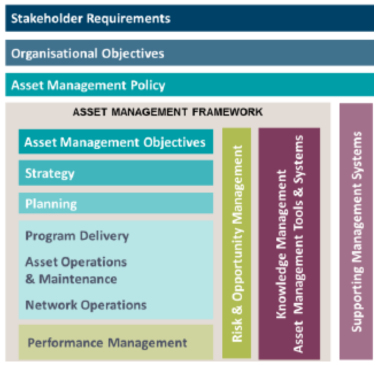
# Telecommunications Concept Design & Application

## Guideline

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### RESPONSIBILITIES

Western Power's Engineering & Design Function is responsible for this document.

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## Revision Details

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# 1 Introduction

This document is intended to provide guidance on key aspects of the telecommunications design process and has two main objectives.

1. Describe the principles of the conceptual design process. This process includes interpreting design requirements based on an understanding of Western Power's approved telecommunications design solutions, to produce telecommunications conceptual designs meeting those design requirements. This objective is covered in Section 2.

2. The second objective is to describe how Western Power's telecommunications design standards should be applied in practice to deliver telecommunications solutions meeting customer requirements. It includes a description of the underlying principles and concepts of operational telecommunications network solutions. This objective is covered in Section 0.

## 1.1 Purpose and scope

This is a supporting document and is defined as a guideline within Western Power's Asset Management System. Its purpose is to complement telecommunication design standards by providing guidance and instruction for implementation.

## 1.2 Acronyms

| Acronym | Definition |
|---|---|
| ABR | Area Border Router |
| AC | Alternating Current |
| ACMA | Australian Communications and Media Authority |
| ADSS | All Dielectric Self Supporting, a type of overhead fibre cable |
| AEMO | Australian Energy Market Operator |
| AMI | Advanced Metering Infrastructure |
| AMS | Asset Management System |
| CBD | Central Business District |
| COM | Constructability, Operability and Maintainability |
| CUCM | Cisco Unified Communications Manager |
| CUBE | Cisco Unified Binding Element |
| DA | Distribution Automation |
| DC | Direct Current |
| DMR | Digital Mobile Radio |
| DMS | Distribution Management System |
| DMZ | Demilitarized Zone |
| DNP3 | Distributed Network Protocol 3 |
| EDM | Enterprise Document Management |
| EMS | Energy Management System |
| FOBOT | Fibre Optic Break Out Tray |
| FSK | Frequency Shift Keying |
| GNSS | Global Navigation Satellite System |
| GOOSE | Generic Object-Oriented Substation Event, See IEC 61850 |
| HMI | Human Machine Interface |
| HMR | Hazard Management Register |
| ICT | Information & Communication Technology (Western Power function) |
| IDF | Intermediate Distribution Frame, for housing Krone disconnector modules |
| IDU | Indoor Unit |
| IEC | International Electrotechnical Commission |
| IEEE | Institute of Electrical and Electronic Engineers |
| IETF RFC | Internet Engineering Task Force - Request For Comments |
| IGF | Investment Governance Framework |
| IP | Internet Protocol |

| | |
|---|---|
| IP/MPLS | Internet Protocol Multi-Protocol Label Switching |
| IS-IS | Intermediate System to Intermediate System |
| ITU-T | International Telecommunication Union – Telecommunications Standardization Sector |
| LDP | Label Distribution Protocol |
| LER | Label Edge Router |
| LSP | Label Switched Path |
| LSR | Label Switch Router |
| MMS | Manufacturing Message Specification, see IEC 61850 |
| MPLS | Multi-Protocol Label Switching |
| MPLS-TP | Multi-Protocol Label Switching – Transport Profile |
| MTP® | Multi-fibre Termination Push-on, a fibre connector type |
| NIC | Network Interface Controller |
| NMC | Network Management Centre, the telecommunications control centre |
| NMS | Network Management System |
| NRS | Network Reinforcement Schemes |
| ODU | Outdoor Unit |
| OPGW | Optical Ground Wire |
| OSI | Open Systems Interconnection |
| OSPF | Open Shortest Path First, routing protocol, see IETF RFC-1247 |
| OSS | Operational Support System |
| OT | Operational Technology |
| P1, P2 | Protection 1, Protection 2, enumerating the two schemes required by Western Power's Technical Rules Section 2.9.2 |
| PABX | Private Automatic Branch Exchange |
| PAX | Private Automatic Exchange |
| PDF | Portable Document Format |
| PDH | Plesiochronous Digital Hierarchy |
| PLC | Power Line Carrier |
| PoE | Power Over Ethernet |
| PPG | Private Parallel Generator |
| PTP | Precision Timing Protocol, see IEEE 1588 |
| QAM | Quadrature Amplitude Modulation |
| RALI | Radiocommunications Assignment and Licensing Instructions, issued by ACMA |
| RDP | Rack Distribution Panel |
| RMU | Ring Main Unit |
| RSSI | Received Signal Strength Indication |
| RSTP | Rapid Spanning Tree Protocol, see IEEE 802.1w |

| | |
|---|---|
| RTU | Remote Terminal Unit |
| SCADA | Supervisory Control And Data Acquisition |
| SDH | Synchronous Digital Hierarchy |
| SEAL | Substation Ethernet Access Link |
| SLA | Service Level Agreement |
| SNCP | Subnetwork Connection Protection, see ITU-T Rec. G.808.1 |
| SO-EM | ServiceOn Element Manager |
| SyncE | Synchronous Ethernet |
| TDM | Time-division multiplexing |
| TON | Telecommunications Operational Network |
| TPS | Teleprotection system |
| UHF | Ultra-High Frequency |
| UPS | Uninterruptible Power Supply |
| VF | Voice Frequency (0-4000 Hz) |
| VHF | Very High Frequency |
| VLAN | Virtual Local Area Network |
| VoIP | Voice Over Internet Protocol |
| VRF | Virtual Routing and Forwarding |
| WAN | Wide Area Network |

## 1.3 Definitions

| Term | Definition |
|---|---|
| Designer | A suitably qualified person undertaking telecommunications design activities on behalf of Western Power |
| Network | Two or more network elements interconnected by communications channels |
| Network Element | Active equipment used in the provision of a Telecommunications Service |
| Service | A communications channel provided to a customer's equipment for transporting that customer's data to one or more endpoints. |
| Stakeholder | A user of the telecommunications network and can be a party internal or external to Western Power |

## 1.4 References

References which support implementation of this document

**Table 1 References**

| Reference No. | Title |
| --- | --- |
| | Enterprise Risk Assessment Criteria |
| | Network Strategy – SCADA and Telecommunications |

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# 2 Concept Design Guideline

## 2.1 How to use this guideline

This guideline describes accepted practices and standard designs for telecommunications concept design. It provides guidance, common examples and standard requirements encountered in concept design.

## 2.2 Project phases and Design maturity

Western Power projects follow the Investment Governance Framework (IGF) which defines project phases. These phases are intended to align with a level of maturity of the concept design.

**Table 1: Design Maturity in Each Project phase**

| IGF Gates | Project Phase | Design Maturity |
|---|---|---|
| 0 to 1 | Initiation | Consultation Advice |
| 1 to 2 | Scoping | Concept Design |
| 2 to 3 | Planning | Preliminary Design |
| 3 to 4 | Execution | Detailed Design |

Each level of design maturity is intended to provide an increasing level of surety in the design, to meet a specific need at that phase of the project:

- **Consultation Advice**: This level of maturity is intended to provide assurance of feasibility of the project. This phase may include assumptions around the probable service requirements, as detailed service requirements may not be available. The outcome of this advice is to determine whether the project is feasible and to identify any significant risks to project delivery (for example, line-of-sight for microwave, environmental constraints, land acquisition)

- **Concept Design**: At this level of maturity, solution options should be considered and evaluated. Sufficient detail should be provided for each option to allow for comparison of the options through cost-comparison, project delivery risk, safety and environmental risk and strategic benefits. The outcome of this phase is to provide a shortlist of recommended options to the Project Sponsor for selection.

- **Preliminary Design**: With a preferred option selected, the objective of preliminary design is to refine the design to allow a highly accurate estimate and project management plan/schedule to be developed. Any remaining assumptions should be addressed, and mitigation plans for outstanding delivery risks should be identified.

- **Detailed Design**: The objective of detailed design is to produce documentation of sufficient detail to allow the construction, commissioning, and maintenance of the assets in the design. The documentation includes design reports, bills of materials, construction scopes of work and commissioning plans. As the project is now committed, permanent records may be created for the new or modified assets.

## 2.3 Concept Design Deliverables

### 2.3.1 Design Advice memo

The Design Advice memo is the main deliverable for telecommunications Concept Design, which details the proposed telecommunication solution(s) and the associated justification(s).

This document also records inputs, requirements, options considered, assumptions and risks. The document contains links to other deliverables.

The memo is typically produced at the Concept Design phase and updated at Preliminary Design phase. Where required in the Consultation Advice phase, a memo may also be produced. In Detailed Design, refinements or changes to the solution are captured in the design report.

### 2.3.2 Hazard Management Register (HMR)

The project Hazard Management Register (HMR) is produced prior to detailed design, as the ability to eliminate hazards is greater when they are identified earlier in the project. This document records the minutes of meetings in which Safety-in-Design is discussed. Any hazards which can be mitigated by design changes are to be recorded.

The Hazard Management Register is typically produced at concept design.

### 2.3.3 Constructability, Operability, Maintainability (COM) Review Meeting Minutes

Early identification of Constructability, Operability or Maintainability (COM) issues also increases the likelihood that these issues can be eliminated through design changes. In addition, identification of these issues can improve the accuracy of the project scope of work and estimate. This document records the meeting minutes of this discussion with relevant parties in the business.

A COM review is typically carried out at Preliminary design phase. Two COM reviews are carried out in detailed design: a logical COM review and a physical COM review.

### 2.3.4 Cost Estimate

The required estimate accuracy is dependent on the phase of the project as shown in Table 2.

**Table 2: Estimate Accuracy Requirements per Project Phase.**

| Concept Design Maturity | Estimate Accuracy | Estimate Classification |
|---|---|---|
| Consultation Phase | L: +100% to -50%<br>H: +50% to -20% | Class 5 |
| Concept Phase | L: +50% to -30%<br>H: +20% to -15% | Class 4 |

| Concept Design Maturity | Estimate Accuracy | Estimate Classification |
|---|---|---|
| Preliminary Phase | L: +30% to -20%<br>H: +10% to -10% | Class 3 |

## 2.4 Interpreting Telecommunication Requirements

There are many different stakeholders of the Western Power Telecommunication Network and, as a result, a variety of stakeholder requirements. These include internal Western Power departments as well as external customers and customer account managers.

It is crucial to correctly identify the specific telecommunications requirements as these inform the solution provided.

Where the telecommunications requirements are unclear, there may be a need to translate a stakeholder's project scope into a telecommunication requirement. Therefore, it is often incumbent on the telecommunications designer to seek broader context of the project from the stakeholder, as nuances in the scope can influence the solution provided. There also may be opportunities in this dialogue to influence the requirements, shaping the solution to meet the stakeholder's budget and schedule.

As a starting point, the Western Power internal stakeholder requirements in Table 3 should be considered when discussing a new project.

