUBSTATION SINGLE-MODE FIBRE OPTICAL CABLE CORE ALLOCATIONS

Table A:1: Allocation of fibre cores within 48 to 144 core OPGW, underground and ADSS cables

Fibre core numbers	Tube colour	Allocated function
1-12	Blue	Protection
13-24	Orange	Protection
25-36	Green	Protection
37-48	Brown	48c cable: Communications, else protection
49-60	Grey	60c cable: Communications, else protection
61-72	White	Can be allocated to communication in peripheral sub-transmission network if not required for protection
73-84	Red	
85-96	Black	
97-108	Yellow	
109-120	Violet	
121-132	Pink	
133-144	Aqua	Communications

Table A:2: Allocation of fibre cores in 12 core OPGW - pre 2006

Core numbers	Colour	Allocated function
1	Blue	Protection
2	Orange	Protection
3	Green	Protection
4	Brown	Protection
5	Slate /Grey	Communications
6	White	Communications
7	Red	Protection
8	Black	Protection
9	Yellow	Protection
10	Violet	Protection
11	Rose	Communications
12	Aqua	Communications

Note: 12 core OPGW cables were deployed prior to 2006 and the table reflects the allocations made at the time.

Table A:3: Allocation of fibre cores within 24 core OPGW

Core no.	Colour	Allocated Function
1	Blue	Protection
2	Orange	Protection
3	Green	Protection
4	Brown	Protection
5	Slate /Grey	Protection
6	White	Protection
7	Red	Protection
8	Black	Protection
9	Yellow	Protection
10	Violet	Protection
11	Rose	Protection
12	Aqua	Protection
13	Blue with black ring	Can be allocated to communication in peripheral sub-transmission network if not required for protection
14	Orange with black ring	
15	Green with black ring	
16	Brown with black ring	
17	Slate/ Grey with black ring	
18	White with black ring	
19	Red with black ring	Communications
20	Black with black ring	Communications
21	Yellow with black ring	Communications
22	Violet with black ring	Communications
23	Rose with black ring	Communications
24	Aqua with black ring	Communications

ANNEXURE A.1 INTER-SUBSTATION OPGW TERMINATION



ANNEXURE B UHF RADIO INSTALLATION AND EARTHING

This section sets out detailed requirements for the earthing of radio antenna masts, correct bonding of radio equipment to earth, and the connection of radio equipment to other sensitive electronic equipment in the substation.

ANNEXURE B.1 GENERAL

A radio mast is considered to be shielded from direct lightning strikes where it is positioned at least five (5) metres away from any lightning masts (to reduce the likelihood of side flashes) and the mast does not fall within the protection zone of the lightning mast as set out in SDI 520.

Where the radio mast is attached to a building and the mast is lower than the roof top, the mast is considered to be protected from direct lightning strikes.

It is desirable to have all radio antenna equipment protected from lightning strikes through the use of strategically placed lightning masts so that the lightning mast establishes a zone of protection providing shielding for the radio antenna mast. Zones of protection shall be determined in accordance with SDI 520.

- The basic philosophy for protecting sensitive electronic equipment from lightning effects is to:
- Provide shielding for the antenna mast from a direct lightning strike;
- Divert as much of the lightning energy away from sensitive equipment;
- Provide protection in depth on all sensitive equipment; and provide single point earthing for all sensitive equipment.

The radio antenna shall not be mounted on a lightning mast.

Within the substation, there shall be only one earthing system where the antenna tower, lightning masts and telecommunication/control cabinets are all bonded to the main earth grid.

The connection between the radio and the SCADA RTU shall be via the substation LAN using an Ethernet switch with an RS232 terminal server port. As the LAN utilises fibre optic interconnections this provides electrical isolation between the radio and RTU. An RS 232 optical isolator with a minimum 2kV electrical isolation shall be used for existing substations where no LAN is installed.

An earthing kit shall be installed to provide a solid bond between the earth riser and the coaxial cable screen on the vertical part of the antenna coax where it leaves the mast. The earth tail shall run parallel to the mast and shall be bonded to the substation earth grid as close as possible to the point where the mast earth down-lead bonds to the grid.

The final design will depend on whether the radio antenna mast can be shielded from direct lightning strikes by adjacent lightning masts or buildings in close proximity to the antenna as outlined below.

Antenna poles, coaxial cable conduits and earthing points nominated for use by radio communications technicians should where feasible be installed as part of the substation design and construction.

