Safety and Maintenance Clearances

Design Standard

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

CONTACT

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Contents

Revision Details[1]

Version	Date	EDM Version	Summary of change
0	21/06/2013	1	Original Issue
1	21/03/2017	2	Updated with changes from new AS2067:2016 version
2	21/03/2020	3	Converted to AMS format. Hazard management register added. No new items in the issues register.
3	10/03/2023	4	Includes updates covering items 9 &10 of *Register – Engineering Design Instruction, Construction Technical Specification Information & Drawing Issues Register.*
4	2/1/2024	5	Standards Online Update

[1] See Western Power Internal Document

1 Introduction

Clearances between items of electrical equipment serve two basic functions. These are to protect the integrity of the equipment by prevention of flashover and to ensure the safety of personnel, vehicles, plant and equipment involved in operational or maintenance activities. Electrical clearances determine the mounting heights, separation and screening requirements of substation equipment.

Maintenance clearances must be adhered to during the design process. After the substation has been constructed it will need to be maintained for its lifetime of over 40 years.

The purpose of this Engineering Design Instruction, EDI, is to assist engineers in designing transmission substations with adequate clearances allowing personnel to safely and easily access and work on plant whilst adjacent circuits are still in service.

1.1 Purpose and scope

This design instruction specifies the clearances required and how to apply them in Western Power transmission substations. The specified clearances are mandatory and must be followed for new designs in both Greenfield and Brownfield substations.

1.2 Acronyms

Acronym	Definition

1.3 Definitions

Term	Definition
Clearance (AS 2067 definition)	Distance between two conductive parts along a string stretched the shortest way between these conductive parts (The taut string distance).
Closed electrical operating area (AS 2067 definition)	An area dedicated for the operation of electrical installations and equipment to which access is intended to be restricted to skilled or instructed persons or to lay personnel under the supervision of skilled or instructed persons, e.g. by opening of a door or removal of protective barrier only by the use of a key or tool, and that is clearly marked by appropriate warning signs. NOTE: Examples of such locations include substations, enclosed switchgear and distribution installations, transformer enclosures, enclosed switchgear bays or cubicles, distribution installations in sheet metal housings or in other closed installations.
Danger zone (AS 2067 definition)	Area limited by the non-flash over distance (N) around live parts that are without complete protection against direct contact. NOTE: Infringing the danger zone is considered the same as touching live parts.

'Ground Approach Distance' (Energy Safety WA, no definition given in Work Practice Manual)	The distance to be maintained by personnel from the mobile plant (vehicle, stabilizers, outriggers) when deployed within the danger zone of electrical apparatus
Isolating distance (AS2067 definition)	Clearance between open contacts meeting the safety requirements specified for equipment.
Isolation (AS2067 definition)	Switching off or disconnection of an installation, a part of an installation or equipment from all non-earthed conductors by creating isolating gaps or distances.
Live part (AS2067 definition)	Conductor or conductive part intended to be energised in normal operation, including a neutral conductor but by convention not a PEN conductor or PEM conductor or PEL conductor.
Taut string distance (AS2067 definition)	The distance between two parts measured along a taut string stretched the shortest way between those parts.
Voltage Range I (AS2067 definition)	Voltage in the range 1 kV < Um ≤ 245 kV.
Voltage Range II	Voltage in range Um > 245 kV
Working clearance (AS2067 definition)	Minimum safe distance to be observed between normally exposed live parts and any person working in a high voltage installation or any conductive tool (or object) directly handled. NOTE: Values for electrically skilled or instructed persons are given in Figure 11.1. This refers only to non-live working. Specific definitions related to live working practices are found in IEC 60050(651).
'G' Ground safety clearance (AS2067 definition)	The minimum distance required between the earthed end of any exposed insulator carrying or containing live parts and ground or the floor of permanent walkways used for normal inspection and operational functions. This distance is equivalent to the reach of a person at ground level (2440 mm), which includes an allowance of 300 mm for tools.
'G' Ground safety clearance (WP SS Work Practices Manual definition)	The minimum *clearance* required between the earthed end of any exposed insulator carrying or containing live parts and ground or the floor of permanent walkways used for normal inspection and operational functions. This distance is equivalent to the reach of a person at ground level (2440 mm), which includes an allowance of 300 mm for tools.
'H' Horizontal work safety clearance (AS2067 and WP SS Work Practices Manual definition)	The minimum distance measured horizontally between live parts and the work object. Where work is to be carried out from a ladder or from the equipment, the horizontal work safety clearance is applied from extremities of the work object horizontally to the nearest live parts. This distance includes an allowance of 300 mm for tools.
'HV' (AS2067 definition)	Voltage exceeding 1000V a.c.
'LV' (AS2067 definition)	Voltage exceeding 50 V a.c. but not exceeding 1000 V a.c.
'N' Non-flashover distance (AS2067 and WP SS Work Practices Manual definition)	The minimum phase to earth clearance that includes a margin of 10% (for clearances of 1300 mm or less) and 6% (for clearances of greater than 1300 mm) to allow for variations in construction dimensions.

'S' Section Safety clearance (AS2067 and WP SS Work Practices Manual definition)	Safety clearance required for access for operational purposes. The non-flashover distance (N) plus the ground safety clearance (G) measured along a taut string between the ground or operating platform and the live part.
'SAD' Safe approach distance (ENA NENS 04 definition. Similar to WP's 'MAD'	The minimum separation in air from an exposed conductor that shall be maintained by a person, or any object (other than insulated objects designed for contact with live conductors) held by or in contact with that person.
'MAD' Minimum Approach Distance. Formally replaces 'SAD'	The minimum separation distance that must be maintained by a trained and competent person, mobile plant (including its load) or any object (other than insulated objects designed for contact with live conductors) from electrical apparatus.
'U' 'Nominal voltage (U)' (ENA NENS 04 definition)	The a.c. (phase to phase r.m.s.) or d.c. voltage by which a system of supply is designated. *Similar to Un*
'Um' Highest voltage for installation (AS2067 definition)	Highest r.m.s. value of phase-to-phase voltage for which the installation is designed in respect of its insulation.
'Un' Highest voltage of a system (AS2067 definition)	Suitable approximate value of r.m.s. phase to phase voltage used to designate or identify a system. *Similar to U*
'Ur' Rated voltage (AS2067 definition)	The voltage assigned by a manufacturer for a specified operating condition of a component, device or equipment and which it will withstand when tested in accordance with the appropriate Australian Standard.
'V' Vertical work safety clearance (AS2067 definition)	The minimum distance measured vertically between live parts and the highest part of the work object. Where work is to be carried out from a ladder, the vertical work safety clearance shall be applied from the highest parts of the work object vertically to the nearest live parts. This distance includes an allowance of 300 mm for tools.
'V' Vertical work safety clearance (WP SS Work Practices Manual)	The minimum distance measured vertically between live parts and the highest part of the work object. Where work is to be carried out from a ladder *or from the equipment,* the vertical work safety clearance shall be applied from the highest parts of the work object vertically to the nearest live parts. This distance includes an allowance of 300 mm for tools.
Work object	Plant item being worked on

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 Engineering Design Instruction complies with all higher-level Western Power technical documents and relevant Australian Standards.

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: Relevant Documentation

Document Title
Network Standard – Transmission Network Configuration and Planning
Technical Specification – Substation Electrical Construction

Table 3.2: Australian Standards

Standard Number	Standard Title
AS/NZS 3000	*Electrical Installations (The wiring rules)*
AS/NZS 4036	*Safe working on or near low-voltage electrical installations and equipment*
AS2067:2016	*Substations and high voltage installations exceeding 1 kV a.c.*
ENA NENS 03	*National Guidelines for Safe Access to Electrical and Mechanical Apparatus.*
ENA NENS 04	*National Guidelines for Safe Approach Distances to Electrical and Mechanical Apparatus.*
AS/NZS 7000	*Overhead line design - Part 1: Detailed procedures*

[2] See Western Power Internal Document
[3] See Western Power Internal Document

4 Functional Requirements

This Design Instruction is intended to be used by Substation Engineering staff and by external design vendors completing outsourced design work for Western Power. It outlines Western Power's requirements pertaining to safety and maintenance clearances.

Safety and maintenance clearances within a substation must:

1. Allow personnel to safely install, maintain, operate and remove equipment without coming into contact with live equipment.
2. Allow access for vehicles required safely install, maintain and remove equipment without coming into contact with live equipment.

This includes consideration of the current needs of the substation as well as those in the foreseeable future. As the life of the substation plant is less than the life of the substation, this requirement dictates that all plant must be able to be removed and replaced without impacting adjacent equipment.

5 Safety in Design[4]

Safety and Maintenance Clearances are critical Safety in Design areas to be considered when completing substation design work. This document outlines the fundamental principles to be followed with the aim to eliminate and mitigate potential hazards during the design phase of the project. All projects are required to have a SID Hazard Management Register to include evidence of all measures implemented to eliminate or reduce risks. The following prompt questions can facilitate the hazard identification process:

1. Staging of construction – can alternative construction methodologies/sequences be used to ensure a safer outcome?
2. Can the layout be optimized to provide a safer outcome?
3. Is the layout logical and intuitive?
4. Can physical barriers be installed to restrict access where required?

The Hazard Management Register and relevant design drawings shall be included in a Construction, Operation and Maintenance (C.O.M) review at relevant stages of the project.

6 Overview of the Main Design Elements

Western Power transmission zone and terminal substations must be safe for personnel to enter, operate and maintain.

This document provides guidance on the following main topics:

1. Basic Electrical Clearances: ground clearance, non-flashover distance and section safety (Section 8).
2. Maintenance Clearances: horizontal, vertical and section (Section 9).
3. Application of Safety Clearances (Sections 8 and 10).

[4] See Western Power Internal Document

4. Equipment and Vehicles used for Maintenance (Section 9).
5. Maintenance Access to Equipment in buildings (Section 11).
6. Standard Designs and the clearances involved, their derivation and allowable deviations (Section 12).
7. Egress Requirements in Buildings (Section 13).
8. Derivation of Electrical Clearances (Section 8).
9. Compliance to Australian Standards (throughout document.)

7 General Requirements

The purpose of safety clearances is to ensure that personnel can walk around in a substation and undertake the required maintenance at ground level without being subjected to hazardous voltages. The purpose of maintenance clearances is to ensure that the minimum amount of plant can be isolated for routine maintenance. Network security requires that equipment can be replaced without removing adjacent circuits from service.

Design must allow for the current and future development of the site. This is especially important in terminal yards where the requirement for a high level of circuit availability makes it difficult to obtain outages. Circuits should be spaced such that future construction near live equipment can take place, without the need for outages, whenever possible.

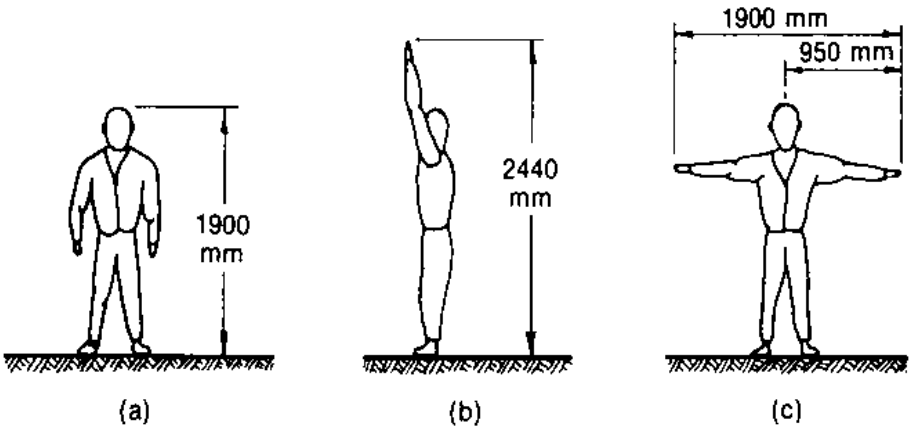
8 Basic Electrical Clearances

8.1 Derivation and General Discussion

The safety clearances employed in Western Power substations are based on AS 2067.

8.1.1 Height and Reach of a Tall Person

The ground safety clearance is based on the height and reach of a tall person. It has been assessed that a tall person holding a small hand tool or material up to 300mm in length would have a maximum reach of 2440mm vertically or 1900mm horizontally. This dimension is as per AS2067. Refer to Figure 8.1 below.



NOTE: Extreme dimensions include an allowance for small hand tools.