**Table 3: Common Internal Western Power Stakeholder Requirements**

| Western Power Functions | Project Scope Item | Typical Telecommunication Requirement |
|---|---|---|
| Grid Transformation, Access Solutions, Asset Performance | Establish new Transmission Line | Duplicated (i.e. P1 and P2) Digital Differential Protection circuits. The circuits should be diverse from each other and terminating at the relay rooms in which the relevant Protection Relays will be installed. |
| Grid Transformation, Access Solutions, Asset Performance | Establish new Automation Gateway | Duplicated Transmission Automation connections to the EMS.<br>Remote access connection to each Automation router (typically two) |
| Grid Transformation, Access Solutions | Establish new Generator connection | Duplicated Transmission Automation connections to the EMS. Provision new telephone service at Generator control room.<br>Remote access connection from new Fault Recorder or Power Quality Meter. |

| Western Power Functions | Project Scope Item | Typical Telecommunication Requirement |
|---|---|---|
| Grid Transformation, Access Solutions | Establish new NRS | Duplicated Point-to-point Ethernet services (following the same path through the telecommunications network), connecting Automation switches in a ring topology. |
| Property & Fleet | Deploy electronic security system | Remote access connection to security firewall |
| Property & Fleet | Establish depot corporate network connection | Provision new high-capacity bearer (single or duplicated) to provide corporate network connectivity. |
| Grid Transformation, Access Solutions, Asset Performance | Establish new control room or switch room | Provision new telephone service in new room. |
| Grid Transformation, Access Solutions, Asset Performance | Establish new transformer with capacity > 55MVA | Provision remote access to transformer monitoring equipment. |
| ICT, Customer Account Manager | Dark Fibre service | Provision dark fibre cores as per project scope. |
| Access Solutions | New PPG Connection | Provision as per PPG Guideline (). |

On occasion a project will include non-standard requirements. In these cases, the following questions should guide conversations to establish the telecommunications requirement:

- What are the end-points or end devices of the service? Where are the end-points/devices located? What interface type does the end device have? Can the customer provide a datasheet?
- What other non-communications infrastructure is being planned for installation?
- What reliability of service is required? What are the consequences of failure of the service? Are duplicated end-devices required?
- What latency of service is required? Less than 20, 100, 1000 milliseconds end-to-end?
- What capacity of data is being transported? Kilobits, megabits, tens of megabits, 100s of megabits or gigabits per second?
- Does the service have any specific performance requirements (e.g., Jitter/wander, symmetric bidirectional delay)

- Is a Service Level Agreement (SLA) required to be established for this service and how will this be implemented and monitored for compliance?

Additional questions to the above may be required to define the solution as more context is available.

## 2.5 Developing the Concept Design Solution

Once the requirements for a project are identified, the telecommunications scope may be developed. Refer to Section 0 of this document and 'Design Standard - Telecommunications Design' for a description of the telecommunications network, architectures and how these services are typically delivered.

The steps to determine the concept design solution are as follows:

1. Determine the concept design requirements as per Section 2.4 of this document.
2. Review the existing site, equipment, and bearers.
3. Review planned approved & planned unapproved changes to equipment and bearers.
4. Assess the existing and planned equipment for capability (i.e., is this equipment approved to carry the service) and capacity (e.g., physical ports, logical, bandwidth) to deliver the services.
5. Propose new bearers, new equipment, and/or modifications to equipment to deliver the services. Ensure the new assets own requirements are met, for example synchronisation requirements and NMS.
6. Review the Concept Design Considerations in Section 2.6 of this document.
7. Prepare the deliverables as per Section 2.3 of this document, ensuring to capture assumptions, project delivery risks and dependencies as required.

## 2.6 Concept Design Considerations

Decisions and considerations made in concept design have direct impact on scope, cost, and schedule. Considered thinking in concept design can prevent surprises in execution phase.

The following list of questions can be useful for preparing concept design. The designer may be required to engage other Western Power departments for input or analysis to address these.

### 2.6.1 General Considerations (all phases)

- Are there any known project dependencies or interactions with this request?
- Have I met legal and regulatory requirements in my design? Examples:
    - Technical Rules, clause 2.9.2 – Duplication of Protection
    - Technical Rules, clause 2.9.4 – Maximum Total Fault Clearance Times
    - Technical Rules, clause 3.3.4.3 – (Generator's) Communications Equipment
    - AEMO's Power System Operation Procedure: Communications and Control Systems
    - Safety in Design requirements
- Have I recorded my assumptions and risks?

### 2.6.2 Consultation Design Advice Considerations

- What standard design solutions could apply to this concept design?
- What existing infrastructure could be leveraged for this concept design?
- Are there any activities which could significantly impact the viability, cost, or schedule of the project?
- Are there any early undertakings which could mitigate any of the risks identified?
- Are there any third-party assets which conflict or interact with the design?

### 2.6.3 Concept Design Advice Considerations

- Have I considered all standard solutions for this design?
- Have I considered whether non-standard designs could result in a lower whole-of-lifecycle cost or an accelerated schedule (including internal approvals) while still meeting the requirements of the project? Are there cases outside Western Power with successful implementation?
- Have I considered new technology options?
- Have I considered non-design activities required to roll-out non-standard solutions?
- Does the solution align with 'Network Strategy – SCADA and Telecommunications[1]'? If not, have I consulted the relevant asset manager to seek their endorsement?
- Have the space requirements for the telecommunications infrastructure been considered in this solution?
- Will standard solutions for power supply work for this design?
- Will standard solutions for network management work for this design?
- Have I identified any interface points which require management through future design phases?
- Have I captured the cost estimate using the standard estimation tool building blocks?
- Are there any key safety, environmental or cybersecurity concerns to include in the HMR?

### 2.6.4 Preliminary Design Advice Considerations

- Have I considered and recorded any scope uncertainties which could potentially impact the design in terms of scope, cost, or schedule?
- Have I identified and engaged other disciplines to assess the impacts of the telecommunications design on other projects? For example: confirming media interfaces for automation, confirming the use of direct fibre, and supplying prospective lengths, assessing space for new comms racks.
- Have I confirmed the project delivery methodology with all relevant stakeholders?
- Are there any non-standard activities which require cost estimation?

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[1] Western Power internal document

- Have I inspected and adjusted the cost estimate to account for non-standard elements of the design?

## 2.7 Solutions Option Analysis

A key part of concept design is the presentation of solution options.

Prior to finalisation of the Concept Design Advice memo, the designer should consider discarding options that:

- do not meet the key stakeholder's requirements,
- are technically unviable,
- are disproportionately expensive,
- present an unacceptable safety risk,
- propose an unacceptable environmental or heritage impact,
- are not constructable, operable, or maintainable,
- do not meet Western Power's legal and regulatory obligations,
- present an unacceptable cybersecurity risk.

To assess the above, a risk assessment may be performed (against the Enterprise Risk Assessment Criteria), consulting all relevant stakeholders as necessary. Justification for the decision to discard an option may also be sourced from the 'Network Strategy – SCADA and Telecommunications'[2]. Discarded options and justification can be recorded in the memo as an appendix.

Examples of occasions where options are discarded are presented in Table 4 and Table 5.

**Table 4: Example 1 of Options Analysis During Concept Design Advice development: Transmission Customer Connecting by Underground Cable.**

| | |
|---|---|
| Example | Transmission customer connecting by underground cable. |
| Context | A transmission customer requesting a connection to their proposed substation which is 3km from an existing Western Power substation. The electrical network solution proposed is to build a new 3km 132kV underground transmission cable to the customer and establish a Western Power control room at the customer's substation to house line protection relays and duplicated automation gateways. The existing substation has duplicated TDM multiplexers and diverse SDH fibre bearers connecting to the broader network. |
| Telecoms Options Analysis | The telecommunication engineer considers both duplicated underground single-mode optical fibre on either side of the transmission cable, and duplicated microwave connectivity for the new substation, but ultimately discards the microwave option due to disproportionate cost. |

[2] Western Power internal document

| | |
|---|---|
| Example | Transmission customer connecting by underground cable. |
| Options Discarded | • Microwave bearer. |
| Selected Option | • Duplicated underground fibre installed on either side of the transmission cable. |

**Table 5: Example 2 of Options Analysis During Concept Design Advice development: Transmission Customer Connecting in a Tee'd Line Configuration.**

| | |
|---|---|
| Example | Transmission customer connecting in a tee'd line configuration. |
| Context | A transmission customer requesting a connection to their proposed substation which is 5km from an existing 35km Western Power 132kV transmission line. The electrical network solution proposed is to tee into the existing line and build a new 5km 132kV transmission line Section to the customer and establish a Western Power control room at the customer's substation to house line protection relays and duplicated automation gateways. The existing line does not have OPGW and the existing line protection is carried over diverse SDH microwave bearers between the two existing Western Power substations. |
| Telecoms Options Analysis | The telecommunication engineer considers several options: new underground fibre, new OPGW or ADSS, and new microwave bearers. Unfortunately, new underground fibre proves disproportionately expensive, as does retrofit of OPGW and ADSS. Therefore, the engineer pursues microwave options and discovers that direct microwave connectivity between the proposed customer substation and one of the Western Power substations is obstructed by a hill. The engineer then assesses several properties in the area for a new microwave communications site to establish an intermediate tower and selects a preferred option. |
| Options Discarded | • Underground fibre.<br>• OPGW.<br>• ADSS.<br>• Direct Microwave link.<br>• Several unviable locations for intermediate communications site. |
| Selected Option | • Microwave via intermediate communications site. |

It is expected that several options may still be viable at the completion of Concept Design. To select between these, options analysis is formally performed by the business based on the outputs of the Concept Design Advice memo and other deliverables at this stage. This activity is typically undertaken by the Project Sponsor, or by the relevant asset engineer. The key parameters needed by the business to evaluate options are the options' Cost, Schedule Duration and Delivery Risk. The designer is responsible for the 'Design and Materials' component of these items but may also contribute insights based on project experience.

At the commencement of Preliminary design, ideally the business has selected the preferred option for the project.

## 2.8 Assumptions

At the early stages of concept design, there will be uncertain elements of scope and to progress the design, assumptions will be necessary. The purpose of an assumption is to allow the designer to propose a solution with incomplete information.

When carrying out concept design, the designer should be mindful of missing inputs, options presented by other disciplines and open queries with the stakeholders involved as these will likely result in the designer assuming. The designer should also be mindful of the completeness and currency of information used to make design decisions.

Once the above uncertainties have been identified, the designer should then quantify them as follows:

1. Identify how the information could be provided.
2. Determine the most likely outcome if current and complete information was provided. Standard designs should form the basis of this outcome.
3. Propose a design solution based on the most likely outcome.
4. Determine the worst-case outcome if current and complete information was provided. Typically, this is the outcome whereby the above design solution is no longer technically viable.
5. Propose a design solution based on the worst-case outcome.
6. Assess the differences in the design solution in cost, schedule duration, and delivery risk.
7. Record the assumption in the Design Advice memo.
8. Where the impact of this uncertainty is deemed large with respect to the concept design level of accuracy (e.g., 10% for Preliminary Design), this risk should be escalated to the design lead, Project Sponsor and Project Manager (if assigned). This may result in the early undertaking of validation of the assumption.

