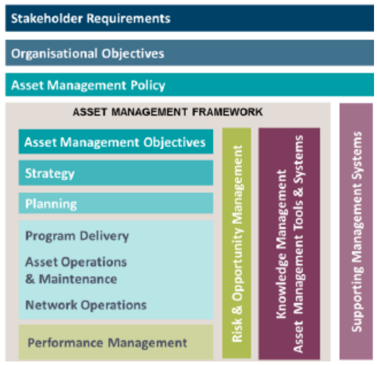
Substation Structures and Foundations

Design Standard



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Revision Details

Version	Date	EDM Version	Description
0	August 2019	3	First issue
0(a)	January 2020	4	Amended cable trench covers weight limit (page 21).
0(b)	June 2020	5	Clarification on soil bearing checks (pages 14 and 15) Adding design requirements for excavation activities (page22)
1	October 2021	6	Refer to the side bar on this document
2	February 2024	7	Standard Online Update

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1 Introduction

The purpose of this Engineering Design Instruction (EDI) is to provide a set of guidelines on how to design and check the design of substation foundations and structures commonly used at substations.

1.1 Purpose and scope[1]

This EDI applies to all Greenfield substations, as well as Brownfield augmentation and asset replacement works. It applies to both Terminal and Zone substations.

This document provides the technical standards for the civil and structural design for the substation structures and foundations.

The scope of this Engineering Design Instruction is limited to electrical equipment support structures and foundations which are commonly used at substations, gantries, lighting and lightning masts and substation fences and gates.

1.2 Acronyms

Acronym	Definition

1.3 Definitions

Term	Definition
AHD	Australian Height Datum
AS	Australian Standard
Brownfield site	Site with existing or had electrical assets previously
CIRIA	Construction Industry Research and Information Association (UK)
EDI	Engineering Design Instruction, describes in detail a particular type of design. This is the "how" to implement a design with clear boundaries defined
FRP	Fibre Reinforced Plastic
GFRP	Glass Fibre Reinforced Plastic
Greenfield site	New site with no previously installed electrical assets
HMR	Hazard Management Register
HV	High Voltage
IFC	Issued For Construction
NCC	National Construction Code

[1] See Western Power Internal Document

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PCB	Polychlorinated Biphenyl
RL	Reduced Level
SEQT	Safety, Environment, Quality and Training Function
SFAIRP	So far as is reasonably practicable
SiD	Safety in Design

1.4 References

References which support implementation of this document

Table 1.1 References

Reference No.	Title

2 Supporting Documentation[2]

3 Compliance[3]

This EDI complies with the latest revision of higher- level Western Power technical documentation such as Network Standards and Functional Specification.

This Engineering Design Instruction should encompass all requirements of the relevant Australian Standards which are current at the time of issue. These relevant Australian Standards are listed in Table 3.1 below. A period will be set when the standard needs to be reviewed. If significant changes occur on an Australian Standard which affects safety, then an out of cycle review can be completed.

Table 3.1: Standards and Guidelines

Standard Number	Standard Title
AS 1170	Structural Design Actions, Parts 0-4
AS 1163	Structural Steel Hollow Sections
AS 1214	Hot-dip Galvanised coatings on threaded fasteners (ISO metric coarse thread series)
AS 1252	High Strength Steel Bolts with Associated Nuts and Washers for Structural Engineering
AS 1554	Structural steel welding
AS 1597	Precast reinforced concrete box culverts
AS 1657	Fixed platforms, walkways, stairways, and ladders- design, construction, and installation

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[3] See Western Power Internal Document

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Standard Number	Standard Title
AS 2067	Substations and high voltage installations exceeding 1 kV a.c.
AS 2159	Piling design and installation
AS 2312	Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings
AS 3600	Concrete structures
AS 3610	Formwork for concrete
AS 3678	Structural Steel – Hot rolled plates, floor plates and slabs
AS 3679	Structural Steel – Hot rolled bars and sections
AS 3735	Concrete structures for retaining liquids
AS 3996	Access covers and grates
AS 4100	Steel Structures
AS 4291	Mechanical properties of fasteners made of carbon steel and alloy
AS 4586	Slip resistance classification for new pedestrian surface
AS 4600	Cold-formed steel structures
AS 4671	Steel reinforcing materials
AS 4678	Earth-retaining structures
AS 5216	Design of post-installed and cast-in fastenings in concrete
AS 7000	Overhead Line Design – Detailed Procedures

4 Functional Requirements

This Engineering Design Instruction is intended to be used by Substation Engineering staff and by companies completing outsourced design work for Western Power, as it outlines the Western Power requirements pertaining to structure and foundation design for transmission substations.

