GROUNDLINE

Memo – Transpower Standard GIP-220kV DC Both Circuits					
Date:	21/11/2024	**Pages:**	14	**Rev:**	2
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Company:	Transpower	**Company:**	Groundline Engineering		
Subject:	**220kV Double Circuit Grid Injection Point Development Remote Substation**				

1. Background

Transpower (TP) engaged Groundline to carry out a study to standardise the double circuit 220kV Grid Injection Point (GIP) which includes support and input for the line's component of this design. The substation component is not in scope for this study.

This study is to standardise the below options:

- Grid Injection Point of a double circuit from a double circuit (DC) 220kV line into an inline installed substation which is installed in span
- Grid injection point of a double circuit from a double circuit (DC) 220kV line into a remote substation, not located within the line span, requiring a tee-off connection to the substation via additional structures

An optioneering study was prepared to determine the two most feasible options out of four for the substation connections. Option three involves the use of a 2DD-HST tower, while option four incorporates poles. This report details the results of these selected options for a **remote substation**. The optioneering study is included as Appendix A to this memo report.

2. Design Criteria

To maximise the loads and conductor swings of GIP, the line will be designed with the following input:

Table 1: Design Parameters

Design Parameter	Description and/or Minimum Requirement
Altitude Assumed for Design Criteria	Structure groups will be defined as follows: 0-800m (S Zone – Snow and Ice Zone)
Maximum Wind	Wind Region - A7 -46m/s 300-year return period to tower line 300-year return period to pole
Snow and Ice Zone	S - NA
Snow and Ice	S – Extreme Snow 3cm S – Extreme Ice 5.5cm
Minimum Temp	-14 degrees
Maximum Operation Temperature (MOT)	120 degrees
GIP Cable	Duplex Zebra - 460mm Spacing
Tensions	Between Inline Structures: VDC %23 – 30.337kN Downleads to Pi-Poles: VDC %2.5 – 3.298kN Downleads to Armless Poles: VDC %2.5 – 3.298kN
External Clearances	TP12.02 – To Ground - 7.5m+0.5m=8.0m TP12.02 - To Substation Building – 6.0m+0.5m =6.5m
Outages	Only single circuit outages are possible on this line.

3. Hardware Information

Standardising hardware and insulator sets in GIP projects simplifies procurement and aligns with Transpower standards for any future application.

Transpower utilises two types of insulator sets for terminal spans, called Line End Sets and Gantry End Sets. The suggested standard insulator set numbers used in the design are tabulated below in **Table 2**. All insulator sets are to be confirmed by TP.

Table 2: Standard Insulator Sets

Location	Proposed Set	Description
Gantry - Line Side	865D	Duplex ACSR, Terminal Span - Gantry End, Zebra
GIP Tower/ Pole Strain - Download	866B	Duplex ACSR, Terminal Span - Line End, Zebra

4. Substation Layout

The substation and gantry structures are arranged according to a preliminary layout from Transpower, with 31.5 metres spacing between the line-in and line-out gantries and a 71.5 metres gap between circuit centres. In Double Circuit (DC) configurations, to ensure required clearances, the terminal structures are positioned perpendicular to the gantries, 60 metres from the 220kV substation gantries as shown in **Figure 1**.

This arrangement will need to be revisited to align with the final substation location for specific projects.

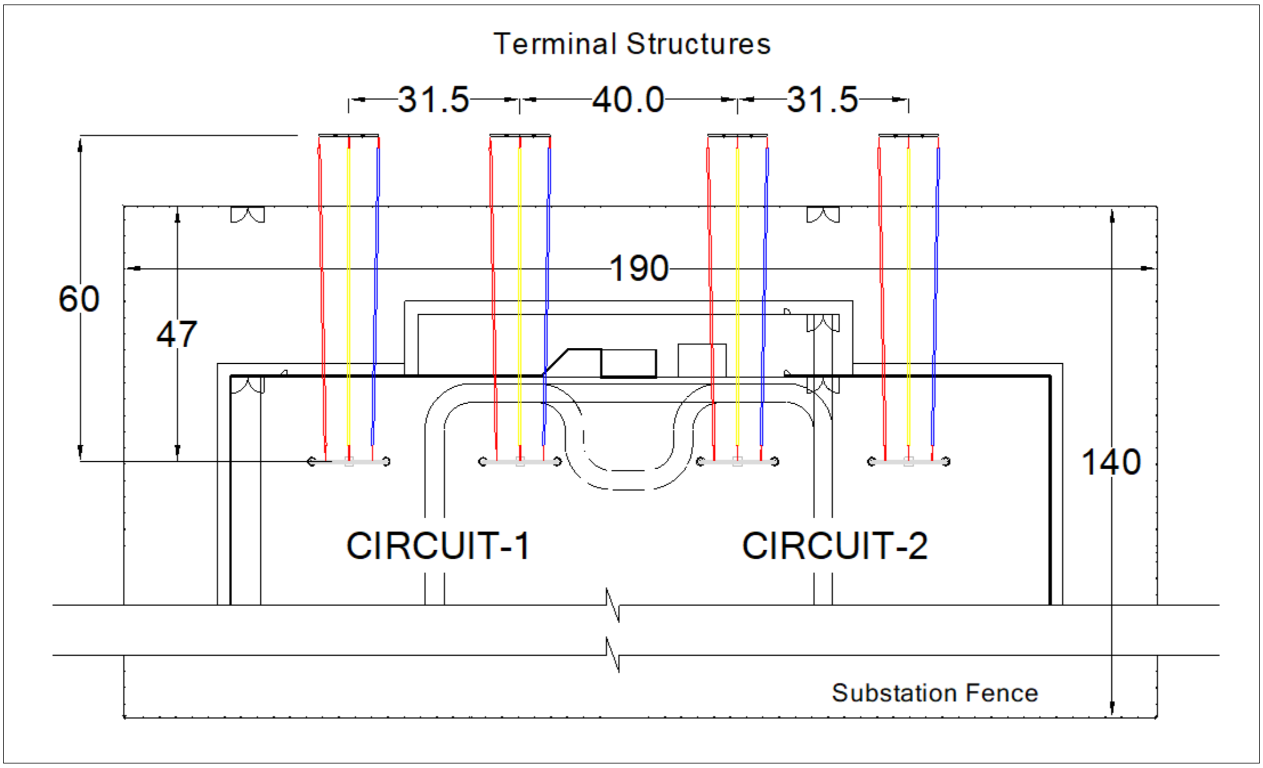

Figure 1: Substation General Plan Layout

5. Remote Substation GIP with 2DD-HST Tower and Tee-Off Poles

5.1. Standardising Design

For this study, a 2DD-HST structure has been selected, featuring the following configuration:

- Six-crossarms to support a double circuit of Grid Injection Point (GIP), along with six single poles to allow undercrossing of the inline conductors.

