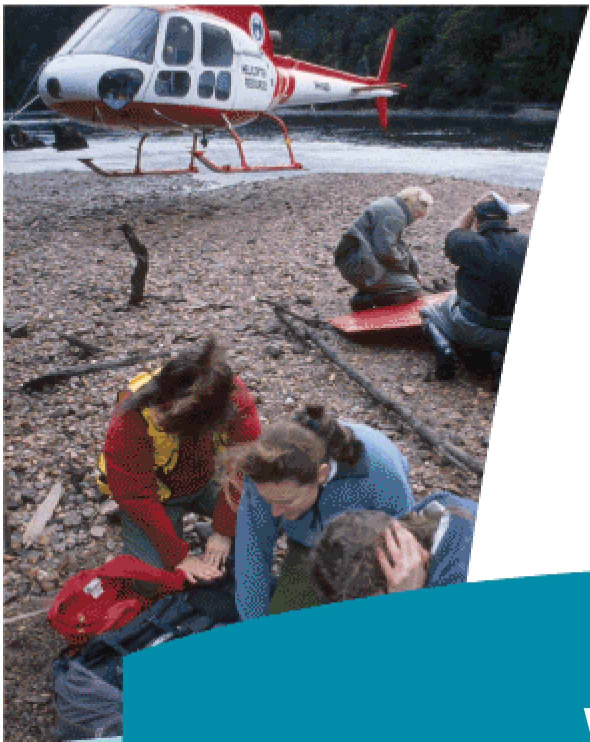
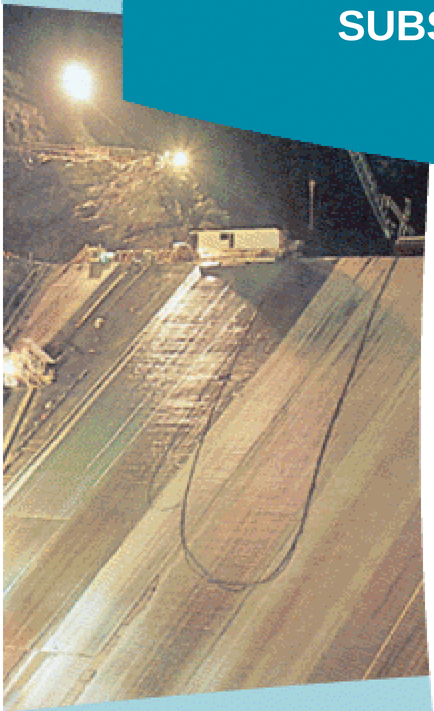
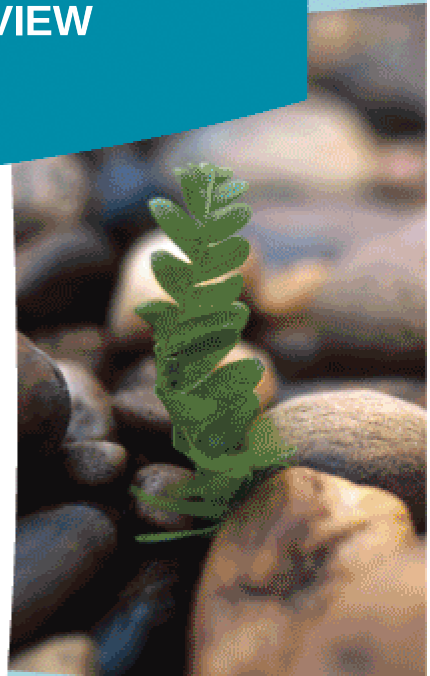


Hydro Tasmania Consulting

# WESTERN POWER
# SUBSTATION DESIGN STANDARD REVIEW





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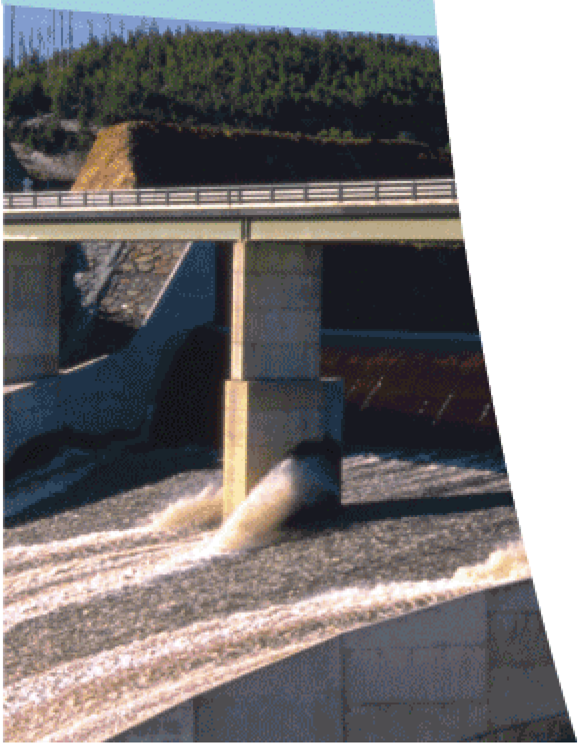


Prepared by
**Hydro-Electric Corporation**
ARBN: 072 377 158
ABN 48 072 377 158
4 Elizabeth Street, Hobart
Tasmania, Australia


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| | **A Millers** | **[PEG]** | Sign | | Date | 22-8-2008 |
| | **Roger Hughes** | **[HAMP]** | Sign | | Date | 22-8-2008 |
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# EXECUTIVE SUMMARY

Hydro Tasmania Consulting was engaged by Western Power to undertake a high-level review of a set of documents that it had prepared to standardise and document its current approach to substation design. The documents cover:

- Western Power's Transmission Standard Designs Policies,
- Functional and conceptual requirements for 132/22 kV Zone Substations and 330/132 kV Terminal Yards,
- 132 kV Underground Cable Circuits

The review covered three key areas; Primary, Secondary and Civil design. Comments on detailed aspects for each of these disciplines are included in Section 3 of this report. These comments are intended to improve document readability and cross-referencing, and amend minor errors.

In general the review found that Western Power's approach is considered, well documented, and based on philosophies, design parameters and methodologies consistent with, and currently being implemented by other utilities in Australia.

It was noted, however, that the documentation provided does not include the underlying technical reasoning behind some of the requirements or methodology in the documentation. As this documentation is intended to be a knowledge capture, it is recommended that the design reasoning also be documented as an aid to those undertaking future design revisions. A good example of such a document is Western Power's "HV Extruded Cables Design and Installation Guide".

