GROUNDLINE

Memo – Transpower Standard GIP-220kV DC Both Circuits

Date:	17/12/2024	**Pages:**	13	**Rev:**	2
To:	Michael Turnbull	**From:**	Ert Keles / Basil Sabu		
Company:	Transpower	**Company:**	Groundline Engineering		
Subject:	**220kV Double Circuit Grid Injection Point Development Inline Substation**				

1. Background

Transpower 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 an offline 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 an **inline installed 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 Parametres

Design Parametre	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 Gantry: VDC %4.5 2DD-HST Structure Downleads to Gantry: VDC %2.5 Pole Structure
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.

- Loads were generated from Transpower's "*WC & LC Generator Master Rev H*" which is part of this document *"NZ-6609_GIP_Standard_GIP-PLS-CADD WC & LC Generator Master Rev H_rev0a."*

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 3**. 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. Inline Substation GIP with 2DD-HST Tower

4.1. 2DD-HST Tower Connection

The substation and gantry structures are positioned according to a preliminary layout provided by Transpower, with a 40 metres separation between them. In double circuit (DC) configurations, to achieve the necessary clearances, the GIP structures are placed at distances between 60 and 80 metres from the 220kV substation gantries, with a minimum of 60 metres required due to the substation fence, as shown in **Figure 1**.

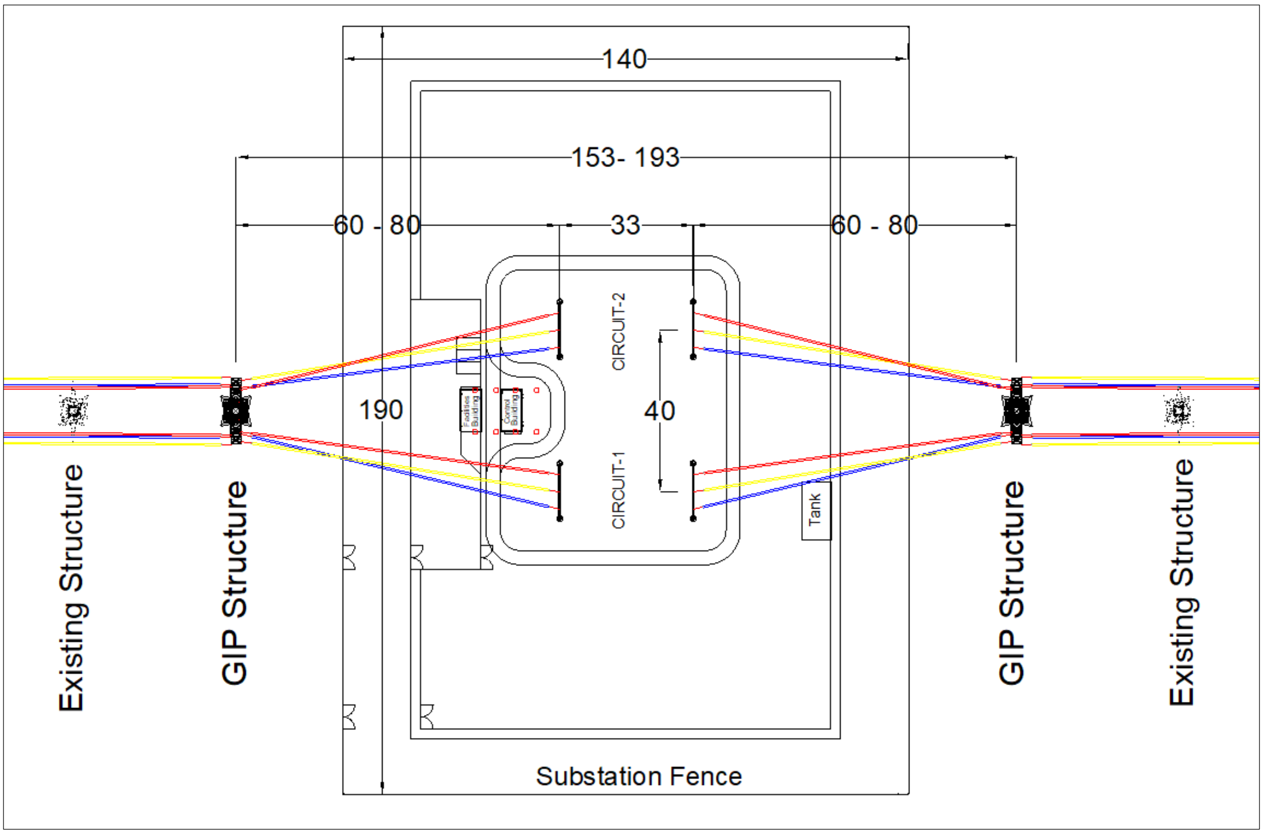

Figure 1: GIP General Plan Layout with 2DD-HST Tower

A general layout drawing is attached to this report for all investigated options.

4.2. 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)

As a starting point the ground between the Gantry and GIP structure is considered level, with the substation ground level positioned 0.5 metre higher than the centre of the GIP tower. Initially, the attachment heights are set to be equal (0 metre difference) between the gantry and the GIP structure. The GIP structure is positioned adjacent to the substation fence, considering the placement of the tower foundations.