The ground between the Poles and GIP structure is initially assumed to be level. Attachment heights are set with a 12 metres differential between the poles and the GIP structure, which represents the minimum height difference required to achieve internal clearance standards.

This arrangement is illustrated in **Figure 2** below.

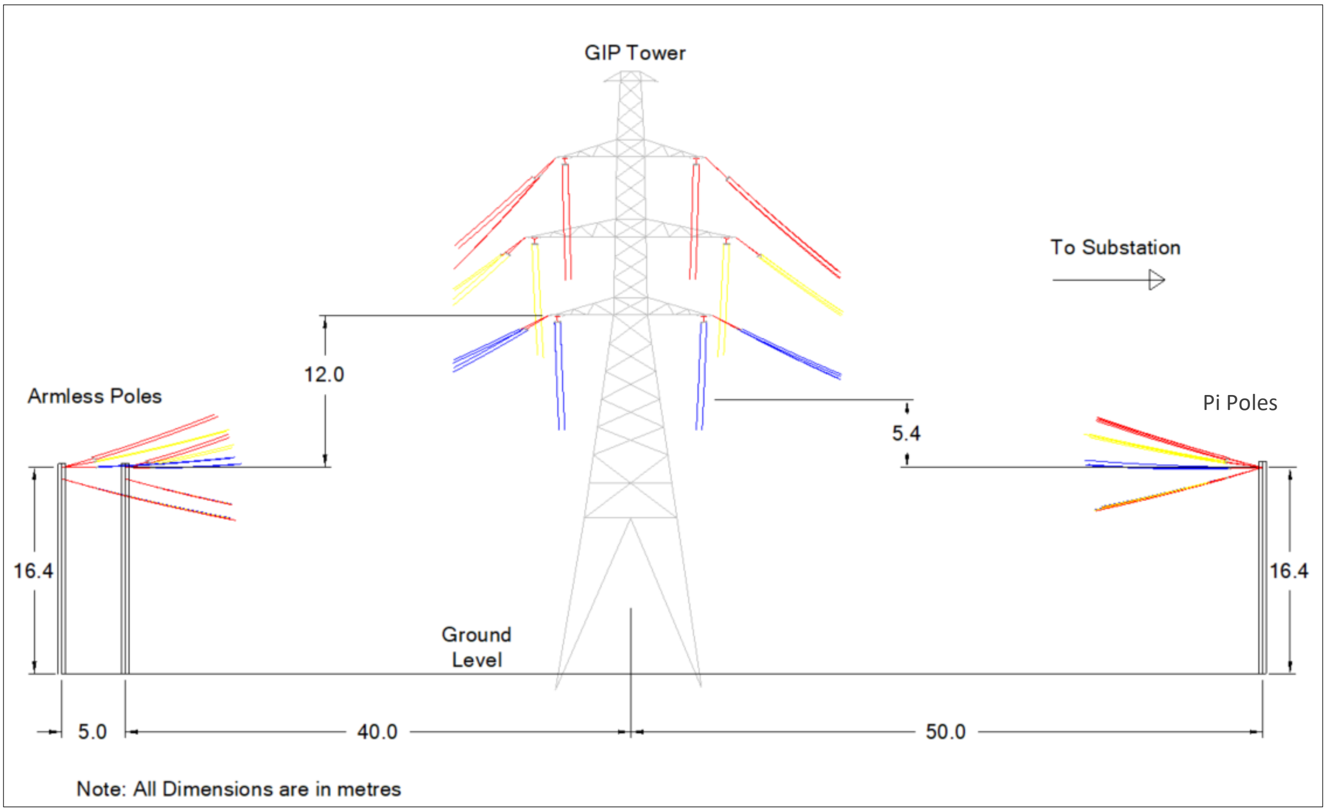

Figure 2: Initial Setup of GIP with 2DD-HST Tower and Poles

The initial plan view setup of poles from tower centre illustrated in **Figure 3** below.