It is understood that Western Power is currently undertaking a project to review its future substation requirements. These documents provide an excellent starting point for such a review, which can include consideration of alternative technologies to Air Insulated Substations (AIS) such as Gas Insulated Switchgear (GIS) and Mixed Technology Switchgear (MTS).

The review process was necessarily at a high level but Hydro Tasmania Consulting is able to provide additional assistance in specific areas, including consideration of future technologies, if this is required.

# CONTENTS

# 1. INTRODUCTION

Western Power has completed a review project to standardise its current designs to address inefficiencies and inconsistencies across the design function. Hydro Tasmania Consulting was engaged by Western Power to review these standards for the following three key areas:

- Electrical Primary Design
- Substation Electrical Secondary Design
- Civil Structural Design

# 2. PROJECT SCOPE

The scope for the project was:

- To obtain all documentation and drawings to facilitate an initial review and identify opportunities for potential improvement or clarifications, along with any suggested fine detail modifications

- For the three discipline leaders from Hydro Tasmania Consulting to meet with Western Power Representatives to discuss the output from the first stage and any other broader issues that require resolution

- To complete the review report and dispatch this at least two weeks ahead of a presentation at Western Power.

Hydro Tasmania Consulting was advised at the meeting held at Western Power that the documents to be reviewed were prepared as a knowledge capture exercise. The purpose was to document the basis of design and the designer's intent that had been involved in preparation of the standard:

- 132/22 kV Zone Substation design;

- 330/132 kV Zone Substation design; and

- Cable Installation design.

The documents have been reviewed on this basis.

# 3. DOCUMENT REVIEW

The documentation supplied has been reviewed for consistency and technical content. The functional and scope documents for the zone and terminal substations and cable design has been edited using Microsoft Word's Track Changes feature to simplify the capture of editorial changes.

The review has been carried out taking into account Western Power's draft Transmission Standard Designs Part 1 - Policies.

Each of the document parts were reviewed for clarity and from a high technical overview perspective. The following is commentary on the three disciplines to be addressed: Primary, Secondary, and Civil Design.

## 3.1 Primary Design

### 3.1.1 General

Review of the supplied documentation reveals that Western Power has adopted a specific approach in designing its 330 kV and 132 kV networks and that the standard designs provided have been developed to facilitate this approach.

The documents provide a good overview of Western Power's approach for the substations but, from a newcomer's perspective, an explanation and examples of how they fit into the system would assist in understanding how the substations enable the system development philosophy.

The following are general comments for improving the documents:

- There is an inconsistency in the use of the words "shall", "should", "will", and "would". This should be reviewed to ensure those items that are mandatory are clearly and consistently identified.

- In a number of places generic or non-specific terms are used that to convey the idea that best performance is required but do not define what that ultimate is, eg use of the terms "optimum impact", "optimise the operation of the substation", "minimum impact", greater than, etc. This may be acceptable for internal use of the documents but would nevertheless aid interpretation if these concepts were clarified.

- In numerous places references are made to other documentation, such as "DMS Reference No. 347636v2". It is recommended that that the version number be removed so that it reads "DMS Reference No. 347636" because the document will need to be updated every time the referenced document is altered. This additional step is likely to be omitted in practice and could cause confusion or serious error. A general statement should be included indicating that "the latest version of referenced documents shall be used". The referenced documents should also include a cross-reference advising the editor to review other documents to ensure any changes are properly captured and addressed.

- Consideration should be given to standardising the introduction to each document part. This could be achieved by having the first four sections the same, or combined under one main heading with sub headings.

- Abbreviations used in the document should be clearly stated at the beginning of each document part. In some cases within the document there is a mixture of abbreviations with the full description.

### 3.1.2 Electrical Clearances

The electrical clearances adopted by Western Power are in accordance with the current AS 2067 but should be reviewed when the new edition of AS 2067 – High Voltage Substations is released (third quarter of 2008).

It is noted that the table supplied does not require provision for additional phase-earth and phase-phase clearance for birds and vermin at voltages up to 22 kV, as is typical for some authorities.

Some authorities specify minimum clearances that vary from those in AS 2067. For example, one authority has adopted the following values:

| Voltage (kV) | Phase-Earth Clearance (mm) | Phase-Phase Clearance (mm) |
|---|---|---|
| 22 | 280 | 450 |
| 66 | 690 | 800 |
| 220 | 2,300 | 2,650 |
| 330 | 2,850 | 3,300 |

### 3.1.3 Electromagnetic Fields

As a general comment it should be noted that the ARPANSA recommendations for allowable electric and magnetic field exposure have not yet been finalised. However, it is strongly recommended that EMFs are minimised at the substation boundary as far as is practical. Recently a local council stipulated that the maximum level they would accept is 2 mG, a level that is extremely difficult to achieve in practice. For this reason, power transformers and reactors should be located near the centre of the substation to minimise the boundary magnetic field.

### 3.1.4 Critical Infrastructure

Authorities in some states are reviewing security at their critical infrastructure such as substations and are applying differing security measures, depending on the accessibility of the site and its importance.

The documentation provided indicates that varying standards of security are applied, but does not refer to risks of terrorist attack. There are simple security measures that can be adopted, such as introducing a tight bend in access roads near the substation so that vehicle speed is controlled to minimise the risk of "ram-raids" being successful.

Cigré Technical Brochure 253, "Substation Physical Security Trends", was released in 2004 following an international survey and provides data on security strategies adopted by authorities in different countries.

### 3.1.5 Functional Specifications 132/22 kV Zone Substations

An edited electronic version of the supplied document is included with this report. The following comments relate to key issues identified in the document:

**Section 4. Definitions**

- The definition for *Transformer Maximum Continuous Rating* should identify that it is applicable "in the Rated Physical Environment".

**Section 6. Substation Electrical Specifications**

- The reference to "*Extended Service Environment*" should refer to "*Extended Physical Environment*".

**Section 6.3, Figure 1: Zone Substation Single Line Diagram**

- Surge arresters are not shown on the 132 kV line entrances (they are shown on drawing SS1/30/5/500/1).

**Section 6.5.1 General**

- NCR is referenced here – it should be defined as Normal Cyclic Rating at its first occurrence.

**Section 6.7 Reliability**

- The term “Outage Rate” should be defined at the beginning of this section.

**Section 6.12 Substation Lightning and Earth Potential Rise Protection**

Should include statements re:

- Whether or not the earthing system is to be a stand-alone system – ie whether or not it must meet the required performance without assistance from external earthing via cable screens, overhead earth wires, etc.