Figure 8.1: Height and reach of a 'tall' person (from AS2067)

8.1.2 Voltage Based Clearances

All other clearances are determined by the system voltage. Refer to Table 8.1.

8.2 Explanation of Clearances

8.2.1 Ground Safety Clearance ('G')

The ground safety clearance is the minimum distance from the earthed end of equipment insulators to the ground or a walkway. It is 2440mm for all voltages (above 1kV). This dimension is based the AS2067 definition of a tall person and assumes that a 1900mm tall person has a vertical reach of 2440mm. See Figure 8.1.

8.2.2 Non-Flashover Distance ('N')

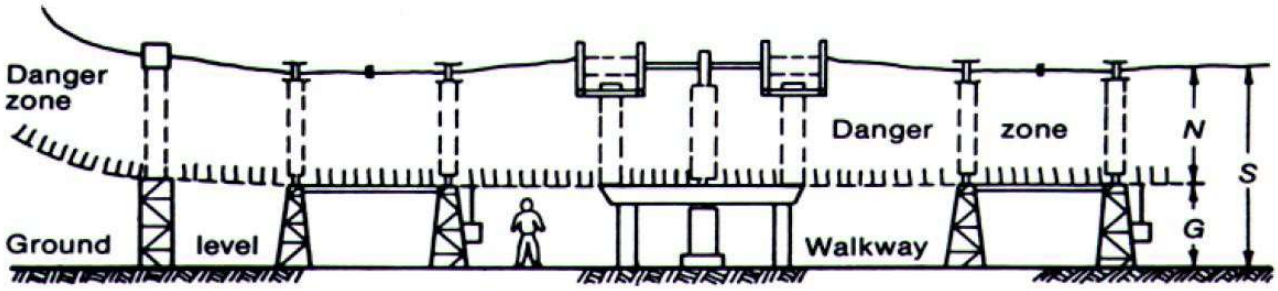
The non-flashover distance is the minimum phase to earth distance that includes a margin of 10% (for clearances of 1300mm or less) and 6% (for clearances of greater than 1300mm) to allow for variations in construction dimensions.

It is the minimum distance for which a flashover will not occur for voltages up to the system highest voltage (110% of nominal). See Figure 8.2 below for illustration.

8.2.3 Section Safety Clearance ('S')

The section safety clearance shall be applied from the foot position vertically or from the foot position over guard rails or screens by taut- string measurement to the nearest live parts. In Figure 8.2 below the Section

Safety Clearance ('S') is shown as the sum of the Non-Flashover Distance ('N') and the Ground Safety Clearance ('G') for a person standing on the ground. Refer to Section 12.1 for an example of the Section Safety Clearance when a protective barrier is in place. Refer to Section 9.1 for an example of the Section Safety Clearance when working from a platform.



G = ground safety distance (2440 mm)
N = non-flashover distance
S = section safety clearance (*G* + *N*)

Figure 8.2: Illustration of Ground, Non-Flashover and Section Safety Clearances

8.2.4 Danger Zone

The "Danger Zone" is the envelope around live equipment that is within the non-flashover distance from the live parts. Refer to Figure 8.2 above.

The Section, Vertical and Horizontal Work Safety Clearances are based on the principle that when a person is inspecting or operating live substation equipment or working on isolated equipment, they should not be able to reach into any "Danger Zone" surrounding live equipment.

Applying the principle described above, it follows that the distance to live equipment must always be at least the dimension of the "Danger Zone" plus the Horizontal Work Safety Clearance (Section 9.1.1) or the Vertical Work Safety Clearance (Section 9.1.2) as appropriate.

8.3 Clearance Requirements[5]

All substations must meet the minimum clearances specified in Table 8.1 shown below. These clearances are derived from AS2067:2016 Tables 3.1 and 3.2 and must be used for all new design work. Note that the 330kV phase to phase clearance was increased from 2530mm to 3100mm in this latest edition.

AS2067 gives two tables for voltages greater than 275kV. Table 3.1 is for rod to structure geometry and Table 3.2 for conductor to structure geometry. For voltages of 220kV and below, rod to structure geometry is used so values from Table 3.1 apply. At 330kV conductor to structure geometry is used so the values from table 3.2 apply.

[5] See Western Power Internal Document

In relation to AS2067 Tables 3.1 and 3.2, Western Power uses the higher values for 132kV (Table 3.1) and 330kV (Table 3.2) and the middle value for 220kV (Table 3.1).

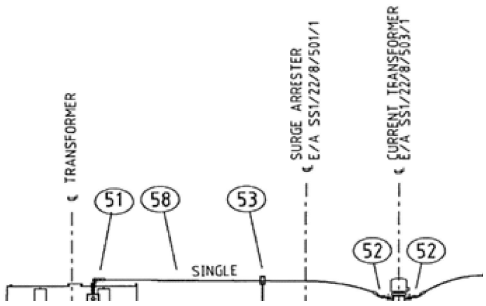
Table 8.1: Minimum clearances as per AS2067:2016, chosen for Western Power application

Nominal Voltage kV	Design Clearances (mm)			Ground Safety Clearance (G) (mm)	Safety Clearances for Operational Purposes and Maintenance Work (mm)		
	Phase to Earth clearance	Phase to Phase Clearance	Non-Flashover Distance (N)		Section Safety Clearance (S)	Horizontal Safety Clearance (H)	Vertical Safety Clearance (V)
Up to 3.6	60	70	65	2440	2505	1965	1405
6.6	90	105	100		2540	2000	1440
11	160	185	175		2615	2075	1515
22	280	325	310		2750	2210	1650
33	380	440	420		2860	2320	1760
66	630	725	695		3135	2595	2035
132	1300	1495	1430		3870	3330	2770
220	1900	2185	2015		4455	3915	3355
330	2200	3100	2330		4770	4230	3670

8.3.1 Earthed Base of Plant used as part of Ground Clearance

The lowest part of any insulation shall not be less than the ground safety distance G = 2440 mm above accessible surfaces unless other suitable measures to prevent access are provided. An example is the upper edge of metallic insulator bases. Suitable methods to restrict access are discussed in Section 12.3 Protective Barriers.

The earthed base of the plant can be used as a portion of the ground clearance. Refer to Figures 8.3 and Figure 8.4 below for illustration. Care must be taken when determining the earthed section of the plant.



G

Figure 8.3: Ground safety clearance ('G') – 2440 mm

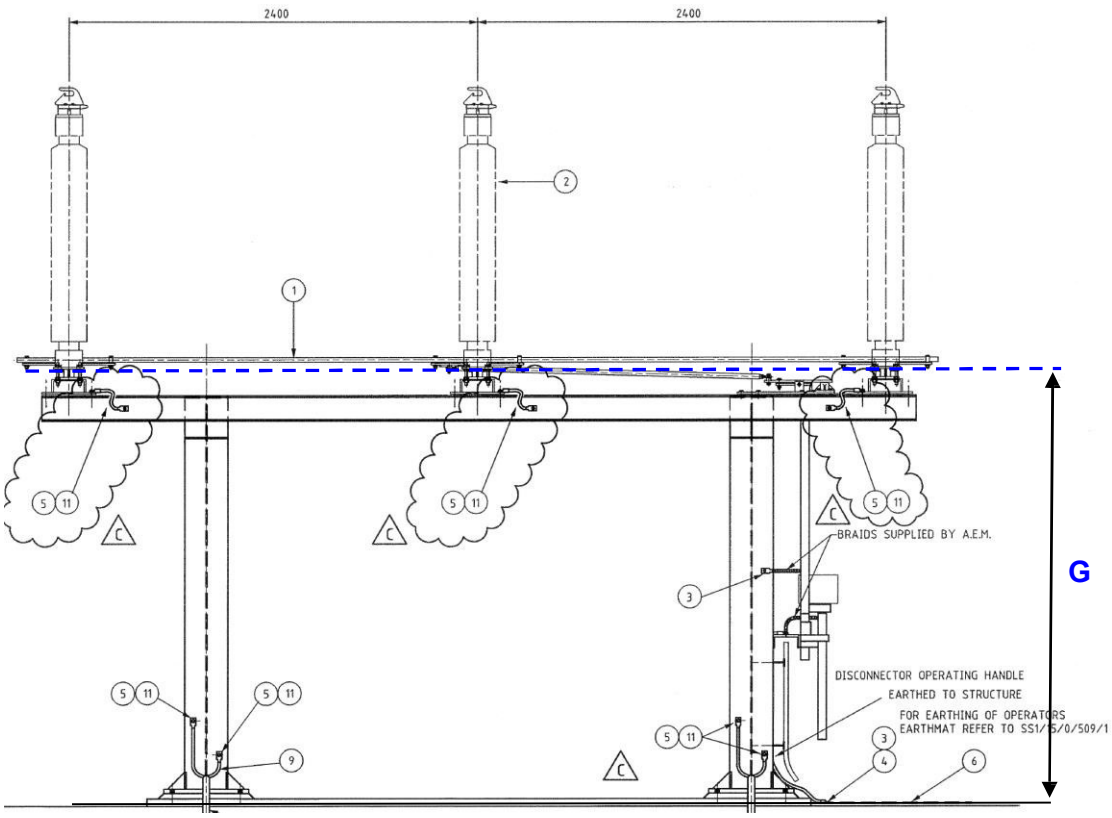


Figure 8.4: Disconnector showing ground safety clearance ('G') – 2440 mm

8.4 Clearances under Special Conditions

The clearances listed in Table 8.1 are minimum clearances and special conditions as discussed in this Section may drive the requirement for larger distances. These conditions are requirements as set by AS2067 Section 3.5.

8.4.1 Different Voltages (Insulation Levels)

Where a clearance exists between conductors or equipment of different voltages, the required clearance must be at least 125% of the minimum clearance of the higher voltage. See Appendix A.1 for an example of this calculation.

8.4.2 Short Circuit Forces

During a short circuit, high current flowing in the conductors cause large electromagnetic forces which act on adjacent conductors, pulling towards or repelling them from each other. The distance that the conductors can move towards each other depends on the amount of sag in the conductor.

Under fault conditions, when the conductors have swung towards each other, 50% of the phase to phase or phase to earth clearance must be maintained in the position of maximum displacement. For more information, see Engineering Design Instruction – Busbars and Conductors. See Appendix A.2 for an example.

8.4.3 Wind Forces

When conductors swing towards each other under the influence of wind, 75% of the phase to phase or phase to earth clearances shall be maintained. This is further covered in the *Engineering Design Instruction – Substation Busbars and Conductors.* See Appendix A.3 for an example.

8.4.4 Rupture of Insulator Strings[6]

For the event of one chain in a multiple chain insulator string breaking, 75% of the minimum phase to phase or phase to earth clearances shall be maintained.

Western Power only has single chain insulator strings.

8.4.5 Type Testing

Clearances specified in Table 8.1 can be reduced for substation equipment which has been type tested. The type test proves the ability of this equipment to meet the required voltage. See *AS 3439.1* for more information.

[6] See Western Power Internal Document

9 Clearances for Safe Access

9.1 Maintenance Clearances[7]

The substation shall be designed and laid out in a way as to allow the required maintenance to be undertaken in a safe and efficient manner. Routine maintenance must be able to be safely carried out without the need to remove adjacent circuits or busbars from service.

During asset replacement work which currently do not meet this requirement the plant being replaced should be repositioned such that the circuit does comply where practicable.

The designer must take special care when adding circuits in Brownfield sites. Many older circuits do not comply with current requirements and may require parts of the busbar or adjacent circuits to be taken out of service for maintenance or construction work to occur. This is not acceptable for new installations, and hence new designs must be checked.

Refer to Appendix B for an example illustration.

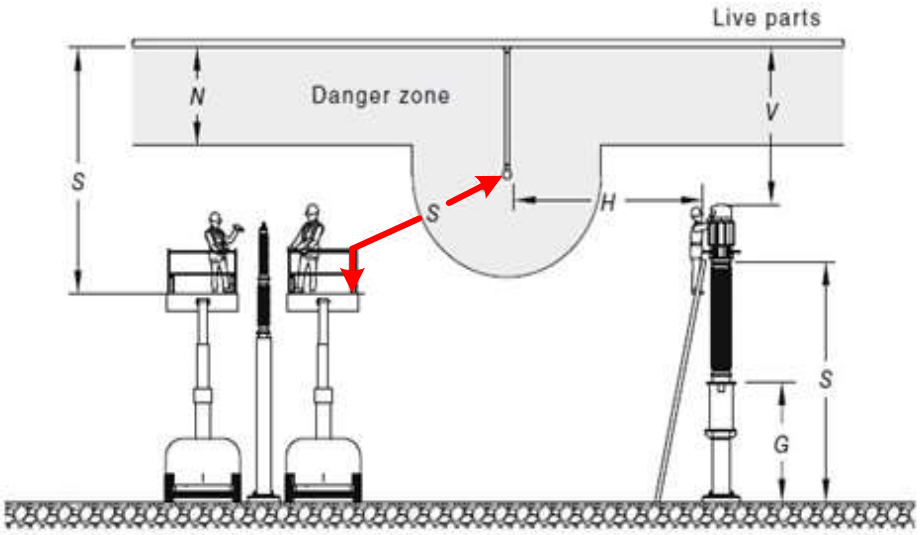
9.1.1 Horizontal Work Safety Clearance ('H')

Horizontal Work Safety Clearance is the minimum distance required measured horizontally between the nearest live parts and the highest part of the work object.