5 Safety in Design[4]

Safety in Design (SiD) process shall be adhered to in all design processes for designing the substation structures and foundations. Any potential risks which may cause harm, affect the operation and maintenance of assets, or impact the environment or construction activities shall be identified during the design stages.

All projects are required to have a SiD Hazard Management Register (HMR) and these risks shall be registered in the HMR and eliminated or minimised so far as is reasonably practicable (SFAIRP).

6 Overview of the Main Design Elements

The designer shall design substation structures and foundations to the following process:

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- Determine all applicable loads as per loading criteria in Section 7.
- Analyse the substation structures and foundations as per Section 8.
- Design the substation structures and foundations as per Section 9.
- Check the deflection criteria as per Section 10.

7 Loading Criteria for Substation Structures and Foundations

All substation structures and foundations shall be designed to withstand the applicable loads. This section provides guidelines for determining the applicable loads and load combinations for substation structures and foundations.

7.1 Design life of structural components

Design life in this document refers to the ability of the substation civil/structural works to maintain functionality and operation safely and effectively. All substation civil/structural works shall be designed to withstand all applicable loads to ensure the civil/structural works achieve, as a minimum, the required design life.

Designers shall ensure all structural components of the civil and structural works can have a design life of 50 years.

7.2 Importance level

All substation structures and foundations shall be designed with an importance level of 3 per the relevant Australian Standards.

7.3 Annual probability of exceedance

- Ultimate limit states

  The annual probability of exceedance for wind and earthquake loads shall be 1/1000
- Serviceability limit states

  The annual probability of exceedance for the wind and earthquake loads shall be 1/25

7.4 Load types

Electrical equipment support structures and foundations shall be designed to withstand the following applicable loads per AS 1170 Parts 0 to 4.

7.4.1 Permanent loads (Gs)

Permanent loads shall be per AS/NZS 1170.1, including the self-weight of the structure, foundation and electrical equipment with all ancillaries and act as a vertical load.

7.4.2 Wind loads (W)

Wind loads shall be calculated per AS/NZS 1170.2, based on the annual probability of exceedance in clause 6.3 and applied to structures, electrical equipment, and conductors. The site wind speed shall be calculated per AS/NZS 1170.2, and parameters provided in Table 7.1.

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Table 7.1: Wind load factors

Description	Factor
Regional wind speed	Region B
Directional Multiplier (M_d)	0.9
Terrain Category	2
Shielding Multiplier (M_s)	1.0
Climate Change Multiplier (M_c)	1.05

Table 7.1 wind load factors have been used in developing substation standard foundation and structure drawings listed in Section 17 of this document.

Site specific load factors:

The regional wind speed and directional multiplier shall be determined based on the project location for the following:

- Fencing projects including new fence design, assessing existing fence and modifying existing fence foundation/structure
- Assessment of existing foundations and structures
- Reinforcement of existing structures and foundations
- Site Specific design where a standard design solution cannot be implemented.

7.4.3 Earthquake loads (E)

Earthquake loads shall be calculated per AS 1170.4 and load parameters provided in Table 7.2. Seismic conditions for support structures are related to the mass of the electrical equipment, sub-soil class and structural behaviour under dynamic effects.

Using an equivalent static analysis method is acceptable for calculating the seismic forces.

Table 7.2: Seismic load parameters

Description	Factor
Hazard Factor(Z)	0.15
Earthquake Design Category	II
Structural ductility factor(μ)	2
Structural performance factor (S_p)	1

Site sub-soil classification shall be obtained from the geotechnical investigation report for the particular site.