- The limits of surface voltage rise outside the substation during an earth fault – eg it may be a requirement to contain the 1000 V surface voltage contour within the substation site security fence.

- Whether or not the earth grid is permitted to extend beneath and/or include connection to the security fence.

**Section 7.1 Substation Site**

- Reference should be made to whether or not provision is to be made for crane access, lighting, and fencing (both perimeter and security).

**Section 7.2 Substation Site Selection**

- **Adverse Conditions** – “*resistance*” should be “*resistivity*”

- **Vehicular traffic** – Comment could be added re prevention of ram-raids and whether or not vehicle barriers, etc are required or permitted within the substation.

- **Landscaping** – it may not be practical to meet community expectations: eg there may be a requirement to build it underground so that it is not visible. This wording may require further definition.

**Section 7.4 Substation Building**

- The BCA does not specifically cover substation buildings and this should be addressed in this section.

**Section 7.4.1 Switchrooms and Relay/Control Room**

- Footnote 14 should be corrected to read "… does not have any direct means of access to another area".

**Section 8.2 c) Life Cycle Costs**

- This could include reference to selecting MV/EHV power cable cross-sectional area such that the capitalised value of losses and the cable cost are minimised over the cable life (the capitalised value of transformer load loss can be used to establish this).

**Section 8.6 Environmental Compliance**

- **Dust** – add to end of first sentence "… and contamination to substation insulation."

- **Services and Auxiliaries Interfaces** – ensuring that step and touch potential rises and electromagnetic fields, etc are managed on site and not transferred off-site is not practical. Limits of EMF and the allowable surface and transfer voltages at the substation boundary during faults should be nominated. Reference may be made to ARPANSA requirements for EMFs when these are finalised (currently under consideration).

### 3.1.6 Functional Specifications 330/132 kV Terminal Yards

Similar comments to those made in the previous section also relate to the Functional Specifications 330/132 kV Terminal Yards document.

### 3.1.7 Functional Specifications 132 kV UG Cable Circuits

This document covers the requirements for a cable installation in a clear and concise manner. A few comments are included below:

**Section 6.2.5 Communications and cable Monitoring Facilities**

- Requirements for the distributed temperature system monitoring equipment are not identified.

**Section 8.6 Environmental Compliance**

- The adoption of 4 mG as the upper limit of magnetic field is consistent with the levels being adopted internationally (refer comment in Section 3.1.3 above).

### 3.1.8 HV Extruded Cable Design & Installation Guide

The document provides a good and comprehensive overview of the principles that underlie a cable installation design. The reasons behind preferred installation methods, such as flat spacing vs trefoil arrangements, are documented and provide a solid background for future design modifications.

### 3.1.9 Concept Design 132/22 kV Zone Substations

An edited electronic version of the supplied document is included with this report. The following comments relate to key issues identified in the document:

**Section 4 References and Standards.**

- If the concept design document is issued to external parties for implementation then it is recommended that a statement be included to the effect that a proposed list of alternative standards be submitted to Western Power for acceptance/approval.

**Section 5.1 Introduction.**

- **Substation Buildings** – There is no reference to the required Earth Stick Building

- **Site Works** – It is recommended that a distinction be made between the site security fence and the site perimeter fence (assuming one is required). The R&M building is not defined.

**Section 5.2.2 Standard Dimensions and Minimum Electrical Clearances**

- The Standard Dimensions table refers to “height above foundation”. It is unclear if this is intended to refer to “height above switchyard finished level (ie surface level)” as this may be more appropriate.

- It is suggested that Appendix 3A be reserved for the Single Line Diagram as this is the key drawing for the substation and that Appendices 3B and 3C be for the Switchyard Layout Drawings.

**Section 6.1.1 General Description**

- Some sections of AS 2374 are now replaced by AS 60076.1 and AS 60067.4

**Section 6.1.2 Size and Ratings**

- In the second sentence the phasing and connections when viewed from the transformer HV side should be reviewed.

**Section 6.1.3 Design Basis**

- The table of transformer dimensions does not clearly state whether or not the dimensions include the coolers.
- If the document is issued to others, permission should first be sought from Wilson and EBG for the data to be circulated.

**Section 6.4 Combined CT/VTs**

- Some authorities refer to these as CVCTs (Combined Voltage and Current Transformers).

**Section 6.6.2 Size and Ratings**

- "The surge arresters will be of the metal-oxide gapless type and comply with AS 1307.2, with a nominal discharge current of 10kA and line discharge Class 3. Further detail are contained in the table below:" should be replaced with "The surge arresters will be of the metal-oxide gapless type and comply with AS 1307.2 and the table below:" to eliminate duplication of data.

**Section 6.7.2 Design Basis** (Lightning Protection)

- It is noted that lightning masts may be used to mount light fittings. Is there any evidence of lightning strikes to masts causing damage to lighting cabling?

**Section 6.9.3 Design Basis** (Busbars and Connections)

- The sentence below the table refers to "The above maximum span" but there is no other reference to this span.

**Section 6.12.1 General Description** (22 kV Capacitor Bank Feeders)

- Some of the data provided is repeated in Section 6.12.2.

**Section 6.14.1 General Description** (Substation Services Transformers)

- Reference to "off load" tap changer should be "off circuit".

**Section 6.17 Substation Earthing System**

- Drawing SSTTT/3/4/1 shows an internal and external grading ring at the security fence. It is possible that the internal grading ring may not be required and comment should be made that this should be reviewed. Note that, to reduce the risk of inadvertent voltage transfer, in some jurisdictions it is not permissible to connect the security fence to the earth grid. In this case the grid must lie totally within and no closer than 2 metres from the security fence.

- The document could note that the forthcoming ENA Earthing Guide, which provides for a probabilistic earthing design approach, is due to be released in the near future. The document should state whether a probabilistic approach is acceptable.

- It should be stated whether or not the resistivity of the surface layer (eg crushed rock) is permitted to be taken into account when calculating allowable step and touch voltage levels. This is allowed for in the ENA Earthing Guide but is not permitted by some authorities. The minimum, thickness and resistivity of this layer should be specified (eg 100 mm, 3,000 Ωm).

- It should be stated that it is mandatory for the earth grid to be tested by the current injection method (it is not clear if this is a requirement in Section 6.17.3, which refers to standard DMS No. 1326076.