Where work is to be carried out from a ladder, on the equipment or a work platform, the horizontal work safety clearance shall be applied from the extremities of the work object in any horizontal direction to the nearest live parts.

Refer to Figure 9.1 below for an illustration of 'H'.

[7] See Western Power Internal Document



LEGEND:
N: Non-flashover distance
G: Ground safety clearance (2440)
S: Section safety clearance (*N* + G)
H: Horizontal work safety clearance (*N* + 1900)
V: Vertical work safety clearance (*N* + 1340)

DIMENSIONS IN MILLIMETRES

Figure 9.1: Minimum working clearances within a substation (taken from AS2067, Figure 5.8)

9.1.2 Vertical Work Safety Clearance ('V')

Vertical Work Safety Clearance is the minimum distance measured vertically between the nearest live parts and the highest part of the work object.

Where work is to be carried out from a ladder, on the equipment or from a work platform, the vertical work safety clearance shall be applied from the extremities of the work object in a vertical direction to the nearest live parts.

See Figure 9.1 above and Figure 9.2 below for illustrations of 'V'.

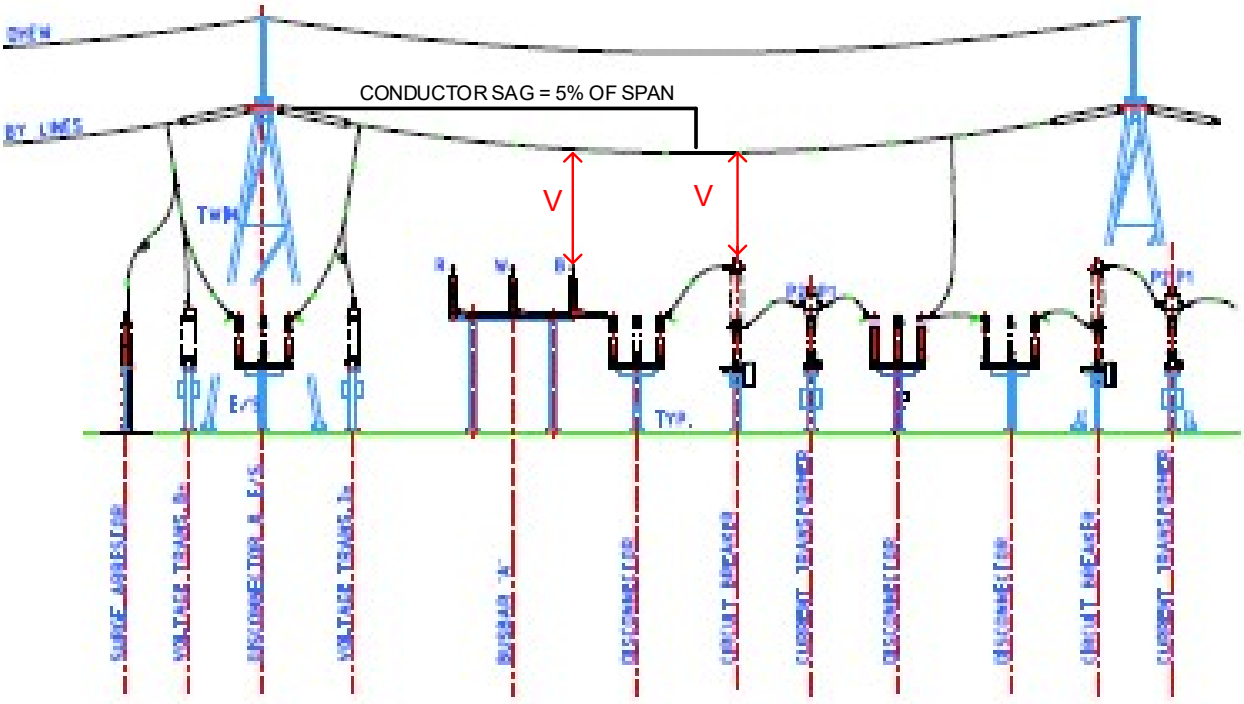


Figure 9.2: Vertical clearance from live HV equipment to overhead gantry-gantry conductor

9.1.3 Clearance Requirements and how to apply them to Substations

Figures 9.3 and 9.4 below show the required clearances in a substation

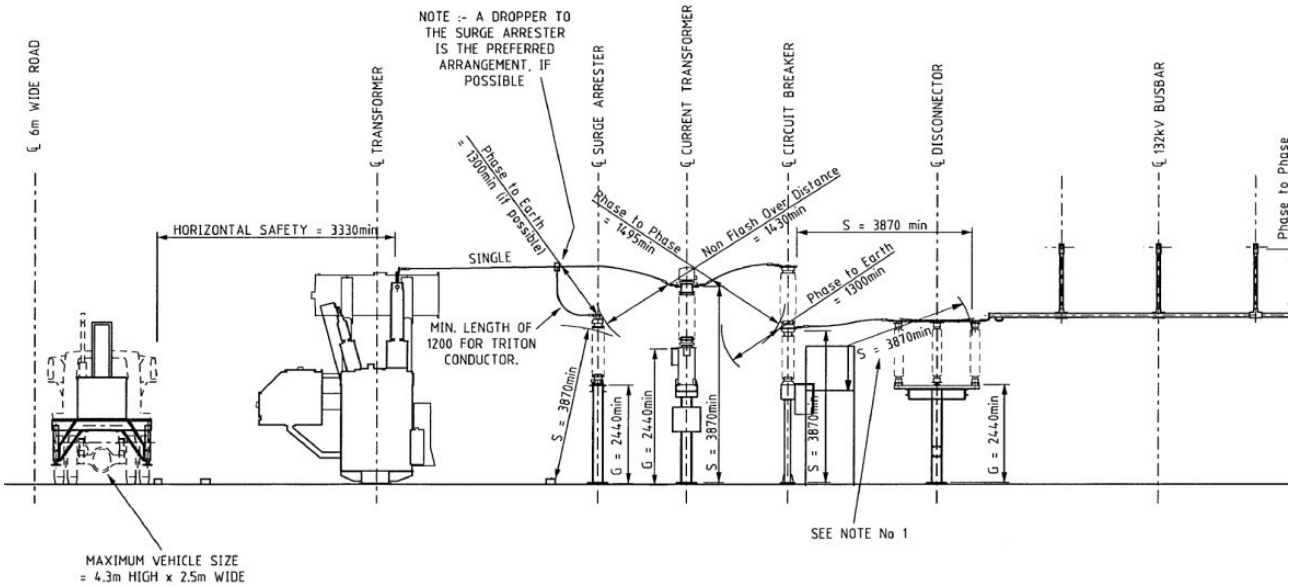


Figure 9.3: Required clearances in a standard zone substation transformer circuit

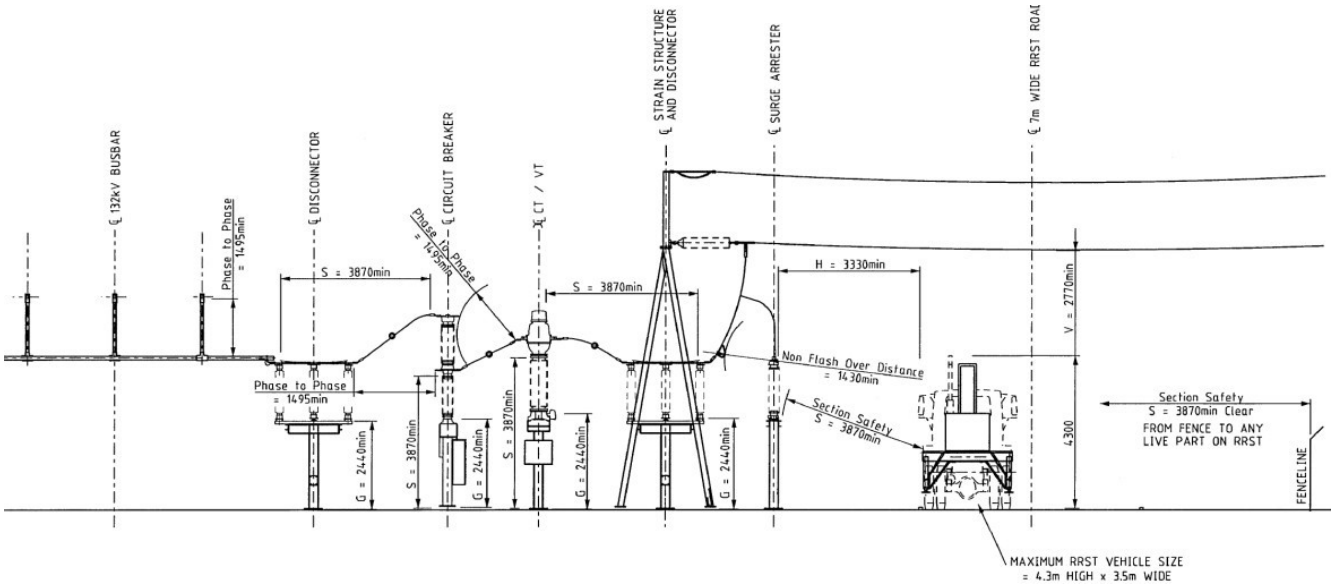


Figure 9.4: Required clearances in a standard zone substation overhead line circuit

Clearance drawings such as these must be completed and issued for all Greenfield sites and for significant work in Brownfield sites. It is important to issue these drawings so that there is a permanent record of the clearance requirements. It is also a useful tool so that Construction can validate and confirm the clearances are achieved on site.

9.1.3.1 Voltages Less than or Equal to 33 kV

Generally, for outdoor equipment of voltages of 33kV or less, maintenance is performed from a ladder or scaffolding.

Circuit breaker maintenance is usually performed on the disconnector side of the circuit breaker. This is due to the lack of space between the current transformer (connected to the other side of the circuit breaker) and the circuit breaker for maintenance to occur.

Care must be taken that ‘V’ ‘H’ and ‘S’ are applied from the extremities of the plant being worked on. For horizontal clearance, this is usually from the outer edge of the plant palm to the nearest live point. For

22kV and 33kV outdoor busbar arrangements, the nearest live point may be the live side of the circuit disconnector, the busbar or the droppers from the busbar to the disconnector.

An example of this is in Figure 9.5. The ‘H’ clearance from the circuit breaker to the live side of the disconnector has been met. However, the high busbar arrangement is such that the 22kV busbar is closer to the circuit breaker than the circuit disconnector. The busbar will still be live when the circuit disconnector is open; therefore, the live busbar is within the H dimension from the circuit breaker. For this circuit breaker to be maintained, this portion of the 22kV busbar will have to be de- energised. This is poor design resulting in additional cost every time this circuit needs to be maintained.