The Hazard factor shall be determined based on the project location for similar reasons to choose a site-specific load factor as per Section 7.4.2.

Foundation weight shall be accounted for in the earthquake load calculation in stabilizing and destabilising effects for shallow foundations like conventional electrical equipment support foundations.

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7.4.4 Short-circuit loads (Fsc)[5]

Short-circuit currents produce an electromagnetic field that causes forces on the bus conductors, equipment and support structure and foundation.

7.4.5 Conductor loads[6]

The attached conductor imposes forces on the equipment, structure, and foundation. The following are the conductor forces:

- Horizontal component of the conductor tension in the longitudinal/transverse direction when subject to design wind pressure (F_{tw})
- Horizontal component of the conductor tension in the longitudinal/transverse direction when subject to no wind (F_{te})
- Vertical loads of conductors and hardware (G_c)

7.4.6 Switching loads (Q)

Switching loads result from operating switching devices e.g., circuit breakers and disconnectors. These forces shall be obtained from the equipment manufacturer.

7.4.7 Other loads

Any other load that might be considered appropriate such as, but not limited to, maintenance/construction loads, temperature, vibration, fatigue, and loss of conductor tension.

7.5 Load combinations

The load factors and resistance factors shall be per relevant Australian Standards, such as 1170, AS 3600, AS 4100, AS 7000 and AS 2067. The load combination shall suit the functionality of the structure while incorporating the load and resistance factors outlined in relevant Australian Standards. The following load combinations shall be considered for substation equipment support structures and foundations :

- Ultimate limit states load combinations for stability and strength:
  a. Stabilizing effect

     $0.9(G_c+G_s)$

  b. Destabilizing effect and strength
     (i) Maximum wind load

        $1.1G_s+1.25G_c+1.25Ft_{wu}+W_u$

     (ii) Seismic

        $1.1G_s+1.3G_c+1.25F_{te}+E_u$

     (iii) Short circuit

        $1.1G_s+1.25G_c+1.25F_{te}+F_{sc}+0.25W_u$ (equipment without switching loads)

        $1.1G_s+1.25G_c+1.25F_{te}+F_{sc}+0.25W_u+1.5Q$ (equipment with switching loads)

        $1.1G_s+1.25G_c+1.25F_{te}+1.25F_{sc}+0.25W_u$ (only for gantry structure)

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[6] See Western Power Internal Document

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- Serviceability limit states load combinations:
  a. Service wind load

     $G_s+G_c+W_s+F_{tws}$

  b. Service earthquake load

     $G_c+G_s+E_s$

8 Method of Analysis

A structure analysis requires a model that defines the structural configuration, connection characteristics, boundary conditions and loading cases. The solution generates the displacements, support reactions and internal forces or stresses.

Elastic analysis considering the second-order effects could be used to analyse the substation structures and foundations. Dynamic analysis maybe used to accurately model the mass distribution and stiffness characteristic of a structure and electrical equipment for seismic loads, if required.

9 Design Criteria

All substation structures and foundations shall be designed to current ultimate limit states design requirements considering load and resistance factors. The load and resistance factors shall be per this document and relevant Australian Standards such as 1170, AS 3600, AS 4100 and AS 2067.

Substation foundations and structures shall be designed to following two limit states:

9.1 Ultimate limit states

This state corresponds to the maximum load-carrying resistance of a structure or section of a structure and shall be considered for the below two states:

9.1.1 Stability limit state

The structure as a whole or any part of it shall be designed to prevent instability due to overturning, uplift and sliding.

With consideration of the limit state of static equilibrium, it shall be confirmed that:

$$E_{d,stb} \geq E_{d,dts}$$

Where:

$E_{d,stb}$=design action effect of stabilizing actions

$E_{d,dts}$=design action effect of destabilizing actions

The conditions shown in Section 9.1.1.1 to Section 9.1.1.3 shall be checked and satisfied.

9.1.1.1 Sliding

It is generally accepted that passive pressure should not be used to resist sliding forces on foundations simply because the soil needs to be mobilised before full passive pressure can be activated (refer to Table J2 of AS4678). Such lateral movement may cause undesirable effects on structural elements.