- In Section 6.17.4 it is not clear if the portable earthing systems have been tested. It is recommended that each assembly be tested as they are safety devices. A note should be included to ensure that, if the standard design is modified, the revised assembly must be re-tested for the design fault level.

### 3.1.10 Concept Design 330/132 kV Terminal Yards

Similar comments to those made in the previous section also relate to the Concept Design for the 330/132 kV Terminal Yards document.

## 3.2 Secondary Design

### 3.2.1 General

It was noted that inconsistent terms are used throughout the document; it is recommended that standard terms be adopted.

The report uses expressions such as “sufficient electronic storage”, “serial communication capability”, “etc”. These types of statements should be avoided or reference should be made to a current standard document which contains Western Power’s current equipment requirements.

To provide better clarity of Western Power’s methods, additional information could be included in certain areas. References to DMS documents where more information is available may be sufficient. Because DMS documents were not provided, as they were not part of this scope, it is not clear what information is contained in these documents and how these documents complement the reviewed documents.

It may be useful to the reader if the DMS documents listed in the appendix are grouped in their respective disciplines.

As the document is intended to capture knowledge, there would be benefit in adding historical information on why certain methodology is adopted within Western Power’s network. This would help young engineers and new engineers gain a better understanding of how and why Western Power has taken this approach.

Microprocessor relays currently on the market need to be configured; there is no mention in the Functional Specification or Concept Design documents on Western Power’s requirements for standardisation, e.g. inputs, outputs, etc.

Reference is made to “local SCADA System”; for clarity and less confusion, the term Substation Control System (SCS) is recommended.

It is recommended that the term “modern” be deleted.

### 3.2.2 Functional Specification 330 / 132kV Terminal Yards

**Section 6.14 Terminal yard Auxiliary Supplies (AC/DC)**

- The reference made to the 50V DC supply should state the source of the supply i.e. from the 50V battery bank.

- The DC battery capacity in hours stated for the terminal yard when loss of AC supply occurs seems high. Microprocessor protective relays consume much more power than the earlier protective relays; therefore higher DC battery capacity would require a larger DC battery bank. Generally, battery banks are rated for 12 hours. If Western Power has remote terminal yards that are not accessible within 12 hours then a higher capacity battery would be required. Additionally this section should indicate the battery capacity necessary to operate equipment for a specified time that meets Western Power requirements.

### 3.2.3 Concept Design - 330 / 132kV Terminal Yards

**Section 5.2.4 Building Design Features**

- -48V DC communication batteries are not mentioned and it is assumed they will be located in the communication hut.

**Section 6.11.3 Design Basis**

- This text needs to be corrected to meet requirements for the 132kV system. The current text makes reference to 22kV.

**Section 7.1 Protection system**

- The term “duplicate” is used with reference to protection under option (a) Protection 1 - Interlocked Current Differential and Protection 2 – interlocked Distance / IDMT Earth Fault schemes. This is not a duplicated scheme.

- The statement “The design shall be modular and flexible allowing easy testing and isolation facilities.” should include more information on how Western Power lays out their cubicles, or refer to a template (or DMS). Each power utility has a defined panel layout based on their testing and isolation methods.

- The statement "if mounted in the same cubicle, be separated vertically by a suitable insulating material" should be accompanied with stated minimum requirements for insulation between Protection 1 and Protection 2, or refer to a reference document.

- The statement "Separate supervision relays shall be used when relays with self-diagnostic features are not used" does not make clear what supervision is required, for example "trip circuit supervision, loss of DC supply, etc.

**Section 7.1.1 330kV Line protection**

- The term "speed requirements" is an undefined term, it would be better to use the term "fault clearance time requirement".

**Section 7.1.4 330 kV/132 kV Transformer Protection**

- The table shown below the statement "The complete scheme will consist of duplicated fully independent and discriminative protections." lists Protection 1 and Protection 2 required protection functions. The protection functions are not duplicated; however there is redundancy between the two sets of protection.

**Section 7.1.5 132 kV Capacitor bank Protection**

- The protection function listed does not provide protection from overvoltage across the capacitors. It is recommended that a protection relay designed for capacitor banks be considered.

**Section 7.1.6 22/0.415 kV Station Transformer Protection**

- This section should be reviewed by Western Power for clarity.

**Section 7.1.12 Metering Information & Indication**

- No mention of CT or VT requirements for revenue metering. Meters for revenue metering are placed on separate CT cores that meet the required CT class for revenue metering.

**Section 7.1.13 Fault Recorder**

- The term "*investigation section*" is used and it is not clear if this is a Western Power group or comes under Protection and Control. If there are standards available on determining where fault recorders are placed, then reference should be made to this document.

**Section 7.2.1 Communication Requirements – Protection**

- The Statement “Duplicated digital differential protection on a three-ended line may require a third physically diverse bearer path between two of the three sites.” should include reference to the section that determines if a third bearer path is required or reference to a Western Power standard for guidance.

**Section 7.3 SCADA System**

- Reference is made to 48V DC; this should be changed to 50V DC to maintain consistency throughout the document.

**Section 7.3.1 Remote Terminal Unit (RTU)**

- This section should refer to a standard document where Western Power outlines its current RTU requirements e.g. number of spare DI, DO & AI that is required and what communication protocols are required on the RTU.

**Section 7.3.7 Human Machine Interface (HMI)**

- The HMI supply is referred to as 48V DC and should be changed to 50V DC to maintain consistency.

**Section 7.3.8 Power Supply**

- The RTU supply is referred to as 48V DC and should be changed to 50V DC to maintain consistency.

**Section 8.2 DC Auxiliary Power Supply System**

- Refer to comment under Section 6.14 regarding battery capacity.

### 3.2.4 Functional Specification 132 / 22kV Zone Substations

**Section 6.13 Substation Auxiliary Supplies (AC/DC)**

- Additional information should be added to indicate what needs to be operated at the specified time after loss of AC supply.

**Section 6.9.2 Control**

- Little information is given on the philosophy of how Western Power parallels its transformers. If a DMS document for this is available then reference to it should be included.

### 3.2.5 Concept Design - 132 / 22kV Zone Substations

**Section 7.1 Protection system**

- The term "duplicate" is used with reference to protection, under option (a) Protection 1 - Interlocked Current Differential and Protection 2 – interlocked Distance / IDMT Earth Fault schemes. This is not a duplicated scheme.

- The statement "The design shall be modular and flexible allowing easy testing and isolation facilities." should include more information on how Western Power lays out their cubicles, or refer to a template (or DMS). Each power utility has a defined panel layout based on its testing and isolation methods.