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

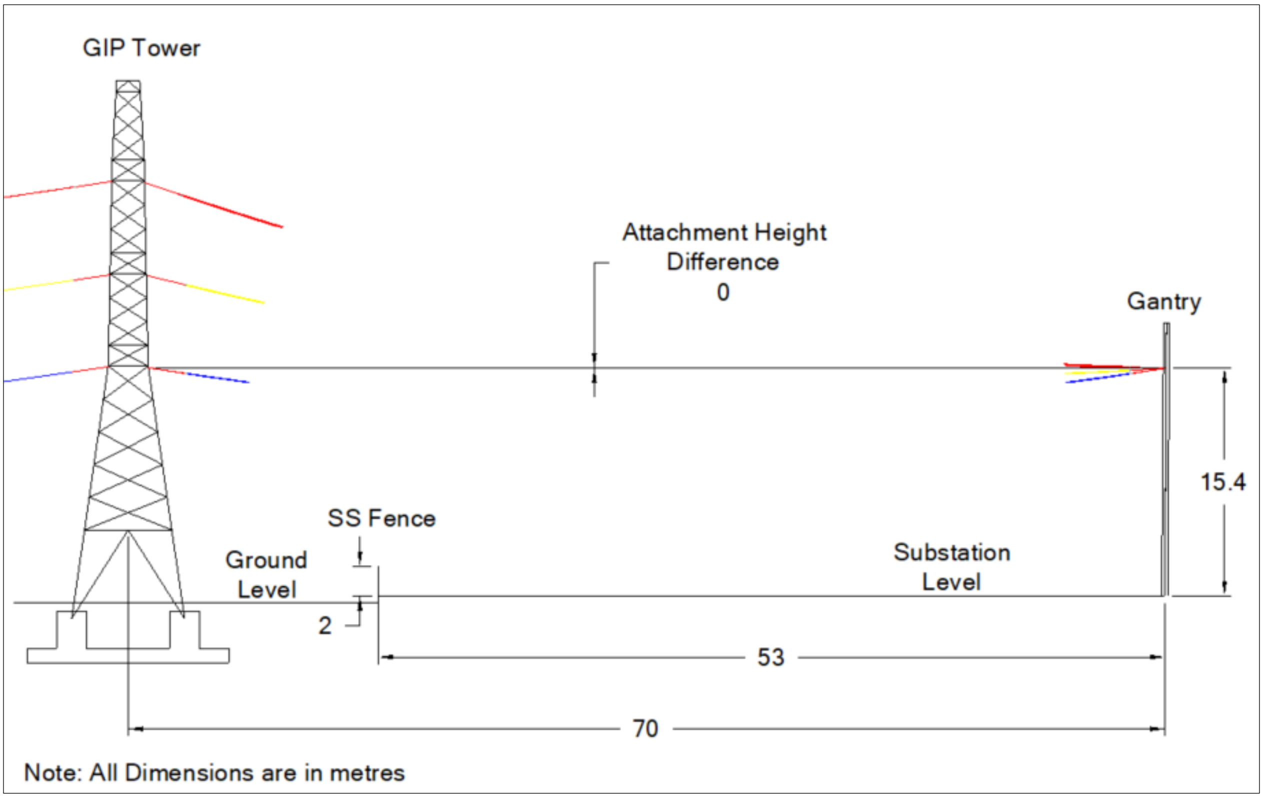

Figure 2: Initial Setup of GIP Connection with 2DD-HST Tower

4.3. External Clearances

With the attachment heights set to 0 metre difference between the gantry and the GIP structure, an analysis was conducted at the Maximum Operating Temperature (MOT) of 120°C to determine the maximum external clearances at distances of 80 metres from the substation gantry structures. 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.

Table 3: External Clearances

	To Building (m)	To Ground (m)					
	MOT	MOT	EDD	HWD	SDS	TIS	EIS
Required Clearance (m)	**6.5**	**8.0**					
Achieved Clearance (m)	8.9	12.0	12.6	13.0	12.9	13.1	12.8

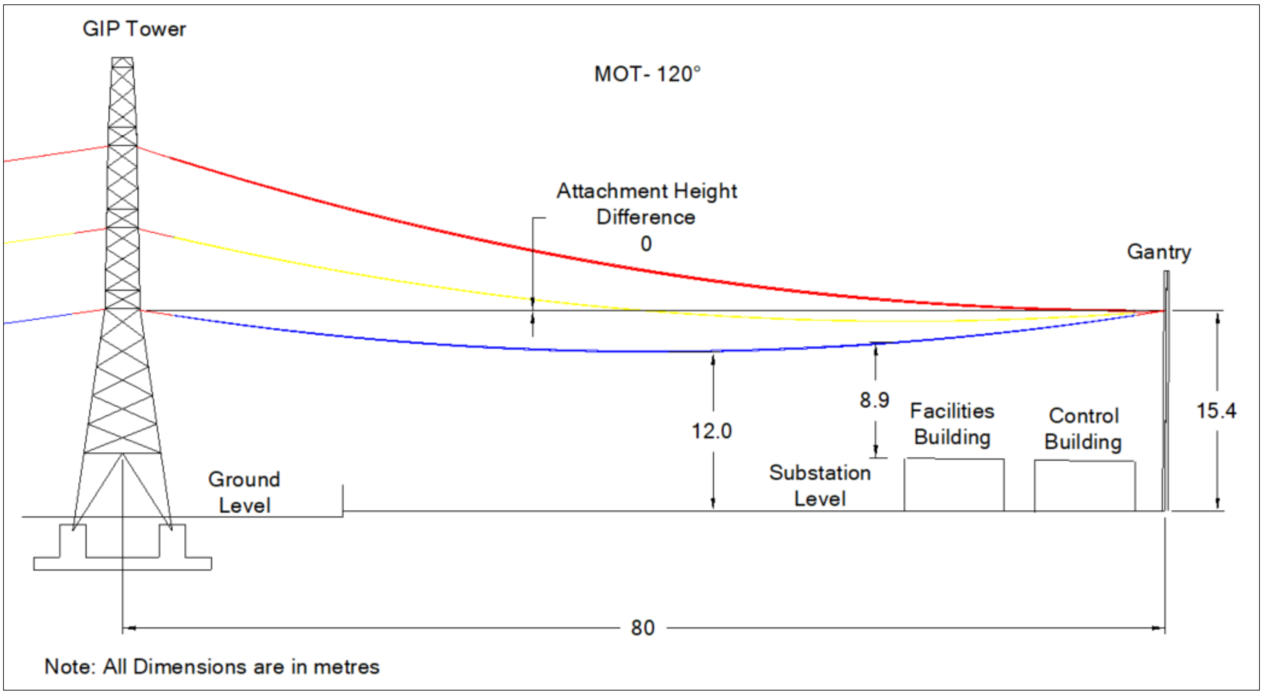

Figure 3: MOT120 External Clearances at 80 metres

4.4. Internal Clearances

The internal clearance between phases in terminal towers to gantries is essential for maintaining electrical safety, as it prevents short circuits by ensuring proper insulation and avoiding electrical arcs.