A well-written assumption has the following characteristics:

- Is a provable or disprovable statement.
- Is intended to be tested and validated in a later stage of design.
- Is based on sound engineering judgement and/or recent project experience.
- Baselines the designer's view of the most likely outcome of the testing or validation.

While an assumption records a risk to the technical viability of the solution, it is likely to also have a project delivery impact or a safety impact to the project. It is important to record these separately in their respective registers (e.g., HMR) and/or Sections of the Design Advice memo.

## 2.9 Project Delivery Risks

Project Delivery Risks are those which have an impact to cost and schedule. The Project Manager is accountable for Project Delivery Risks and the designer shares some responsibility. The responsibilities of the designer are to identify the technical risks and advise the Project Manager on likelihood, technical risk mitigations and consequences.

Project Delivery Risks are a key input into the Project Management Plan, which is a key artefact required for the project to proceed into the Execution phase.

These risks can also be recorded in a Quantitative Project Risk Register, prepared by the Financial Estimation team. The calculation result of this tool forms the business case value of the project. Therefore, accurate inputs to this process are essential for the project to be successful.

Risks may have a cost impact, a schedule impact or both.

Some standard examples of Project Delivery Risks are:

- **Up-to-date Design**: If Western Power's project priorities change between completion of design (especially ConnectMaster/OSS Pack) and commencement of commissioning, the design may lose its validity due to communication network changes. If this risk eventuates, design rework will be required to allow commencement of commissioning.
- **Microwave Site Selection**: If land acquisition of the proposed microwave sites is not successful, design rework is required to locate alternative sites. This may result in wider changes to the design such as additional tower height at other sites or even relocation of other sites.
- **Radio Path Obstruction**: Desktop analysis shows the radio path proposed meets design criteria, however an obstruction may exist on site. If a line-of-sight survey or RSSI study finds an obstruction, design rework may be required to propose an alternative link.
- **Fibre Route Selection**: If third-party approvals are not successful or other issues are discovered that prevent the construction of the fibre route, design rework will be required to propose an alternative.
- **Project Coordination:** Project scope is found to be dependent on other projects. The Project Managers of the respective projects should coordinate and communicate regularly to ensure that the project schedules align to manage the dependency.

## 2.10 Cost Estimation

It is important that the costs estimated for the project are justified, as Western Power is a regulated business. There should be a relationship between each item in the cost estimate and the scope of works in the Design Advice memo. The accuracy of the estimate should be as per Table 2. The format of any such estimate shall be in the prescribed format, in sufficient detail to satisfy Western Power's legal and regulatory obligations.

## 2.11 Estimating Concept Design Effort

Often a stakeholder will request a 'maturity cost estimate', this is an estimate of the effort required to complete an estimate. This is used for project scheduling and budgeting for the pre-execution phases of the project.

The designer should consider the following questions about the requirements when preparing the maturity cost estimate:

- Are the requirements clear or do they require investigation?
- Are these requirements standard or are they novel?
- Are the requirements for a point-to-point service or are they multi-point?

- Does the service require redundancy or switching in the event of failure?
- What reliability of service is required?
- What protocols will the customer traffic be using?
- Are the interfaces to the customer equipment available as part of the approved material list?

The designer should also consider the following about the likely solutions:

- What telecommunications infrastructure is already present in the area?
- What head-end infrastructure is required and is it in place?
- Will development of the solution require a site visit?
- Are there iterative design tasks to be carried out in developing the solution, for example fibre route development or microwave site location?
- Will the solution introduce new assets or networks to Western Power?
- Will consultation be required with the wider business?
- Are inputs required from other design disciplines?

With the above considerations, the designer should map out the concept design activity and allocate effort to each task, being mindful of requirements such as the COM review, Safety in Design meeting and technical review process.

# 3 Application Guide

## 3.1 How to use this guide

This guide records how telecommunication technology is applied in Western Power to deliver services required for the business's operations. It captures standard approaches and network architecture to provide a starting point for design activities and ensures that the objectives of the 'Network Strategy – SCADA and Telecommunications[3]' are met.

## 3.2 Western Power's Telecommunications Network

Western Power owns and operates a telecommunications network that spans the area of its Transmission and Distribution network. This network's purpose is to provide critical telecommunications services which allow the operation of the Transmission and Distribution networks and to meet Western Power's obligations under the Technical Rules.

Specifically, the purpose of the network is to transport data between physically separated sites.

This network comprises of telecommunications equipment installed at transmission substations (generation sites, terminal substations, and zone substations), distribution substations, distribution pole-mounted equipment, control centres, data centres, cable pits, cable conduits and standalone communications sites.

In most cases, the reliability, latency, and diversity (and many other) requirements of the services needed to operate the electricity network preclude the use of commercial telecommunication services, except for niche scenarios.

The network comprises of several physical and logical sub-networks including:

- Telecoms Operational Network (TON)
- Telecoms Field Network
    - TDM network
    - MPLS-TP Network
    - SEAL Network
    - Layer 3 Networks
    - Radio Networks

These sub-networks are interconnected and interrelated but have their own architectures and design requirements. Each has been developed to meet a specific need of the electricity network and/or the requirements of a Western Power internal or external customer.

## 3.3 Relationship to other Networks

The telecommunications network forms its own OT domain alongside SCADA (transmission & distribution), and AMI/Metering. As a service provider to the other networks, the telecommunications field network interfaces between most OT "Head-end" Environments and their respective OT "Field" Environments.

[3] Western Power internal document

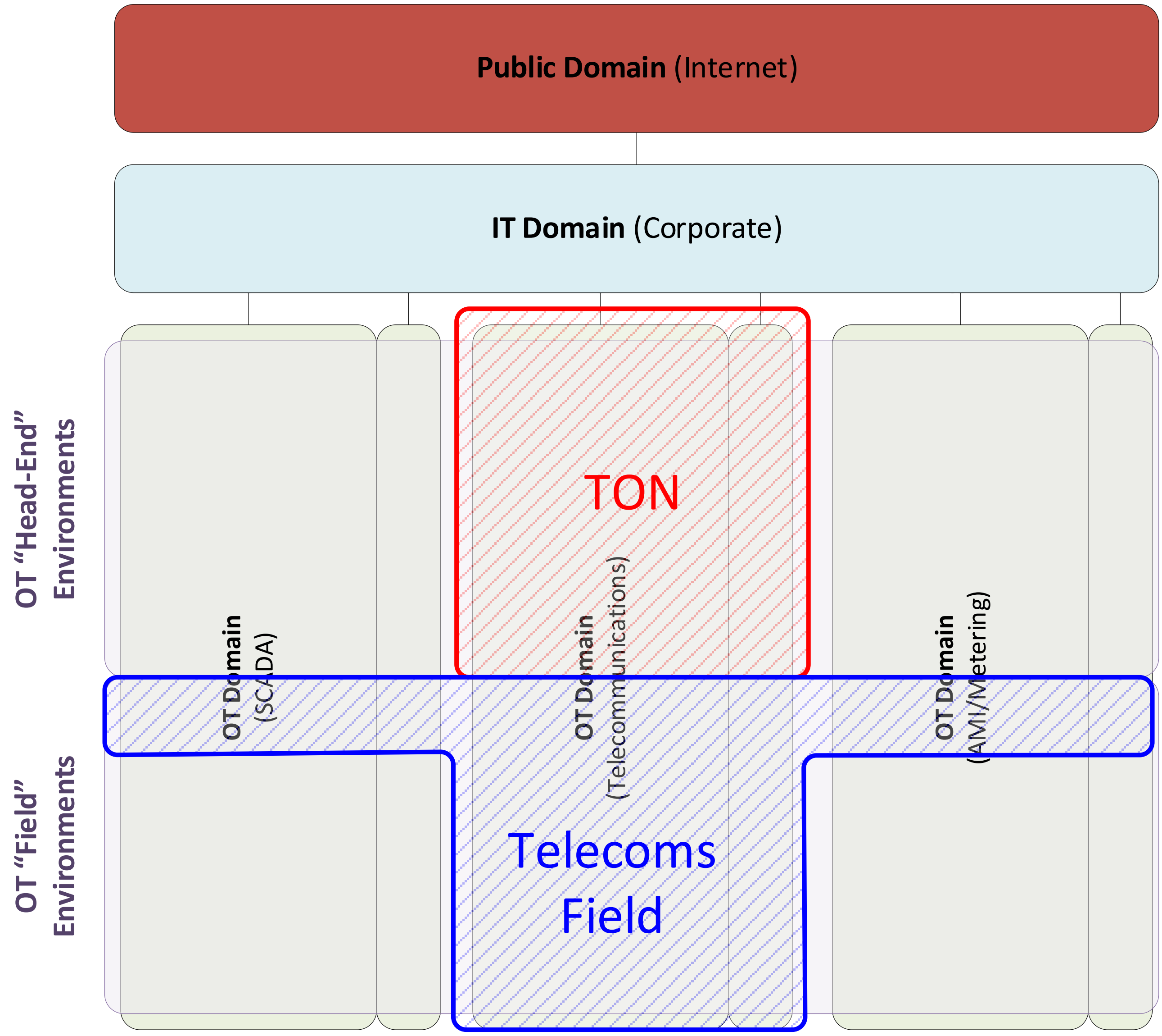


**Figure 1: High Level Overview of Western Power's Domains**

## 3.4 Components of a Telecommunications Installation

The telecommunications installation at sites usually comprises of the following components:

**Table 6: Components of a Telecommunications Installation**

| Component | 'Network Strategy – SCADA and Telecommunications' Classification | Description |
|---|---|---|
| Transmission Medium or Bearers | SCADA and Telecommunications Cabling, and<br><br>Telecommunications Radio | The physical medium which is carrying the data between sites. This could include fibre optic cable, a radio channel, Powerline carrier channels, or a pilot cable. |

| Component | 'Network Strategy – SCADA and Telecommunications' Classification | Description |
|---|---|---|
| Equipment to interface with the Transmission Medium | Telecommunications Network Access | This equipment interacts directly with the media, encoding, transmitting and receiving data from the media. Examples include fibre transceivers, Powerline carrier termination equipment and radio equipment |
| Multiplexing & Networking equipment | Telecommunications Network Access | Typically, the limiting factor in the design of telecommunications installations is the Transmission Medium. Hence, multiplexing equipment is used to combine multiple data streams into a single stream over the Transmission Medium. Multiplexing may be deterministic (e.g., time-division multiplexing) or statistical (e.g., Ethernet). Modern multiplexers are able to interface to sources of data using a variety of different protocols and interface types. |
| Network Monitoring Equipment | Telecommunications Supporting Infrastructure | Equipment is installed to monitor the health of the telecommunications installation and environmental factors such as ambient temperature. |
| Power supply | Backup DC Power | Most telecommunications equipment is active, i.e., requiring a supply of electricity to function. Therefore, telecommunications installations include a power supply, usually -48VDC. This also includes batteries for continuity of supply in event of a mains failure. |
| Housing | Telecommunications Supporting Infrastructure | To ensure the telecommunication equipment operates within its environmental limits and to provide security to the equipment, housing is required. This can include telecommunications shelters, cubicles / racks, pits, conduits. In addition, because some equipment such as microwave antennas require mounting at height to perform their function, antenna support structures are included in this category. |

## 3.5 Site Installations

A typical transmission substation installation includes the following: -

In the relay room,

- -48V DC rectifier system rack (dual bus) and battery expansion rack, with approximately 48 hours Battery backup.
- Two 19", 60mm deep equipment racks containing
    - 2x hybrid SDH/PDH/MPLS-TP multiplexers (one in each rack),
    - 1x Ethernet switch for network monitoring,
    - Intermediate Distribution Frames with Krone disconnector modules, Patch panels and other cabling infrastructure,
    - One or more FOBOTs or Microwave IDUs.
- Telephone on the relay room desk.