- The statement "if mounted in the same cubicle, be separated vertically by a suitable insulating material" Should be accompanied with stated minimum requirements for insulation between Protection 1 and Protection 2 or refer to a reference document.

- The statement "Separate supervision relays shall be used when relays with self-diagnostic features are not used" does not make clear what supervision is required e.g. "trip circuit supervision, loss of DC supply, etc.

**Section 7.1.1 132kV Line protection**

- The term "speed requirements" is an undefined term, it would be better to use the term "fault clearance time requirement".

**Section 7.1.2 132 kV / 22 kV Transformer Protection**

- The table shown below the statement "The complete scheme will consist of duplicated fully independent and discriminative protections." lists Protection 1 and Protection 2 required protection functions. The protection functions are not duplicated; however there is redundancy between the two sets of protection.

**Section 7.1.3 under Voltage Load Shedding**

- Resetting of lockout trip relays remotely should be avoided. Lockout trip relays are reset once the faulted equipment has been inspected and cleared for service.

**Section 7.1.4 22 kV Circuit Protection - General**

- The statement "The transformer LV overcurrent and LV earth fault protection shall provide backup protection" does not make clear what it is backing up .e.g. feeder protection.

- The statement "When the transformer protection cannot provide adequate sensitivity, a low impedance bus zone relay capable of measuring individual circuit currents shall provide backup protection:" does not make clear if it is referring to the 22kV switchgear busbar protection.

**Section 7.1.6 22 kV Capacitor bank Protection**

- The protection function listed does not provide protection from overvoltage across the capacitors. It is recommended that a protection relay designed for capacitor banks be considered.

**Section 7.1.12 Metering Information & Indication**

- Meters for revenue metering are placed on separate CT cores.

**Section 7.1.13 Fault Recorder**

- The term "*investigation section*" is used and it is not clear if this is a Western Power group or comes under Protection and Control. If there are standards available on determining where fault recorders are placed, then reference should be made to this document.

**Section 7.3 SCADA System**

- Reference is made to 48V DC; this should be changed to 50V DC to maintain consistency throughout the document.

- This section should refer to a standard document where Western Power outlines its current RTU requirements e.g. number of spare DI, DO & AI that is required and what communication protocols are required on the RTU.

**Template Drawings**

Drawings submitted for review were examined and the following observations are made:

Drawing numbers: SSYYY/5/80201/1B, SSYYY/5/80201/1C, SSYYY/5/80201/1D, SSYYY/5/80202/1, SSYYY/5/80202/1A, SSYYY/5/80202/1B, SSYYY/5/80202/1 were examined and the following noted:

- Wire number labels for the supply rails are not logical. The wire number labels are shown on some connection branches and not on others.
- The power supply connection should be placed at the end of each supply loop; this will give better supervision of the supply rail in the event a loop connection is broken after the cubicle fuse.
- On the same sheet, connections are shown as a wired schematic and as a general schematic.

## 3.3 Civil Design

### 3.3.1 General

The supplied Functional Specifications, Concept Design documents and template and standard drawings generally indicate that Western Power is pursuing a product and service level that is consistent with best practice nationally. Minor suggestions or additions are highlighted in the supplied documents that align the Civil Design content with current practice nationally.

Currently the 1993 version of AS 1170.4 Earthquake actions in Australia, adopted by Western Power in the documentation (which is linked to the current version of the Building Code of Australia), is under revision. When it is reissued as a joint Australian/New Zealand standard it should be reviewed to see if it is still relevant for Western Power's design purposes. An alternative is for Western Power to specify design criteria from the latest version of AS 1170.4.

### 3.3.2 Infrastructure

#### 3.3.2.1 General

The following observations on the basic guidelines for firewalls, noise abatement walls and durable concrete structures are suggestions based on industry practice in Australia. The comments include references to the Building Code of Australia where the terminal yard and substation are to be constructed in potentially 'built up' areas.

#### 3.3.2.2 Fire Rating of Walls

Transformers shall be separated by a minimum three-hour fire rated wall(s) between transformers when the separation distance is less than a set dimension which is dependent on the MVA rating of the transformers concerned. The separation distance can vary between 25 metres reducing to 15 metres for lesser rated transformers. Refer to the Building of Australia (BCA) Part C2 for the requirements when the substation is sited in a built up area. The cooling requirements of the transformers shall be addressed when designing the separating fire walls.

#### 3.3.2.3 Noise Control

Based on noise level design calculations referenced to the substation boundaries and as required, on site noise measurements there may be a requirement for constructing noise abatement walls around the transformer bunds. Consideration should be given to taking into account the future additional installation of transformers on the level off noise produced. The level of noise attenuation required for each site will partially depend on the ambient noise and development of residential areas. The cooling requirements of the transformers and access to the transformers shall be addressed when designing the noise abatement walls.

For built up areas Part F5 of the Building Code of Australian should be referred to when considering noise abatement measures.

#### 3.3.2.4 Durability

Generally to address durability issues of substation reinforced concrete structures reference is made to AS 3600.

In areas of reactive soils it is generally not economical to remove the soil therefore the structures are designed to AS 3600. Installation of external membrane coatings is considered when countering extreme conditions.

### 3.3.3 Functional Specifications – 330/132kV Terminal Yards

**Section 8.6 Environmental Compliance**

- **Oil Filled Equipment**: Addition of subsurface agricultural drains draining to sumps or an oil containment tank especially in high water table areas can be installed to supplement the bunded areas to capture hydrocarbon spills that result from maintenance on the transformers or other electrical equipment.

**Section 9.2.3 Physical Withstand Environment**

- Referencing **Minimum Design Criteria for Civil Works** a heading and paragraph should present a general statement which states that the following load conditions applies to all civil works including earthworks and structures within the Terminal Yards where applicable, (not specifically only applicable to the 'shelter').

- Referencing the listed design criteria for wind loads Western Power's coverage zone apply to Wind Regions A1, A4 and B, not the cyclonic region C. In turn the Average Recurrence Interval (ARI) of 1 in 1000 years is nominated as an acceptable wind design criteria. The Importance Level is to be revised with reference to the current issue of the Building Code of Australia (BCA), Part B1, Table B1.2a.