4.4.1. Span Effect

The study shows that placing the tower closer to the gantry improves internal clearances. However, due to the substation fence the minimum possible distance between the GIP tower and gantries is 70 metres considering the foundations of the GIP structure. Additionally, wider spans pose internal clearance challenges, particularly under differential swing conditions (EDS-EDD). To thoroughly investigate this effect, models with spans of 70, 80, and 90 metres were developed with the attachment heights set to 0 metre difference between the gantry and the GIP structure, as outlined in **Table 4** below.

Table 4: Internal Clearance changes for different spans under 4.5% VCD Tension

GIP Span	Conductor	EDS-EDS 1.9m	EDD-EDD 1.9m	EDS-EDD 1.9m	HWD-HWD 0.75m
70 metres	Phase to Phase	2.385	2.367	1.967	2.38
80 metres	Phase to Phase	2.381	2.365	1.909	2.378
90 metres	Phase to Phase	2.377	2.362	1.848	2.375

As shown in the table above, the most appropriate of the three different span values is 70 and 80 metres. More detailed work can be done between these distances to improve this value.

4.4.2. Phase Elevation Effect

There will always be an elevation difference between the conductor phase connection points depending on the ground elevation difference between the gantry and the tower. In this standardising study, although a flat ground and a 1 metre difference between the attachment points is assumed, two additional models were created and examined to confirm the decision. 90 metres GIP span excluded on this study as we cannot achieve the internal clearances.

The internal clearance results from modelling an elevation difference of 0 metre to 2 metres are as shown in **Table 5**.

Table 5: Internal Clearance changes for different phase elevations under 4.5% VCD Tension

GIP Span	Phase Elevation Difference	Conductor	EDS-EDS 1.9m	EDD-EDD 1.9m	EDS-EDD 1.9m	HWD-HWD 0.75m
70 metres	**0 metre**	Phase to Phase	2.385	2.367	1.967	2.38
	1 metre	Phase to Phase	2.383	2.365	1.963	2.378
	2 metres	Phase to Phase	2.381	2.363	1.959	2.376
80 metres	**0 metre**	Phase to Phase	2.381	2.365	1.909	2.378
	1 metre	Phase to Phase	2.379	2.363	1.906	2.376
	2 metres	Phase to Phase	2.377	2.36	1.902	2.373

EDS-EDD becomes more critical as the elevation difference between the phases increases. The design parameter outlined in **Table 1** will influence result. For an 80 metres span with **maximum 2 metres attachment height difference**, the internal clearance is 1.902 metres, meeting the 1.9 metres clearance limit.

A span of 70 to 80 metres with an elevation difference of up to 2 metres between the GIP structure and the gantry provides a suitable window from an internal clearance perspective to standardise the design under the assumed extreme weather conditions.

Detailed investigation of the body and leg extensions were deemed unnecessary at this stage and will be part of future GIP projects according to site specific ground elevations.

4.5. Gantry Loads

Design gantry loads are required to assess the gantry and insulator connection points. In the scenario where a 4.5% VDC tension is applied with an 80 metres span and 1metre elevation difference, the conductor will exert the following maximum loads on the phase attachment points:

Table 6: Maximum Gantry Phase Loading – GIP with 2DD-HST

Load Case	Weather Case	Vertical (N)	Transverse (N)	Longitudinal (N)
Max. Vertical	EI0050_8 (Extreme Ice)	**5139**	10411	45261
Max. Transverse Wind (Ice Conditions Excluded)	MW2500_A8 (Max. Wind)	1994	**7001**	20103
Max. Longitudinal	EI0050_8 (Extreme Ice)	5034	5562	**46058**

Also given below are gantry attachment loads for main weather cases:

Table 7: Gantry Phase Loading under Main Weather Conditions – GIP with 2DD-HST

Weather Case	Vertical (N)	Transverse (N)	Longitudinal (N)
EDS (Everyday Still Air)	1232	1476	11699
EDW (Everyday Wind	1258	2532	11685
HWD (High Wind Deflection)	1257	2057	12218
MW2500 (Maximum Wind Deflection)	1254	2978	21493

4.6. Construction of GIP Structures

A practical approach involves sequentially relocating each circuit to enable the construction of both GIP towers adjacent to the substation. This method provides a favourable construction window, particularly if the existing tower near the GIP structures needs to be removed.

The feasibility of this approach depends on the positioning of the existing towers relative to the GIP structures and the span between them. Relocation using temporary poles is illustrated in **Figure 4** below.