Outside the relay room,

- If microwave is used, an antenna support structure with one or more ODUs, antennas and feeder cables to the IDUs. This structure will be a self-supporting tower or monopole.
- If fibre is used, one or more lead-in cables from a pit outside the substation or from an OPGW splice cannister at the substation gantry.

Other common equipment in the room may include:

- A DA/DMR rack, containing VHF radios providing distribution automation and mobile radio services to the surrounding areas. Antennas installed on the antenna support structure outside.
- An AMI access point, providing metering services to mesh radio enabled household meters in the vicinity of the substation. Antenna may be installed on the antenna support structure if available or mounted on side of the relay room.
- Network Monitoring Equipment such as an RTU for hardwired alarms and ambient temperature sensor.

A communications-only site would typically require:

- A communications shelter with AC power supply.
- Fencing and surfacing.
- Access track.
- Similar equipment to the transmission site, except the second multiplexer if it is not required for protection service diversity.
- The antenna support structure may be a guyed mast.

Installations at substations connecting electricity generation would typically require:

- The same equipment as a transmission substation, plus
- Telephone in the generation customer's control room.

A Depot site would typically require:

- Ethernet switch powered from ICT UPS backed AC supply.
- FOBOT for terminating inter-site fibre cable, or Microwave IDU powered off ICT UPS backed AC supply.
- External plant corresponding to the incoming transmission medium.

## 3.6 Transmission Medium

Western Power employs a variety of transmission media in the telecommunications network. The higher capacity media are optical fibre and microwave radio. The lower capacity media used are VHF/UHF Radio, pilot cables and powerline carrier.

### 3.6.1 Optical Fibre

Both single mode and multimode fibres are used in the network, however single mode is primarily used between sites. Multimode cable is primarily used for interfacing locally from telecommunications equipment to customer's equipment.

Single mode cable is usually multi-core cable arranged in tubes of 12. Typically, 48 or 144 core cable is used. This can be installed as underground fibre, Optical Ground Wire (OPGW) or All-Dielectric Self-Supporting (ADSS) cable.

Underground fibre is installed in conduits and requires the installation of fibre pits to allow for splicing of cables together and to aid in hauling of the cable during installation and maintenance. Currently, conventional fibre is installed, as opposed to blown fibre cables which were installed in the past. Conventional fibre includes optical fibres pre-installed in the cables, while blown fibre requires fibre cables to be blown through the tubes of a blown fibre cable as they are required.

On many transmission lines, OPGW is installed. This cable takes the place of the earth or ground wire on transmission structures. For new installations this can be economical as the incremental cost for OPGW vs traditional ground wire is often relatively small. The cable is terminated at OPGW cannisters where it is spliced to either the next run of OPGW or to an underground fibre. These cannisters can be installed on intermediate transmission structures or at transmission substation gantries. These cables are hardy as the earth wire provides mechanical protection to the central fibre cables.

An alternative to OPGW is ADSS which is fibre cable designed to be installed on transmission or distribution structures and is usually slung under the conductors. This cable is 'all dielectric' meaning it has no conductive parts. A key design consideration for ADSS is the additional load on the structures and maintenance of ground clearance.

Optical fibre has a very high bandwidth for data, limited by the interfacing equipment. Currently, up to 10Gbit/s MPLS-TP and STM4 SDH links have been implemented over fibre in the network.

Western Power uses multicore MTP®-terminated cables to provide fibre connectivity between racks. Use of multicore cable, rather than individual patch-leads, ensures new cables do not need to be run for each new requirement, while MTP® connectors provide easy installation without requiring field splicing.

### 3.6.2 Microwave Radio

Western Power utilises microwave radio where fibre is uneconomical or faces deployment issues, typically outside the metro area. Western Power uses licenced bands as defined by the Australian Communications and Media Authority's (ACMA) *Radiocommunications Assignment and Licensing Instructions (RALI) FX03: Microwave Fixed Services*. Typical link parameters are shown in the table below.

**Table 7: Typical Microwave Link Parameters**

| Band | Channel Spacing/Bandwidth | Modulation | Capacity | Link Distance |
|---|---|---|---|---|
| 6 GHz | 28 MHz | 128QAM | STM1 | >20 km |
| 6.7 GHz | 40 MHz | 64QAM | STM1 | >20 km |
| 7.5 GHz | 14 MHz | various | nxE1 + Ethernet | >10 km |
| 8 GHz | 28 MHz | 128QAM | STM1 | >10 km |
| 11GHz | 40 MHz | 64QAM | STM1 | >5 km |
| 13 GHz | 28MHz | 128QAM | STM1 | <5 km |

For improved availability, Western Power prefers to use lower frequencies and lower modulation. Where possible, 6.7GHz band is preferred due to the lower modulation requirement for an STM1 link.

### 3.6.3 UHF and VHF Radio

Western Power uses UHF and VHF point-to-point links to connect sites with low-capacity requirements to the wider network. These are typically sites providing distribution automation (bases or end devices), transmission automation or analogue mobile radio. Both 150MHz and 450MHz are used for this purpose. The current implementation utilises IP radios which are able to transport Ethernet services natively and Serial via an internal terminal server.

While in the past protection signalling (typically for distance protection) had been transported using this medium, this is no longer considered acceptable.

Western Power also uses UHF and VHF point-to-multipoint installations for distribution automation, AMI and mobile radio. These are described further in Section 3.7.7.

Typical radio parameters are given in Table 8.

| Radio Equipment | Radio band | RF Bandwidth | Modulation | Data Rate |
|---|---|---|---|---|
| Tait TB9100 | 150 MHz | 12.5 kHz | FM | 1200 baud |
| Trio ER450 | 450 MHz | 12.5 kHz | GMSK or 4-level FSK | 9100 baud |
| GE Orbit | 150 or 450MHz | 12.5, 25 or 50 kHz | QPSK, 16QAM, or 64QAM | Varies as per modulation and bandwidth |

**Table 8: VHF and UHF Radio parameters**

### 3.6.4 Power Line Carrier

Western Power currently has a handful of power line carrier (PLC) installations. This technology injects VHF frequencies onto a phase conductor or pair of phase conductors to transport information between sites. The capacity of this technology is small, so the number of services which can be transported is low. It is uncertain whether differential protection could be transported by PLC.

In addition, the interface to high voltage equipment introduces potential hazards to operation and maintenance of the equipment. As a result, PLC is not suitable for new installations.

### 3.6.5 Pilot Cable

Pilot cables are a legacy transmission medium consisting of multi-cored copper cables installed on transmission and distribution structures or installed underground. These cables transport low frequency signals such as VF or 50Hz signals. They were used extensively for Pilot Protection as described in Section 3.8.1.1 but also transported Transmission Automation (via VF modems) and other services for transmission substations. Western Power is in the process of decommissioning the pilot cable network and replacing it with optical fibre.

### 3.6.6 Third-Party Networks

Western Power utilizes services of third-party networks such as Telstra's network where aligned with the 'Network Strategy – SCADA and Telecommunications'. These are typically options of last resort.

Where these networks are used to transport customer traffic, they are generally not considered to be telecommunications equipment.

## 3.7 Networks

### 3.7.1 Telecommunications Operations Network (TON)

The Western Power telecommunications network can be broadly divided into the Telecommunications Operations Network (TON) and various Field Networks. The TON comprises of several zones which each serve a different purpose. Broadly, the TON includes the head-end services for the Telecommunications Network, provides interconnection to the Corporate IT Domain, adjacent OT Domains, and provides interfaces to Operators in the Network Management Centre (NMC).

### 3.7.2 Time Division Multiplexing

Time division multiplexing was developed for use in legacy telephony networks and is based on data streams with fixed frame structure and length, repeating every 125µs. This period of repetition is derived from the Nyquist rate (i.e., twice the signal bandwidth) for sampling an up to ~4000Hz human voice frequency signal (i.e., a telephone call). Standard encoding of signals at this sampling frequency is one byte per 125µs which gives a data rate of 64kbit/s. To transport the data between nodes of the telephony networks, higher data rates were required hence the development of PDH networks, where up to 30-32 64kbit/s circuits (E0 circuits) could be transported using a single 2048kbit/s E1 frame, depending on frame structure. Each E0 circuit is allocated its own timeslot in the E1 frame. Unused timeslots are still reserved, and the frame repeats every 125µs. As data requirements grew, SDH was developed which could carry 63 E1 circuits in a single STM1 frame. This technology has more functionality than PDH and stricter timing requirements but preserves the 125µs period.

Western Power operates a time-division multiplexing network which is comprised of SDH and PDH multiplexers, which includes most Transmission substation sites and communication sites. Most services were historically transported by this network. This includes Analog Mobile Radio, Telephony, SCADA (Transmission & Distribution), Protection, and NMS. Various circuit topologies have been employed including point-to-point, multidrop and protected circuits (E0 level and Subnetwork Connection Protection, SNCP)

The network is frequency synchronised using a primary reference clock (as per ITU-T G.811) at Southern Terminal with a secondary clock at Cannington Terminal. Both clocks are GNSS synchronised. There are regenerator clocks spread through the network to ensure the SDH network meets its synchronisation requirements.

Most transmission substations will require two hybrid TDM Multiplexers to be installed to meet the requirements of digital differential protection and automation services. There will typically need to be at least two links of capacity STM1 to provision the services and meet their redundancy requirements. To enable through-traffic and continuity of network management services, an SDH link between the multiplexers is also required.

### 3.7.3 Substation Ethernet Access Link (SEAL)

Western Power operates a Layer 2 (see Open Systems Interconnection model, OSI model) Ethernet network called the Substation Ethernet Access Link (SEAL). This network transports most network management services (NMS) as well as VoIP telephony and digital mobile radio (DMR).

Most sites have a single switch to provide SEAL connectivity. Where the site is connected using microwave, SEAL is typically provisioned as Ethernet over SDH and allocated a VC-3 (approximately 50Mbit/s) within the STM1 over the microwave bearer or as an Ethernet side-channel on the radio.

### 3.7.4 LineRunner Network

Another layer 2 network which is still in operation is the LineRunner network. This network is used to provide CBD distribution automation services and is comprised of Keymile LineRunner switches connected in a ring topology spanning several CBD distribution substations. One switch is designated the Master and connects to the SCADA head end via Ethernet. The other switches in the ring are configured as Slaves and connect to the local SCADA RTU via V.28. The LineRunners fibre loop is single fibre working, meaning only one core of fibre is required to connect adjacent sites. The switches use a proprietary protocol to communicate with each other and can reroute traffic around the loop after a fibre failure.

This technology is considered legacy and has been superseded by the CBD IP network described in Section 3.7.6.1.