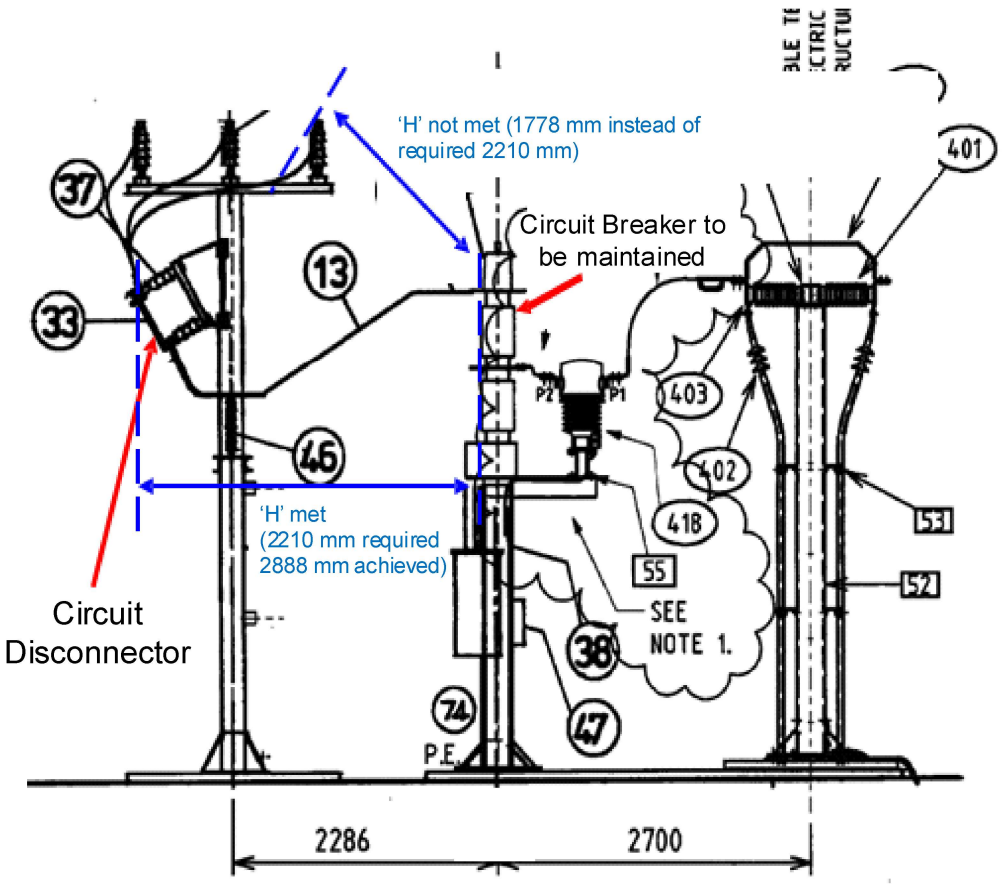


Figure 9.5: Example of poor design practice resulting in 'H' clearance not being met

9.1.3.2 Greater than or Equal to 66 kV

Work on plant at 66kV or higher is done using an Elevated Work Platform (EWP). Therefore, the design must take into account the available access to the circuit with an EWP and the clearances required for the work to take place.

Wherever possible, section safety should be applied in a horizontal direction from the extremity of the work object to the nearest live parts. Refer to Figure 9.6 below.

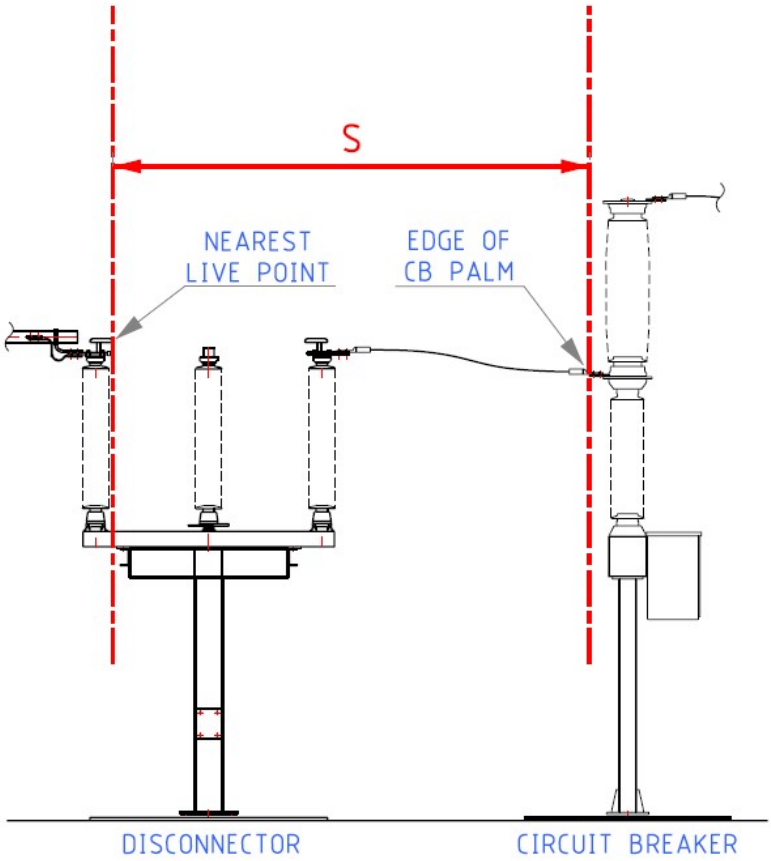


Figure 9.6: Preferred section safety clearance for maintenance

If the above requirement is not achievable, the two following conditions must be met:

1. Horizontal clearance must be applied in a horizontal direction (i.e. in a horizontal plane) between the extremity of the work object and the nearest live parts
2. Section safety clearance must be applied as a taut string measurement, from the foot position over the EWP bucket railing to the nearest live parts. For this check, the bucket (with a width of 650mm and railing height of 1100mm) can be placed no closer than 450mm to the plant being maintained.

See Figure 9.7 below for an example.

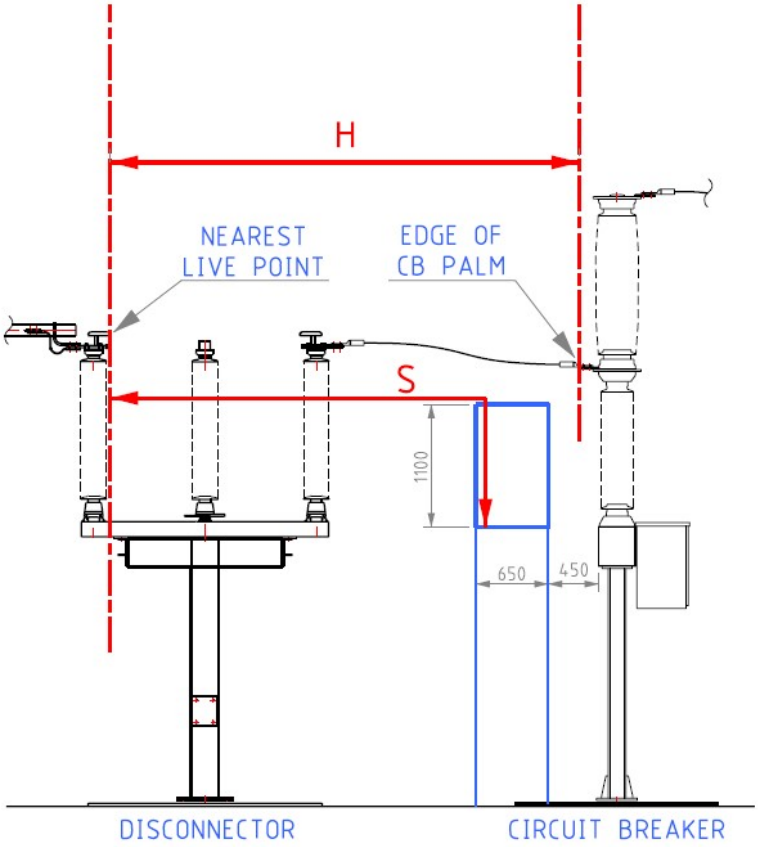


Figure 9.7: Requirements for 'S' and 'H' for work from an EWP on a 132 kV circuit breaker (see section 9.1.4 for bucket dimensions)

9.1.4 Working from a Moving Platform

Where mobile equipment can be moved whilst being stood or sat upon, the greater of the following clearances shall be applied:

1. Section safety clearance (S) is applied from any part of the vehicle or mobile plant where a person would normally sit or stand to live parts.
2. Clearance X = N + 1900 is applied horizontally from the extremities of the vehicle when against the kerb line or side of the access way to live parts and exposed conductors.

Refer to Figure 9.8 for an example.

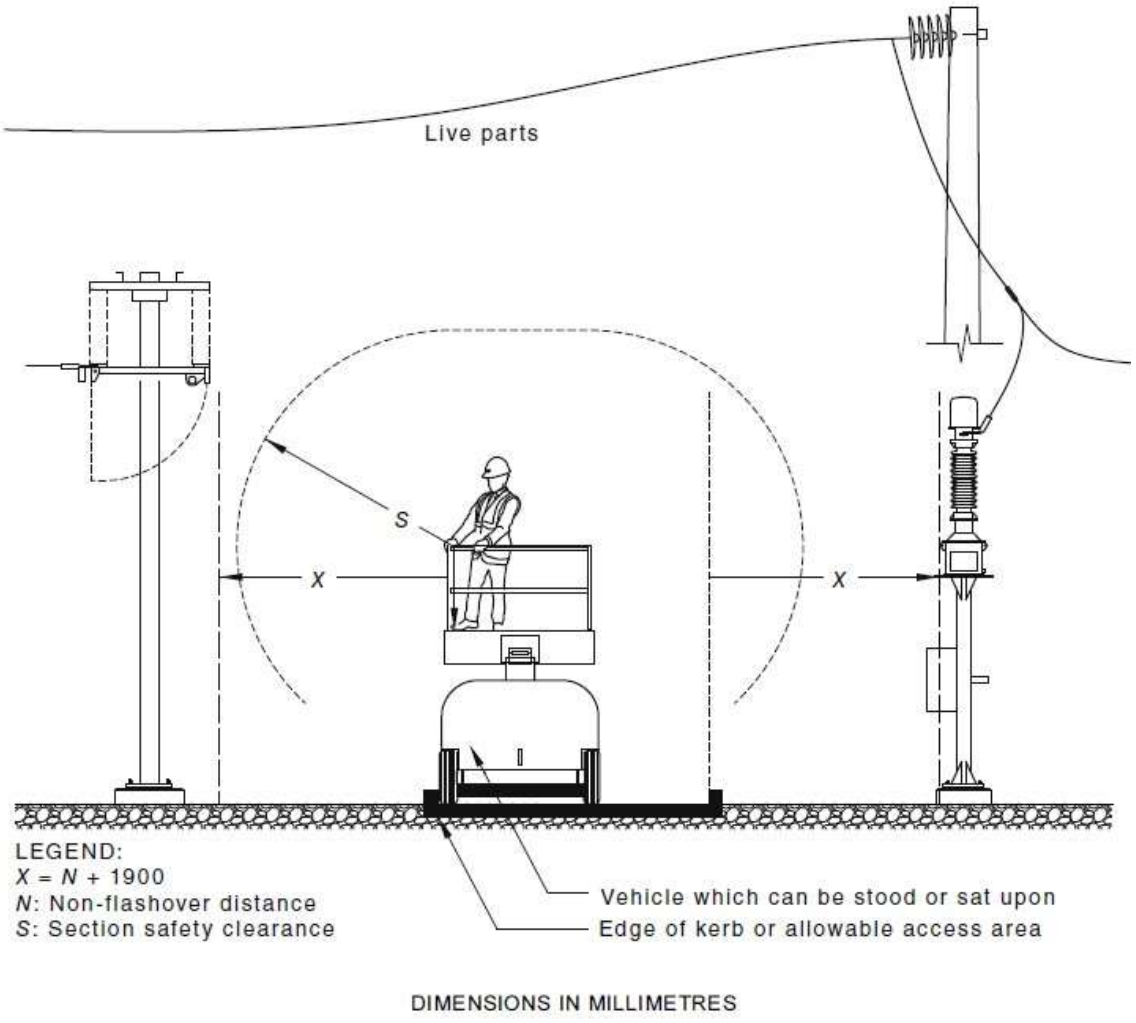


Figure 9.8: Minimum working clearances within a substation (taken from AS2067 Figure 5.3)

The types of plant used by maintenance is outlined in *Transmission Maintenance – Fleet Vehicle and Equipment Used within Substations.*

A bucket size of 870 mm wide, 650 mm deep and 1100 mm high shall be assumed in all substation design work.

If the nearest live conductor is overhead, then V must be met between the extremity of the work object and the nearest live part. See Figure 9.2.

9.2 Transport Clearances

9.2.1 Types of Vehicles in Substations[8]

The following vehicles may be required to enter a substation:

[8] See Western Power Internal Document

1. Cars
2. Trucks
3. Low loader
4. Cranes
5. Hiabs

See Table 9.1 below for a summary of the common vehicle dimensions.

Table 9.1: Summary of common vehicles and machinery used in Substations.

