GROUNDLINE

Memo – Transpower Standard GIP					
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To:	Michael Turnbull	**From:**	Elif Pelit & Ert Keles		
Company:	Transpower	**Company:**	Groundline Engineering		
Subject:	**110kV Grid Injection Point Development**				

1. Background

Transpower engaged Groundline to carry out design assistance to standardise Grid Injection Point (GIP) of 110kV lines. The substation component has been mostly completed by Transpower and Transpower has requested Groundline to provide support and input for the line's component of this design.

It is requested to investigate and standardise the below options:

- Grid Injection Point of single circuit from a double circuit (DC) 110kV line.
- Grid Injection Point of single circuit from a single circuit (SC) 110kV line.

2. Design Criteria

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

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	VDC %2.5 – 3.3kN
Span	40m – Between Gantry Centre to Tower Centre
External Clearances	TP12.02 – To Ground - 6.5m+0.5m=7.0m TP12.02 - To Substation Building – 5.0m+0.5m =5.5m
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-6495_GIP_Standard_GIP-PLS-CADD WC & LC Generator Master Rev H_rev0a."*

3. GIP Layout

The substation and gantry structures were placed based on a preliminary substation layout from Transpower. The GIP structure is placed 40m from 110 kV substation gantries in single circuit (SC) configuration and the distance between the gantries is measured as 33.5m as shown in **Figure 1**.