Design internal friction angle of soil (ϕ^*)shall be calculated as follow:

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$\phi^* = \tan^{-1}(\Phi_{u\phi}(\tan\phi))$

$\Phi_{u\phi}$=partial design uncertainty factor for friction of the soils=0.90

ϕ =characteristic internal friction angle of soil

9.1.1.2 Overturning

Passive pressures should not be used to resist overturning forces for the similar reasons stated in Section 9.1.1.1.

9.1.1.3 Uplift

The buoyancy effect shall be considered in the design where applicable. Information about groundwater level could be found in the geotechnical investigation report for the particular site.

9.1.2 Strength limit state

The foundations and structures including all members, connections and holding down bolts, shall be designed to this state, and confirmed that:

$R_d \geq E_{d,}$

where:

R_d = design capacity

E_d = design action effect

The following, but not limited to, conditions shall be checked and satisfied where applicable:

- Bending
- Shear
- Punching shear
- Axial forces
- Soil bearing pressure

  Calculated soil bearing pressure based on the ultimate design action shall be less than the design ultimate limit state bearing capacity (factored ultimate bearing capacity- Φ R_u) provided in the geotechnical report for the particular site. If a capacity reduction factor (Φ) is not provided in the geotechnical report, a capacity reduction factor of 0.5 could be used.

  If the design serviceability limit state bearing capacity (maximum allowable working bearing capacity) is provided in the geotechnical report, it can be factored up by 1.5 to convert the design serviceability limit state bearing capacity into a design ultimate limit state bearing capacity.

9.2 Serviceability limit states

This state corresponds to conditions beyond which the structure cannot perform adequately for normal use under expected actions.

The designer needs to consider all the factors that may deteriorate the structural adequacy of the structures and foundations over the intended design life and incorporate appropriate measures to mitigate any adverse effects. Such factors may include but are not limited to the following:

- Deflection

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- Corrosion
- Creep
- Shrinkage
- Soil bearing pressure

  Calculated soil bearing pressure based on the serviceability design actions shall be less than the design serviceability limit state bearing capacity (maximum allowable working bearing capacity)
- Concrete crack width needs to be limited to 0.2mm for liquid retaining structures e.g., transformer bund, and 0.3mm for other structures. AS 3600 and AS 3735 do not explicitly give any guidance on how to calculate the crack width but rather limit reinforcement bar stress. Either method is acceptable. The Construction Industry Research and Information Association (CIRIA) publication C766 could be used to calculate the concrete crack width.

9.3 Minimum reinforcement

The structural foundation shall satisfy the minimum reinforcement specified in AS3600. The minimum required reinforcement depends on the nature of the structural elements subjected to shear, bending or axial forces.

9.4 Soil parameters

Soil parameters used in the design of structural foundations shall be obtained from the geotechnical report for the particular site. In the absence of a geotechnical report, the following conservative soil parameters shall be used:

- γ_{soil} = density of soil = 16 kN/m^3
- c = cohesion = 0 kPa
- ϕ = angle of internal friction = 28^0
- ΦR_u, design ultimate limit state bearing capacity (factored ultimate bearing capacity) bearing pressure = 75 kPa
- K_s=subgrade modulus =20000 kN/m^3

9.5 Software and computer modelling

The following computer software maybe used to analyse and design the substation structures and foundations:

- SpaceGass
- CSI Safe
- CSI Sap

Using Finite Element Analysis and Design software such as CSI Safe is a common practice for designing foundations. In the absence of such software, traditional general-purpose frame analysis software such as SpaceGass can also be used by modelling soil with spring supports.

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9.6 Foundation types

All the following foundation types shall be designed and checked for the conditions outlined in this document.

9.6.1 Pad foundation

The pad foundation is commonly used to support single column structures like lighting and lightning masts.

9.6.2 Strip foundation

The strip foundation is commonly used to support primary plant supporting structures, e.g., CT, VT, and Disconnectors.

9.6.3 Raft foundation

The raft foundation is commonly used in transformer compounds or where soil differential settlement may be excessive.