ANNEXURE B.2 ANTENNA INSTALLATIONS NOT SHIELDED FROM LIGHTNING

Where lightning shielding protection cannot be provided to antenna masts then the following guidelines shall apply. Given the tall nature of the structure, an antenna not shielded by lightning can have a visual impact on the surrounding environment. Therefore, an environment impact assessment shall be carried out at the design stage.

a. Down-leads

All radio masts not shielded from lightning shall be steel with one (1) down conductor bonded to the substation earthing grid in accordance with the guidelines specified in SDI 520.

b. Down-lead earth terminations

Radio masts shall be located close to the main earth grid and bonded to the earth grid at the shortest distance. An earth electrode shall also be located immediately adjacent to the base of the mast. The earth electrode shall comply with the requirements of SDI 520.

The down-lead cable shall be bonded to the top of the communication mast and the earth grid as set out in EDI 516.

c. Radio enclosure

The radio and power supply including the battery shall be installed in an enclosure mounted as close as possible to the radio mast on a wall near the coaxial cable entry into the substation building.

Enclosures shall be constructed from a suitable insulating material and all fittings or metal work within the cubicle shall be isolated from the substation earth to a withstand voltage of 15kV.

No exposed earths are permitted within one (1) metre of the enclosure.

An insulated mat or platform, with a withstand value of 15kV, shall be installed in front of the cubicle to allow staff to work safely on equipment within the cubicle.

An earth cable, rated according to EDI516, shall be either exothermic welded, or a bolt and tinned copper lug terminated on an earth bar installed inside the enclosure. The other end of this cable shall be bonded to the substation earth grid as close as possible to the point where the mast down-lead bonds to the earth grid.

The radio chassis and negative power input shall be bonded using 6 sq mm earthing cable to the earth bar.

AC supply to the radio enclosure shall be from a separate feed from the substation distribution board. The earth for the power outlet shall be derived from the earth bar within the radio enclosure. A surge protection device (similar to Critec DIN rail mounted DSF20A275V) shall be installed close to the distribution board to suppress the surge voltages appearing across line, neutral and earth as a result of possible lightning strikes to the antenna mast.

A lightning strike counter shall be installed on the antenna mast earthing wire at the base of the tower.