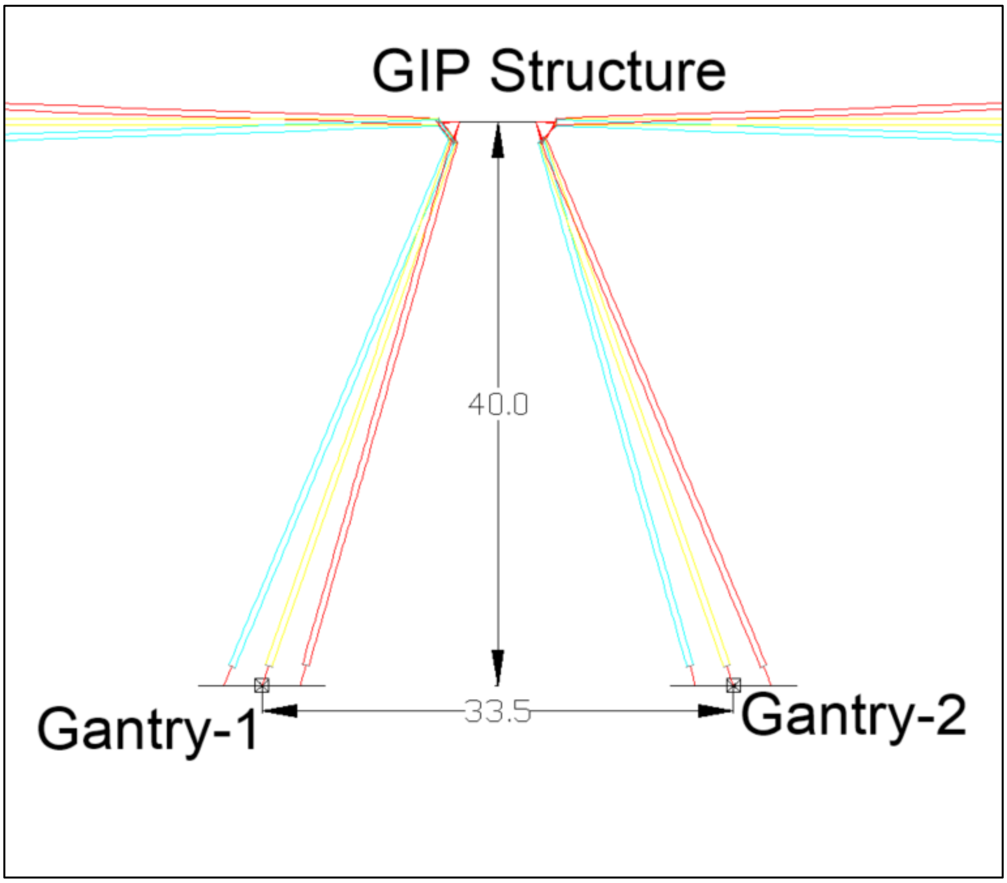

Figure 1: GIP General Layout

Different distances between the Gantry and GIP structure, such as 25m, 30m, 40m, 60m, and 80m, have been considered, and the results for these options have been reported. Internal clearances were the governing factor investigating the distance between GIP point and the Gantries and are given in the next sections of the report.

4. Structure Information

For both double and single circuit lines, a pole stick figure with a six crossarm configuration is used, as poles have a smaller footprint and shorter construction time compared to towers. The dimensions are taken as in the Figure-2 and are determined using a C2000 Type double circuit tower configuration for 110 kV line as an example.

Given the expected differences in the heights of the forward and back span structures, detailed investigation of the GIP pole height can be a check for the future GIP projects.

For this project, various attachment point heights between Gantry attachments and GIP pole attachment were considered to have an idea about both internal and external clearances.

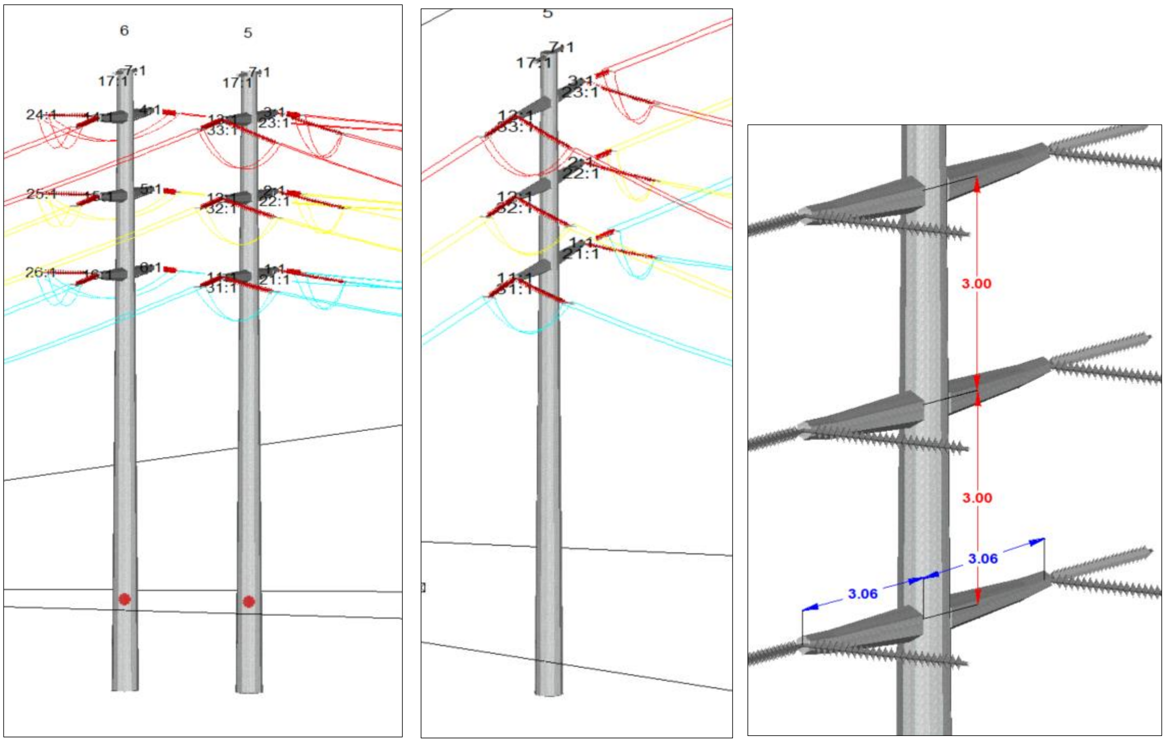

Figure 2: Pole Figures for SC and DC Line

For double circuit GIP an additional strain pole is used to carry the other circuit not going into the GIP. Six crossarm stick figures are placed as back and forward structures to create line model.