Note:

- Foundations adjacent to HV cables shall have a minimum depth of 1 m.
- Steel rebar shall not be used in the concrete foundation supporting ground-mounted air-core reactors in the designated area specified by the equipment supplier. Alternative design solution such as using mass concrete, non-metallic fibre reinforced concrete or non-metallic rebar like Fibre Reinforced Plastic (FRP), or Glass Fibre Reinforced Polymer (GFRP) could be implemented.

9.6.4 Short bored pile foundation

Short bored pile is another type of structural foundation commonly used at substations. In general, piles are designed to resist vertical and lateral loads. The vertical load is resisted by the end bearing of the pile and skin friction. Short bored piles have minimal frictional resistance against vertical loads; therefore, frictional resistance should be ignored. The lateral resistance of short piles could be calculated by either Brinch Hansen or Brom calculation method. A comparison between the two methods is shown in Table 9.1.

Table 9.1: Comparison between Brinch Hanson and Broom

Design Method	Advantage	Disadvantage
Brinch Hansen	1. Applicable to c-ϕ soil. 2. Applicable to layered system.	1. Applicable only for short piles. 2. Trial & error to find solution.
Brom	1. Applicable to long and short piles. 2. Consider both purely cohesive and cohesionless soils. 3. Consider fixed-head and free-head piles.	1. Not applicable to layered soil. 2. Does not consider c-ϕ soil.

The designer shall ensure that the pile acts as a short pile before using the Brinch Hansen method. A short rigid pile can be described as one where the embedded length does not exceed ten times its diameter or by satisfying the stiffness criteria specified by Broom:

The pile is considered short if L / T ≤ 2, where:

$$T = \left(\frac{EI}{\eta_h} \right)^{1/5}$$

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E = Young's modulus of pile material.

I = Moment of inertia of pile cross-section.

L = Pile embedment length.

η_h = coefficient of subgrade reaction for cohesionless soil (kN/m^3) refer to Table 9.2.

Table 9.2: Typical values of η_h for sands

Description of soil	η_h Dry (MN/m^3)	η_h Submerged (MN/m^3) (Terzaghi)
Loose sand	2.5	1.4
Medium sand	7.5	5.0
Dense sand	20.0	12.0
Very loose sand & normally consolidated clays	-	0.4

As stated in AS2159, the pile shall be designed such that the geotechnical strength ($R_{d,g}$) is not less than the design action effect (E_d), i.e.:

$$R_{d,g} \geq E_d$$
$$R_{d,g} = \phi_g R_{d,ug}$$

$R_{d,ug}$ = Design ultimate geotechnical strength.

ϕ_g = Geotechnical strength reduction factor to be determined as per Clause 4.3 of AS2159, or may be found in geotechnical investigation report for the particular site

Where there is a possibility of trenching, cabling or excavation adjacent to the pile foundations, the length of the pile, equivalent to the depth of trenching, shall not be considered to contribute to the load carrying capacity of the pile.

9.7 Design of anchor bolts

All anchor bolts, either cast-in concrete or post-installed, shall be designed per AS 5216 and AS 3850 Appendix B for the ultimate limit states such that the design action S^* does not exceed the value of the design resistance ϕR_u.

$S^* \leq \phi R_u$

S^* = Ultimate design action determined as per section 7 of this document.

R_u = capacity of the fastener for a single anchor or an anchor group per AS 5216 and AS 3850

ϕ = capacity reduction factor per AS 5216 clause 3.2.4

The anchors shall be designed for steel and concrete failure modes for the following conditions:

- Tension: steel failure, pull-out failure, concrete cone failure, splitting failure and blow-out failure
- Shear: steel failure, concrete edge distance failure and concrete pry-out
- Combined tension and shear

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In cases where the Australian Standard does not provide sufficient information, international additional reference standards or guidelines such as European Union publications CEN TS 1992-4-1, CEN TS 1992-4-2, CEN TS 1992-4-3, CEN TS 1992-4-4, CEN TS 1992-4-5, or American Concrete Institute Standard ACI 318 could be used, if required subject to Western Power Substation Design approval. The design methodology is based on the latest development in anchor bolt design and is based on the Concrete Capacity Design method. This method has been proven to be more accurate than the traditional method of assuming a 45 degree concrete failure cone.