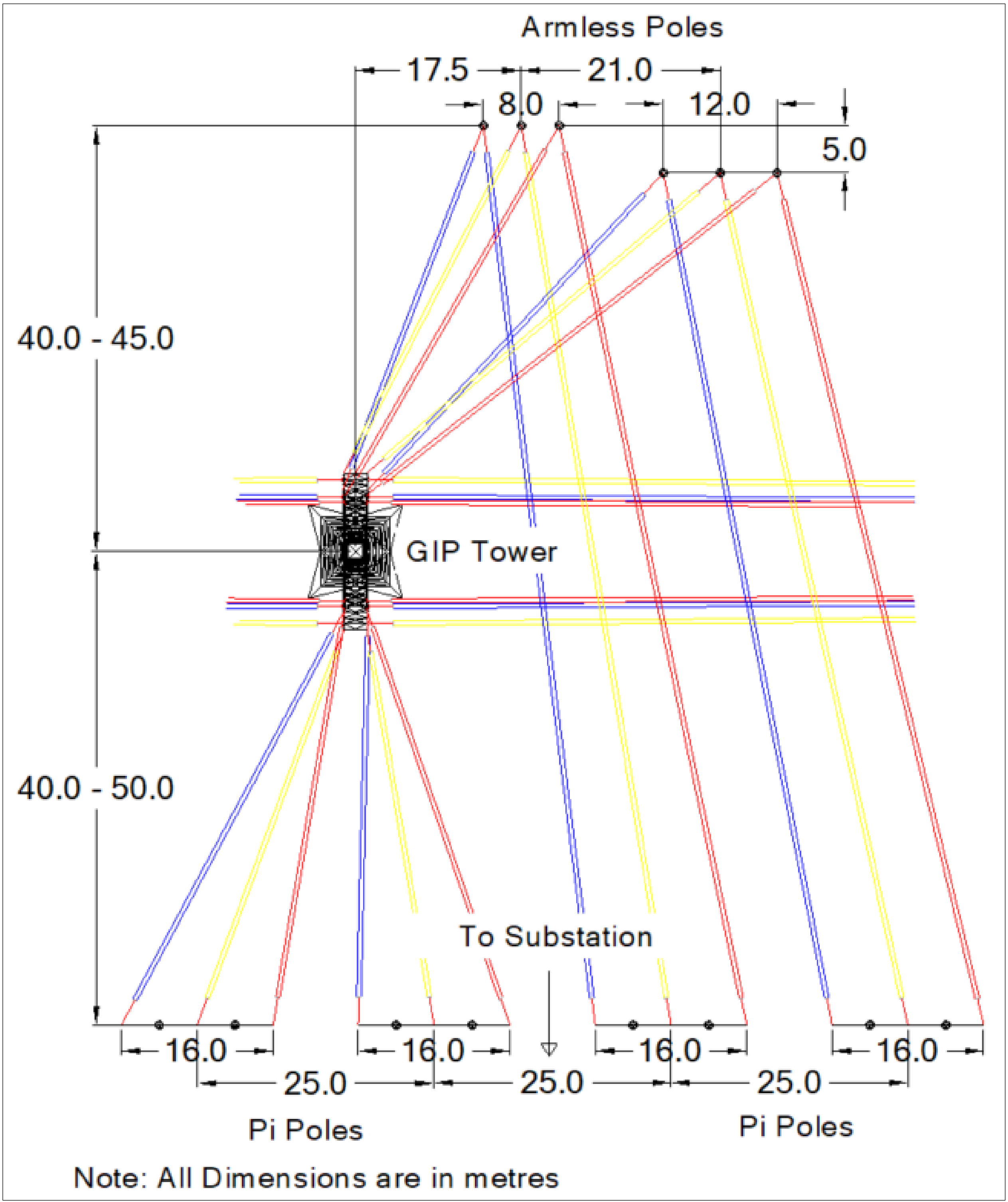

Figure 3: Plan View of Initial Setup of GIP with 2DD-HST Tower

5.2. External Clearances

With the attachment heights set to 12 metres difference between the poles and the GIP structure, an analysis was conducted at the Maximum Operating Temperature (MOT) of 120°C to determine the minimum external clearances at distances of 95 metres between the crossing poles. These distances represent the feasible maximum distance where internal phase-to-phase clearances can be achieved. By comparing the results with TP.DL 12.02, Issue 2.1, the required clearances were confirmed, as presented in **Table 3** below. Increasing the tension between the poles can improve this clearance as needed for ground level adjustments.

Table 3: External Clearances – %2.5 VDC

	To 2DD-HST Structure (m)	To Ground (m)					
	HWD	MOT	EDD	HWD	SDS	TIS	EIS
Required Clearance (m)	**0.75**	**8.0**					
Achieved Clearance (m)	10.61	8.30	8.75	10.70	8.84	8.90	8.84

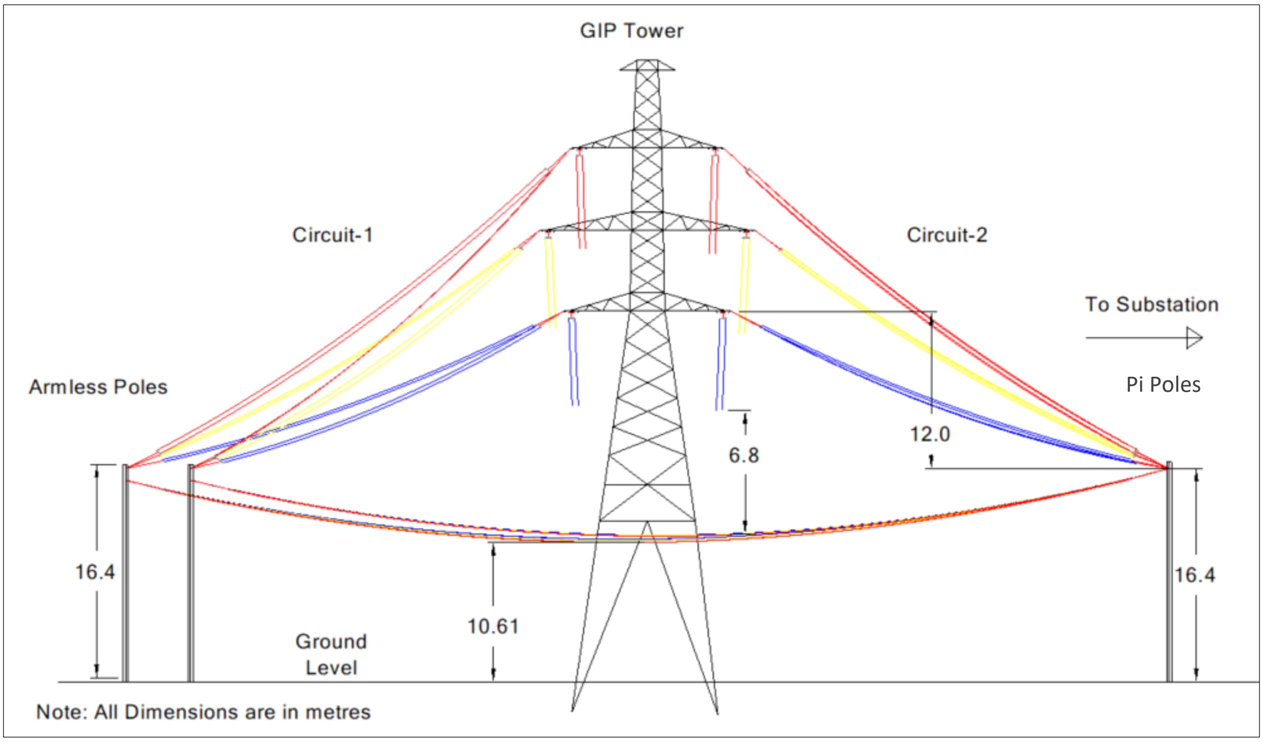

Figure 4: MOT120 External and Crossing Clearance

5.3. Internal Clearances

The internal clearance between phases in terminal towers and poles is a critical design parameter to ensure electrical safety, preventing short circuits by maintaining sufficient insulation and mitigating the risk of electrical arcing.

5.3.1. Span and Phase Elevation Effect

This GIP connection to the remote substation study evaluates both span and phase elevation simultaneously. It highlights that wider movement of armless poles within the span reduces elevation differences in the first circuit before the undercrossing.

This study evaluates the movement range for Armless Poles, considering displacements of up to 5 metres in the Y direction, spanning 40 to 45 metres, and up to 7.2 metres in the X direction, ranging from 6.3 to 13.5 metres relative to the 2DD-HST structure centre.