Vehicle Type	Used for	Length	Width	Height
Car	Utility	5.7	2.1	2.25
Heavy Crew Truck with Oil Trailer	Transformer maintenance	15.17	2.5	3.4
Crane truck	Transformer maintenance	11.2	2.5	3.6
Truck with EWP trailer	Circuit breaker and disconnector maintenance	10.9	2.31	2.5
Mini crawler crane (leguan)	Circuit breaker and disconnector maintenance	2.715	0.75	1.44

The maximum size vehicle designed for in the 'standard' substation is 4.3m high and 2.5m wide. The maximum RRST vehicle size is 4.3m high and 3.5m wide.

9.2.2 Types of Roads in Substations – Restricted and Non-Restricted

All roads in Greenfield substations should be non-restricted roads. However restricted roads exist in many Brownfield substations identified by a chain across the road and an accompanying sign. See Engineering Design Instruction – Substation Identification, Signage and Labelling for signage wording.

All roads within the substation must be clearly marked. In Greenfield sites, all roads are marked with a kerb line, however in Brownfield sites the road may just be gravel or sand. When work is done in Brownfield sites where the road is not marked, this problem must be rectified.

9.2.3 Clearances Required

Where vehicles move on marked roads within substations, the following clearances must be checked for vehicles located anywhere on the marked road.

1. Section Safety Clearance must be met from the highest point on a vehicle where a person would normally sit or stand and any live conductor.
2. Horizontal Clearance must apply between the extremities of the vehicle (when it is parked against the kerb) and any live conductor. See Figure 9.9 below.

3. According to AS2067, Transport clearance ‘T’ (= ’N’ + 100mm (500mm min)) is to apply between the highest point of a vehicle (where personnel cannot sit or stand) and any live conductor. This was introduced in the 2008 revision of AS2067. This was previously a vertical ‘V’ clearance. Maintenance prefers the vertical clearance ‘V’ from the highest point on the vehicle to any overhead live conductor. Hence vertical clearance ‘V’ shall be applied wherever possible.

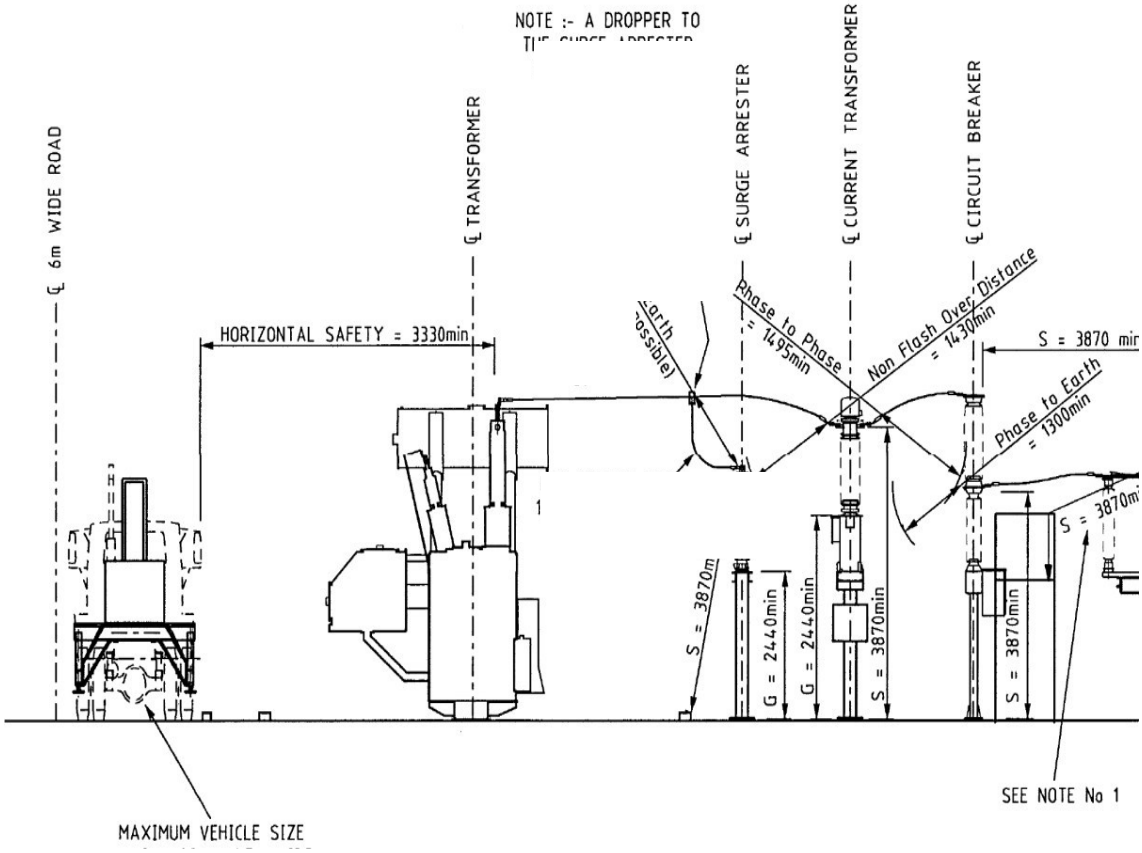


Figure 9.9: Horizontal clearance from live HV transformer bushing to vehicle

9.2.4 Gate Access

Front gate entry should be designed such that the car/truck can pull off the road out of traffic whilst the gate is being opened.

10 Clearance Applications

10.1 Boundary Clearances

10.1.1 Horizontal Clearance

For outdoor substations, section safety clearance S must be achieved from all live equipment to the boundary fence (except for capacitor banks which must meet clearances in Section 12.3). AS2067 states that where the boundary fence type is a solid wall, the minimum clearance required in N + 1000 mm,

however this does not allow for maintenance on the wall, which is not practicable. For this reason, section safety clearance has been selected by Western Power and must always be achieved. See Figure 10.1 below. For a fence of mesh construction, the maximum opening in the wire shall be 50mm.

10.1.2 Vertical Clearance

The height of the incoming line over the substation fence is determined by the required height outside the substation. This is outlined in AS7000, Table 3.5 which is referred to in AS2067.

Table 10.1: Minimum height for clearance over substation boundary fence (from AS7000 Table 3.5)

MINIMUM CLEARANCE FROM GROUND, LINES OTHER THAN INSULATED SERVICE LINES

Nominal system voltage *U*	Distance to ground in any direction m		
	Over the carriageway of roads	Over land other than the carriageway of roads	Over land which due to its steepness or swampiness is not traversable by vehicles more than 3 m in height
Bare or insulated conductor or any other cable $U \leq 1000$ V	5.5	5.5	4.5
OR			
Insulated conductor with earthed screen $U > 1000$ V			
Insulated conductor without earthed screen $U > 1000$ V	6.0	5.5	4.5
Bare or covered conductor			
1000 V $< U \leq$ 33 kV	6.7	5.5	4.5
33 V $< U \leq$ 132 kV	6.7	6.7	5.5
132 kV $< U \leq$ 275 kV	7.5	7.5	6.0
275 kV $< U \leq$ 330 kV	8.0	8.0	6.7
330 kV $< U \leq$ 400 kV	9.0	9.0	7.5
400 kV $< U \leq$ 500 kV	9.0	9.0	7.5

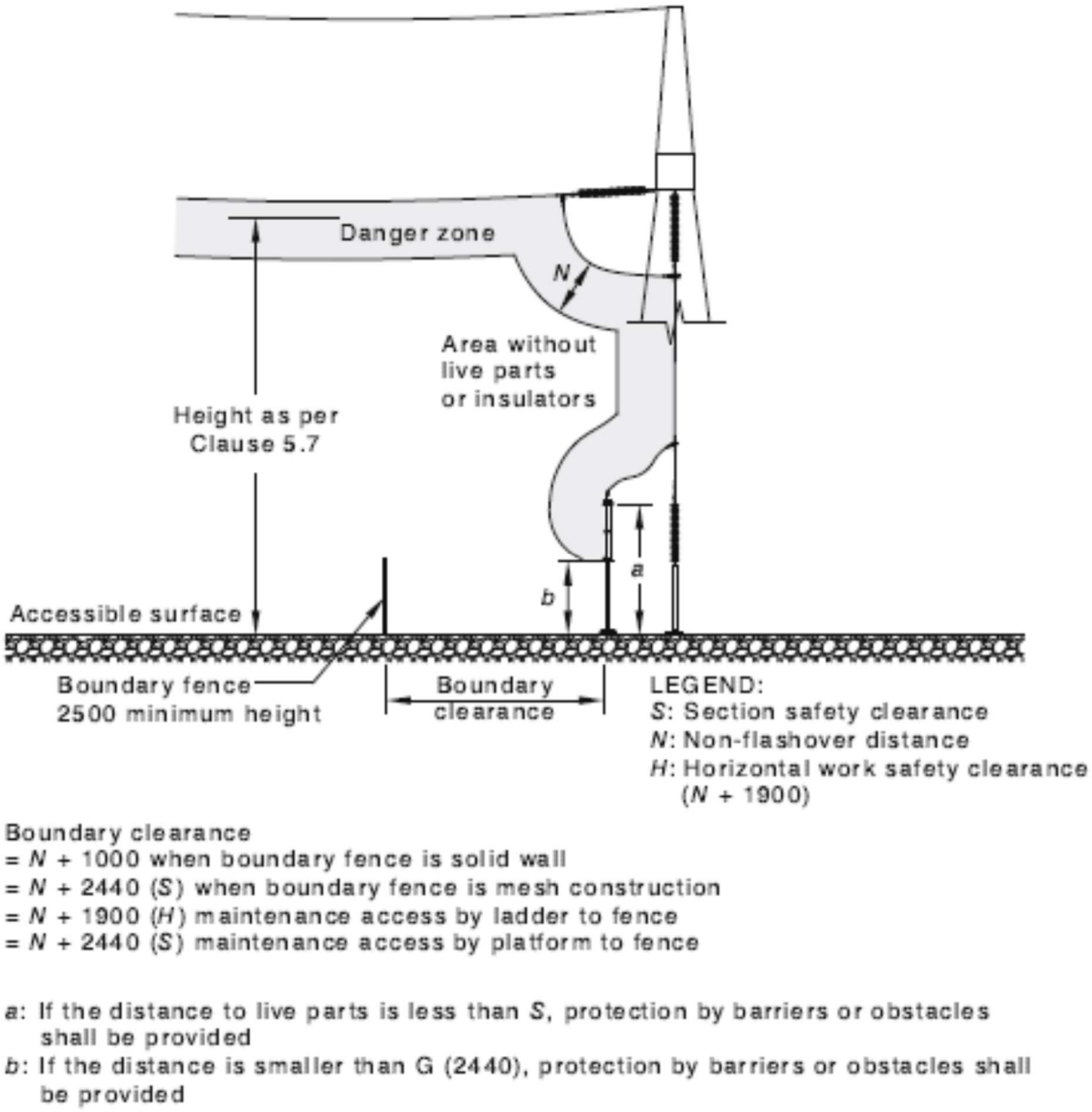


Figure 10.1: Substation boundary fence clearance required (AS2067, figure 5.7)

10.2 Buildings

Where possible, it is preferred that substations are designed such that conductors do not have to cross over the top of buildings. However, if crossovers are required, they must meet the requirements outlined in this Section.

When bare conductors cross overhead of a building within the substation the following requirement must be met:

1. For an installation where the roof can be accessed, a minimum height of section safety clearance 'S' must be maintained from the roof to the conductor at maximum conductor sag

All building rooves must be assumed to be accessible since maintenance work will need to be done on the building rooves on a regular basis (cleaning gutters etc).