### 3.7.5 Multi-Protocol Label Switching (MPLS)

MPLS is a routing technique used to direct traffic based on a label rather than a network address. Traffic is prefixed with a MPLS header containing one or more labels. The ‘multi-protocol’ part of the name refers to the fact that the payload can be of a number of different protocols including most commonly Ethernet.

A Label Switch Router (LSR) reads the labels and forward the packets based on an exact match in its forwarding table. A Label Edge Router removes the MPLS header and transmits the payload to the customer’s equipment. This is distinct from IP routing where the packet is forwarded based on the best match in the routing table, making MPLS forwarding faster than IP routing when it was first conceived.

There are two types of MPLS: IP/MPLS and MPLS-TP. In IP/MPLS, there is a control plane which uses traditional IP routing and Label Distribution Protocol (LDP). This protocol determines the Label Switched Path (LSP), which determines which route the packets take based on their label.

In MPLS-TP, there is no control plane and LSPs must be defined statically.

#### *3.7.5.1 Transport Profile (MPLS-TP)*

Western Power currently deploys multiplexers which are capable of SDH, PDH and MPLS-TP and is in the process of expanding the MPLS-TP network to eventually replace the SDH & PDH networks.

The architecture of the network includes a Core network which is present at the larger metro Transmission terminal switchyard rooms. These sites are intended to form a ring architecture. Sub-rings are intended to connect other transmission substations and communication sites to the Core network. The future topology of the MPLS-TP network is expected to mimic the topology of the existing SDH network.

This network currently transports Transmission Automation services using DNP3 over IP protocol. It is planned to carry Protection services in future, however this requires the deployment of Synchronous Ethernet (SyncE) and Precision Timing Protocol (PTP). SyncE is intended to provide frequency alignment across the MPLS-TP network, while PTP also provides phase alignment and time-of-day synchronisation.

#### *3.7.5.2 Internet Protocol (IP/MPLS)*

Future Section to be written.

### 3.7.6 Layer 3 Routed Networks

These networks provide services in Layer 3 ‘Network Layer’ of the OSI model.

#### *3.7.6.1 CBD & DA IP Network (OSPF & VRF-lite)*

The CBD & DA IP network comprises of three parts: the OT ‘head end’ interface, the OSPF core and the OSPF Area loops. This network is based on IP, OSPF and VRF-lite.

The OSPF core comprises of four core routers with a full mesh of connections between them. The routers are split geographically.

These routers connect to SCADA switches which are the interface between the field network and the SCADA Green Zone. The routers also connect to Telecommunications Switches which interface to the Telecommunications Operational Network (TON).

Each service in this network is allocated its own Virtual Routing and Forwarding (VRF) instance in each router. These Virtual routers share the hardware but are not logically interconnected, which keeps the traffic for each service segregated. Each VRF network runs its own instance of OSPF. The Core switches act as the main routers of Area 0 for each OSPF instance and each VRF network.

Remote sites are connected using individual routers which form a ring topology. These connect back to Area 0 through two Area Border Routers (ABR)for each ring. The ABRs are connected to each other using a direct fibre connection between the two sites.

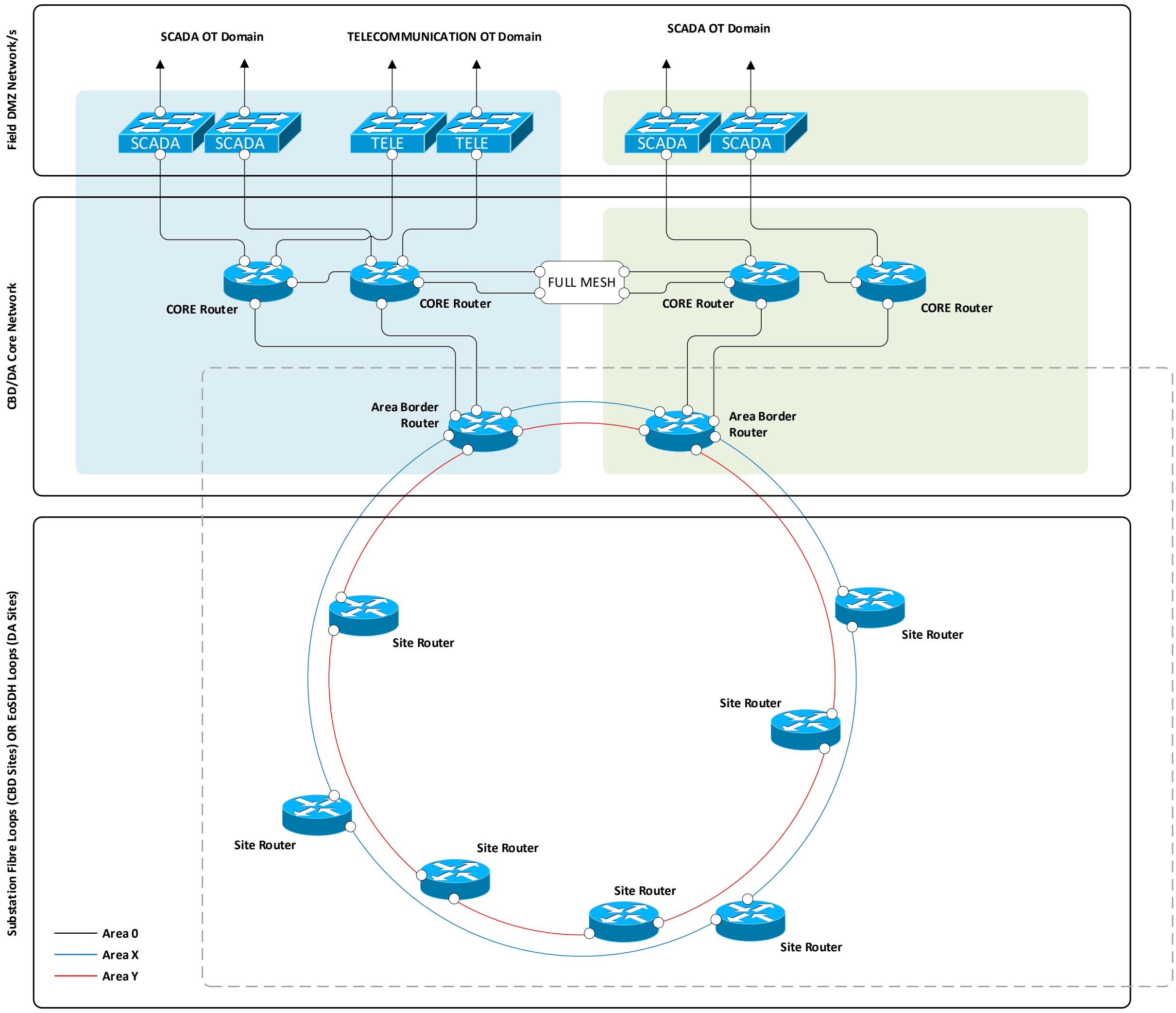


**Figure 2: CBD/DA IP Network**

At present the following VRFs and Services are provisioned on this network

- VRF1 – Cisco Network Element Management
- VRF2 – CBD SCADA services
- VRF6 – Distribution Automation SCADA Services (including remote management of SCADA devices)
- VRF7 – Radio Network Element Management

### *3.7.6.2 SEAL Routed Services*

For most services the SEAL network provides only Layer 2 connectivity but for the following services, the SEAL network participates in the layer 3 routing:

- DMR IP Network (OSPF routing)
- In-band management network for SEAL switches (IP routing only)

Each of these services connect between the TON and SEAL networks, and traverse Field Routers. These routers transport traffic between the TON and SEAL VLANs. Within these routers, each service is allocated its own VRF, except for the Marconi/Ericsson SDH management service which uses the default routing table (IS-IS routing is not compatible with VRF).

Each SEAL device is managed using the in-band management network and has an IP address allocated for this purpose.

In addition, the DMR IP network requires that the SEAL device local to the DMR base also participates in the OSPF routing. To segregate this traffic from Cisco management, these devices also use VRF. Local DMR radios are all part of a /24 (or 255.255.255.0) subnet, with OSPF used to distribute routes to the TON and rest of the DMR network. The SEAL routers in this network are all allocated to OSPF area 0 in this VRF instance.

##### *3.7.6.3 Keymile Management*

The Keymile management network also uses OSPF. The Field Routers are part of Area 0, as well as a set of Keymile XMC20 multiplexers at metro Terminal Substation sites and Head Office. These multiplexers also act as ABRs for the network. Each area of the network is defined by geographical location. The nodes within each area are interconnected using Ethernet over SDH, given one VC-12 capacity. Some nodes are also connected to the local SEAL switch. Each Area has its own SEAL VLAN to provision this connectivity.

##### *3.7.6.4 Marconi Management*

The Marconi management network uses IS-IS routing as opposed to IP routing. This network traverses the TON Field Routers.

### 3.7.7 Radio Networks

Western Power utilises a number of UHF and VHF bands to connect remote sites. These provide last mile communications where a high availability is typically not required. This generally applies to distribution devices and metering services.

The radio networks and common frequency bands include:

- Analogue Mobile Radio – 80MHz
- Digital Mobile Radio – 170MHz
- Country Distribution Automation – 150MHz
- Metro Distribution Automation – 450MHz
- Advanced Metering Infrastructure – 900MHz

The Analogue Mobile Radio Network consists of a number of sites, each with a single 80MHz base station providing coverage to surrounding areas. These bases are connected by VHF and UHF point-to-point radios, or by VF circuits over the multiplexer network. The bases are interconnected in a ‘multi drop’ circuit arrangement such that they form geographic regions. Users of the network can communicate to other users in the same geographic region and to the head-end systems at NMC and the electricity network control centres. Only one user may transmit in each geographic region at a time.

The Digital Mobile Radio Network consists of numerous sites, each with one or more (normally 3) 170MHz base stations providing coverage to the surrounding areas. The DMR network is connected using IP and more details can be found in Section 3.7.6.2. Details on the service performance can be found in Section 3.8.5.2

The country and metro Distribution Automation networks have a mixture of technologies. Historically these consisted of base stations connected via V.28 TDM channels. These stations had sometimes been connected in a multi-drop arrangement, aggregating them in a similar manner to analogue mobile radio. The most recent implementation includes IP bases which are connected to local routers participating in the CBD & DA OSPF/VRF network. See Section 3.7.6.1.

The AMI network is a meshed radio network and is described further in Section 3.8.4.

## 3.8 Services and Standard Requirements

The following Sections identify the most common services and requirements for telecommunications connections.

### 3.8.1 Teleprotection

Protection systems for the electricity network can sometimes require telecommunications to perform their function. There are several types of protection that can require telecommunications:

- Transmission Line protection including:
    - Pilot protection
    - Distance protection, for example: Permissive Overreach or Blocking
    - Digital Differential protection
- Intertrips, including circuit-breaker failure intertrips

These services are typically point-to-point services, with end-points defined by the Protection Engineer.

As per the technical rules clause 2.9.2, the main protection system must comprise of two fully independent schemes of differing principle. These schemes are typically called P1 and P2. This requirement is interpreted to require that the telecommunication system serving P1 must not share any common equipment or transmission medium with P2. This means that most transmission substations will have two multiplexers and at least two different high-speed, high-capacity bearers (fibre or microwave).