- Referencing the listed design criteria for earthquakes from AS 1170.4. 1993, AS 1170.0 2002 Appendix D has been provided to link the requirements of AS 1170.4. 1993 with the new requirements in Part B1 of the Building Code of Australia (BCA) which include policy criteria in the form of importance levels and the associated annual probabilities of exceedance. The importance factor (I) has been replaced by the variation of annual probability of exceedance. The Structure Type is replaced by importance level. The Acceleration Coefficient maps of Western Australian Figures 2.3(d) and (e), AS 1170.4. 1993 specifies the values to be considered at each substation site.

- Currently the 1993 version of AS 1170.4 is under revision. When it is reissued as a joint Australian/New Zealand standard it should be reviewed to see if it is still relevant for Western Power's design purposes. An alternative is to specify design criteria from the latest version of AS 1170.4, currently 2007 (where the Acceleration Coefficient maps of Western Australian Figures 2.3(d) and (e), AS 1170.4. 1993 are replaced by Hazard Factor (Z) for Western Australian Figures 3.2(C) and (D)).

### 3.3.4 Concept Design – 330/132kV Terminal Yards

**Section 9.1 Site**

- Specify the site development to include a balanced cut and fill method to construct the platform for terminal yard sites where suitable foundation material exists. The disturbed foundation material shall be compacted with a minimum of four passes of a vibrating 10 tonne roller.

- This section should specify the maximum cut/fill batter angles when constructing the terminal yard platform, for example 1 on 3 for sand.

- The maximum slope of the terminal yard platform for drainage purposes is to be 1 in 40. Where sites are flat the minimum slope shall be 1 in 100.

- The maximum slope of the access ramp(s) from the main road to the platform is 6% to allow the placement of the RSST unit within the terminal yard. The minimum road width on the platform should be 5 metres with corners to suit size of transformer delivery equipment, for example 15 to 20 metre radii.

**Section 9.3 Footings**

- Typical footing templates should be indicated for sand foundation material, sandy gravel foundation material and gravelly clay foundation material in Appendix 3 D. These footing templates may consist of a typical thick slab or typical pier footing to cover various foundation materials from predominately sand through clay to rock.

- Additionally typical dimensioned footing templates, both slab and pier can be specified to apply to Wind Regions A1, A4 and B covered by Western Power. The templates are to be placed in Appendix 3 D.

**Section 9.4 Structures**

- Specify the respective Wind Regions, either A1, A4 and B and provide corresponding typical electrical equipment structural steel support templates to suit each region assuming say Terrain Category 2, Shielding Multiplier 1.0 and Topographical Multiplier 1.0.

**Section 9.5 Outdoor Cable Trenches**

- Reference the required maximum traffic loading (as axle loading or wheel loading) on the types of reinforced concrete box culverts and concrete lids in this clause or list the relevant template design drawings that state the maximum loadings.

- Specify, if relative levels allow, installing subsoil drains from the cable trench outfalls draining to the oil containment system or dedicated sump or pit collecting stormwater drainage prior to discharging off the site.

**Section 9.6 Oil Containment**

- Referring to the general description and issued drawings of Western Power's oil containment system the outflow would struggle to comply with a limit of a maximum of 15 parts per million of hydrocarbons released into the environment if the bund Oil Stop isolation valve failed during a transformer failure especially during a storm event where the resultant oil/water mix would form an emulsion as it passed through the series of holding tanks prior to discharging into the soak-well.

- An alternative, especially applicable in a high water table area, is to provide an above ground bunded area, free of gravel infill, surrounded by bund walls of 300mm minimum height with the Transformer supported on a 150mm to 300mm high raised plinth. The leaking oil is drained quickly through a pipe system that comprises flame traps and sediment traps into a containment tank. The tank is sufficiently sized to capture oil between internal baffles and use the time emulsified oil takes to flow through the tank to separate the oil from the emulsion and reduce the parts per million released into the environment. For smaller sites the oil containment tank can be reduced in size and coalescing plate separators installed downstream of the tank to separate the emulsified oil prior to discharging.

- For the oil containment arrangement above including the bunded catchment area feeding into the oil containment tank, the system shall be designed for a site rainfall of a 1 in 20 year event occurring simultaneously with a transformer failure.

- Install subsoil drains to surround electrical equipment that contain small volumes of oil or areas where oil may be spilt and drain to the oil containment system or a sump where stormwater drainage can be monitored prior to discharging from the site.

**Section 9.11 Stormwater**

- To assist in draining areas that trap water, for example where raised tops of cable ducts form barriers, an option is to install subsoil drains that discharge into drainage pits acting as a sediment trap prior to discharging off the site.

**Section 9.13 Roads, Vehicle Access and Car Parking**

- **Access Road Construction -** Where generally a 25mm Hot-mix layer is currently specified for internal road surfacing, a 40mm Hot-mix minimum thickness layer is suggested for the apron roads over which the transformers are transported.

  Similarly where cable ducts cross these apron roads specify the maximum load ratings for the ducts and the trafficable cable trench covers or list the design drawings on which the maximum load ratings are specified.

### 3.3.5 Drawing Template - Terminal Yard – 330kV

**Drawing SSTTT/11/10/1 - Cable Trenches Layout**

- Refer to the listed culvert load ratings including drawing number in the relevant Transmission Standard Designs documentation.

**Drawing SSTTT/11/10/2 - Cable Trenches Detail**

Referring to “Typical section through insitu trench” - increase mesh reinforcement to a minimum size of SL92 to increase control over cracking.

Referring to drawing Notes:

- Modify note 1. to include ‘with a compaction method of a minimum of 6 passes of a vibrating plate compactor.’ and delete ‘to 8 blows/300mmof a standard penetrometer.’

- Modify note 6. to include ‘surround blue metal in (Section B) drain detail with geotextile to ensure surrounding foundation material does not contaminate the blue metal.’

**Drawing SSTTT/11/9/1 - Foundations Detail**

- Bund Plan General Comment: Specify sufficient reinforcement to provide good control over concrete cracking as per AS 3600.

**Site Preparation** (Notes – Footings)

- Modify note 1. to include 'with a compaction method of a minimum of 8 passes of a vibrating plate compactor.' and delete 'to 8 blows/300mm of a standard penetrometer.'

- An alternative to note 2.for localised areas is to delete 'to a minimum of 95%maximum M.D.D. in accordance with AS 1289 Clause 5.2.1' and replace with 'with a compaction method of 6 passes of a vibrating plate compactor.' Specify also a compacted 150mm minimum deep layer of fine crushed rock (FCR) or a 100mm minimum deep layer of 20 MPa concrete to be used as levelling fill over the cohesive soil and gravel subgrade.

- Modify note 6. to include 'with 6 passes of a vibrating plate compactor' and delete 'to its original state'.