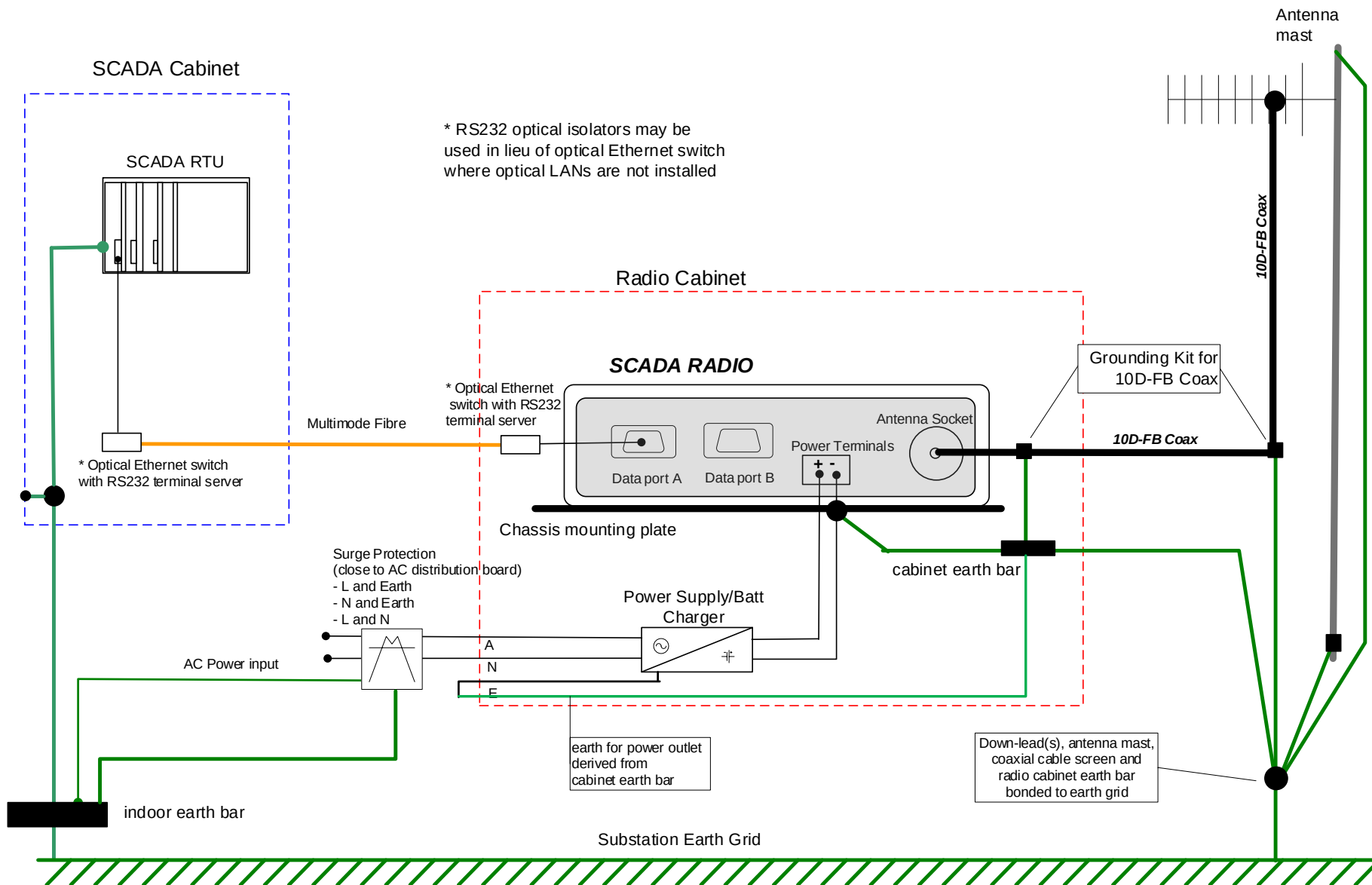


Figure 7-1 - Antenna Installations Not Shielded From Lighting

ANNEXURE B.3 ANTENNA INSTALLATION SHIELDED FROM LIGHTING

Where shielding is available to protect antenna masts from direct lightning strikes, the following guidelines shall apply:

- The antenna mast shall be solidly bonded to the substation earth grid as set out in EDI516. Where the radio antenna is mounted on a wooden pole, the down conductor shall be run on the opposite side of the pole to the radio coaxial cable;
- The coaxial cable screen shall be bonded to the antenna mast earth with an earthing kit where the coaxial cable leaves the mast;
- A radio, rectifier and the battery shall be installed in the communications equipment cabinet;
- An earth bar of minimum size 25mm x 6mm, if not already present, shall be installed inside the communications equipment cabinet to form a common earthing bar in accordance with SDI 526;
- The cabinet body shall be bonded to the earth bar above by a 70sq mm earth cable;
- An earth cable, rated according to EDI 516, exothermically welded to the antenna mast earth shall connect the mast and the communications equipment cabinet earthing bar, providing a low impedance path for surge currents;
- The earth for the power outlet supplying the radio shall be derived from the earth bar within the communications equipment cabinet.
- The radio chassis and negative power input shall be bonded using a 6sq mm earth cable to the cabinet earth bar; and
- The interconnection between the thicker 10D-FB coaxial cable from the antenna and the shorter flexible RG213 cable connected to the radio shall occur through a power frequency blocking coaxial gas discharge surge arrester having specifications below (similar to Polyphasor IS-B50LN-C1/ 50MHz to 700MHz) mounted on the cabinet earth bar. The arrester will block and shunt the power frequency surges (occurring during HV feeder earth faults) flowing through the centre conductor whilst solidly bonding the coaxial screen to the earth bar.

Parameter	Requirement
Arrester type	Gas discharge tube
I _{max} * (defined below)	at least 20kA
Turn on voltage	90V < at 100 V/s
Frequency range	300 - 1000 MHz
Characteristic Impedance	50 ohm
Insertion loss	< 0.1db over the frequency range
Voltage Standing Wave Ratio (VSWR)	< 1.1 over the frequency range
Maximum radio frequency power	at least 50W Peak Envelop Power
Connection	N -type

Table 4 - Coaxial surge arrester specification

* I_{max} is the peak value of the 8/20 μ s wave shape current impulse that a surge protection device can successfully handle at least once [AS 1768:2021]