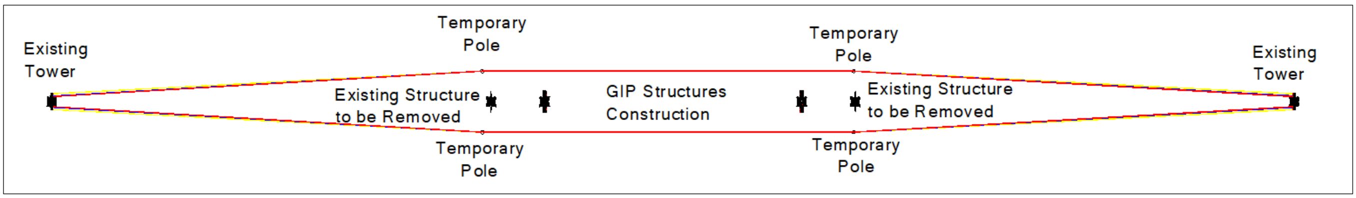

Figure 4: Construction Window by Using Temporary Poles

This needs to be agreed with the subconsultant according to the position of existing towers which are next to the GIP towers. The substation goes in the space between two GIP structures and in the next section substation construction will be discussed.

4.7. Construction of Substation

The proposed plan involves continuing substation construction while keeping both circuits live. In this configuration, conductors will be transferred to and strung between the GIP structures, allowing uninterrupted power flow throughout the construction phase.

A thorough clearance assessment based on this setup was conducted to ensure safe and adequate operational distances with live circuits. However, with the calculated distance between the GIP and gantry structures, and the maximum elevation between them, it appears that maintaining sufficient clearance is not feasible.

As shown in **Figure 5**, the bottom conductor sits lower than the gantry structure, which limits the construction window for substation activities.

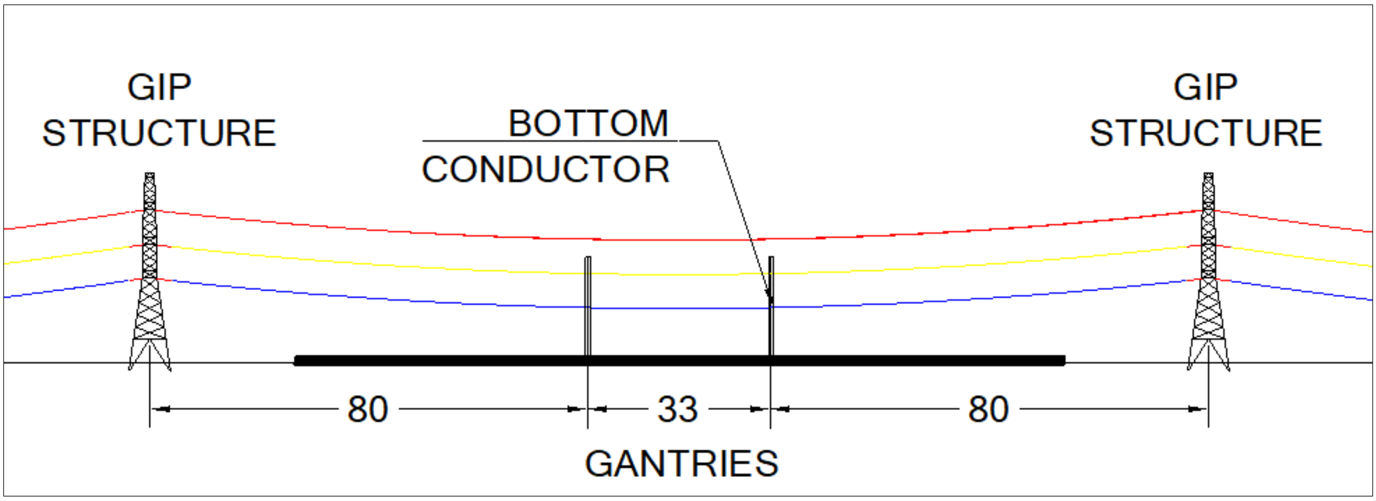

Figure 5: Substation Construction Window

Therefore, prior to constructing the substation and GIP structures, the line will need to be temporarily relocated using additional poles. All construction activities, including stringing the line between gantries and GIP structures, should be completed within this designated construction window.

For substation and GIP Structures, this construction window needs to be expanded with additional poles, as shown in **Figure 6** below.

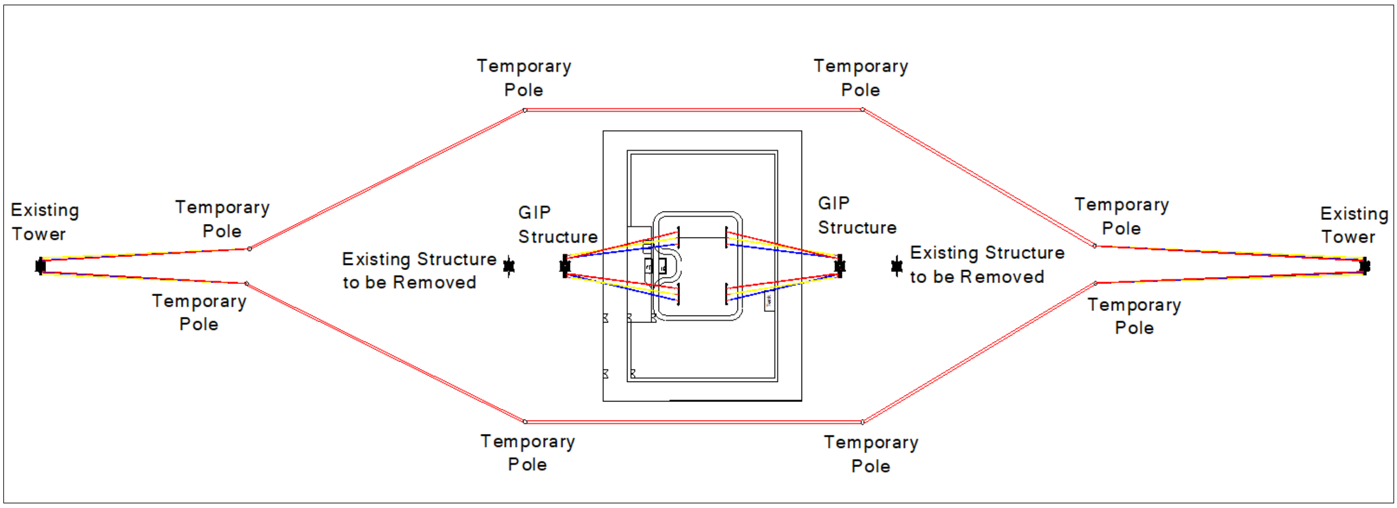

Figure 6: Typical Construction Window Setup

5. Inline Substation GIP with Poles

5.1. Pole Connection

The pole structures are placed at distances between 60 and 80 metres from the 220kV substation gantries, with a minimum of 60 metres required due to the substation fence, as shown in **Figure 7.**