**Concrete** (Notes – Footings)

- Modify note 5. to remove the second reference to 'steel trowel' and insert 'wood float' to provide a non-skid finish.

**Formwork** (Notes – Footings)

- Modify note 2. to specify surface finishes to AS 3610 as indicated on drawing SSTTT/11/10/2.

**Drawing SSTTT/11/9/2 - Foundations Detail and SSTTT/11/9/3 Foundations Detail**

- The above drawings apply to sand foundations. For non sand foundation areas or areas with high water tables change the layout of the transformer bund by replacing the deep bund and included aggregate with an 'above ground' shallow bund where water or discharged oil is quickly drained via flame traps to an oil containment tank eliminating the need for aggregate infill. Bund reinforcement detail is to provide good control over cracking. The bund valve and pit is optional. The included flame traps and oil containment tank are to comply with relevant environmental standards.

### 3.3.6 Functional Specifications –132/22kV Zone Substation

#### Section 8.6 Environmental Compliance

- **Oil Filled Equipment** - Addition of subsurface agricultural drains draining to sumps or an oil containment tank especially in high water table areas can be installed to supplement the bunded areas to capture hydrocarbon spills that result from maintenance on the transformers or other electrical equipment.

#### Section 9.2.3 Physical Withstand Environment

- Referencing **Minimum Design Criteria for Civil Works** a heading and paragraph should present a general statement which states that the following load conditions applies to all civil works including earthworks and structures within the Terminal Yards where applicable, (not specifically only applicable to the 'shelter').

- Referencing the listed design criteria for wind loads Western Power's coverage zone apply to Wind Regions A1, A4 and B, not the cyclonic region C. In turn the Average Recurrence Interval (ARI) of 1 in 1000 years is nominated as an acceptable wind design criteria. The Importance Level is to be revised with reference to the current issue of the Building Code of Australia (BCA), Part B1, Table B1.2a.

- Referencing the listed design criteria for earthquakes from AS 1170.4. 1993, AS 1170.0 2002 Appendix D has been provided to link the requirements of AS 1170.4. 1993 with the new requirements in Part B1 of the Building Code of Australia (BCA) which include policy criteria in the form of importance levels and the associated annual probabilities of exceedance. The importance factor (I) has been replaced by the variation of annual probability of exceedance. The Structure Type is replaced by importance level. The Acceleration Coefficient maps of Western Australian Figures 2.3(d) and (e), AS 1170.4. 1993 specifies the values to be considered at each substation site.

- Currently the 1993 version of AS 1170.4 is under revision. When it is reissued as a joint Australian/New Zealand standard it should be reviewed to see if it is still relevant for Western Power's design purposes. An alternative is to specify design criteria from the latest version of AS 1170.4, currently 2007 (where the Acceleration Coefficient maps of Western Australian Figures 2.3(d) and (e), AS 1170.4. 1993 are replaced by Hazard Factor (Z) for Western Australian Figures 3.2(C) and (D)).

- Referencing the design criteria for rainfall, specify an Average Recurrence Interval (ARI) for the substation of 1 in 20 year rainfall with the duration being site specific.

### 3.3.7 Concept Design – 132/22kV Zone Substations

**Section 6.10.1 General** (RRST Installation)

- Specify design wheel or axle loads for the RRST concrete apron in the standard or specify the drawings that list the design loads.

**Section 9.1 Site** (Civil and Structural)

- Specify the site development to include a balanced cut and fill method to construct the platform for terminal yard sites where suitable foundation material exists. The disturbed foundation material shall be compacted with a minimum of four passes of a vibrating 10 tonne roller.

- This section should specify the maximum cut/fill batter angles when constructing the terminal yard platform, for example 1 on 3 for sand.

- Specify the maximum slope of the terminal yard platform for drainage purposes is to be 1 in 40. Where sites are flat the minimum slope shall be 1 in 100.

- Specify the maximum slope of the access ramp(s) from the main road to the platform is 6% to allow the placement of the RSST unit within the terminal yard. The minimum road width on the platform should be 5 metres with corners to suit size of transformer delivery equipment, for example 15 to 20 metre radii.

**Section 9.3 Footings**

- Typical footing templates should be indicated for sand foundation material, sandy gravel foundation material and gravelly clay foundation material in Appendix 3 D. These footing templates may consist of a typical thick slab or typical pier footing to cover various foundation materials from predominately sand through clay to rock.

- Additionally typical, dimensioned footing templates, both slab and pier can be specified to apply to Wind Regions A1, A4 and B covered by Western Power. The templates are to be placed in Appendix 3 D.

**Section 9.4 Structures**

- Specify the respective Wind Regions, either A1, A4 and B and provide corresponding typical electrical equipment structural steel support templates to suit each region assuming say Terrain Category 2, Shielding Multiplier 1.0 and Topographical Multiplier 1.0.

**Section 9.5 Outdoor Cable Trenches**

- Reference the required maximum traffic loading (as axle loading or wheel loading) on the types of reinforced concrete box culverts and concrete lids in this clause or list the relevant template design drawings that state the maximum loadings.
- Specify, if relative levels allow, installing subsoil drains from the cable trench outfalls draining to the oil containment system or dedicated sump or pit collecting stormwater drainage prior to discharging off the site.

**Section 9.6 Oil Containment**

- Referring to the general description and issued drawings of Western Power's oil containment system the outflow would struggle to comply with a limit of a maximum of 15 parts per million of hydrocarbons released into the environment if the bund Oil Stop isolation valve failed during a transformer failure especially during a storm event where the resultant oil/water mix would form an emulsion as it passed through the series of holding tanks prior to discharging into the soak-well.
- An alternative, especially applicable in a high water table area, is to provide an above ground bunded area, free of gravel infill, surrounded by bund walls of 300mm minimum height with the Transformer supported on a 150mm to 300mm high raised plinth. The leaking oil is drained quickly through a pipe system that comprises flame traps and sediment traps into a containment tank. The tank is sufficiently sized to capture oil between internal baffles and use the time emulsified oil takes to flow through the tank to separate the oil from the emulsion and reduce the parts per million released into the environment. For smaller sites the oil containment tank can be reduced in size and coalescing plate separators installed downstream of the tank to separate the emulsified oil prior to discharging.
- For the oil containment arrangement above including the bunded catchment area feeding into the oil containment tank, the system shall be designed for a site rainfall of a 1 in 20 year event occurring simultaneously with a transformer failure.
- Install subsoil drains to surround electrical equipment that contain small volumes of oil or areas where oil may be spilt and drain to the oil containment system or a sump where stormwater drainage can be monitored prior to discharging from the site.