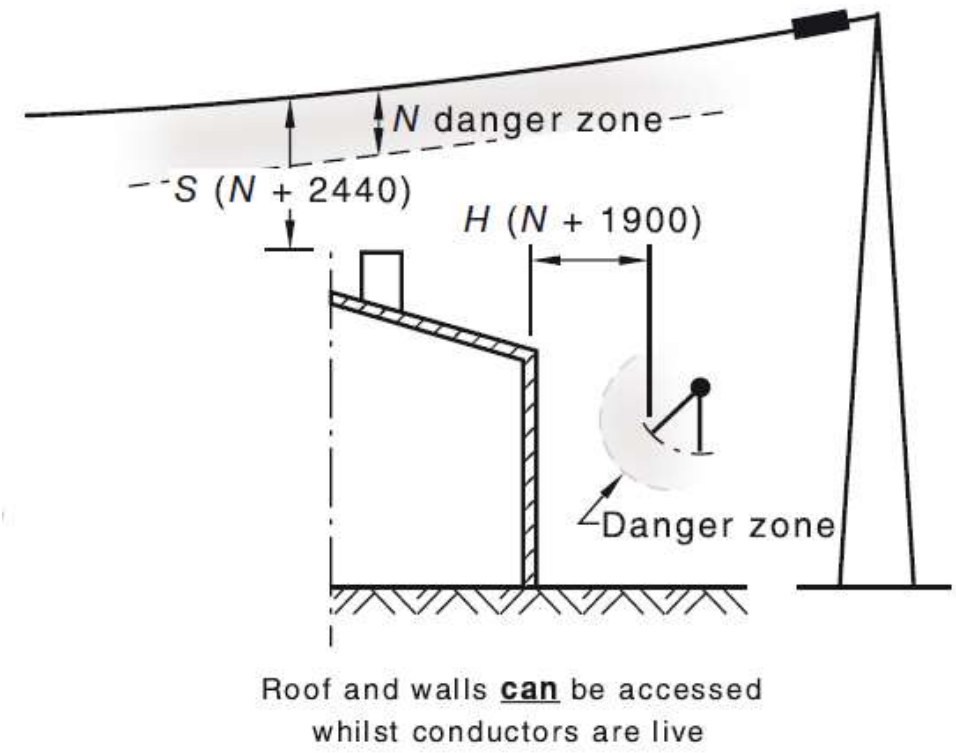
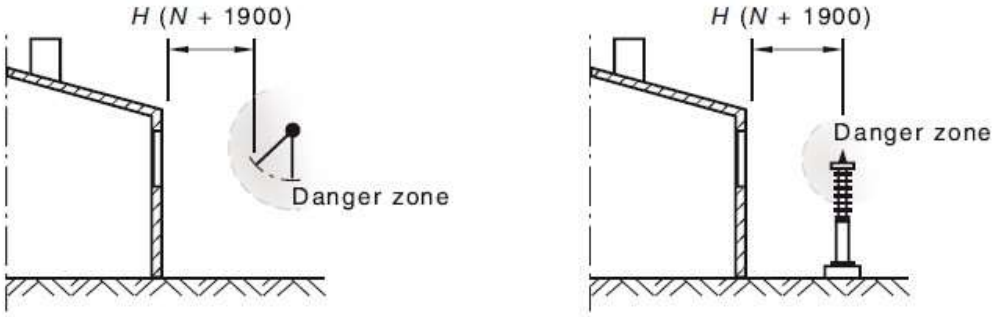


Figure 10.2: Approaches to buildings within substation – outer wall without windows (from AS2067 figure 5.9)

When bare conductors approach buildings within substations, the following clearances must be maintained under maximum sag and swing of conductors:

1. If the building has unscreened windows, the minimum clearance required is horizontal work clearance 'H'
2. If the building has screened windows, the minimum clearance required is N + 300mm (minimum 600mm). Screening must be in accordance with Clause 5.2.2 in AS 2067.
3. If the wall has no windows, the minimum clearance required is N + 300mm (minimum 600mm)
4. If the roof and wall is assessable, the minimum clearance required is horizontal clearance 'H' from the end of the roof towards the conductor in a horizontal plane.



NOTE: This applies whether or not the roof and/or walls can be accessed when the conductors are live.

DIMENSIONS IN MILLIMETRES

Figure 10.3: Approaches to buildings with unscreened windows with substations (from AS2067 figure 5.11)

Since all rooves within substations are assumed accessible, the minimum distance between the building wall and any live part is horizontal clearance 'H' plus the maximum swing distance of the conductors.

10.3 Capacitor Banks

For capacitor banks, it is important to ensure that the location within the substation is such that someone cannot directly access the capacitor bank after climbing the external fence or poke an object into the capacitor bank compound from outside the substation. For these reasons the following distances must be maintained.

1. For boundary fences of open construction such as weldmesh, chain link or palisade, the capacitor bank fence must be at least 6m from the boundary fence.
2. For solid boundary fences such as concrete or brick, the capacitor bank fence must be at least 2m from the boundary fence. If this distance is not achievable, the capacitor bank must have a roof, however this is not desired as it creates problems for maintenance and should only be used as a last resort. If a roof is required, it must be constructed of removable sections to allow for capacitor back maintenance or replacement.

10.4 Lighting Masts[9]

Refer to *Engineering Design Instruction – Substation Lighting Design* for the requirements of lighting within greenfield and brownfield applications. Where lights are installed on 8 or 12m see- saw masts in a substation, the mast must be lowered to the ground for the globes to be replaced. When existing see saw masts are used within the substation, the clearance must be checked for the swing of the mast.

The position of all lighting masts must be checked to ensure that they do not restrict maintenance access to equipment. Where possible, the masts should be installed as per the standard layout. Where masts must be

[9] See Western Power Internal Document

moved or extra masts added in, and discussed at the COM review (with approval from the Substation Design Principal Electrical Design Engineer).

10.5 Handrails

Where handrails are installed in a substation, they must be of a non climbable construction. This means that any rungs must be vertical.

Where climbable handrails (type with a bottom horizontal rung) exist in substations, section safety clearance is required from the bottom rung of the handrail to the nearest live parts.

The substation is a controlled environment and everyone who enters the substation has undertaken training on allowable movements while in a substation (or is under close supervision of someone who has been trained). Standing on the lower rung of the handrail is strictly prohibited, however clearances should be met from the lower rung of the handrail to cover for a situation where a person stands on the lower rung.

The layout of the handrail and access must be checked to ensure that there are sufficient access points (i.e. stairs between the two levels) for people to use. Insufficient designated access points may encourage people to take a short cut and climb over a handrail.

10.6 Surge Arrestors

10.6.1 Phase to Ground[10]

In general the clearance between a surge arrestor and a grounded object should be the same as the phase to ground clearance of the relevant voltage. In some cases, this distance can be reduced but must be checked on a case-by-case basis depending on the surge arrestor and installation conditions[11].

10.6.2 Same Phase

In normal operating conditions, the clearance between the surge arrestor and other equipment connected to the same phase (bushings or post insulators) is usually not a problem. However, in polluted conditions the voltage distribution along the insulator surface may become uneven and create high voltage stresses between the surge arrestor housing and other nearby equipment. To eliminate this problem, half the phase to earth clearance should be maintained from the energised end of the surge arrestor to the energised end of any other equipment. See Figure 10.3 below where D is phase to earth clearance.

[10] See Western Power Internal Document

[11] 1HSM 9543 16-01EN Insulation withstand and clearances with EXLIM and PEXLIM surge arresters – Ed2 2015

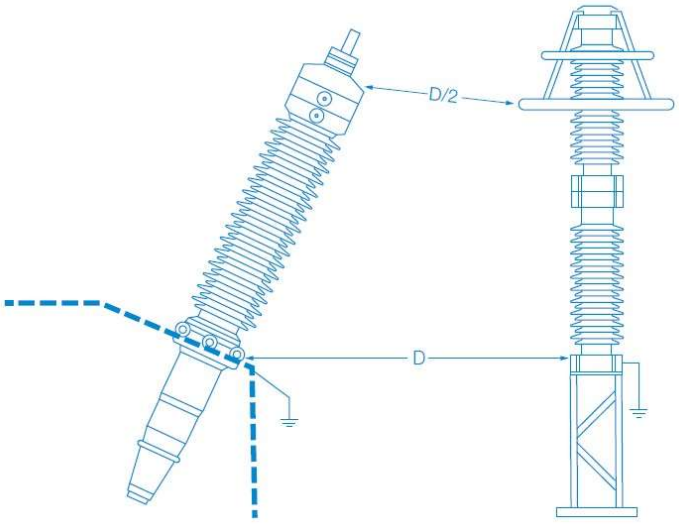


Figure 10.3: Clearance from surge arrestor to other high voltage equipment in the same phase[12]

Figure 10.3 shows these recommendations, where D is the selected phase-to-ground clearance for the selected EXLIM or PEXLIM surge arrester. For the case with a vertically mounted bushing and if a PEXLIM arrester is used with a better pollution performance than a porcelain type EXLIM arrester the suggested required distance D at the lower end may be omitted.

Where possible, the placement of the surge arrestor should allow for the dropper to be disconnected and the circuit put back into service for a surge arrestor failure. To achieve this, there must be phase to earth clearance between the overhead conductor and the top of the surge arrestor. The importance of this requirement is reduced for polymeric type surge arrestors and therefore it can be relaxed where it is not possible to achieve. This is because the polymeric surge arrestors are quite light compared to the porcelain type and therefore can be removed without the need for an EWP, minimising the time to remove the surge arrestors and get the circuit back into service if required.

10.7 RRST Temporary Fence

The RRST has bare exposed equipment and clearances also need to be maintained. Given that the RRST can be climbed onto once parked into position it is important that the temporary fencing is installed prior to it being energised. This will prevent people from climbing onto the RRST and breaching clearance.

Ensure that on the RRST plans for the site that the temporary fence is shown around the RRST.

If, for clearance purposes, it is important for the RRST to be parked in an exact location, then guides should be installed or painted on site to aid the location of the RRST.

[12] 1HSM 9543 16-01EN Insulation withstand and clearances with EXLIM and PEXLIM surge arresters – Ed2 2015, Figure 3

11 Maintenance Access to Equipment

11.1 Space between Circuits

Circuits within substations must be spaced to allow construction and maintenance work to be done on one circuit without the need to remove the adjacent circuit from service. This requires that there are not only sufficient safety clearances between the circuits but also room to manoeuvre equipment between circuits. The standard zone substation layout designates 21 m between circuits to allow maintenance access past the transformers to the transformer circuits.

Since the required space between circuits can strongly influence the overall layout of the substation and sometimes determine whether a new circuit addition is possible, this must be proposed and discussed at the concept design stage and then reviewed again at the detailed design stage.

11.2 Access Ways

The substation designer must consider how the equipment being installed in going to be maintained through its lifetime when doing the initial design. The designer must ensure that all equipment is able to be accessed by crawler crane and an elevated work platform.

For all Greenfield substations and for major work in Brownfield sites, an access plan must be created and issued showing the routes for maintenance equipment. The access plan must be practical and be developed in conjunction with the Maintenance group during the COM review.

For new transformer installations, an access way is required between bunds to allow maintenance on the transformer circuit. This will determine the overall circuit spacing of the site. Maintenance prefer not to drive over transformer bunds to access transformer circuits.

See Figure 11.1 for an example of how access routes on a site should be considered with relevant clearance distance.

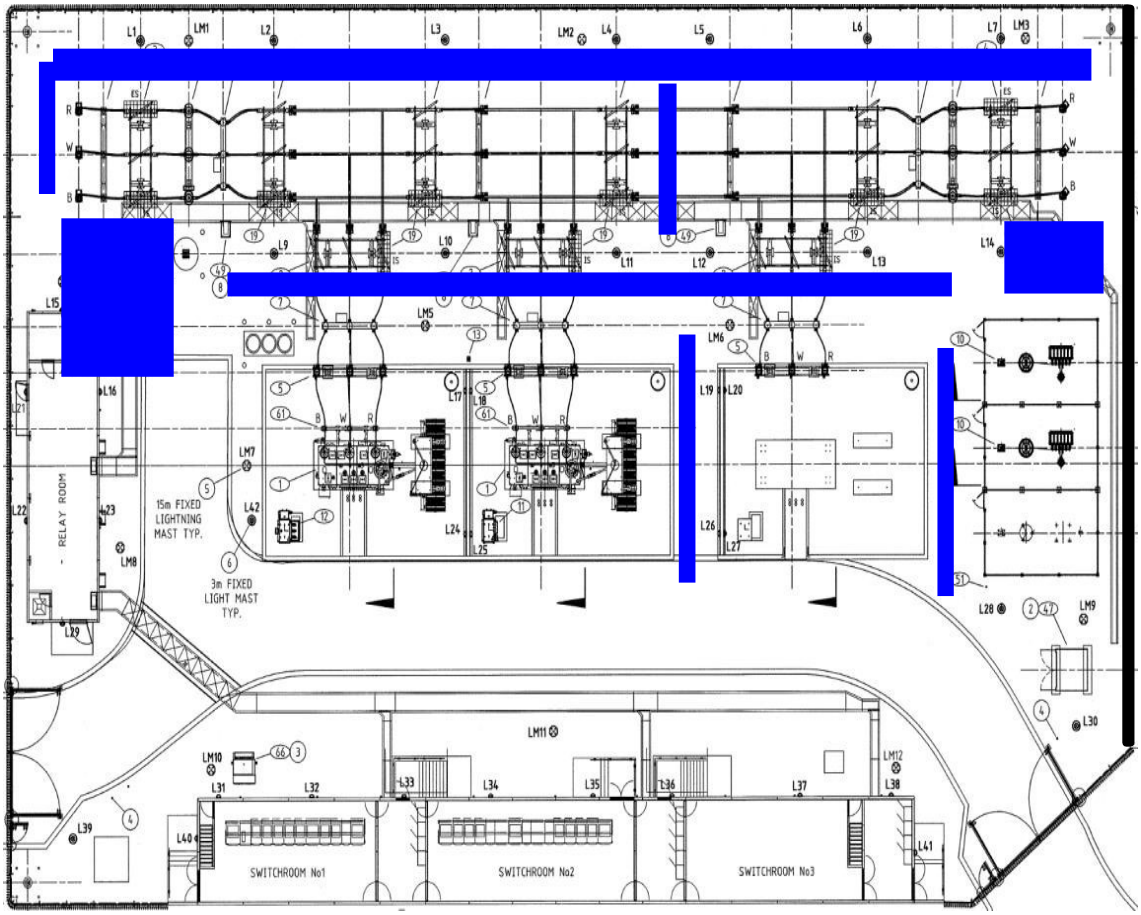


Figure 11.1: Example of consideration of access ways for maintenance in the initial design of a new substation

11.3 Capacitor Bank Fencing[13]

The capacitor bank fencing requires that the outer edges of the compounds to be lower than the shared fence line to improve maintenance access. When the capacitor bank cans fail, a small crane needs to be positioned to lift an individual can out.