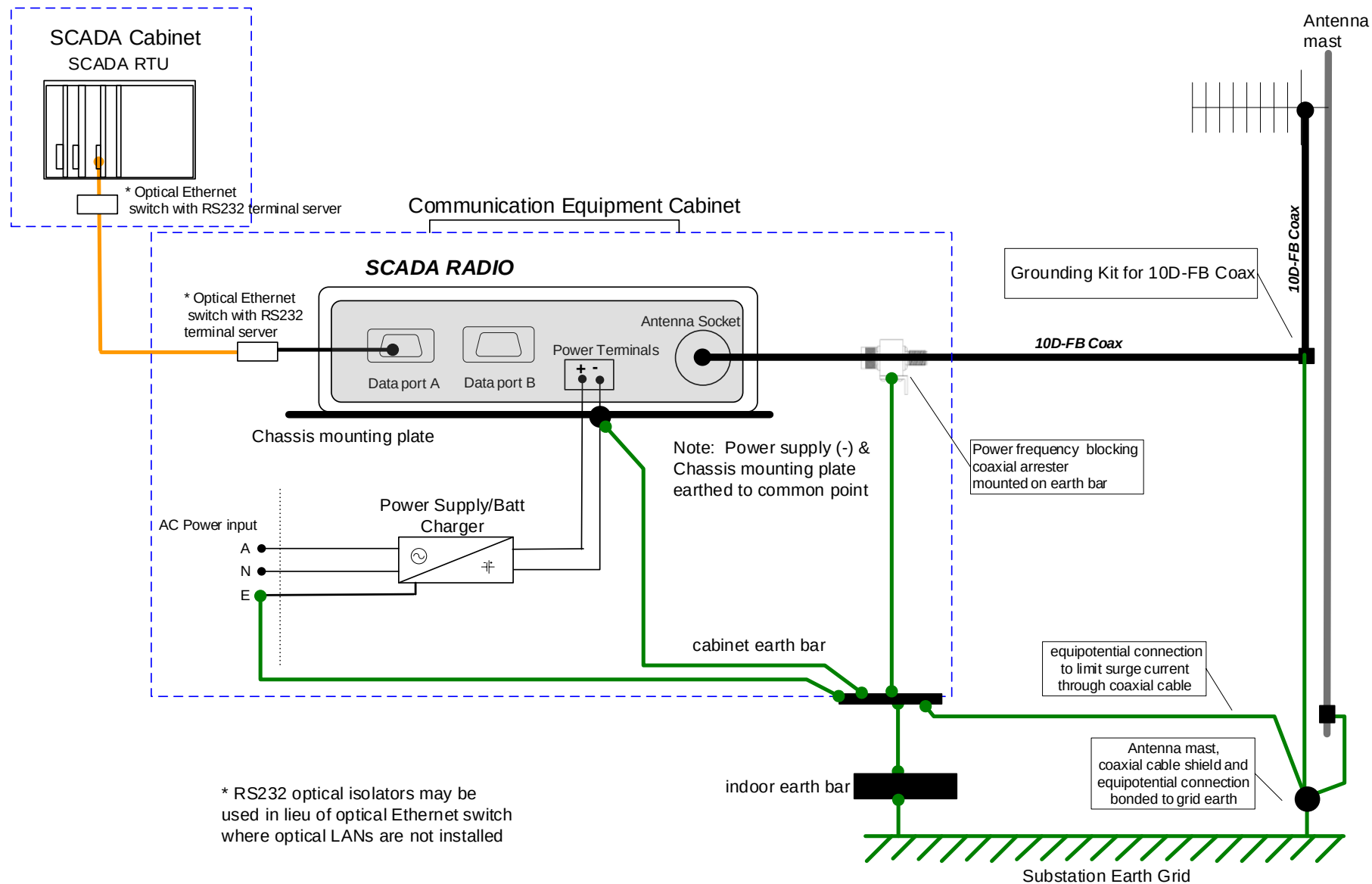


Figure 7-2 - Antenna Shielded From Lightning

ANNEXURE C NAMING CONVENTIONS

ANNEXURE C.1 GENERAL

This section describes the naming convention to be used in labelling communication devices (including routers), FTPs and patch cords (optical or Category 6 copper) used in substation Ethernet LANs.