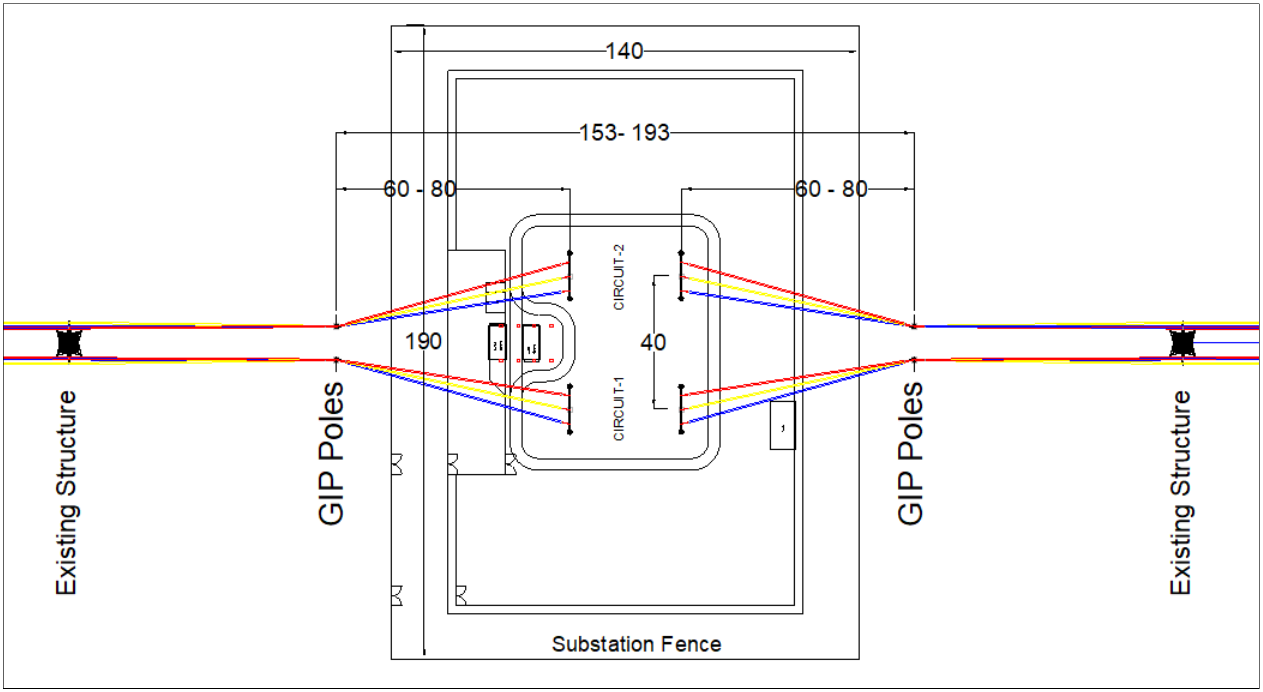

Figure 7: GIP General Plan Layout with Pole Structure

Since the existing structures adjacent to the gantry will remain in place, positioning the pole structures closer to the gantries will increase the span between the new and existing structures. This arrangement helps to minimise the potential uplift of suspension insulators on the existing structures.

5.2. Standardising Design

In this study, an armless pole structure has been selected, with jumper connections planned between the conductors of the ahead and back spans using post insulators.

Initially, the objective is to use the pole configuration to enable the construction of substation structures; hence, attachment heights are set with an 8-metre difference between the gantry and the pole structures. The pole structures are positioned close to the substation fence, with tower foundations designed as auger-type for efficient placement.