5. Hardware Information

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

Transpower has two types of insulator sets for terminal spans. These are called Line End Sets and Gantry End Sets. The suggested standard Insulator set numbers used in the design are tabulated in **Table 2**. All insulator sets need to be confirmed by TP before further changes.

Table 2: Standard Insulator Sets

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

6. Standardising Design

6.1 Attachment Elevation Difference Adjustment

Assumption: Flat ground between Gantry and GIP structure, and substation ground level is 0.5m higher than GIP tower centre.

The insulator attachment points are aligned at the same level as the bottom crossarm of the GIP structure and the insulator attachment level of the substation gantry, as shown in **Figure 3.**

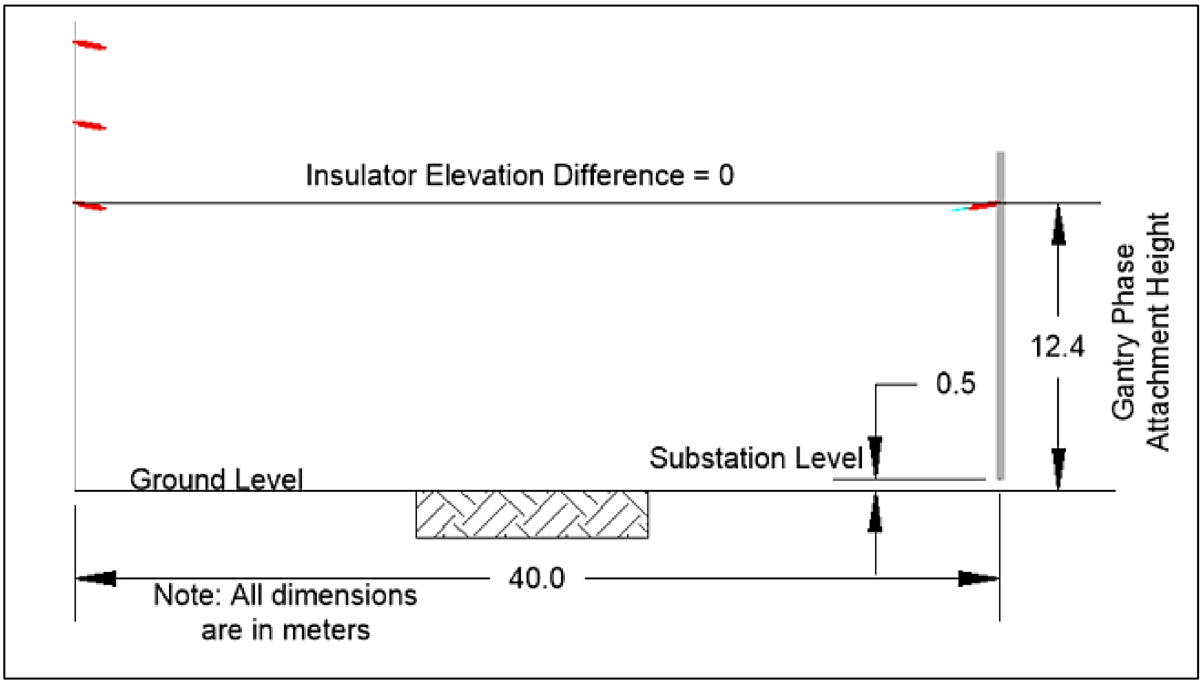

Figure 3: Attachment Height Difference

6.2 External Clearances

By setting the;

- Minimum attachment height difference,
- Distance between gantry and GIP structure and
- Tension on conductors (VDC %2.5 -Refer **Table 1**)

We can achieve the minimum external clearance requirement of TP.DL 12.02, Issue 2.1 as shown in **Table 3**. Please refer to **Figure 4** for the visualisation of the Maximum Operating Temperature (MOT120).

