SLADEVALE SUBSTATION

LFI & EMF STUDY REPORT

15F001-RP-E-5-008

POWER GRID SOLUTIONS PTY LTD

Document Control

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Table of Contents

Table of Figures

List of Tables

1 EXECUTIVE SUMMARY

LFI & EMF studies have been performed considering maximum load on the new 33kV Double Circuit between Sladevale Substation and Warwick Substation.

The results show that magnetic, electric fields and step and touch potentials are well below the recommended limits.

Based on the results of these studies, no safety harzards or concerns have been identified. Hence, no further mitigations are required.

2 INTRODUCTION

2.1 Plant Description

LendLease Services is constructing the Warwick Solar Farm (WSF) in the Warwick area which is within 3km proximity of Ergon Energy Corporation Limited's (EECL) Warwick 33kV Bulk Supply Point substation in Queensland. The overall WSF effectively comprises two separate connection points and generators: WSF1 and WSF2. Each generator comprises 24 x Ingeteam Sun Power Max 1640TL B630 inverters connected via a 33kV overhead line to EECL Warwick 33kV bulk supply substation. Under favourable system operating conditions (at 30°C) WSF1 and WSF2 will each have a sent-out capacity of 32.1MW via the Point of Connection (PoC) providing a combined capacity for WSF of 64.2MW.

2.2 Background

Lendlease Services have engaged Power Grid Solutions Pty Ltd to design secondary and primary systems associated with Sladevale Substation. LFI, EMF, Step/Touch potential Studies have been requested for the fence section along the Warwick/ Killarney feeders.

2.3 Purpose

The objective of this LFI / EMF, Step/ Touch potential studies are required to determine and confirm the induced voltage on the near-by fence by the 33kV Double Circuit during normal operation condition do not create any harzardous condition and to ensure these are kept within the limits stupilated by Australian and international standards.

SES CDEGS software package was used for this study. It includes facility to model transmission line and fence to study the LFI/EMF and step/touch potentials under various system operating conditions.

2.4 Simplifying Assumptions and other Considerations

The following simplifying assumptions and considerations have been made:

- Warwick/Killarney double circuit and the fence parallel to it are modelled up to 2.2km.
- Transmission line is considered "Oxygen" type line.
- Maximum load is 440A on Warwick Feeder and 155A on Killarney Feeder as per [1]
- To be conservative, earhing systems associated with Solar Farm, Sladevale Substation area, Solar Farm Substation Area as well as auxiliary earthing systems have not been modelled.

- Soil resistivity around the considered fence was considered as per [2].

2.5 Abbreviations

Abbreviations	Full Description
HV	High Voltage
EECL	Ergon Energy Corporation Limited
LFI	Low Frequency Induction
EMF	Electromagnetic Field
CDEGS	Current Distribution, Electromagnetic Field, Grounding and Soil
PVC	Polyvinyl Chloride
OD	Outside Diameter
AS	Australian Standard
Cu	Copper
TR-XLPE	Tree-Retardant Crosslinked Polyethylene
OHL	Over Head Line
OPGW	Optical Pilot Ground Wire
PoC	Point of Connection
WSF1	Warwick Solar Farm 1
WSF2	Warwick Solar Farm 2

2.6 Reference Documents

The following table lists the related Standards and doucments for the LFI/EMF and Step/Touch Potential Studies.

Table 1: Standards and Site-Specific Documents

No	Doc ID	Revision/Date	Description
[1]	LLS_15F001-RP-E-0-009	A/27/05/2019	Load Flow and Short Circuit Report
[2]	LLS_15F001-RP-E-0-004	Rev 2/ March 209	Earthing & Lightning Protection System Design Report
[3]	ENA EG1	2006	Substations Earthing Guide
[4]	AS/NZS 4853	2012	Electrical hazards on metallic pipelines
[5]	AS/NZS 60479.1	2002	Effects of current on human beings and livestock
[6]	-	-	ARPANSA Radiation Health Series No. 30 – 1989: Interim guidelines on limits of exposure to 50/60Hz Electric and Magnetic Fields
[7]	AS/NZS 2067	2016	Substation and High Voltage Installation exceeding 1kV a.c
[8]	AS/NZS 4853	2000	Electrical Harzards on Metallic Pipelines
[9]	30032335	Rev A	Warwick Solar Farm Geotechnical Interpretive Report
[10]	WSF1-Clean-15FA50DA	05/11/2018	Warwick Solar Farm 1- 534A and 534B letter
		June 2018	Warwick Solar Farm 1- Generator Performance Standards
[11]	WSF2-Clean-15F98B57	05/11/2018	Warwick Solar Farm 2- 534A and 534B letter
		June 2018	Warwick Solar Farm 2- Generator Performance Standards