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

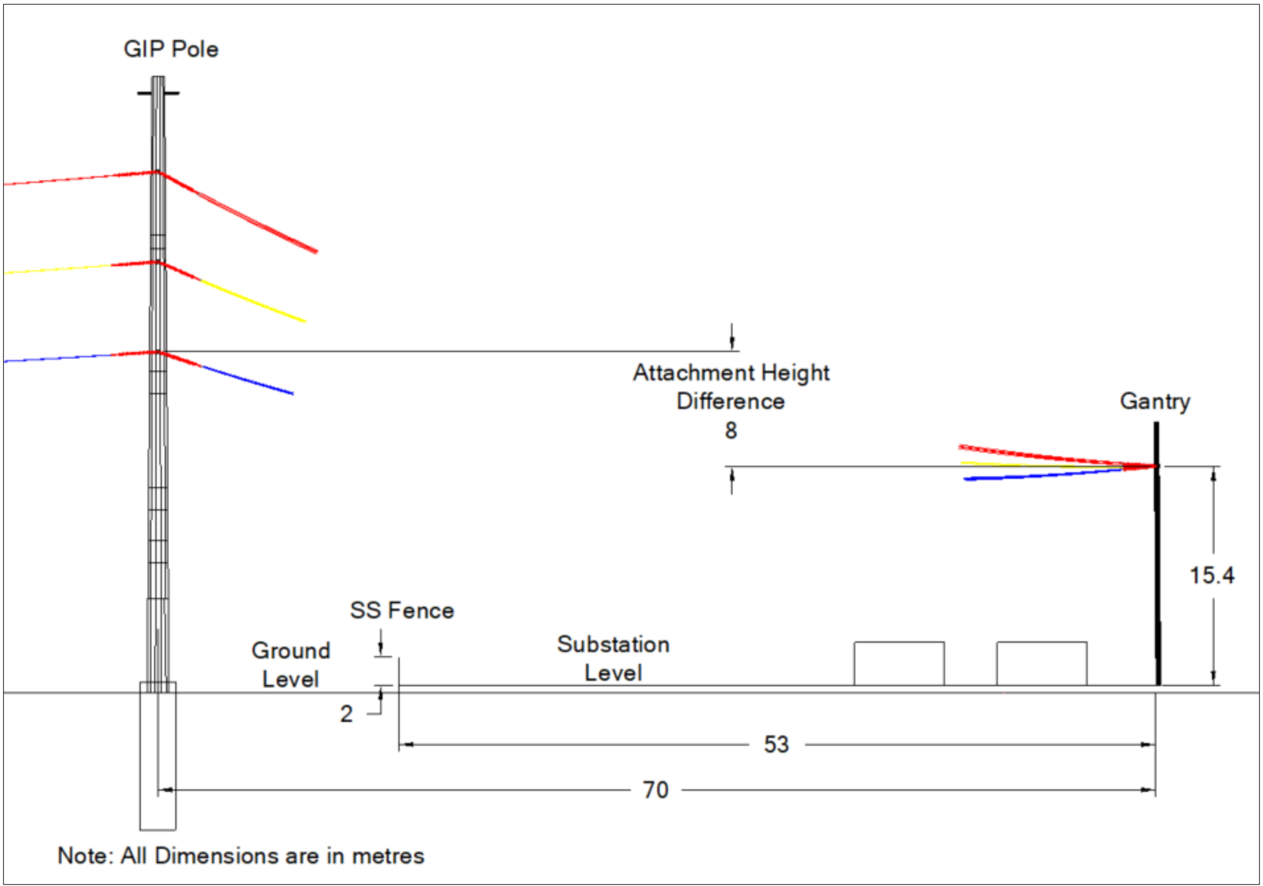

Figure 8: Initial Setup of GIP Connection with Poles

5.3. External Clearances

An analysis was carried out with the attachment heights set to an 8 metres difference between the gantry and GIP Pole structure, focusing on the Maximum Operating Temperature (MOT) of 120°C. This analysis is aimed to establish the minimum external clearances at a 70-metre distance from the substation gantry structures, as this represents the maximum feasible distance for maintaining internal phase-to-phase clearances. For spans of 60 metres between the gantry and poles, the external clearance exceeds 70 metres, so these spans are excluded from the table below. Comparison with TP.DL 12.02, Issue 2.1 confirmed that the required clearances are met, as shown in **Table 8** below.

Table 8: External Clearances

	To Building (m)	To Ground (m)					
	MOT	MOT	EDD	HWD	SDS	TIS	EIS
Required Clearance (m)	**6.5**(1)	**8.0**(1)					
Achieved Clearance (m)	11.70	14.2	14.51	14.85	14.6	14.65	14.6