Within this defined range, the elevation difference is capped at a maximum of 3 metres to ensure compliance with electrical design requirements.

Below **Figure 5** illustrating the movement ranges in the X and Y directions for armless poles:

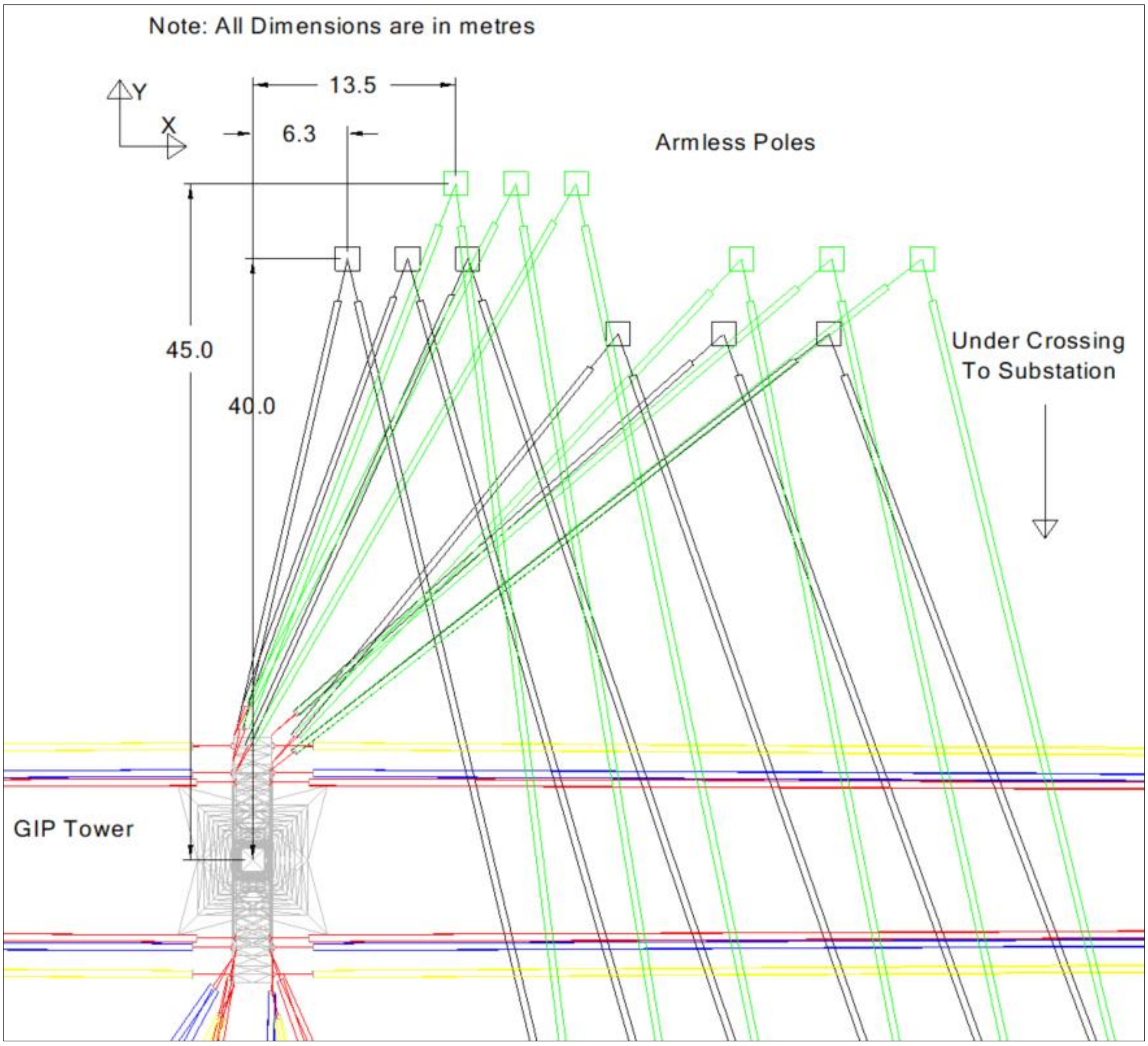

Figure 5: Movement Range of Armless Poles

For the second circuit, the study indicates that positioning the Pi-Poles closer to the GIP enhances internal clearances. This analysis considers spans ranging from 40 to 50 metres and displacements of up to 10 metres in the Y direction. Within this range, the elevation difference is limited to a maximum of 3 metres, consistent with the first circuit.

Below is a figure illustrating the movement ranges in the Y distance from the GIP tower centre and the Y distance separation between poles from the centre of the GIP tower for the Pi-Poles:

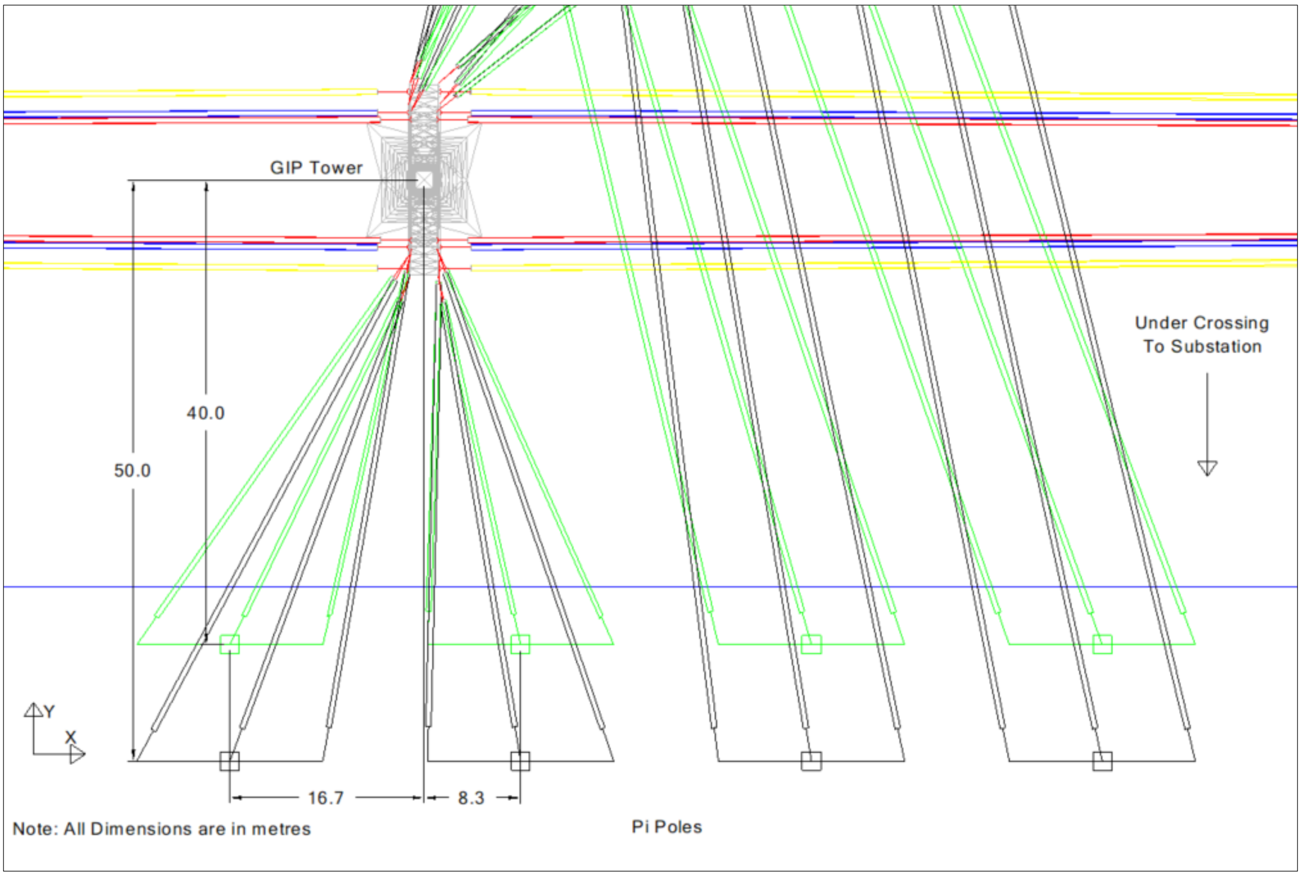

Figure 6: Movement Range of Pi Poles

After testing various span values and elevation differences, the internal clearances achieved for the minimum and maximum ranges, considering a 12 and 15 metres elevation difference and they are detailed in **Table 4 and Table 5** below.

Table 4: Internal Clearance changes for 12m Elevation Difference Under 2.5% VCD Tension

Circuit	GIP Circuit-1 To Armless Poles	Phase Elevation Difference	Conductor	EDS-EDS 1.9m	EDD-EDD 1.9m	EDS-EDD 1.9m	HWD-HWD 0.75m
Circuit 1 To Armless Poles	**Y= 40 metres X= 6.3 metres**	**12 metres**	Phase to Phase	2.131	2.034	1.931	1.733
	Y= 45 metres X=13.5 metres		Phase to Phase	2.101	1.985	1.905	1.656
Circuit 2 To Pi Poles	**Y= 40 metres X= 16.7 and 8.3 metres**		Phase to Phase	2.353	2.133	2.132	1.593
	Y= 50 metres X= 16.7 and 8.3 metres		Phase to Phase	2.775	2.518	2.551	1.767

Table 5: Internal Clearance changes for 15m Elevation Difference Under 3.0% VCD Tension

Circuit	GIP Circuit-1 To Armless Poles	Phase Elevation Difference	Conductor	EDS-EDS 1.9m	EDD-EDD 1.9m	EDS-EDD 1.9m	HWD-HWD 0.75m
Circuit 1 To Armless Poles	**Y= 40 metres X= 6.3 metres**	**15 metres**	Phase to Phase	2.260	2.175	1.933	1.765
	Y= 45 metres X=13.5 metres		Phase to Phase	2.199	2.098	1.904	1.673
Circuit 2 To Pi Poles	**Y= 40 metres X= 16.7 and 8.3 metres**		Phase to Phase	2.151	1.936	1.911	1.466
	Y= 50 metres X= 16.7 and 8.3 metres		Phase to Phase	2.656	2.390	2.30	1.655

Based on the data presented in the tables above, the optimal span, elevation difference, and tension values are as follows:

- **Circuit 1 (To Armless Poles):** A span of 40 metres from the tower centre with a 12 metres elevation difference between insulator attachment heights at 2.5% VDC tension.

- **Circuit 2 (To Pi Poles):** A span of 40 metres from the tower centre with a 12 metres elevation difference between insulator attachment heights at 2.5% VDC tension.

5.4. Gantry Loads

In this study, the GIP tower spans to poles and undercrossing options were analysed. For the gantry loads in the scenario where a 2.5% VDC tension is applied with an 80 metres span and a 1 metre elevation difference between Pi Poles and gantries, the conductor imposes the following maximum loads on the phase attachment points:

Table 6: Maximum Gantry Phase Loadings

Load Case	Weather Case	Vertical (N)	Transverse (N)	Longitudinal (N)
Max. Vertical	EI0050_8 (Extreme Ice)	**4563**	8152	25252
Max. Transverse Wind (Ice Conditions Excluded)	MW2500_A8 (Max. Wind)	1057	**4979**	10171
Max. Longitudinal	EI0050_8 (Extreme Ice)	4563	7693	**25395**

Also given below in **Table 7** are gantry attachment loads for main weather cases:

Table 7: Gantry Phase Loading under Main Weather Conditions

Weather Case	Vertical (N)	Transverse (N)	Longitudinal (N)
EDS (Everyday Still Air)	1117	1931	6173
EDW (Everyday Wind	1116	2156	6198
HWD (High Wind Deflection)	1109	2767	6576
MW2500 (Maximum Wind Deflection)	1057	4979	10171

5.5. Construction of GIP Structures

It would be a step-by-step construction process by starting with the construction of GIP tower. To facilitate the construction of a double circuit GIP tower, tong guys are proposed to enable the construction with both circuits live. A tong guy can be installed under single circuit outages.

The tong guys were used in previous Transpower projects and same setup can be utilised. Please refer to RedEye drawing TP103872.