The post-installed anchors, either mechanical or chemical, can be checked and designed per the supplier design guidelines or software. Supplier shall provide documentation for compliance with AS 5216.

Unless otherwise approved by Substation Design, the anchor bolts shall be at least 20 mm in diameter for major structures such as equipment support structures and fence/wall support structures.

10 Deflection Criteria

Deflection and rotation of substation structures and members can affect the operation of supported electrical equipment, breach the safety clearances, and cause unwanted stresses in structures and electrical equipment. Limiting the deflection is a major part of the design.

The sensitivity of the equipment to deflection of the supporting structure depends on the electrical equipment and its operational requirements. Supporting structures for electrical equipment can be divided into the following classes:

- Class A structures:

  The structures that support equipment with mechanical mechanisms where the structure deflection can affect their operation, such as circuit breakers, disconnectors, cable terminations and earth switches.

- Class B structures

  The structures that support equipment without mechanical mechanisms, where excessive deflection could result in breaching the phase-to-phase or phase-to-ground clearances or cause unwanted stresses in equipment fittings, or bus conductors such as current transformers, voltage transformer, surge arrestors, and station post insulators.

- Class C structures:

  Class C structures support equipment relatively insensitive to deflection or are stand-alone structures that do not support equipment such as lighting/lightning masts and gantries.

Allowable deflection limits for different structure classes are provided in Table 10.1. Equipment manufacturers shall be consulted for any required limitations.

Table 10.1: Allowable deflection limits for the design of substation structures

Member Type	Deflection Direction	Allowable Deflection		
		Class A	Class B	Class C
Horizontal	Vertical	Span/200	Span/200	Span/100
	Horizontal	Span/200	Span/150	Span/100
Vertical	Horizontal	Span/150	Span/150	Span/100

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Other supporting members, which are not covered in Table 10.1, can be checked as per Appendix B of AS 4100 for steel structures and section 2.3 of AS 3600 for concrete structures to applicable deflection limits.

In some cases, which based on the design loads and lower deflection limit for the class C structures, such as lighting/lightning masts, the design can result in a flexible (low stiffness) structure. These structures can be subject to potentially damaging wind-induced oscillations. Such structures can be susceptible to fatigue cracking and failure. In addition to applicable static deflection limits, considerations such as, but not limited to, increasing the stiffness of the member shall be implemented.

11 Assessing Existing Foundations/Structures[7]

Where new electrical equipment is going to be deployed on the existing support structure/foundation as part of an asset replacement project, the following, but not limited to, shall be considered for assessing the existing foundation/structure for implementing a suitable design and construction approach:

- Run checks to assess if the new electrical equipment would fit on the existing structure/foundation.
- Availability of drawings for the existing structure/foundation
- Compliance of the existing structure/foundation with the design criteria of this document
- Practicality of the existing foundation/structure modification, if required. Construction access considering the required equipment and safe clearance shall be considered.
- Condition of the existing concrete structure (e.g., cracked concrete, reinforcement corrosion, etc.), a site visit is required to conduct a visual inspection.
- Condition of the existing steel structure (e.g., rusted members, connections, or bolts, etc.), a site visit is required to conduct a visual inspection.
- Outage constraints for the proposed design solution. The design shall be such to minimise the outage time.
- Condition of the existing holding-down bolts (e.g., corrosion)
- Compliance of new holding-down bolts (either cast-in or post-installed) with the design requirements of this document.
- Note: Cast-in anchor may be preferred for CBs and gantries due to dynamic/high loads
- Running new cables (power or secondary) might require a new foundation to allow conduit installation.
- Environmental issues such as contaminated soil with oil or PCB.
- Design time. Adopting a standard design requires less time than the design of modifications to the existing foundation/structure.
- Cost comparison for the practical options. Modifying the existing foundation could cost more than implementing a new foundation due to over-excavation, drilling, and installing numerous dowel bars, scabbling, etc.
- Demolition/removal of the existing foundation. Methodology of demolition/removal shall be developed to ensure it is safe for construction. This might be done by the civil contractor and reviewed by the designer. In case the existing foundation requires to be lifted, then a safe work method statement including, but not limited to, the following shall be provided:
    a. Lifting study

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b. Crane access and location

c. Lifting attachments

d. Required excavation area for lifting.