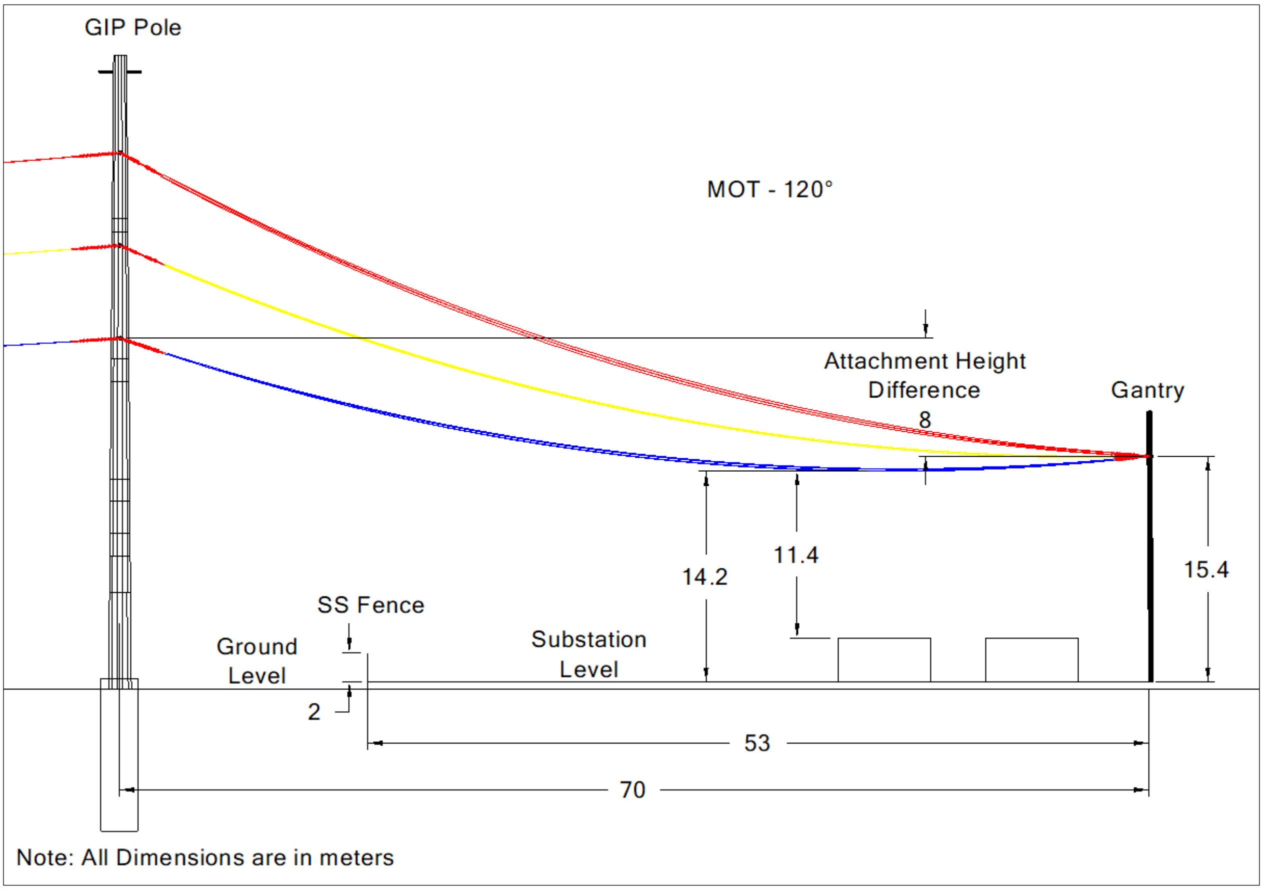

Figure 9: MOT120 External Clearances at 70m

5.4. Internal Clearances

Maintaining internal clearance between phases on terminal poles and gantries is crucial for electrical safety. This clearance prevents short circuits by ensuring adequate insulation and reducing the risk of electrical arcs.

5.4.1. Span Effect

The study shows that placing the tower closer to the gantry improves internal clearances. However, due to the substation fence and the foundation requirements of the pole structure, the minimum feasible distance between the GIP pole and gantries is 60 metres. Wider spans create internal clearance challenges, especially under differential swing conditions (EDS-EDD). To examine this effect in detail, models were developed with spans of 60, 70, and 80 metres, keeping an 8 metres height difference between the gantry and GIP structure, as shown in **Table 9** below.

Table 9: Internal Clearance changes for different spans under 2.5% VCD Tension

GIP Span	Conductor	EDS-EDS 1.9m	EDD-EDD 1.9m	EDS-EDD 1.9m	HWD-HWD 0.75m
60 metres	Phase to Phase	2.880	2.254	2.447	1.157
70 metres	Phase to Phase	2.920	2.058	2.375	0.899
80 metres	Phase to Phase	2.914	1.839	2.252	0.644

As shown in the table above, the most appropriate of the three different span values is 60 and 70m. More detailed work can be done between these distances to improve this value.

5.4.2. Phase Elevation Effect

There will always be an elevation difference between the conductor phase connection points, depending on the ground elevation difference between the gantry and the tower. In this standardising study, to allow a construction window for the substation structures an 8 m difference between the attachment points is assumed, two additional models were created and examined to confirm the decision. 80m GIP span is excluded from this study as we cannot achieve the internal clearances

The internal clearance results from modelling an elevation difference of 7 metres to 9 metres are as shown in **Table 10**.

Table 10: Internal Clearance changes for different phase elevations under 2.5% VCD Tension

GIP Span	Phase Elevation Difference	Conductor	EDS-EDS 1.9m	EDD-EDD 1.9m	EDS-EDD 1.9m	HWD-HWD 0.75m
60 metres	**7 metres**	Phase to Phase	2.894	2.226	2.465	1.184
	8 metres	Phase to Phase	2.880	2.254	2.447	1.157
	9 metres	Phase to Phase	2.866	2.247	2.436	1.129
70 metres	**7 metres**	Phase to Phase	2.925	2.107	2.479	0.920
	8 metres	Phase to Phase	2.920	2.058	2.375	0.899
	9 metres	Phase to Phase	2.908	2.049	2.368	0.877

The HWD-HWD becomes more critical as the elevation difference between phases increases, and the design parameters in Table 1 will impact the results. For 60 and 70-metre spans with a maximum attachment height difference of 9 metres, internal clearances can be achieved.

A span of 60 or 70 metres with an elevation difference of 7 to 9 metres between the GIP pole and the gantry provides an adequate range for internal clearances, allowing for a standardised design even under extreme weather conditions.

5.5. Gantry Loads

Design gantry loads are required to assess the gantry and insulator connection points. In the scenario where a 2.5% VDC tension is applied with an 70 metres span and 8 metres elevation difference, the conductor will exert the following maximum loads on the phase attachment points:

Table 11: Maximum Gantry Phase Loading – GIP with Poles

Load Case	Weather Case	Vertical (N)	Transverse (N)	Longitudinal (N)
Max. Vertical	EI0050_8 (Extreme Ice)	**2460**	3444	23984
Max. Transverse Wind (Ice Conditions Excluded)	EI0050_8 (Extreme Ice)	1756	**7097**	24854
Max. Longitudinal	EI0050_8 (Extreme Ice)	1559	3696	**25591**

Also given below gantry attachment loads for main weather cases:

Table 12: Gantry Phase Loading under Main Weather Conditions – GIP with Poles

Weather Case	Vertical (N)	Transverse (N)	Longitudinal (N)
EDS (Everyday Still Air)	383	959	6263
EDW (Everyday Wind	373	1160	6325
HWD (High Wind Deflection)	340	2602	6719
MW2500 (Maximum Wind Deflection)	176	4947	11058

5.6. Construction of GIP Poles

To facilitate the construction of two poles, tong guys are proposed to create a construction window with both circuits live. A tong guy can be installed during single circuit outages.

As an alternative, pole foundations can be constructed without requiring an outage. During a single circuit outage, poles and conductors can be installed for the affected circuit. To keep poles outside the clearance zone of the other circuit, tong guys can be installed on the second circuit.

This approach should be discussed with the subconsultant during the project stage, as it depends on the location of the existing tower and the distance between the existing tower and poles.

Tong guys were used in previous Transpower projects, and the same setup can be applied here. Please refer to RedEye drawing TP103872 for details.