Table 3: External Clearances

	To Building (m)	To Ground (m)					
	MOT	MOT	EDD	HWD	SDS	TIS	EIS
Required Clearance (m)	**5.5**(1)	**7.0**(1)					
40m, Achieved Clearance (m)	6.84	10.51	10.85	11.04	11.01	11.09	11.01
30m, Achieved Clearance (m)	6.85	11.01	11.3	11.44	11.46	11.53	11.45

(1) The 0.5m of construction tolerance has been taken into consideration in the required values

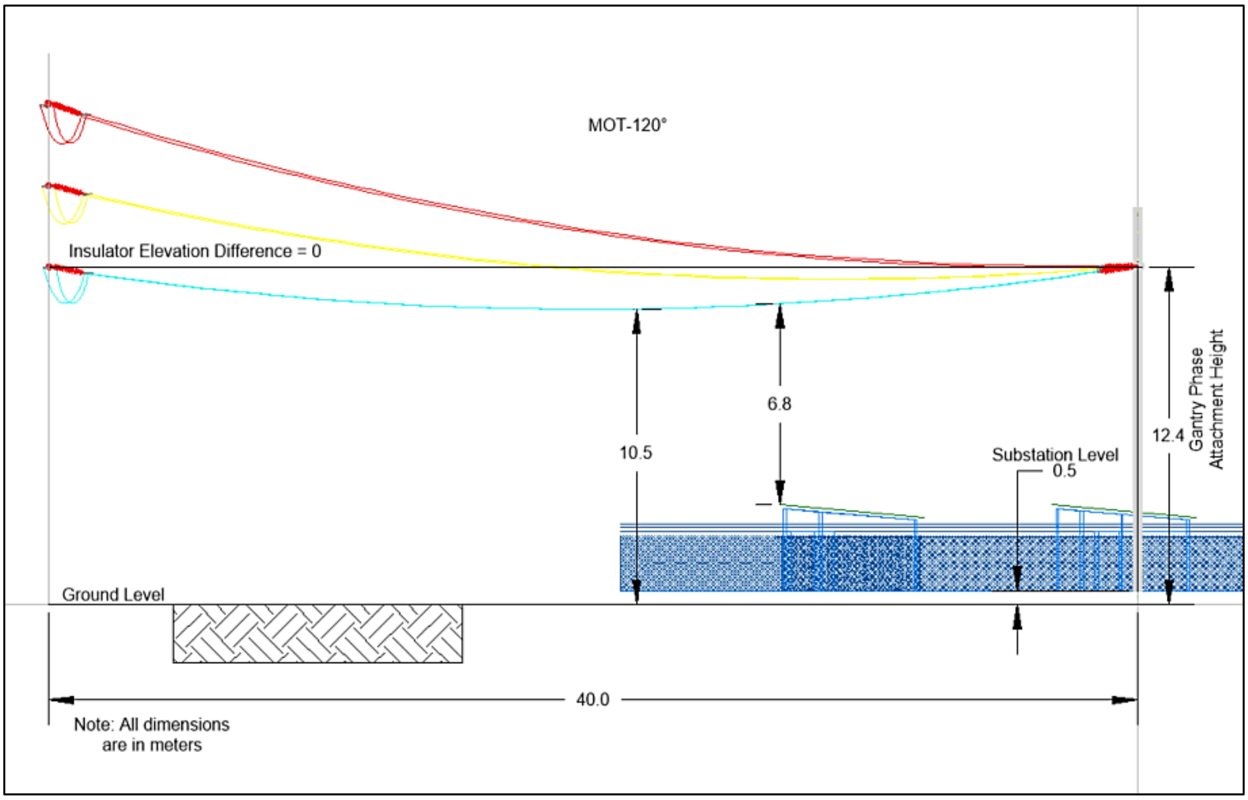

Figure 4: MOT120 External Clearances at 40m with no Elevation Difference

Investigations have confirmed that with 30m and 40m spans, there are no external clearance violations to the ground or substation buildings when the attachment points are at the same elevation.