The dividing fence between capacitor banks need to be a minimum height of 3750mm. The dividing fence needs to be higher so that during maintenance the adjacent circuit can remain on, and the extra height will prevent accidental contact between cranes/equipment and live cap bank circuits.

13 See Western Power Internal Document

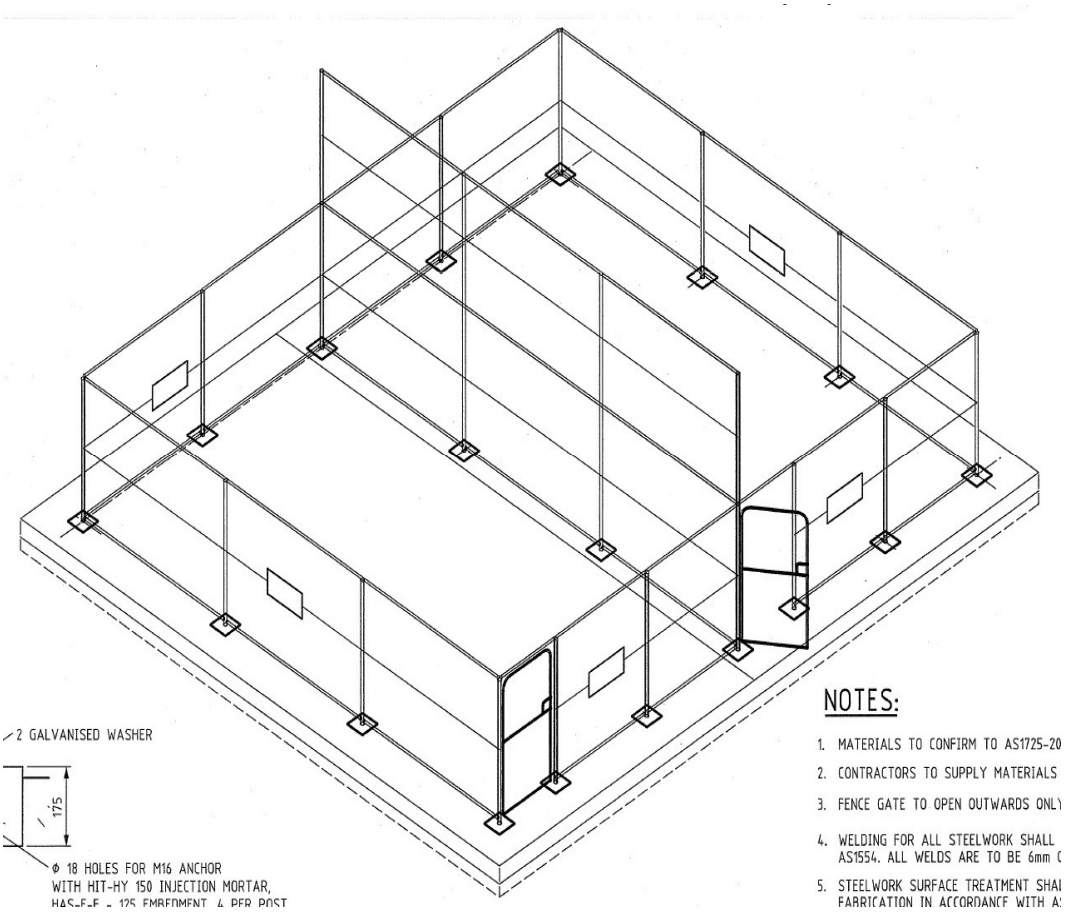


Figure 11.2: Example of capacitor bank fencing to improve maintenance access

11.4 Trafficable Cable Trench Covers

As part of the access plan discussed in Section 11.2, maintenance equipment such as EWPs and mini cranes will be required to cross over cable trenches to access the circuit breakers and disconnectors. An EWP weights approximately 1300kg and a mini crawler crane approximately 2000kg. Therefore, at these crossover points, trafficable cable trench covers are required. The circuit breaker is usually maintained from the disconnector side, hence a trafficable cover section of about 2m between the circuit breaker and disconnector is suggested in standard applications. This requirement should be agreed with the Maintenance group during the COM review.

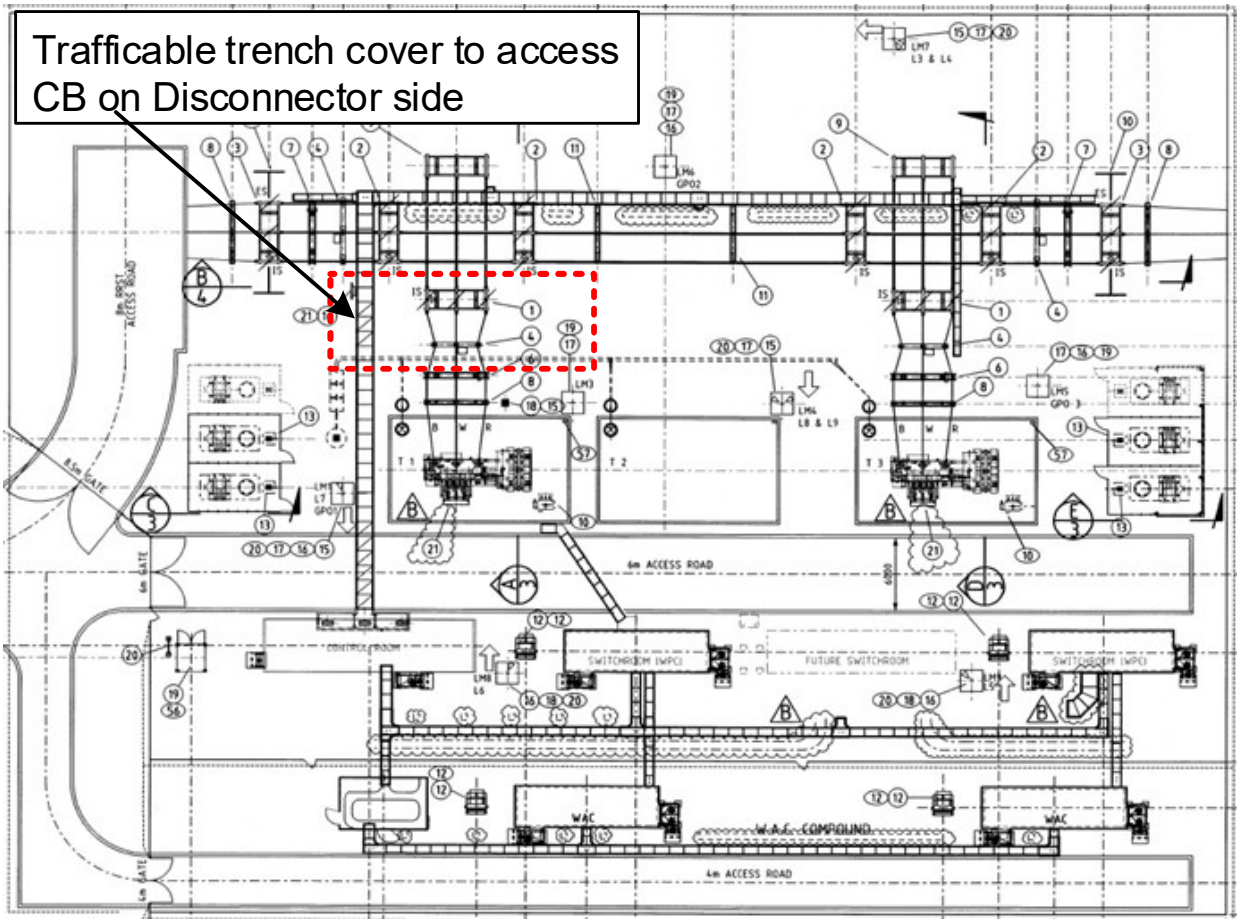


Figure 11.3: Example of where trafficable trench covers have been installed for CB maintenance access

11.5 Set Back Distances from main Access Roads

The main access road/s within a substation are used quite frequently, particularly in construction or scheduled maintenance periods. They are used by different vehicles of many different sizes, the largest being for a new transformer delivery. All non-live electrical equipment must be placed at least 2m from the edge of the road, to avoid it being accidently knocked by a vehicle.

The distance from live electrical equipment to roads is governed by horizontal safety clearance, covered in Section 9.2.3.

11.6 Minimum Structure Height

To allow personnel to safely walk around the substation, the horizontal beam in equipment pi structures should be a minimum height of 2m from the ground. This allows people to walk underneath the beam. When the beams are installed at a lower height, it is easy for people to hit their head or hardhat on the beam. If a structure beam must be installed at a lower height for a site-specific application, reflective tape must be installed along the face of the beam on both sides.

12 Standard Layout Clearances

12.1 Derivation of Standard Layout Clearances

The standard phase spacing used in Western Power substations are outlined in Table 12.1 below. For all voltage levels, these standard spacing are considerably larger than the minimum phase to phase requirements in Table 8.1. These phase spacings have been influenced over time by plant items, particularly disconnectors. The phase spacing on the lower voltages have been increased to reduce the potential for flashovers as a result of birds or animals bridging across two or more phases.

Table 12.1: Phase to phase standard spacing

VOLTAGE LEVEL	STANDARD PHASE SPACING
6.6 kV	750 mm
11 kV	750 mm
22 kV	750 mm[14]
33 kV	900 mm
66 kV	1800 mm
132 kV	2400 mm
220 kV	3500 mm[15]
330 kV	5800 mm[16]

12.2 Deviations to Required Clearances

In some situations, it is not practical to meet the required clearances discussed in the proceeding chapters of this design instruction. This section covers when this is acceptable and what measures must be put into place in these situations.

Deviations to standard clearances should only be accepted where it is not reasonably practical to meet the standard clearances. This may be due to the cost involved or required outages which may be unobtainable from a network point of view to change the configuration. Deviations to the standard clearances are not acceptable in Greenfield applications since the substation is planned and designed with these requirements in mind.

If a deviation is required, a suitable measure (such as a protective barrier) must be implemented to ensure the safety of personnel and plant. The deviation must be approved by the Substation Principal Electrical Design Engineer.

[14] Clearance should be increased to 900 mm to reduce chance of outages due to birds or vermin on circuits that require high reliability. This is supported in AS2067 Section 2.5.1.

[15] Typically, 220kV Greenfield sites are built at 330 kV. Therefore, 330 kV spacing are to be followed. The busbar phase centres for existing 220 kV installations are 3500 mm.

[16] The main busbar centres (without disconnectors) for 330 kV are 4500 mm.

All new work and modifications to existing installations must comply fully with AS2067. When part of a Brownfield substation is modified, only the part being modified needs to be brought up to the current standard.

12.3 Protective Barriers

As discussed in the previous section, protective barriers should not be used in new Greenfield substations since the substation should be laid out in a manner where all clearances should be met. Barriers should only be used as a last resort in Brownfield installations where it is not possible to meet the required clearances.

A protective barrier shall be of substantial construction and shall be designed for the environment in which it is to be installed. Barriers may either be a solid type or an open mesh type.