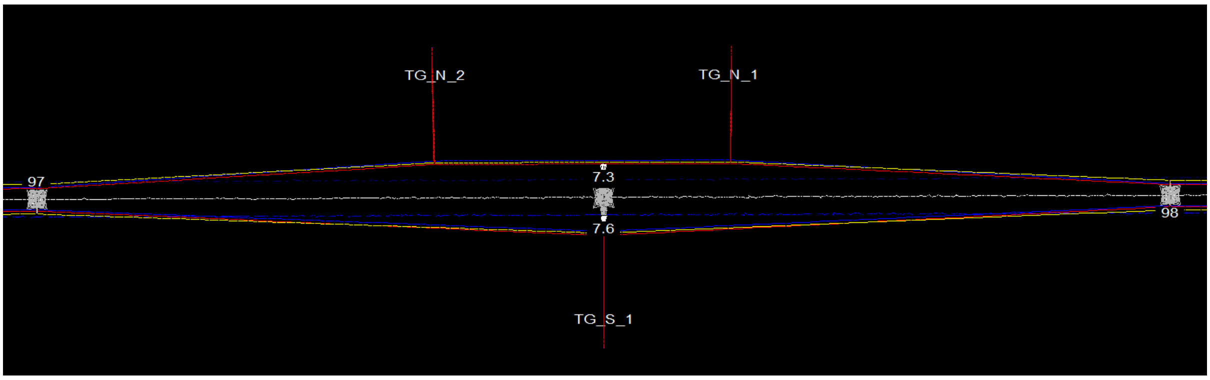

Figure 7: Construction Window by Using Temporary Poles

As the armless poles and pi poles will be around 40 metres from tower centre after enabling the circuits on the GIP structure, these structures can be constructed at the same time with Substation and string the conductors for final connection before the outage. During single circuit outage the downlead conductors can be connected between tower and poles to energise the substation.

6. Remote Substation GIP with Poles

6.1. Standardising Design

For this study, a six-crossarm pole structure has been selected for Circuit 2, while armless poles are used for Circuit 1 at the undercrossing. The configuration is as follows:

- The six-crossarm poles support the first circuit of the Grid Injection Point (GIP), with six single poles enabling the undercrossing of inline conductors.

The ground between the pole structures is assumed to be level, and attachment heights are set with a 12 metres difference between the six-crossarm poles and armless poles to ensure compliance with internal clearance standards, as analysed in Option 1 of this report.

This arrangement is illustrated in **Figure 8** below.

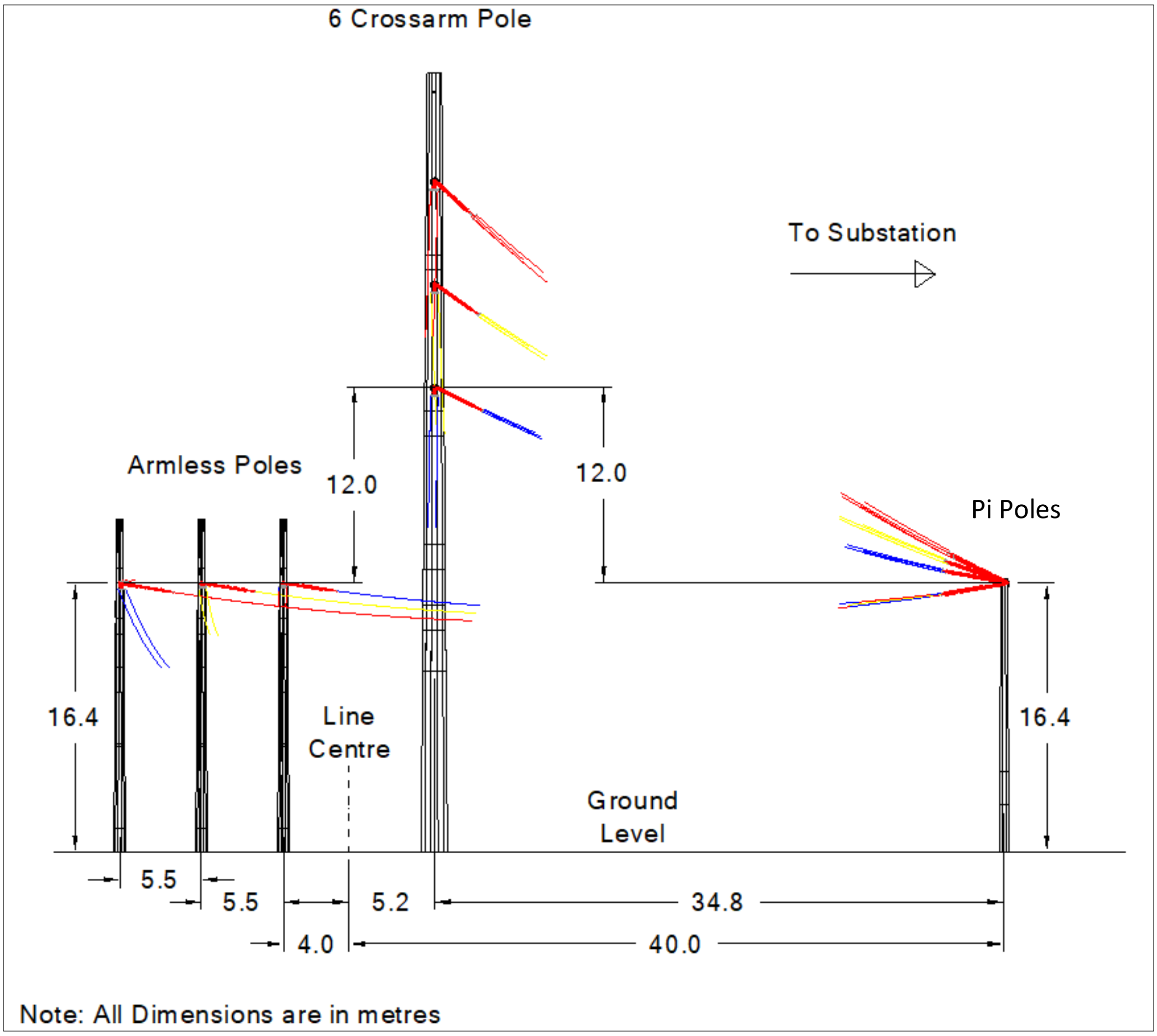

Figure 8: Initial Setup of GIP with Poles

The initial plan view setup of poles from the centre-line as illustrated in **Figure 9** below.