- Undermining nearby existing foundations/cable trenches. Temporary propping, underpinning, or shoring might be required to support the adjacent foundations/structures.

12 Transformer Bund foundation[8]

The transformer foundation and bunded area shall be constructed from cast in-situ reinforced concrete, including the floor slab, bund walls, and plinths. The transformer bund foundation shall be designed for the weight of the transformer, aggregates, earth pressure and any additional transformer installation loads. Firewall between transformers shall be constructed from prefabricated concrete panels if required.

Transformer installation method shall be established by jacking/skating or crane, during transformer bund design. Any possible additional loads on the transformer bund foundation slabs and walls due to locating the crane outriggers pads, jacks, or skating beam supports on the transformer bund slab or adjacent to the bund wall (outside of the bund) shall be considered in the design.

The concrete crack width for the transformer bund shall be limited to 0.2 mm.

The transformer bund shall not have any cut-outs or cast-in conduits below the possible maximum oil level unless it is required for interconnecting two transformer bunds.

Where the top of the transformer bund is more than 300 mm above the finished site level, handrails with two access stairs shall be provided per AS 1657.

The top of the transformer concrete plinth shall be flat with a maximum 3 mm deviation from a 3 m straight edge. This tolerance shall be noted on the drawings.

Transformers shall be secured to the foundation using holding-down bolts. The holding-down bolts shall be checked and designed per the design requirements of this document for the seismic loads.

13 Cable Trenches and Trench Covers[9]

Cable trenches, and conduits shall be used to run the secondary/protection cables inside the switchyard, from the electrical equipment to substation Switchroom/Relay Room building. The cable trench's size and layout shall be designed to allow for the ultimate substation development.

The cable trench's wall and base shall be constructed from cast in-situ reinforced concrete or prefabricated concrete modules. Should prefabricated concrete panels be used, then corner junctions, T junctions, changes in the levels and widths shall be constructed from cast in-situ reinforced concrete.

Intersection walls in the cable trenches shall be chamfered to suit the cable bending radius. Bell mouth conduit fittings shall be cast into the concrete cable trench wall to protect the cable from rubbing against sharp edges. Where the conduit cover entering the cable trenches is less than 500mm, then provisions of conduits protection, such as casting them into the lean concrete or sand/cement mix, shall be provided.

The top of the cable trenches shall not be more than 25mm above the finished site level.

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The trench covers, which are not located in the trafficable area, shall be fabricated from Fibre Reinforced Plastic (FRP) covered grating and comply with the load classification of "Class A" per AS 3996.

The trench covers shall not weigh more than 20 kg. The covered grating shall be slip-resistant to Class P3 per AS 4586, yellow colour and not less than 40mm thick in total. The trench covers shall be fully recessed into the cable trench wall to avoid any potential tripping hazard. Each FRP cover panel shall be fitted with two recessed stainless steel (Grade 316) handles with stainless steel backing plates and be secured to the cover with four bolts and nuts.

A steel support beam shall be installed across the cable trenches at the cable trench junctions to support intersection trench covers.

Prefabricated reinforced concrete covers shall be used for the trafficable area. The trafficable concrete covers shall be flush with the road level and fitted with Swiftlift lugs. The trafficable concrete covers shall be rated and designed to "Class D" per the loading classification of AS 3996.

Where the prefabricated culvert units, including the crown and the base, are used for the trafficable area, they shall comply with the "Roadway load class" per AS 1597.

In the Brownfield applications or retrofit works, where steel trench covers have already been used, steel cable trench covers could be used, subject to complying with the design requirements of this document and Substation Design approval. The weight of steel cable trench covers shall be limited to 20 kg.