Table 2: Reference Drawings

No	Doc ID	Revision/Date	Description
1	1078907-02	Rev 0C 30-05-19	Warwick Solar Farm Warwick-Killarney 33kV Double Circuit – Transmission Line Overhead Line Profile Sheet 2 of 2
2	15F001-DG-C-0-039	Rev 01 20/05/2019	Warwick Solar Farm Fencing and Gates Details
3	15F001-DG-C-0-040	Rev 0A 20/05/2019	Warwick Solar Farm Fencing and Gates Gully Crossing Details

3 INPUT DATA & EVALUATION CRITERIA

3.1 Soil Model

The soil model used was obtained from [2] as is shown in Table 3

Table 3: Soil Model

Layers	Resistivity [Ωm]	Depth [m]
1	20	2
2	10	∞

3.2 Maximum Loading

Maximimum loading has been considered as per [1], below is a summary of loads used in each line for the study (small unbalance was introduced for Killarney Feeder). Refer to Appendix Section for ETAP results for Maximum loading for Warwick/Killarney Feeders.

Table 4: Maximum Loading

	Conductor Phase	Load [A]
Killarney Feeder	Phase A (Closest to Fence)	155A < 0°
	Phase B	150A < 120°
	Phase C	145A < -120°
Warwick Feeder 2	Phase A	440A < 0°
	Phase B	440A < 120°
	Phase C	440A < -120°

3.3 Step and Touch Allowable Limits

As per [2] & [3,7 & 8] the following limits have been considered for evaluation

Table 5: Maximum allowable Step and Touch Potentials

Condition	Touch Potential [V]	Step Potential [V]
Maximum Load	80	<1700
Fault Condition	597 (*)	>9000

Note – although [8] refers to metallic pipelines, the hazard exposure on metallic pipelines will be similar to that on other metallic frames such as fences. Hence, the safety limits set by this standard is deemed applicable to metallic structures located in the vicinity of the powerlines.

(*) is based on Negligible Risk Voltage Target with Risk of Fatality < 10^{-6} for Infrequently visited locations such as solar farm perimeter fence, collector station fence on natural ground with standard footware.

3.4 Electric and Magnetic Field Exposure Limits

The acceptable exposure of limits of EMF to the public is defined in [6], as discussed in the following section. Table 7 lists the exposure limits for electric and magnetic fields. Since this meant for a residential development, the exposure limits for the general public for up to 24 hours /day is used for normal operating condition and few hours/day for fault condition.

Table 6: Electric and Magnetic Field Exposure Limits

Condition	Electric field [kV/m rms]	Magnetic Field [µT rms]
Maximum Load – 24 hr /day	5	100
Fault Condition – Few hours /day	10	1000

4 RESULTS

4.1 EMF Under Maximum Load

EMF under Maximum load condition are shown in Figure 1 & 2. As can be seen, the maximum magnetic and electric fields are 3µT & < 70V/m respectively. These values well below the exposure limits in Table 6.

Note that these maximum values consider full line sag as per Figure 5, Section 6.1

Profile taken for public interest is as follows:

- Profile 1 – 1.6m above the ground, extending 50m either side across the line/fence at the end of the fence (X= ±1100m)