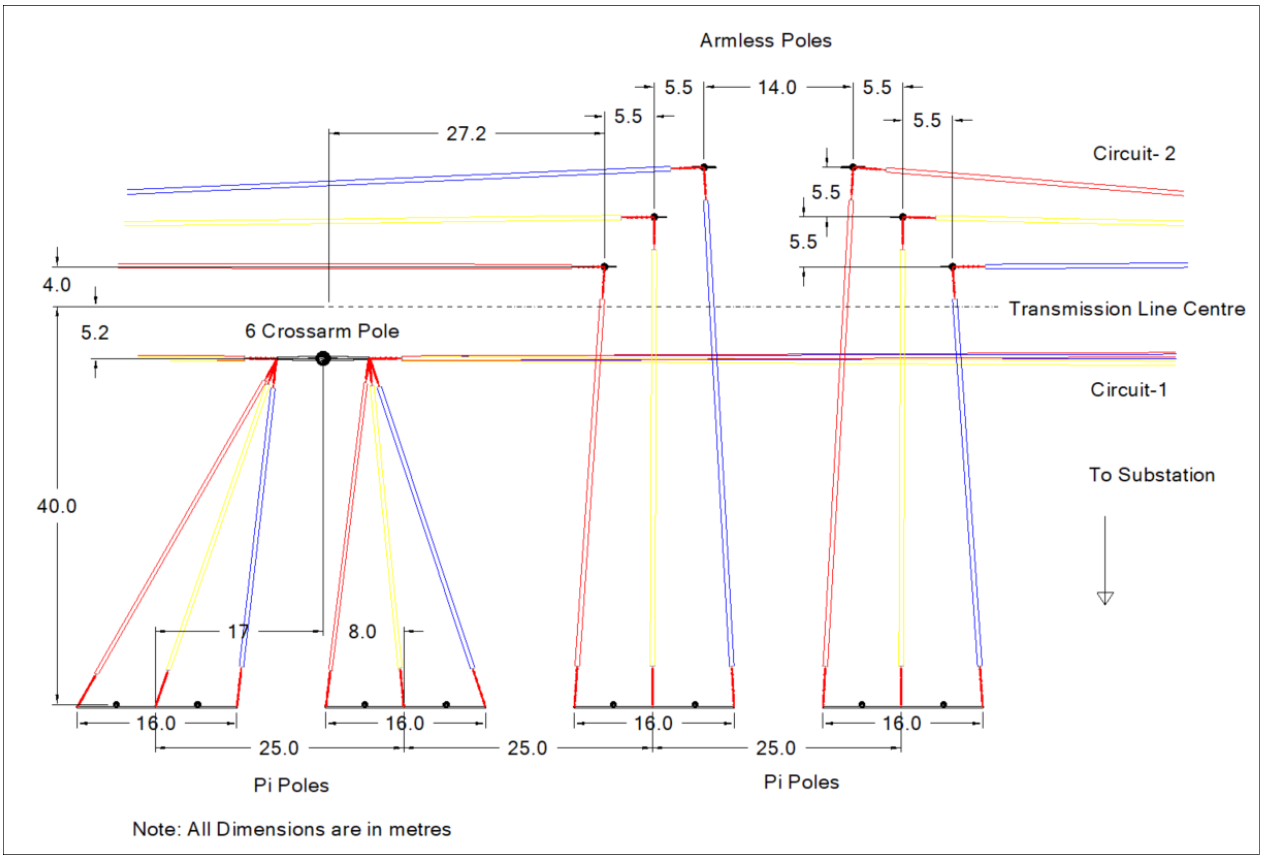

Figure 9: Plan View of Initial Setup of Poles

6.2. External Clearances

With the attachment heights set to 12 metres difference between the six-crossarm pole and the armless poles, an analysis was conducted at the Maximum Operating Temperature (MOT) of 120°C to determine the maximum external clearances at distances of maximum 54 metres between the crossing poles. These distances represent the feasible distance where internal phase-to-phase clearances can be achieved. By comparing the results with TP.DL 12.02, Issue 2.1, the required clearances were confirmed, as presented in **Table 8** below. Increasing the tension between the poles can improve this clearance as needed for ground level adjustments.

Table 8: External Clearances – %2.5 VDC

	To Ground (m)					
	MOT	EDD	HWD	SDS	TIS	EIS
Required Clearance (m)	**8.0**					
Achieved Clearance (m)	13.71	14.13	14.67	14.26	14.34	14.25

To ensure compliance with the external clearance requirements for Circuit 1 between the armless pole and the ahead structure, the pole heights have been maintained at 16.4 metres, consistent with the Option 1 study, despite achieving a ground clearance of 13.7 metres at the undercrossing.