12.3.1 Mesh Type

The mesh type protective barrier shall meet the following requirements:

1. minimum height of 1800mm
2. the greater of:
    a. clearance of N + 300mm between the internal surface and the nearest live parts OR
    b. section safety clearance from the ground outside the barrier over the barrier in a taut string measurement to the nearest live parts
3. degree of protection of at least IP1XB or IP2X (maximum mesh opening of 50mm and 12.5mm respectively – see AS1939 Supp 1 and 2 for IP rating explanation).
4. for non-rigid protective barriers, the clearance values should take into account any possible flex in the barrier and ensure that the clearances are not breached in this situation.

Section safety clearance ‘S’ must be met from the foot position of a person, in a taut string measurement over the barrier to the nearest live part. The mesh barrier must be a minimum of ‘N’ + 300 from the live parts. This is illustrated in Figure 12.1 below.

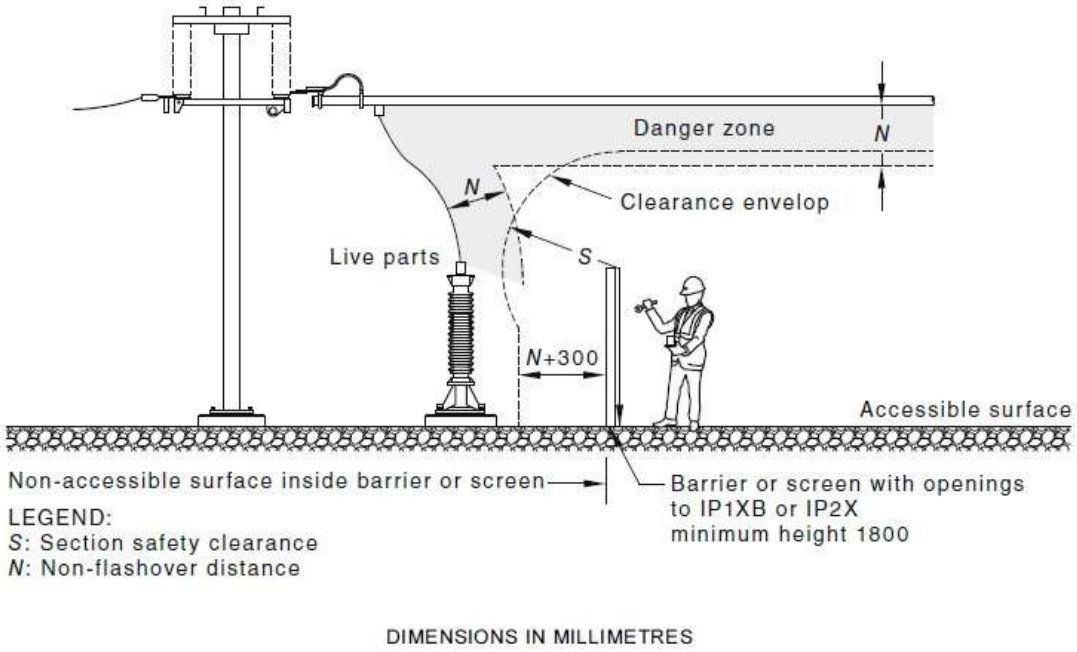


Figure 12.1: Protection against direct contact by using mesh screens (from AS2067 figure 5.5)

In some Brownfield applications when new equipment is installed, the horizontal clearance to the road kerb is not achievable. Designing a mesh type screen along the roadway (with a clearance of more than N+300mm from the live equipment palm to the screen post) will mean that no external parts on vehicles can breach clearances. See Figure 12.2 below for an example of a barrier installation.

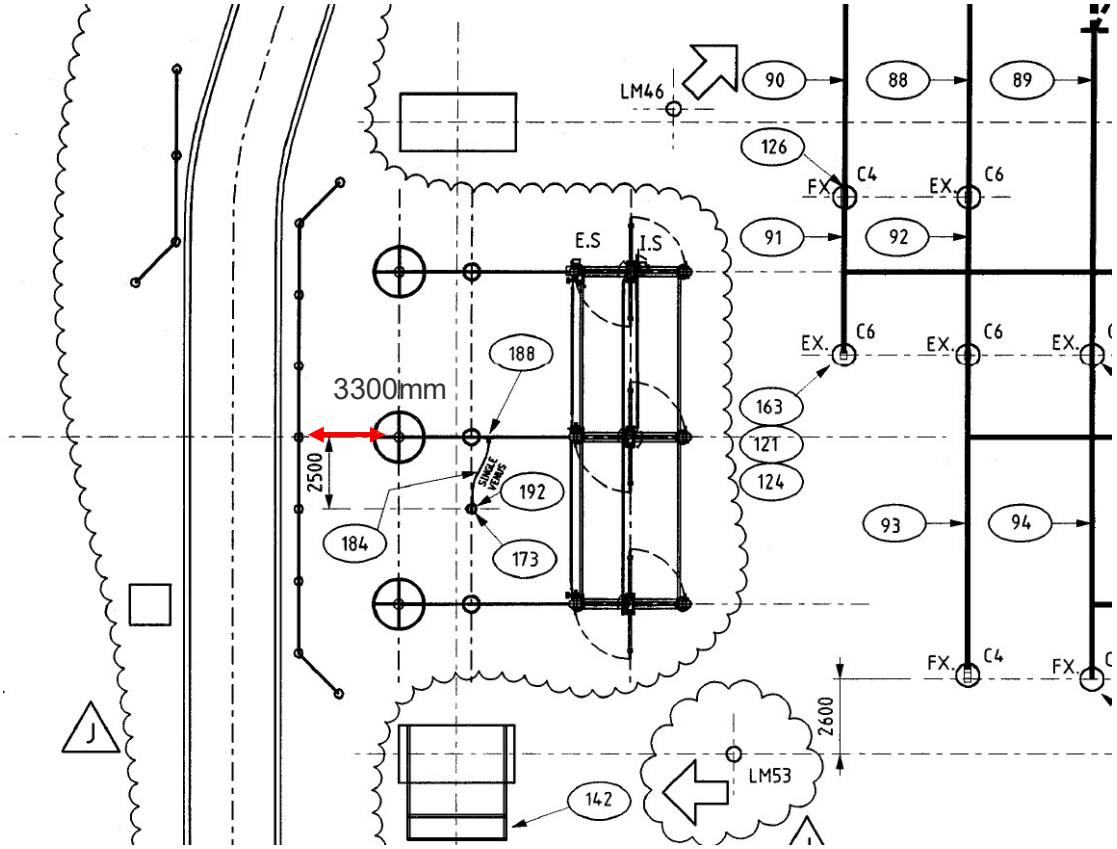


Figure 12.2: Example of where Horizontal Clearance is not met, and a screen has been installed (minimum live equipment to fence distance is N+300 = 2630 mm for 330 kV)

12.3.2 Solid Type

The solid type protective barrier shall meet the following requirements:

1. minimum height of 1800mm
2. the greater of:
    a. clearance of N between the internal surface and the nearest live parts OR
    b. section safety clearance from the ground outside the barrier over the barrier in a taut string measurement to the nearest live parts

Section safety clearance ‘S’ must be met from the foot position of a person, in a taut string measurement over the barrier to the nearest live part. The solid barrier must be a minimum of ‘N’ from the live parts. This is illustrated in Figure 12.3 below.

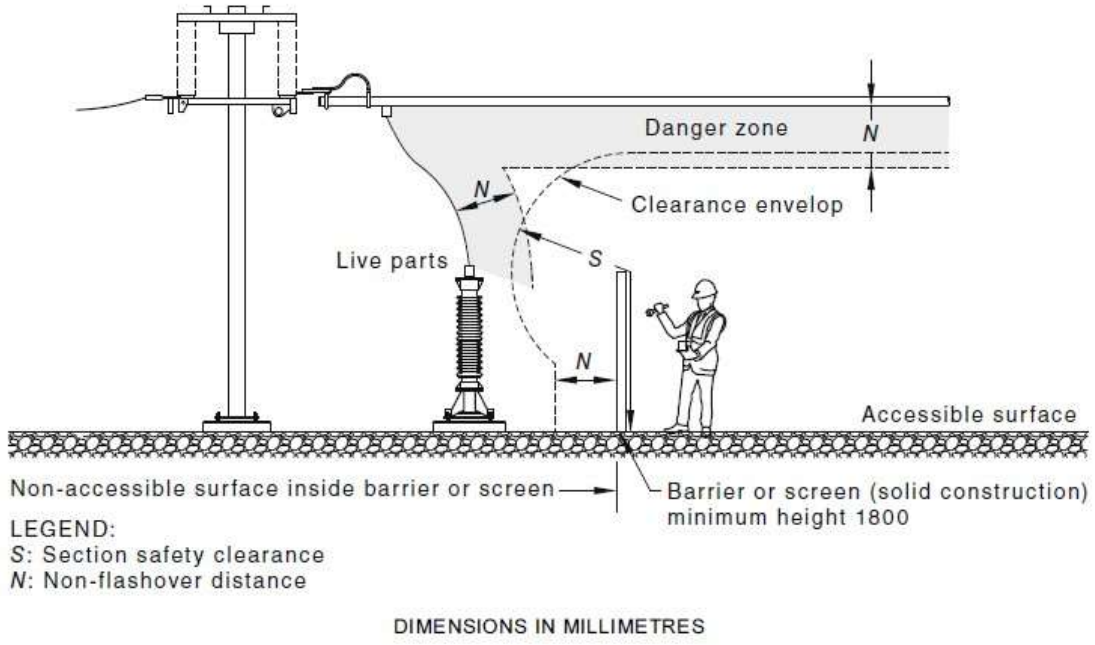


Figure 12.3: Protection against direct contact by using solid screens (from AS2067 figure 5.4)

13 Requirements for Buildings

13.1 Equipment Layout

The following requirements must be considered when designing the building and its layout:

1. The layout of the room must consider the requirements of initial installation, commissioning, maintenance and general use.
2. Evacuation routes shall be at least 600mm wide, even when equipment parts have been removed or cubicle doors are open.
3. To allow for ease of escape in an emergency, doors must close in the direction of egress, where possible.
4. Layout of the substation shall allow easy and unimpeded access to all emergency exits.
5. Arc ducts must be positioned so that damage to property and possible injury to personnel is minimised. They should also be directed towards the internal of the substation and directed upwards.

13.2 Doors

Doors to the substation building must meet the following requirements:

1. Doors must open outwards to allow easy escape.
2. Doors shall be positioned such they do not create a hazard when opened and cannot be inadvertently blocked from the outside.
3. Panic bars must be installed on all outward facing doors in all substation buildings.
4. Outward facing doors shall be a minimum of 1980mm high and 750mm wide.

5. A double door for delivering the switchboard into the switchroom is required.

13.3 Maintenance

For switchboard installations, Maintenance group require a minimum distance of 800mm from the switchboard to the wall at each end of the switchboard and 1000mm at the rear of the switchboard for access. For GIS switchboards the clearance at the rear of the switchboard can be reduced depending on manufacturer and maintenance requirements.

For switch room cable basements, a minimum height of 1900mm is needed for future cable installations and terminations.

14 Documentation Required

As part of the substation design, the following drawings are required:

1. Clearance plans and elevation drawings for all new plant in greenfield and significant installations. These drawings are issued as part of the primary electrical package.
2. Maintenance access plan showing access to all plant. This drawing is to reside in the '/10/' ultimate drawing series.

As part of the substation design, the following documentation is required:

1. Clearance Section of Substation Design Checklist
2. Clearance Section in Substation Design Report outlining:
    a. Any clearance calculations completed
    b. Details of any non-compliance to standard electrical safety clearances and associated risk assessment for reasoning.
3. Any designs with non-compliant clearances must be logged in the *Register - Non-Compliant and Non-Standard Designs.*

This documentation must be completed, checked and signed off as required prior to being saved into the relevant project EDM folder. Endorsement by Principal Electrical Design Engineer and Approval by Substation Design Area Manager is required for all documentation of non-compliant and non-standard designs.

Appendix A: Calculations [17]

A.1: Different voltages (insulation levels) [18]

A.2: Phase to phase under short circuit conditions[19]

A.3: Phase to phase and or phase to earth under wind conditions[20]

Appendix B: Example Clearance Check [21]

Appendix C: Reduced 132 kV Phase to Ground Surge Arrestor Calculation [22]

Appendix D: Approval Record and Document Control[23]

17 See Western Power Internal Document
18 See Western Power Internal Document
19 See Western Power Internal Document
20 See Western Power Internal Document
21 See Western Power Internal Document
22 See Western Power Internal Document
23 See Western Power Internal Document