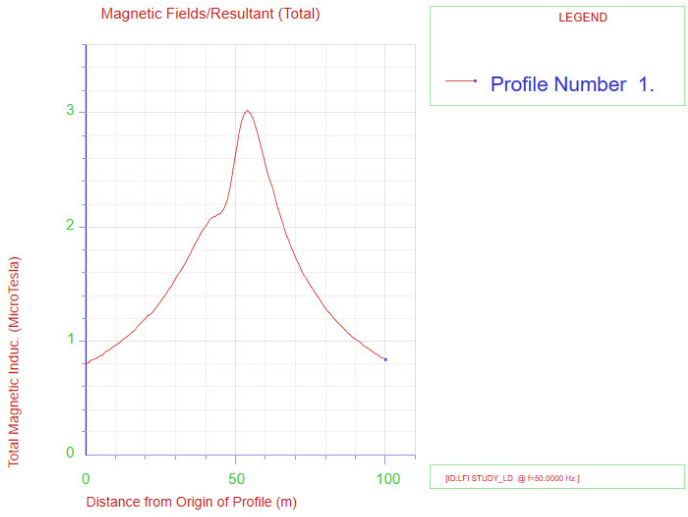


Figure 1: Magnetic Fields under Maximum Load

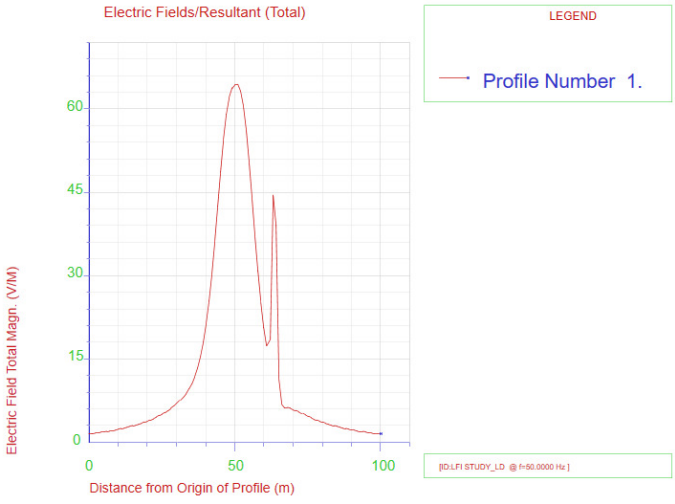


Figure 2: Electric Fields under Maximum Load

4.2 Step and Touch Potential Under Maximum Load

Step and Touch Potentials under Maximum load condition are show in Figures 3 & 4. As can be seen, the maximum touch voltage is 75V & maximum step voltage is 29V, and these are below the maximum allowed in Table 6.The observation profile has been taken +/- 1m from the fence.