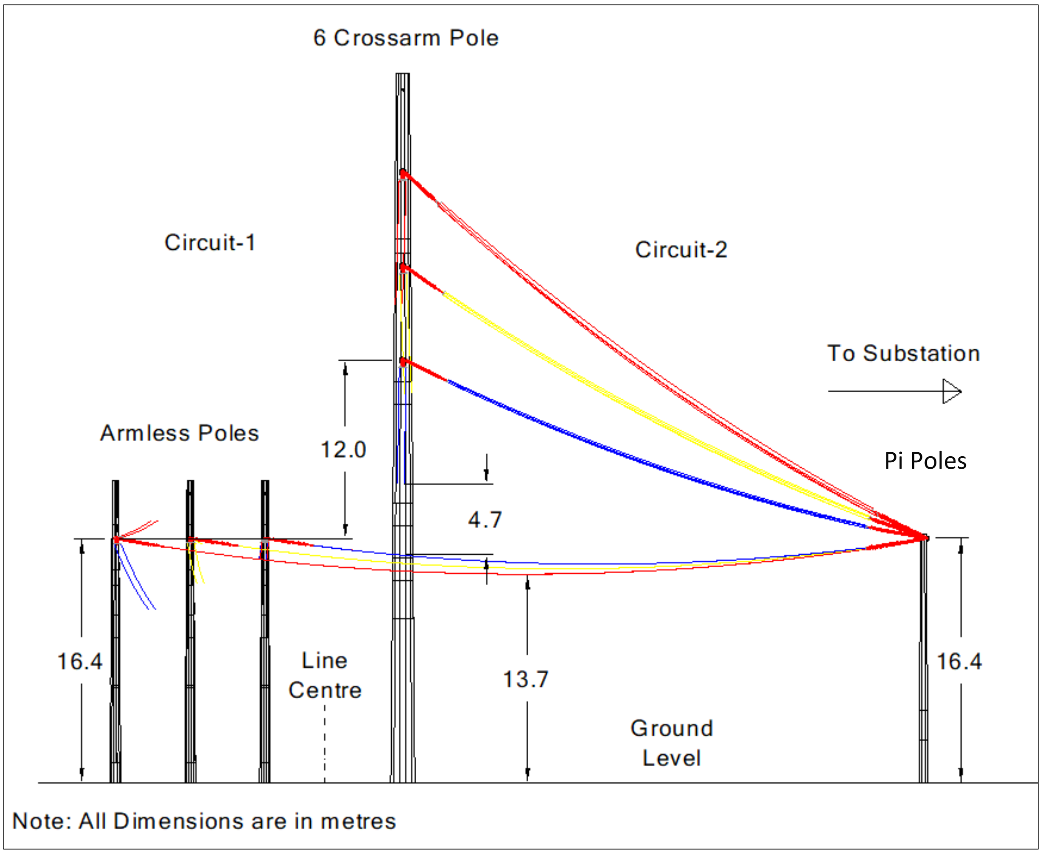

Figure 10: MOT120 External and Crossing Clearance

6.3. Internal Clearances

The internal phase clearances between six-crossarm poles, pi poles, and inline spans to armless poles are essential design parameters, particularly during transitions from horizontal to vertical configurations. These clearances are critical for maintaining adequate insulation, ensuring electrical safety, and minimising the risks of electrical arcing and short circuits.

6.3.1. Span and Phase Elevation Effect

Based on our trials, spacing the armless poles 5.5 metres in both the X and Y directions provides optimal internal clearances under similar swing conditions, effectively reducing associated risks.

For Circuit 2, a spacing of 40 metres between the centre-line and pi poles has been determined as the optimal distance based on prior experience to ensure adequate internal clearance.

Under the span values and elevation differences, the internal clearances achieved for the minimum and maximum ranges, considering 12 metres elevation difference, that are detailed in **Table 9** below.

Table 9: Internal Clearances for 12m Elevation Difference Under 2.5% VCD Tension

Circuit	Phase Elevation Difference	Conductor	EDS-EDS 1.9m	EDD-EDD 1.9m	EDS-EDD 1.9m	HWD-HWD 0.75m
Circuit 1 In Span To Armless Poles	**12 metres**	Phase to Phase	3.125	2.266	2.152	0.809
Circuit 2 From Six-Crossarm Pole To Pi Poles		Phase to Phase	3.182	3.582	3.334	2.951

Based on the data presented in the tables above, the optimal span, elevation difference, and tension values are as follows:

- **Circuit 1 (To Armless Poles):** An optimal separation of 5.5 metres in both the X and Y directions is recommended for an inline span up to 330 metres. This considers a 12-metres elevation difference between the insulator attachment height from a six-crossarm pole, with the conductor tension set at 2.5% VDC.

- **Circuit 2 (To Pi Poles):** A span of 40 metres from the tower centre is recommended, with a 12 metres elevation difference between the insulator attachment height from a six-crossarm pole, maintaining conductor tension at 2.5% VDC.

6.4. Gantry Loads

In this study the GIP tower spans to poles and undercrossing options were analysed. For the gantry loads in the scenario where a 2.5% VDC tension is applied with an 80 metres span and a 1 metre elevation difference between Pi Poles and gantries, the conductor imposes the following maximum loads on the phase attachment points:

Table 10: Maximum Gantry Phase Loading

Load Case	Weather Case	Vertical (N)	Transverse (N)	Longitudinal (N)
Max. Vertical	EI0050_8 (Extreme Ice)	**4563**	8152	25252
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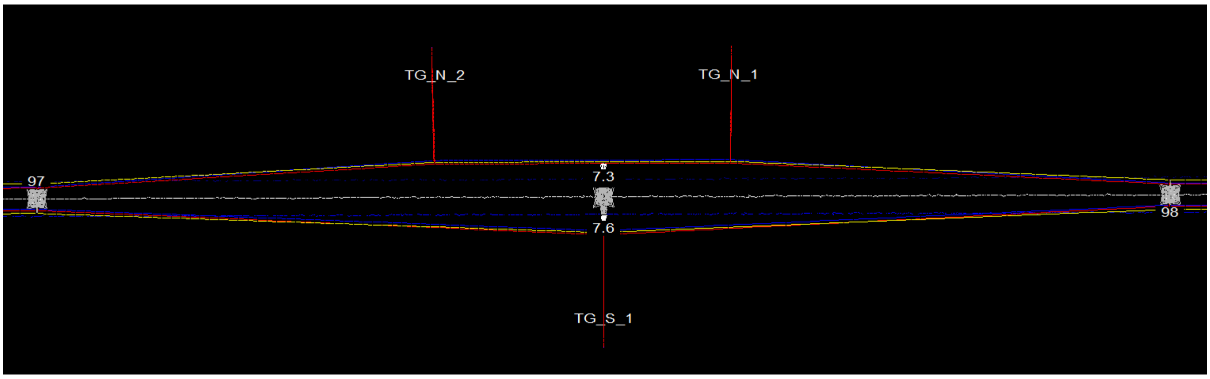

Figure 11: Construction Window by Using Temporary Poles

In this scenario, the substation must be installed first, as the armless pole configuration does not permit an inline connection. During a single circuit outage, the crossing and downlead conductors can be connected between the poles to energise the substation.

7. Conclusion

In conclusion this study by Groundline Engineering for Transpower evaluates two design options for a 220kV double-circuit Grid Injection Point (GIP) at a remote substation. Both designs ensure compliance with Transpower's TP.DL 12.02 standards, meeting internal and external clearance requirements under varying spans, attachment height differences, and weather conditions.

The two options considered are:

- Option 1: A 2DD-HST tower configuration paired with armless poles.
- Option 2: A six-crossarm pole configuration combined with armless poles.

For Option 1, the use of the 2DD-HST tower provides the flexibility to complete construction prior to the substation and a tee-off line installation. This capability offers a significant advantage in terms of a flexible construction sequence. Additionally, it enables inline energy continuity through jumper conductors in the event of an issue with the substation. In contrast, Option 2 does not offer this level of flexibility or capability.

Option 2 requires six terminal poles to handle conductor tensions, approximately 23% of the VDC. This increases the weight and cost of the poles, as well as the foundation requirements, making it more expensive compared to the lighter and simpler armless poles used in Option 1.

Based on these factors, the configuration with the 2DD-HST tower and six armless poles is the preferred option for a remote substation connection due to its flexibility, reliability, and cost efficiency.

Appendices

- **Appendix A:** Optioneering Study Report
- **Appendix B:** Layout Drawings