ANNEXURE C.2 DEVICE NAMING

Communication devices are uniquely identified and listed in the drawings issued for construction and the software within each device. It is important that software systems also use the same numbering system for consistency. The naming convention for devices is expressed by a five character string (tt s nn) as set out in the table below:

Device Type	Device Type Identifier (tt)	System Identifier (s)	Unit identifier (nn)
Router or Multiplexer	RT	<u>Router or Multiplexer end use</u> 0 = SCADA only router 1 = Protection No1 only multiplexer 2 = Protection No2 only multiplexer 3 = Multi-service router (usually MPLS) 8 = Corporate only router	(01 to 99)
Time Server (GPS)	TM	0	
Other Devices	XX	0	

Table 5 - Device Type Naming Identifier

Note: This definition of device identifiers is a direct adaptation of the last 5 digits used in IEC61850 systems.

Device naming examples:

- Station RTU: GW001
- Core SCADA Ethernet Switch 1: ES001
- No 1 Protection Ethernet Switch: ES101
- MPLS router: RT301

ANNEXURE C.3 DEVICE PORT NAMING

Naming of device ports shall be according to the manufacturer's designations.

ANNEXURE C.4 FTP NAMING

Fibre termination points are named FTP001 through FTP999.

ANNEXURE C.5 FTP PORT NAMING

FTP's contain ports. For example an FTP accepting 48 fibre cores contains 48 ports. The identifier for ports is derived by appending a 3 character extension to the device or FTP identifiers as listed in the table below and described in subsequent sections.

FTP	Port identifier		
	FTP identifier		3 character extension
		First extension character	Port number (last two digits xx)
FTP	FTP001 to FTP999	12 port group designation (A-Z)	(01 to 12)

Table 6 - FTP Port Identifier

FTP port examples

FTPs can contain from 12 ports (Panel mounted FTPs) up to 144 ports (rack mounted FTPs). These are usually arranged in groups of 6 duplex ports. Each 6 duplex port group carries an alphabetical designation (A-Z) and contains 12 ports as depicted in the figures Figure 7-3, Figure 7-4, Figure 7-5.