Most new transmission lines use digital differential protection for P1 and P2. This also applies to three-ended lines.

#### *3.8.1.1 Pilot Protection*

Pilot protection uses a pilot (copper) cable to transport a current or voltage, which represents the primary current measured by the protection system at one site, to the other end of the line. The receiving protection relay then compares the remote site’s primary current value to its own locally measured primary current. If there is a mismatch in current, then it is inferred that there is a fault on the transmission line and the relay trips the transmission line circuit breaker.

Some relays convert the primary current into a voltage. Historically where both P1 and P2 use pilot protection, diverse pilot cables are required unless one relay uses Voltage and the other uses Current. Then in the event of pilot cable failure whether open or short circuit, one relay will trip.

This type of protection is considered a legacy technology.

#### *3.8.1.2 Distance Protection*

Distance protection requires the local measurement of current and voltage by the protection relay. The relay then computes the equivalent impedance by dividing the voltage by the current. This impedance becomes reduced when there is a short circuit on the transmission line. Due to errors in the measurements, the relay is set in zones. Zone 1 usually is set to 80% of the transmission line impedance and is set to trip instantaneously when the measured impedance is lower than this limit. Zone 2 is usually set to 120% of the line impedance and is set with a delay of 300ms. This type of protection is called 'Time-stepped distance'. For faults within the first 80% of the line, this protection is faster than digital differential.

Using telecommunication, this delay can be reduced; This type of protection is called 'accelerated distance'. For example, in a Permissive Overreach scheme, if the relay at one site trips in zone 1, this signal can be sent to the remote end which 'permits' the relay to 'overreach' and trip for a Zone 2 fault instantaneously.

To achieve this scheme, the protection relays are typically configured with output contacts. These are energised by the 110V substation supply and connected to the inputs of a 'Teleprotection system' (TPS) device. This device converts the contact signal into another signal ready for transmission to the other site. This could be VF (e.g., over pilot cable or multiplexer), ITU-T V.28, ITU-T G.703, IEEE C37.94 or a proprietary signal for fibre. Where the TPS is connected to a TDM multiplexer, the circuit is provisioned 1 E0 (64kbit/s) of capacity. At the receiving end, the TPS converts the signal back to a contact to feed to the receiving relay.

See Figure 3 for typical connectivity.

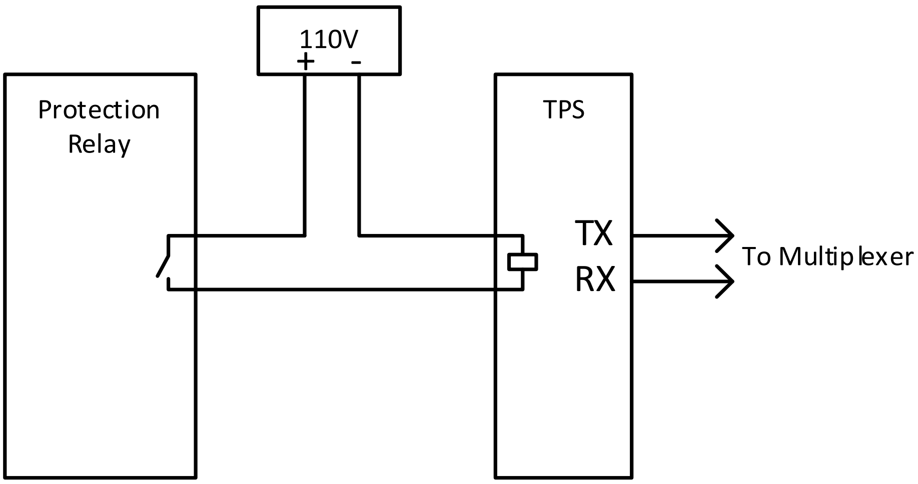


**Figure 3: Typical TPS connectivity**

By default, such an arrangement is simplex, so any return signals require their own cabling. Modern TPS units can accommodate a number of inputs, outputs and protocol interfaces.

For this protection scheme, latency is usually the most important communications parameter, typically requiring less than 10ms one way delay. The TPS is also configured with a number of parameters which trade-off latency and security of the signal, which are application specific.

New installations of distance protection are rare as digital differential is the current standard for P1 and P2.

#### *3.8.1.3 Digital differential protection*

In contrast to pilot protection, which is also a type of differential protection, in digital differential protection the relay converts the measured current from analogue into a digital signal. The relay prepares a frame usually based on a proprietary protocol. The interface to the relay is typically defined at physical layer, for example, ITU-T V.28, ITU-T G.703, or IEEE C37.94.

The relays communicate to each other to determine the channel latency and transfer current measurements to each other as well as statuses.

For this protection, there are several key requirements on the communications channel:

- Channel asymmetry: very low, on the order of microseconds
- Latency: very low, typically less than 10ms, ideally on the order of 4ms
- Jitter: very low

Because of these requirements, Digital differential protection has only been transported over the time-division multiplexed network (SDH and PDH) by Western Power, however in future the MPLS-TP network may be able to accommodate this traffic due to the specific capabilities of the Keymile OPIC2 C37.94 card.

In other cases, digital differential protection can be provisioned as a dark fibre solution. In this case the protection engineer should be consulted, so that the correct relay model can be ordered.

Digital differential is the current standard protection for P1 and P2 of transmission lines.

#### *3.8.1.4 Intertrips*

Intertrips are a standard requirement for most transmission substations, for example: requiring a remote-end circuit breaker to trip for a circuit breaker failure in a busbar fault scenario.

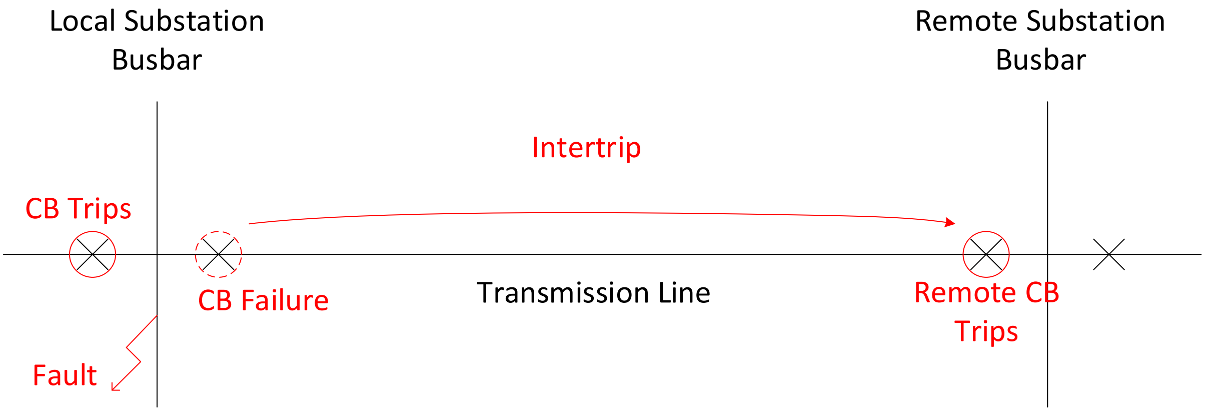


**Figure 4: Example of Circuit Breaker Failure scenario requiring an intertrip**

If distance protection is used with TPS, an additional command may be configured to provide the intertrip between the two sites.

Alternatively, if digital differential protection is used, the relays can be configured to share intertrip data over the differential channel. In this case, no additional telecoms infrastructure is required for the intertrip.

#### *3.8.1.5 N-Ended Line Protection*

Tee'd lines or 3-ended lines are relatively common in the Western Power network and have more complex protection requirements.

Where distance protection is applied to 3-ended lines, the protection engineer defines which signals are required to be transported between which ends of the line. This may be different for P1 and P2, as different protection methodologies may be applied.

Where differential protection is applied to 3-ended lines, the relays at each ends require a full mesh of connections. That is, each relay needs to communicate to the other two relays that are part of its scheme.

There are two main topologies of bearers which allow segregation of P1 and P2 circuits while minimising the number of bearers required, shown in Figure 5.

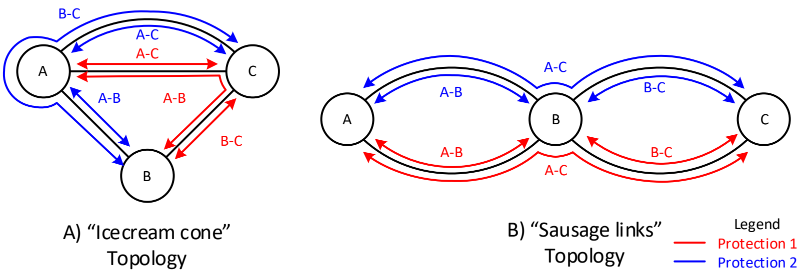


**Figure 5: 3-ended line protection topologies.**

The topologies can be modified if there are intermediate sites. One example is shown in Figure 6. This is worth considering when establishing a new site 'A', if site 'X' is already providing a diverse path between sites 'B' and 'C'. Only two new bearers would be required to establish site 'A' ('X-A' and 'A-C' in Figure 6) as opposed to three (2x 'A-C' and 'A-B' in Figure 5).

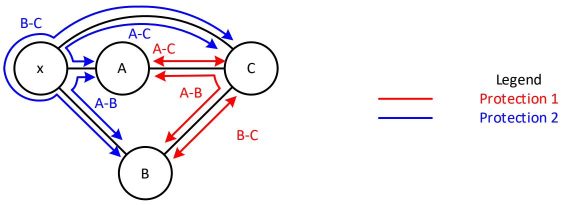


**Figure 6: Modified Ice-cream cone topology with an intermediate site**

For 4-ended lines, the number of viable topologies is increased. Some examples are shown in Figure 7. These can further be modified if there are intermediate sites.

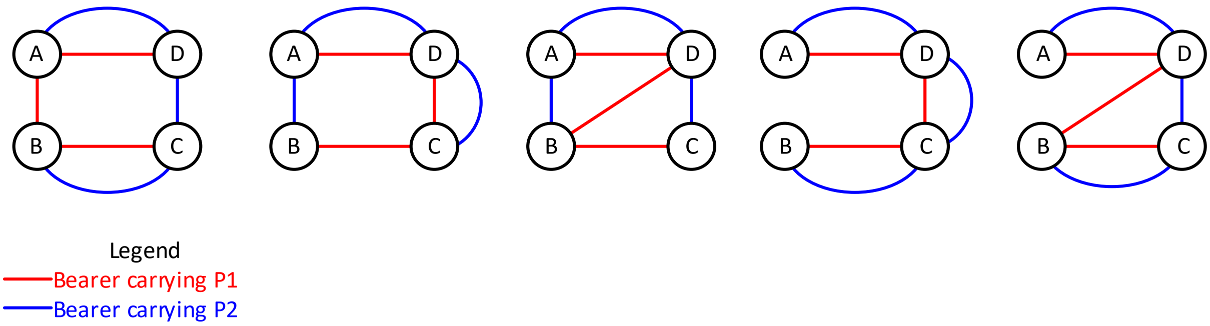


**Figure 7: Possible 4-ended line protection topologies.**

It is worth noting that as the number of line ends increases the minimum number of bearers required increases by 2. That is, a 2-ended line requires 2 bearers minimum, a 3-ended line requires 4 and a 4-ended line requires 6. Therefore, while the electrical network connection may be simpler, the communications topology becomes more complex.