Cable draw pits and conduits system may be used in Brownfield applications, subject to Substation Design and Operation Asset Performance (OAP) approval. Cable pits shall be prefabricated, and pit lids shall comply with the design requirements of this document based on the applications.

14 Retaining Walls

The retaining wall shall be designed per AS 4678 to the ultimate limit states and serviceability limit states. Load combinations and material strength/serviceability reduction factors shall be obtained from AS 4678. The design life shall not be less than the requirements of this document.

Construction of Switchroom/Relay Room building or switchyard structures adjacent to the retaining wall shall be avoided within 3 m of the retaining wall or the maximum height of the retaining wall, whichever is greater. Alternatively, the proposed structure maybe supported on piles to a specific depth.

Subsoil drainage shall be provided for the retaining wall with outlets at low points and flushing points at high points, or the retaining wall shall be designed for the full hydrostatic pressures.

Backfill adjacent to the retaining wall using compaction equipment shall be avoided unless using a small hand compactor or the earth pressure produced by compaction shall be considered in retaining wall design. Limitations of backfilling requirement shall be noted on drawings.

15 Excavation Activities

The designer shall complete the following, but not limited to, for any project related excavations:

- Assess the risk of undermining and destabilising nearby structures such as Switchroom and Relay Room buildings, platforms, boundary walls, fences, gantries, equipment support structures, cable trenches, cables, conduits, transmission, and distribution poles, stay wires, underground services, and neighbour properties. Any excavation risk shall be eliminated whenever possible. Where elimination is not possible, risks should be minimised so far as is reasonably practical.

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- Provide cross-sections of excavation works showing depth and width of excavation, angle of safe slope, nearby structures, underground services, and depth/location of existing features.
- Highlight excavation risk on the IFC drawings and ask the contractor to provide a safe work method statement with a ground supporting system if required.
- Provide information for ground support systems such as battering, shoring, sheet piling, underpinning or any other methods if required.
- Provide details for bracing, propping, and reinforcing any structure that is likely to fall into an excavation.
- Civil/structural engineer to work with substation engineer to design the primary and secondary cable/conduit routes and cable bedding details.
- Cable layout drawing and bedding detail shall be examined and signed off by a civil/structural engineer.
- Register all risks and control measures in HMR per Section 5 of this document, reference the HMR in the construction SoW and highlight high-risk excavation in construction SoW.

16 Design Deliverables

The following, but not limited to, calculations and drawings for the substation foundation and structure design shall be provided:

- Foundations calculation, including overturning, soil bearing pressure, sliding, uplift, punching shear, shear, bending and holding down bolts design.
- Structure calculation including the major and minor structural elements, base plate, beam to column connection, bracing connections, splices, knee bracing and weld design. Digital files of the structure analysis software.
- All required serviceability checks.
- Foundation detail drawings showing the foundation size, required reinforcement, and holding down bolts, foundation RL, design criteria and any construction requirements.
- Steel structural detail drawings showing all member sizes and lengths, connection details, welds, and bolts details, finishes, mass and assembly details.
- Structural design report and HMR for all substation civil structural design

17 Standard Drawings[10]

Substation standard foundation and structure drawings have been developed per the requirements of this document.

The designer shall verify that a standard drawing will serve the project purpose based on the information provided on the standard drawing, design criteria listed in this document and project-specific requirements before using it as part of a design solution.

If a standard drawing could be used, there is no need to provide the calculation listed in Section 16 of this document.

[10] See Western Power Internal Document

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Where a standard drawing cannot be implemented as a part of a design solution, then a site-specific design solution shall be developed based on this document's design requirements. Western Power Substation Design approval shall be sought before a site-specific design solution is implemented.

Should a site-specific design solution be used, drawings with all required calculations listed in section 16 of this document shall be provided.

Refer to Substation Design Drawing Register - EXTERNAL Version for the following standard drawings:

- 22 kV, 132 kV, 220 kV and 330 kV electrical equipment support structure and foundation.
- 132 kV, 220 kV and 330 kV gantry structure and foundation
- Transformer bund foundation
- Lighting/lightning masts

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Appendix A: Approval Record and Document Control[11]

[11] See Western Power Internal Document

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