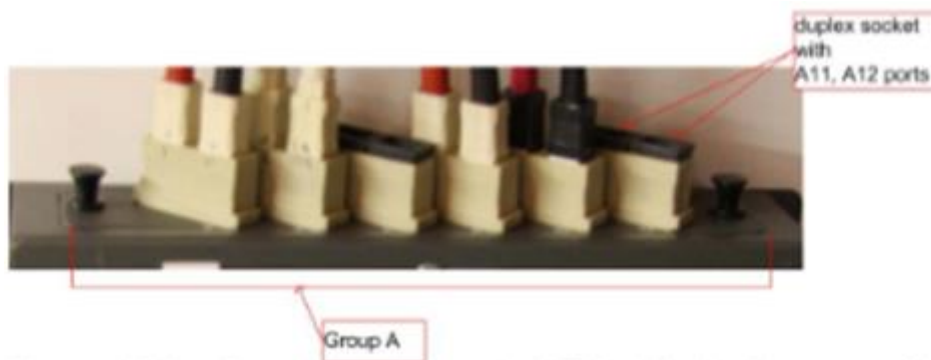


Figure 7-3 - 12 port panel mounted FTP with single group of 6 duplex ports

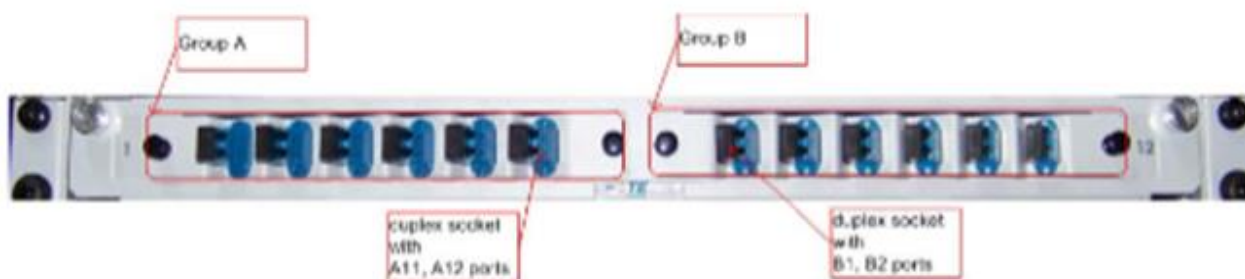


Figure 7-4 – 24 port rack mounted FTP with 2 groups of 6 duplex ports

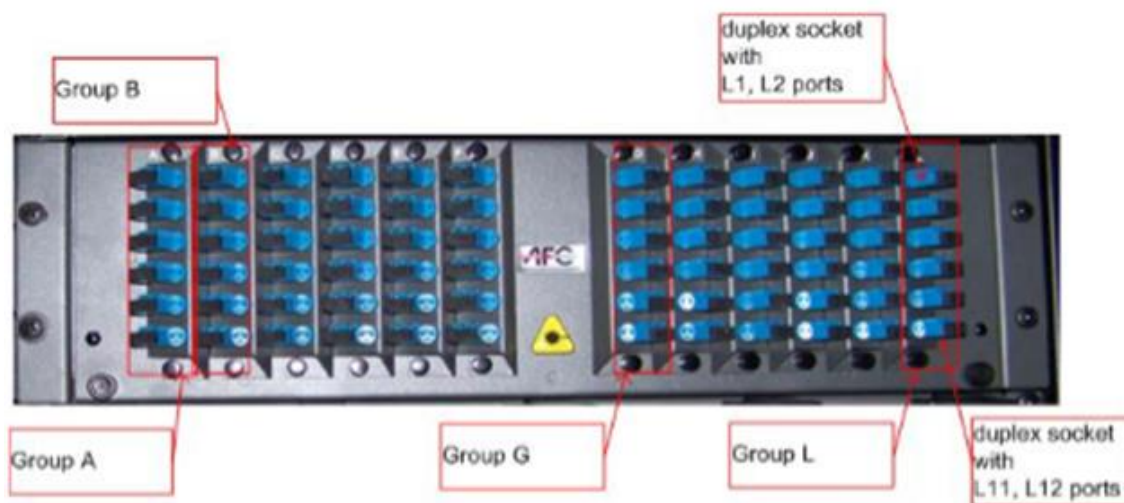
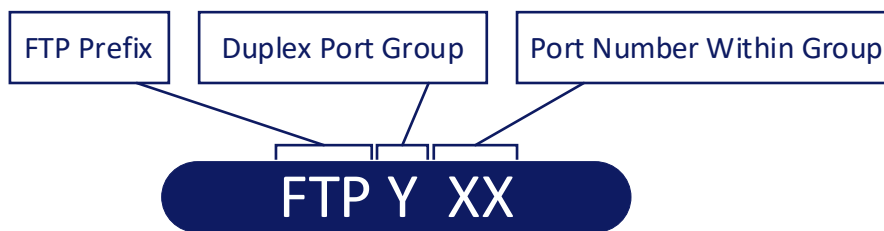


Figure 7-5 - 144 Port rack mounted FTP with multiple port groups

The port identifiers shall be derived by appending the FTP identifier with:



Label Code	Description	Assignment
Y	Designation for the 6 duplex port group in the FTP (see Figure 7-5)	A-Z
XX	Port number within the port group	1-12

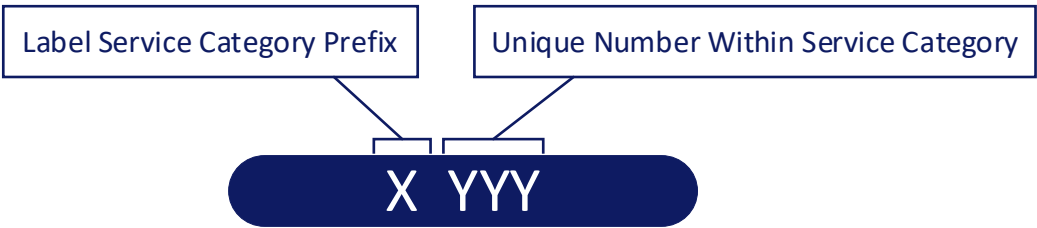
The designation 'A' shall be used where there is only one group of duplex ports, such as in the panel mounted FTP depicted in the diagram A5.1.

Port naming examples:

- Port 1 in Core SCADA Ethernet Switch 1: ES001A01; and,
- Port 12 in group 'B' of FTP001: [FTP001B12](#)

ANNEXURE C.6 PATCH CORD LABELLING

The purpose of the label is to uniquely identify a patch cord within the substation. The text in a patch cord label shall be as follows:



Label Code	Description	Assignment
X	Label Service Category	Specified as per the services listed in 5.4.9
YYY	Unique Number	Incremented starting from 001

For example:

Label	Service Category	Cable Number
A001	SCADA multi-mode application	1
P005	Protection signalling between substations	5
C053	Communications LAN (Non-SCADA / Protection)	53