The above topology methods are useful when considering design of bearers, however each multiplexer is unlikely to be connected to each bearer which can cause complications. Circuit diversity needs to be considered at the equipment level.

### 3.8.2 Automation

Automation, or SCADA, services are required for the remote monitoring and control of the electricity network. Automation services connect the head end systems, or 'Master stations' to the remote sites. Automation services are treated differently for Transmission and Distribution services.

#### *3.8.2.1 Transmission Automation*

Transmission Automation requires the connection of the transmission master station, also called the Energy Management System (EMS) to the Remote Terminal Unit (RTU) or Gateway (as defined in IEC 61850) at a transmission substation.

The EMS system is located in the SCADA Green Zone which is reachable through the Data Aggregation sites.

Historically, these services were provisioned using VF multidrop circuits. These were then transitioned to V.28 multidrop circuits transporting Harris and DNP3 protocols. New circuits are provisioned using DNP3/IP using MPLS-TP and Ethernet over PDH. All of these are still in use.

For VF and V.28 multidrop circuits, the topology in Figure 8 applies. Typically, each RTU has two circuits, but only one is shown in the figure. This figure also shows the alignment of ports at the data aggregation sites and the reservation of V.28 ports for future conversions from VF.

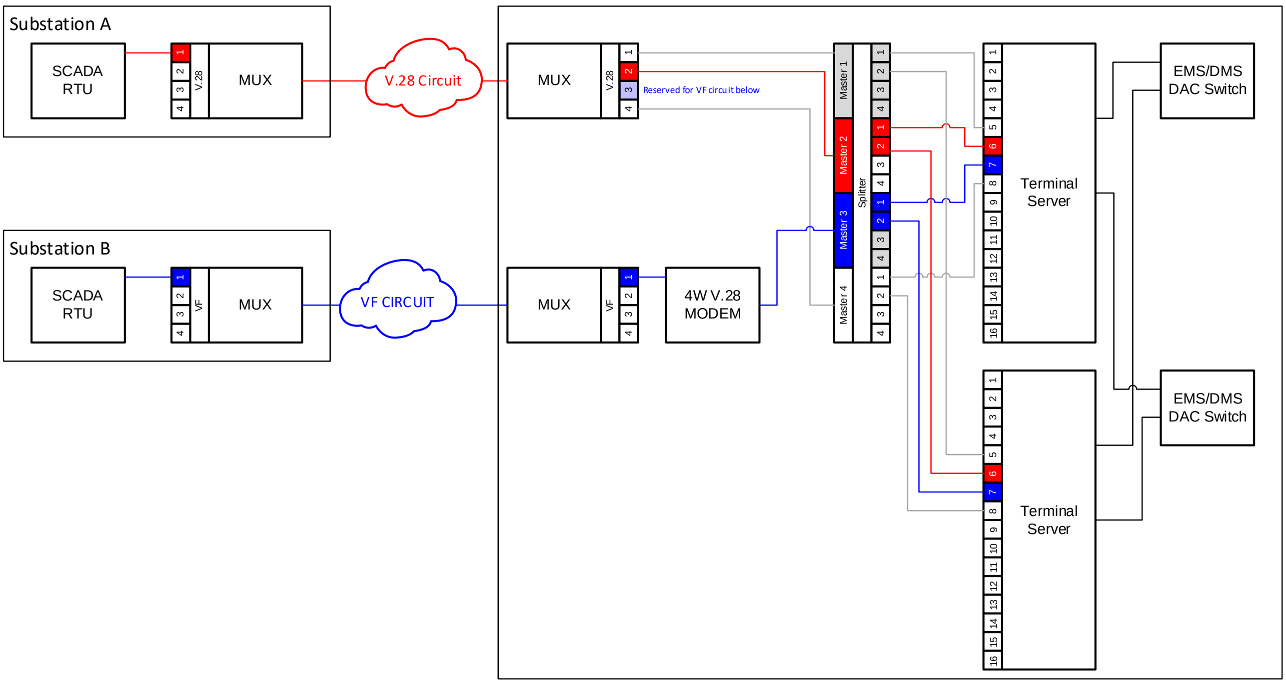


**Figure 8: SCADA VF & V.28 to EMS design**

For MPLS-TP circuits, the Topology in Figure 9 applies.

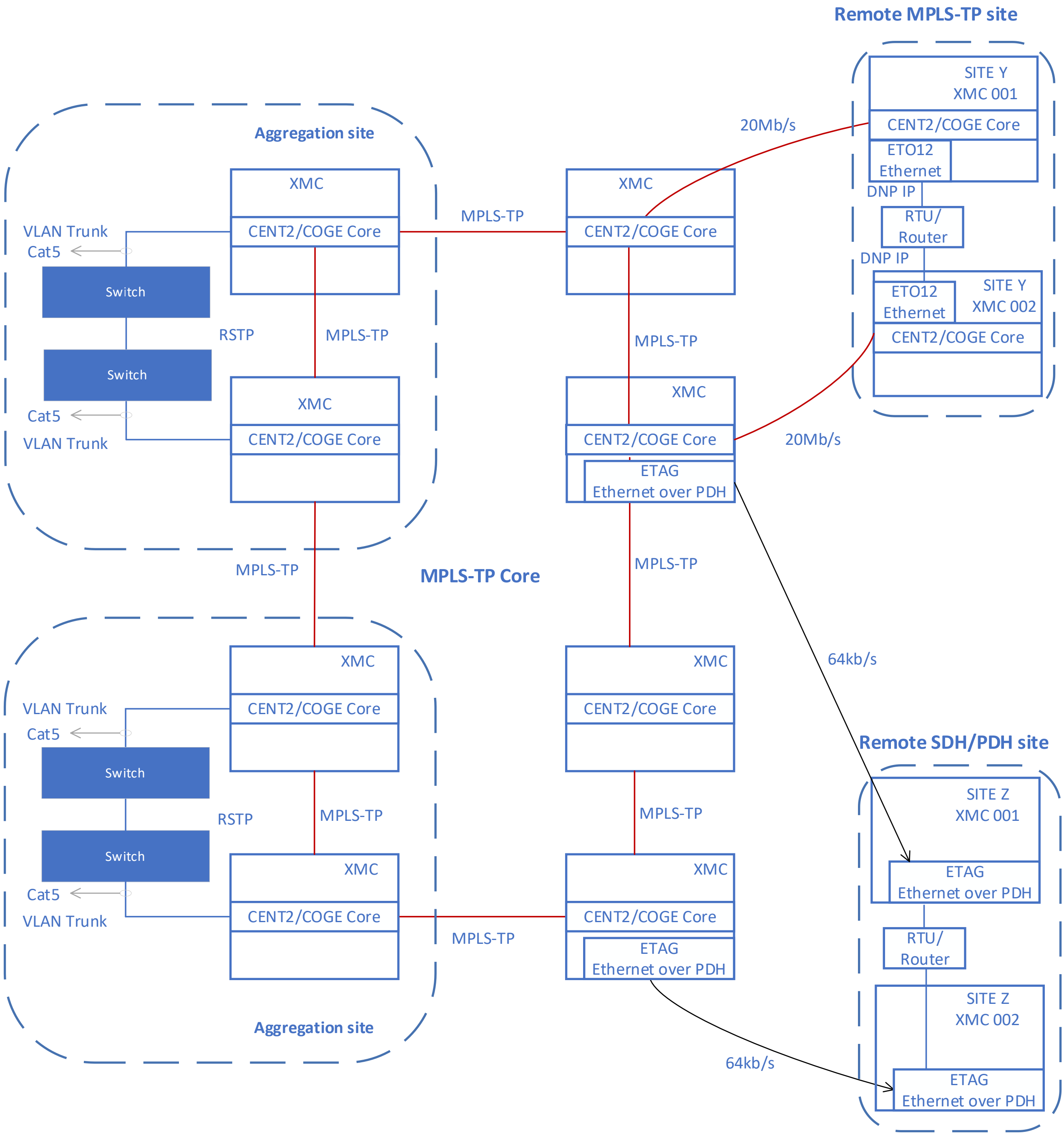


**Figure 9: SCADA IP to EMS MPLS-TP design**

### 3.8.2.2 *Distribution Automation*

Distribution Automation requires the connection of the distribution master station, also called the Distribution Management System (DMS) to devices spread through the distribution network. These devices can be Automated Reclosers and Ring Main Units (RMUs). Due to the greater number of these devices and the geographical spread, the last mile connectivity of these devices typically uses Point-to-Multipoint UHF or VHF radio.

One exception to this is within the Perth CBD (and applied ad-hoc within the broader distribution network), where the increased reliability requirements and density of end-points justifies the use of fibre to connect the distribution devices in redundant rings. The CBD fibre network has experienced a number of generations of technology, most recently OSPF and VRF-lite IP networking. See Section 3.7.6.1.

Like the EMS, the DMS is located in the SCADA Green Zone which is reachable through the Data Aggregation sites.

### 3.8.3 Network Reinforcement Schemes (NRS)

Network Reinforcement Schemes (NRS) are automation schemes which operate on the transmission network. These schemes are typically designed to allow the connection of transmission customers, while deferring reinforcement of the electrical network. They monitor the electrical network, such as the loading on a transformer or line, and take some action when a threshold is reached, such as sending a runback signal to a generator. These schemes can be complex and can require measurements and statuses from many transmission substations.

Historically, these types of schemes were called Special Protection Schemes and utilised TPS in a similar fashion to distance protection (See Section 3.8.1.2). In modern implementations, these schemes utilise protocols from IEC 61850: GOOSE or MMS.

The telecommunication scope for these schemes is usually to provide Ethernet connectivity between duplicated Automation switches at each site to support the transport of GOOSE or MMS. These Ethernet services are usually provisioned as point-to-point services connecting Automation Routers in a duplicated ring and given capacity of 2 Mbit/s. The typical topology is shown in Figure 10. Care must be taken to ensure that the telecommunication devices do not participate in the switching of these services as the Automation switches can run layer 2 protocols such as RSTP.