7. Internal Clearances:

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

7.1 **Span Effect**

Based on our trials, positioning the GIP pole closer to the gantries tends to initially improve internal clearances for similar swing condition, subsequently decreasing the associated risks. However, 25m span difference does not provide an advantage over 30m & 40m spans.

For longer spans, there's an escalation in risk, particularly in scenarios of differential swing. To thoroughly examine this phenomenon, we have developed five distinct models with spans of 80m, 60m, 40m, 30m and 25m to compare the internal clearances. Further span reduction such as 20m span difference not considered as the pole located close to the gantry entrance and the location was found to be unsuitable. The corresponding data shown in **Table 4** summarises internal clearance of various spans with no phase elevation difference.

Table 4: Internal Clearance changes for different spans under 2.5% VCD Tension of conductors

GIP Span	Phase Elevation Difference	Conductor	EDS-EDS 1.1m	EDD-EDD 1.1m	EDS-EDD 1.1m	HWD-HWD 0.4m
80 meters	**0 meters**	Phase to Phase	1.311	1.332	0.774	1.366
60 meters	**0 meters**	Phase to Phase	1.319	1.345	1.033	1.439
40 meters	**0 meters**	Phase to Phase	1.299	1.333	1.173	1.423
30 meters	**0 meters**	Phase to Phase	1.271	1.301	1.206	1.389
25 meters	**0 meters**	Phase to Phase	1.244	1.272	1.192	1.355

As shown in the table above, the most appropriate of the three different span values is determined to be 40 metres when GIP structure and Gantry phase elevation difference is zero. Of course, more detailed work can be done to improve the values. It has been noted that under differential swing conditions of EDS-EDD, 80m and 60m spans do not meet 1.1m internal clearance requirement for lighting-switching.

7.2 Phase Elevation Effect

Depending more on the ground elevation difference between the gantry and the pole, there can be an elevation difference between the conductor phases and connection points. In this standardising study, we created and examined different models with various elevation differences to question the impact of elevation difference on the internal clearances.

The internal clearance results of modelling attachment elevation difference of 0m, 2m and 4m for 40m, 30m & 25m are as shown in **Table 5**.

Table 5: Internal Clearance changes for different phase elevations under 2.5% VCD Tension

GIP Span	Phase Elevation Difference	Conductor	EDS-EDS 1.1m	EDD-EDD 1.1m	EDS-EDD 1.1m	HWD-HWD 0.4m
40 meters	**0 meters**	Phase to Phase	1.299	1.333	1.173	1.423
	2 meters	Phase to Phase	1.282	1.313	1.181	1.436
	4 meters	Phase to Phase	1.261	1.294	1.155	1.436
30 meters	**0 meters**	Phase to Phase	1.271	1.301	1.206	1.389
	2 meters	Phase to Phase	1.24	1.271	1.177	1.394
	4 meters	Phase to Phase	1.214	1.245	1.134	1.356
25 meters	**0 meters**	Phase to Phase	1.244	1.272	1.192	1.355
	2 meters	Phase to Phase	1.238	1.238	1.141	1.33
	4 meters	Phase to Phase	1.179	1.209	1.089	1.283

EDS-EDD condition becomes more critical as the elevation difference between the phases increases in the as shown in the table above. Of course, this is subject to the conditions outlined in **Table 1**.

Given all these different spans and elevation differences, a span of 40m with no elevation difference seems appropriate from the internal clearance perspective to standardise the design under the assumed weather conditions, which are extreme conditions.

8. Gantry Loads:

We have not yet assessed the gantry and insulator connection points due to the absence of design loads for gantries. In the scenario where a 2.5% VDC tension is applied with a 40m span and 0m elevation difference, the conductor will exert the following maximum loads on the phase attachment points.