**Section 9.11 Stormwater**

- To assist in draining areas that trap water, for example where raised tops of cable ducts form barriers, an option is to install subsoil drains that discharge into drainage pits acting as a sediment trap prior to discharging off the site.

**Section 9.13 Roads, Vehicle Access and Car Parking**

**Access Road Construction**

- Where “25mm Hot-mix surface” is currently specified, suggest insert a minimum 40mm Hot-mix surface for transformer apron roads.

**RRST Parking Area Construction**

- Where a “170mm thick slab reinforced with SL92 mesh” is currently specified, suggest the RRST designated parking area is to be constructed of 170 thick concrete with a minimum of one layer of SL81 mesh reinforcement to provide a higher degree of crack control within the parking area slab to improve durability.

**Provision for RRST Access**

- Similarly referencing “Trafficable covers” where cable ducts cut across these RRST apron roads specify the maximum load ratings for the cable ducts and duct covers or list the design drawings on which the maximum load ratings are specified.

### 3.3.8 Drawing Template - Substation – 132/22 kV

**Drawing SSYYY/1/10/1 - Cable Trenches Layout**

- Refer to listed culvert load ratings including drawing number in the relevant Transmission Standard Designs documentation.

- Surround the blue metal in ‘Typical Culvert Drain Detail’ with geotextile to ensure surrounding foundation material does not contaminate the blue metal.

- Referring to drawing Notes: Modify note 5. to include ‘with 6 passes of a vibrating plate compactor’ and delete ‘to its original state’.

**Drawing SSYYY/1/10/2 - Cable Trenches Detail**

Referring to drawing Notes:

- Modify note 1. to include ‘with a compaction method of a minimum of 6 passes of a vibrating plate compactor.’ and delete ‘to 8 blows/300mmof a standard penetrometer.’

- Modify note 2. to increase concrete strength to Grade N32 minimum for coastal region sites.

Referring to 'Typical Insitu Trench Section', increase mesh reinforcement to a minimum size of SL92 to increase control over cracking and improve durability.

Referring to the 'Culvert Drain Detail' surround the blue metal with geotextile to ensure surrounding foundation material does not contaminate the blue metal.

**Drawing SSYYY/1/8/1 - Foundations Layout**

Referring to drawing Notes:

- Modify note 1. to include 'with a compaction method of a minimum of 6 passes of a vibrating plate compactor.' and delete 'to 8 blows/300mmof a standard penetrometer.'

- Modify note 5. to include 'with 6 passes of a vibrating plate compactor' and delete 'to its original state'.

### 3.3.9 Concept Design for 132kV Urban Wood Pole Lines

**Section 5.3 Phase Conductor Insulators** (Line Components/Performance)

- Referring to 5.3.1 should read 25.4mm/kV.

- Similarly, under 5.3.2 Line Post, should read 25.2mm/kV.

**General Notes:**

- All conventional bolted-type suspension clamps used on suspension structures shall be equipped with armour rods to protect the conductor from fatigue caused by Aeolian vibration. Further protection may be achieved by installing Stockbridge vibration damper (*Western Power reported that dampers are not required*).

- OHEW shall be connected to ground wire using 2 x 2 bolt parallel groove clamp (*Western Power reported that current clamps are oversized so 2 are not required*).

### 3.3.10 Drawing Template Standard 132kV Urban Wood Poles

**Drawing T5000/6/3/1 - Suspension Polymer Firtree**

Referring to drawing Notes:

- Modify Note 3. to state backfill around pole to be in 300mm layers and state compaction procedure to be 8 passes of vibrating rammer or plate.

Horizontal post insulator (trunnion type) may not be practicable when used in large angles because it will be very difficult to sit the conductor on the clamp during stringing. (*Robert Fairweather from Western Power has reported that there have not been any problems with 15º so this is not seen as a problem*).

Horizontal post insulator (drop-tongue type) with suspension clamp may be used.

**Drawing T5000/6/5/1 - Suspension Polymer Running Post**

Referring to drawing Notes:

- Modify Note 3. to state backfill around pole to be in 300mm layers and state compaction procedure to be 8 passes of vibrating rammer or plate

**Drawing T5000/6/7/1 - Suspension Polymer Cruciform**

Referring to drawing Notes:

- Modify Note 3. to state backfill around pole to be in 300mm layers and state compaction
- procedure to be 8 passes of vibrating rammer or plate

**Drawing T5000/6/9/1 - Terminal Polymer**

Referring to drawing Notes:

- Modify Note 3. to state backfill around pole to be in 300mm layers and state compaction procedure to be 8 passes of vibrating rammer or plate

In the typical section showing the strain insulator assembly, the eyebolt used was identified as item 3. This should be item 5

**Drawing T5001/6/8/1/1 - Steel Terminal Transition Pole Type TS0/13**

- Under Design Notes Table; for the Venus Conductor under MWT, 18% should be 26%.

**Drawing T5001/6/8/2/4 - Structure Details Steel Terminal Transition Pole Type TS0/13**

- Bending radius of a 2000mm² XLPE with an outside diameter of 138mm ±5% shall be no less than 4.103 m based on the formula 20(d+D) ± 5%.

**Drawing T5001/6/8/2/3 - Structure Details Steel Terminal Transition Pole Type TS0/13**

- Continuous magnetic path around single phase cable leading to potential for inductive heating.  Need to break loop, e.g. aluminium or stainless steel cover.

# 4. SUMMARY

The documentation supplied is generally consistent with standard practices adopted within Australia, taking into account specific requirements that apply in the various States. It demonstrates a solid, consistent, and appropriate approach to meeting the needs of an expanding network.

The reasoning behind the adopted approach, loading conditions, etc should be documented for future reference as this is not provided in the reviewed documents. This is essential as it becomes more difficult to modify the designs if the fundamental technical details underpinning the design are not understood or available. The "HV Extruded Cables Design and Installation Guide" is a good example of such knowledge capture.

The comments made in the evaluation are for general improvement or correction where there is an obvious error. However, as this has been a high-level review, it should not be assumed that all errors have been identified.

For future substation optimisation considerations it should be noted that, amongst others, Cigré Working Groups are currently preparing Technical Brochures on:

- "Circuit Configuration Optimisation";
- "Cost Reduction of Air Insulated Substations" (Publication end August 2008); and
- "Turnkey Substations".