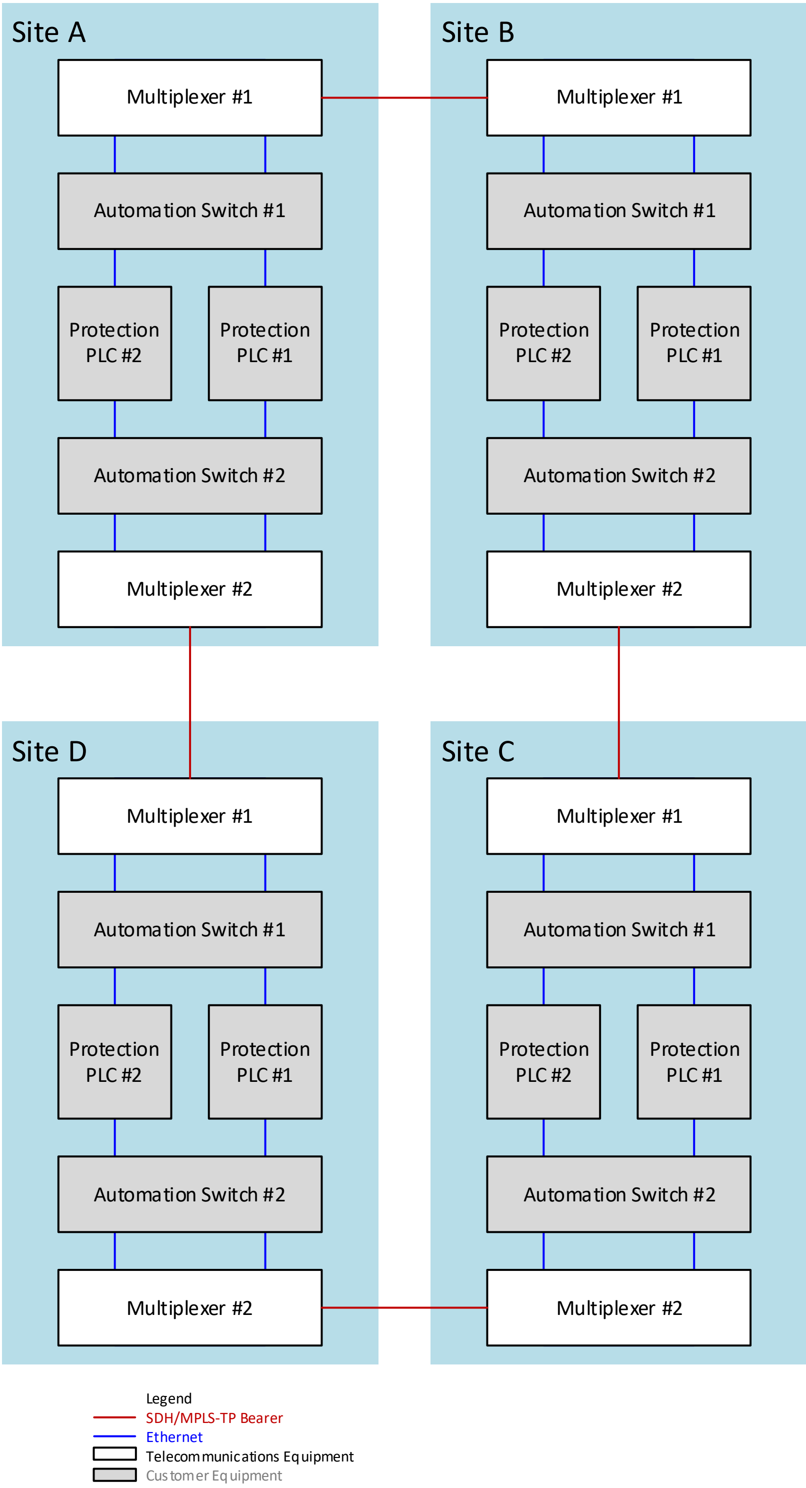


**Figure 10: Typical NRS Topology (Comms)**

### 3.8.4 Advanced Metering Infrastructure (AMI)

AMI refers to the remote reading of smart meters installed at residential low voltage connection points. Enabled meters have a 900MHz mesh radio Network Interface Controller (NIC) installed. The meters are able to connect to each other forming a meshed network. Other devices which connect to this network are relays (not to be confused with protection relays) and access points. Relays are generally installed at height and serve to extend the mesh radio to otherwise unreachable meters. Relays may also have a battery backup to improve the resilience of the mesh network to power outages.

Access points collect the data from the meters and forward it to the backhaul network. Two backhaul options are in use: Cellular and SEAL. Cellular access points are typically installed in the distribution network and utilise 3rd party provided cellular connectivity back to the head end systems. SEAL connected access points are provisioned a VLAN to provide similar connectivity. The head end systems are managed by others within Western Power. Telecommunications is responsible for the access points and relays, and the SEAL backhaul network.

### 3.8.5 Operational Voice

Western Power's telecommunication network carries two main operational voice systems: telephony and mobile radio.

#### *3.8.5.1 Telephony*

Most transmission substation relay rooms have a telephone connected to Western Power's Private Automatic Exchange (PAX) system. Historically, these systems connected to physical exchanges located at various Terminal substations in the network, using PDH circuits. These circuits connected using 2 wire interfaces to phone handsets in the substation.

New implementations use Voice Over Internet Protocol (VoIP) connectivity to an IP enabled telephone. These connections are provisioned on the SEAL switch and utilise Power Over Ethernet (PoE) to power the telephone. The historical PDH circuits still exist and terminate onto VoIP Gateway cards in the Keymile XMC Multiplexers which connect to the TON. These VOIP1 cards are provisioned as a redundant pair in the multiplexer.

The SEAL network connects into the TON at the Data Aggregation to the TON Cisco Unified Communications Manager (CUCM) which manages telephony devices in the field network. The TON CUCM is linked to a counterpart in the Corporate network using Cisco Unified Binding Elements (CUBEs)

Most sites require a single voice channel, which is usually provisioned using the VoIP system above. Where a second independent voice channel is required, this is typically provisioned using a fixed mobile service connected to a commercial telecommunication provider's network.

#### *3.8.5.2 Mobile Radio*

Mobile radio provides field crews with a reliable alternative to commercial telecommunications for operation communications.

The Western Power network has approximately 80% coverage of analogue mobile radio, provisioned from 80MHz Spectra radio base stations. These radios are installed with a VF router (Bitlab) which is able to extract radio alarms from the base station. The routers in a geographic area are connected in VF multidrop circuits. A user transmitting to a base station will have their message repeated out to all users connected to bases in the same geographic region. The multidrop circuits also extend to NMC and Western Power's electricity network control centres and user's messages will be transmitted to these locations as well.

This system is being replaced by a Tier III Digital Mobile Radio solution. This system is provisioned from 170MHz Motorola radio base stations. These stations use FSK and TDMA to provide two over-the-air channels. The bases coordinate and one of them provides a control channel which serves the other co-located bases. Remote radios register via the control channel and receive coordination instructions such that multiple remotes can transmit at the same time. Users can participate in ‘talk-groups’ which are virtual channels, or make calls to specific remotes, or send text messages to specific remotes.

#### 3.8.6 Third Party Services

Western Power provides dark fibre services to a few third parties as well as legacy managed services over the SEAL network. For new requests, dark fibre services are preferred, as a framework for managed services is to be developed.

#### 3.8.7 Network Management Services

Network management services are critical to ensuring the continued availability of the telecommunications network. The structure of network management services is shown in Figure 11.

Each network element is required to have remote monitoring and management capability as per the ‘Network Strategy – SCADA and Telecommunications’. This service is transported by one or more of the networks described in Section 3.7 to the Field facing firewall in the Field DMZ. For most network elements this is the SEAL network, with the exceptions being recorded in Section 3.7.6.

The NMS service traverses the Field DMZ via the Field Delivery Zone and arrives at the Network Management System (NMS). This system is typically software running on a virtual machine on a server within the Green Zone. Some types of equipment have a vendor-specific NMS e.g., FOXMAN, SO-EM. Where the equipment does not have a vendor-specific NMS, the traffic is forwarded instead to the OSS.

Western Power’s OSS is CNMS-NG with ConnectMaster being the repository for inventory data. To translate data from the field devices and the vendor-specific NMS, CNMS-NG employs device drivers hosted on mediation servers in the Green Zone. To enrich the alarm information, CNMS-NG also draws on data from ConnectMaster. The operators interact with CNMS-NG to monitor and address alarms and access the NMS to provision services and access device configurations.

Where a device does not have a vendor-specific NMS, the device is configured to forward SNMP traffic to device drivers hosted on mediation servers in the Field Delivery Zone.

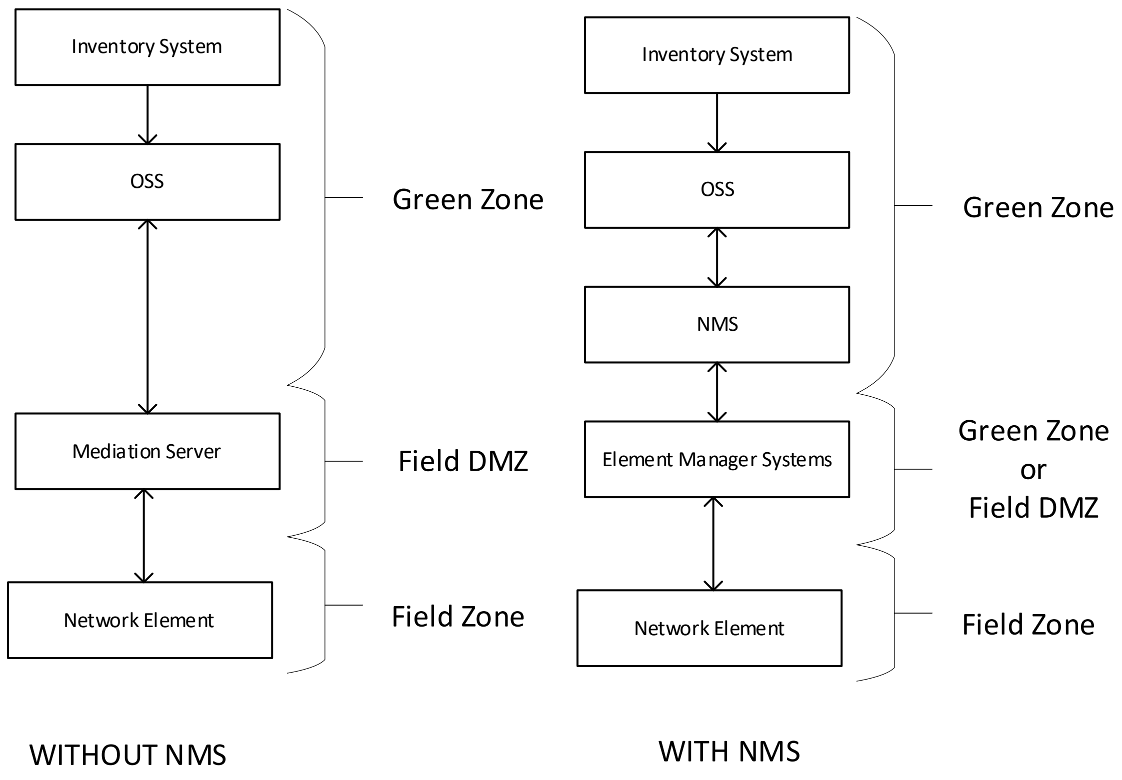


**Figure 11: Architecture overview of a typical Network Management Service. Arrows indicate direction of data flow.**

Some legacy devices and some monitoring equipment do not provide a protocol for network management (such as SNMP). Instead, they may provide physical contacts for alarming. Some common examples of this are equipment shelter PLC alarms (door alarm, air-conditioner fail alarms) at telecommunication sites, and Rack Distribution Panel (RDP) circuit breaker trip alarms. In these cases, Western Power deploys a SNMP capable RTU to capture the hardwired alarms. The RTU then forward the data through the SEAL network toward the TON.

In these cases, remote management by operators may be carried out by the use of Crossbow.

When provisioning a new network element, typically only IP address allocation and connection to the NMS Transport Network is required. See Sections 3.7.6 for exceptions.

Additional TON services are provisioned using the same communication channel – these include authentication, logging, domain name services, and network timing. These services originate in the Field DMZ.

# Appendices