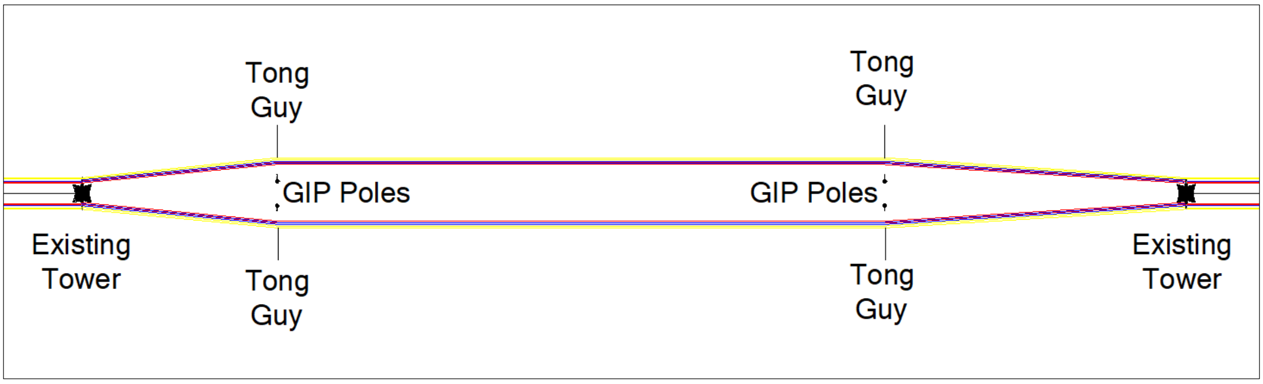

Figure 10: Construction Window by Using Tong Guys

5.7. Construction of Substation

The proposed plan allows substation construction to continue with both circuits live. In this setup, conductors will be transferred to and strung between the GIP structures, ensuring uninterrupted power flow throughout the construction phase. A detailed clearance assessment was conducted to confirm safe and sufficient operational distances with live circuits. By maintaining an 8 metres elevation difference between the GIP poles and gantries, sufficient clearance appears achievable.

As shown in **Figure 11,** the bottom conductor is positioned above the gantry structure, providing a construction window for substation activities as well on HWD conditions.

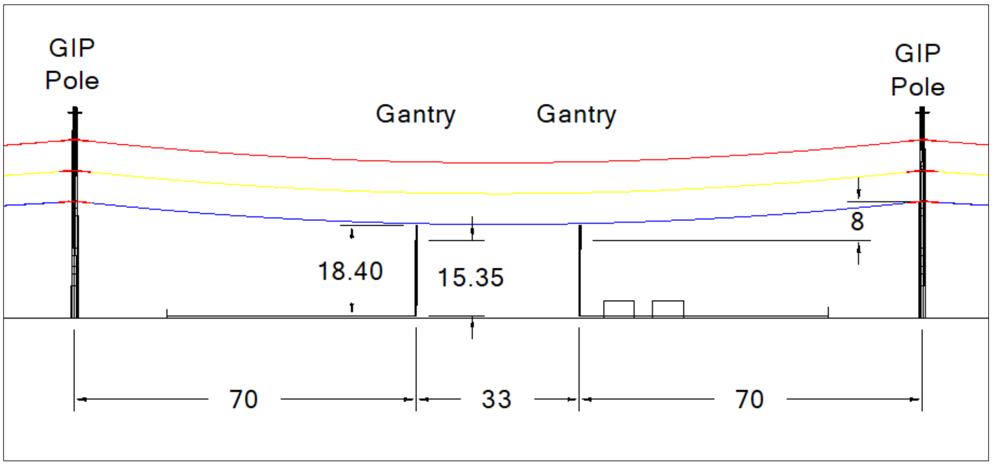

Figure 11: Substation Construction Window

The distances between the conductors and substation gantries achieve the required 5.9 metres per TP.DL 12.02, meeting clearance standards under different weather conditions. The conductor to gantry clearances have been confirmed, as shown in **Table 13** below.

Table 13: Construction Clearances to Gantries

	Conductor To Gantry (m)					
	MOT	EDD	HWD	SDS	TIS	EIS
Required Clearance (m)	**5.9**					
Achieved Clearance (m)	7.81	7.60	6.72	8.08	8.34	7.93

6. Conclusion

This study by Groundline Engineering for Transpower presents a standardized approach for developing a 220kV double circuit Grid Injection Point (GIP) at an inline substation, ensuring that internal and external clearances meet Transpower's TP.DL 12.02 standards across varying spans, attachment height differences, and weather conditions.

For the inline substation with a **2DD-HST tower**, optimal spans of **70 and 80** metres were found feasible for achieving required clearances, with attachment height differences of **0 to 2 metres** between the GIP structure and gantries under a **4.5% Vibration Damage Condition (VDC)** tension on duplex Zebra conductors. A drawback of this setup is the need for additional pole structures to divert the line, creating a construction window for the substation. If required, a taller 2DD-HST tower can be used. However, additional investigation would be required to ensure it is safe and suitable. This option would support the construction of the substation beneath the existing line.

With the **pole configuration**, optimal spans of **60 and 70** metres were identified for maintaining clearances, using attachment heights of **8 to 9 metres** between the GIP poles and gantries under a **2.5% VDC** tension on duplex Zebra conductors. A benefit of this option is that substation construction can proceed while the inline conductors are strung overhead, and gantry loads are lower compared to the 2DD-HST configuration. To ensure safe implementation, a detailed substation construction methodology will need to be developed, outlining the necessary steps and safety measures for this approach.

Since gantry design loads were not available for this study, it is essential to confirm that gantry loads remain within specified limits once the project layout is finalized. If gantry design is still pending, this report's data on maximum phase attachment loads should be considered in the design process.

Appendices

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