Table 6: Maximum Gantry Phase Loading

Load Case	Weather Case	Vertical (N)	Transverse (N)	Longitudinal (N)
Max. Vertical	EI0050_8+E NA- (Extreme Ice)	**1106**	6983	25069
Max. Transverse Wind (Ice Conditions Excluded)	MW2500_A8+E BI-+00 (Max. Wind)	678	**5684**	10743
Max. Longitudinal	EI0050_8+E NA+ (Extreme Ice)	1106	6983	**25069**

Also, observed below gantry attachment loads for main weather cases.

Table 7: Gantry Phase Loading under Main Weather Conditions (Reference: DC 2DDHST connection)

Weather Case	Vertical (N)	Transverse (N)	Longitudinal (N)
EDS (Everyday Still Air)	679	1748	6162
EDW (Everyday Wind	679	2675	6090
HWD (High Wind Deflection)	679	3031	6133
MW2500 (Maximum Wind Deflection)	255	1635	5855

9. Construction:

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.

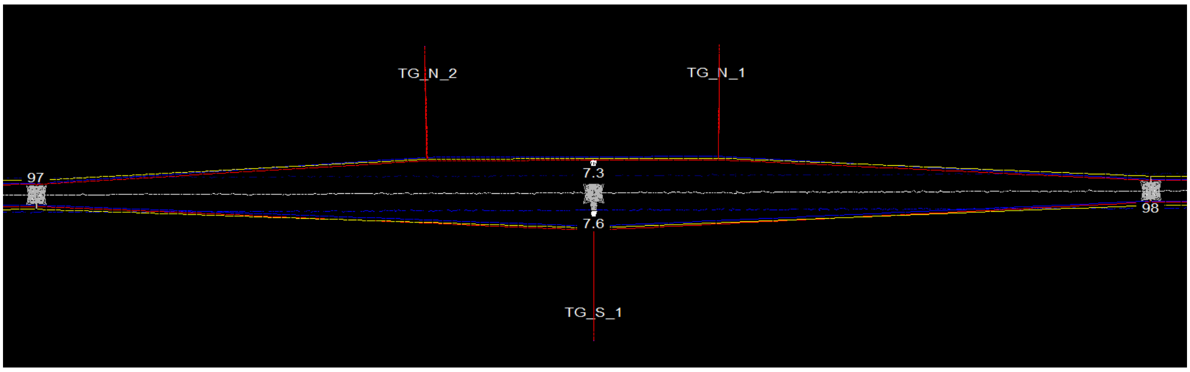

Figure 5: Construction Window by Using Tong Guys

The substation goes in the space between TG_N_1 and TG_N_2. This way, the work of the substation would not be interfered either.

10. Conclusion:

The objective of the development was to create a standardised design for 110 kV GIP, encompassing both single and double circuits. This design considers crucial factors such as phase elevation optimisation, clearance requirements, and environmental obstacles.

In summary, our research indicates that implementing a 2.5% Vibration Damage Condition (VDC) tension on duplex Zebra conductors and strategically placing GIP structures at an 40-meter span can effectively meet both external and internal clearance criteria under extreme weather conditions which shown on **Table 1.** This remains the case even if the elevation of the bottom arm tower attachment point is 0m to 4m higher than the gantry attachment point.

The elevation of the attachment point can be adjusted based on the chosen height of GIP structure, considering I impact on the external clearances for both the back and ahead spans.

As the gantry design loads were not available for this study, it is crucial to verify that the gantry loads do not surpass the specified limits after the project layout has been finalised. If the design of the gantries has not been finalised yet, the report providing the maximum phase attachment loads can be taken into consideration during the gantries' design process.

Appendices

- **Appendix A:** Load Case Generator
- **Appendix B:** Site Specific Wind Speeds
- **Appendix C:** GIP Connection Layouts