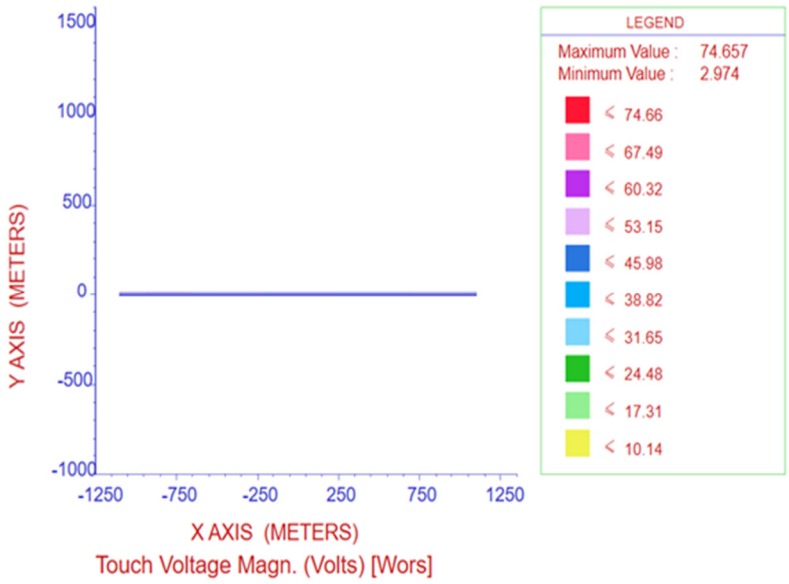


Figure 3: Touch Potential under Maximum Load

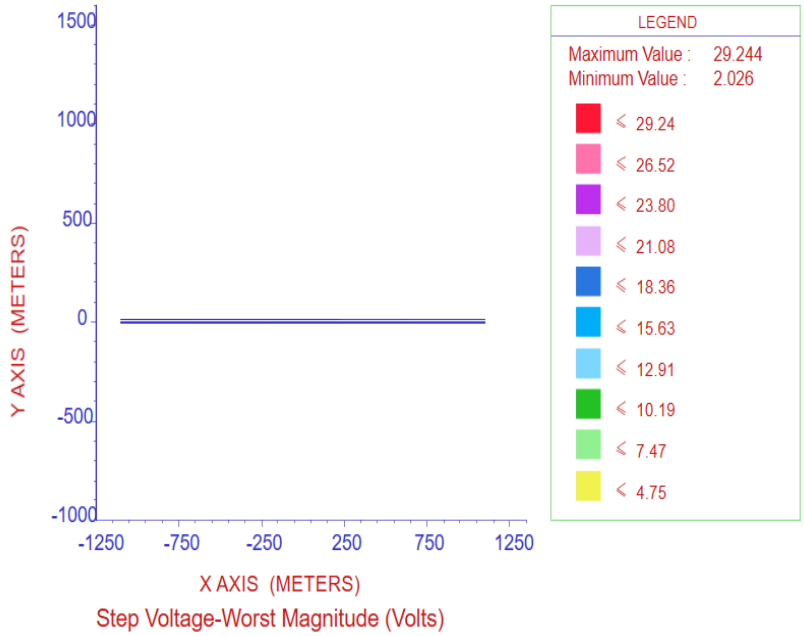


Figure 4: Step Potential under Maximum Load

Note - Given the that auxiliary earthing systems and interconnection between all earthing systems at Warwick Solar farm have not been modelled in this study, step and touch potential are expected to be **much lower than** the simulated results here.

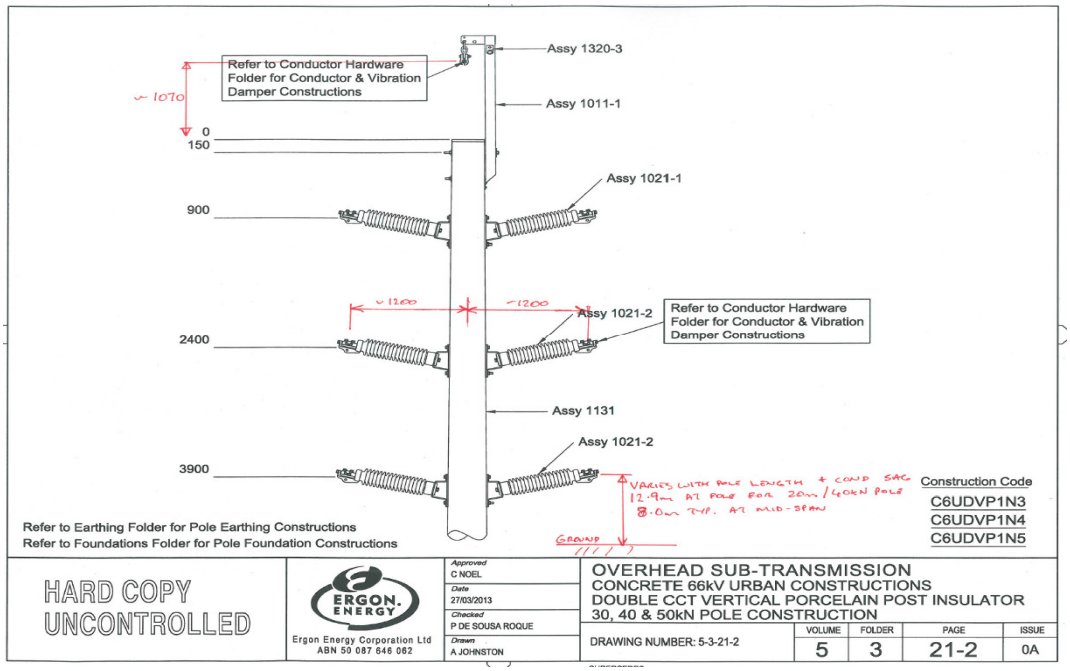
5 CONCLUSION

LFI & EMF studies have been performed considering maximum load on the new 33kV Double Circuit between Sladevale and Warwick-Killarney Substations.

- In all cases, the results show that magnetic and electric fields are well below the recommended limits.
- Under maximum load condition, Electric and Magnetic Fields are 3µT & < 70V/m respectively.
- Under maximum load condition, step and touch potentials are also below the maximum allowable limit.
- It is important to note that the expected step and touch potential will be much lower than the simulated values in this study since the interconnection between earthing systems for the solar farm & auxiliary systems such as transmisison pole earthing will play a key role in reducing and managing the EPR, LFI and EMF related hazards to which personnel or members of the public are exposed under varying operation scenarios.
- Based on the results of these studies, no safety harzards or concerns have been identified. Hence, no further mitigations are required.

6 APPENDIX A – INPUT DATA

6.1 Overhead line configuration



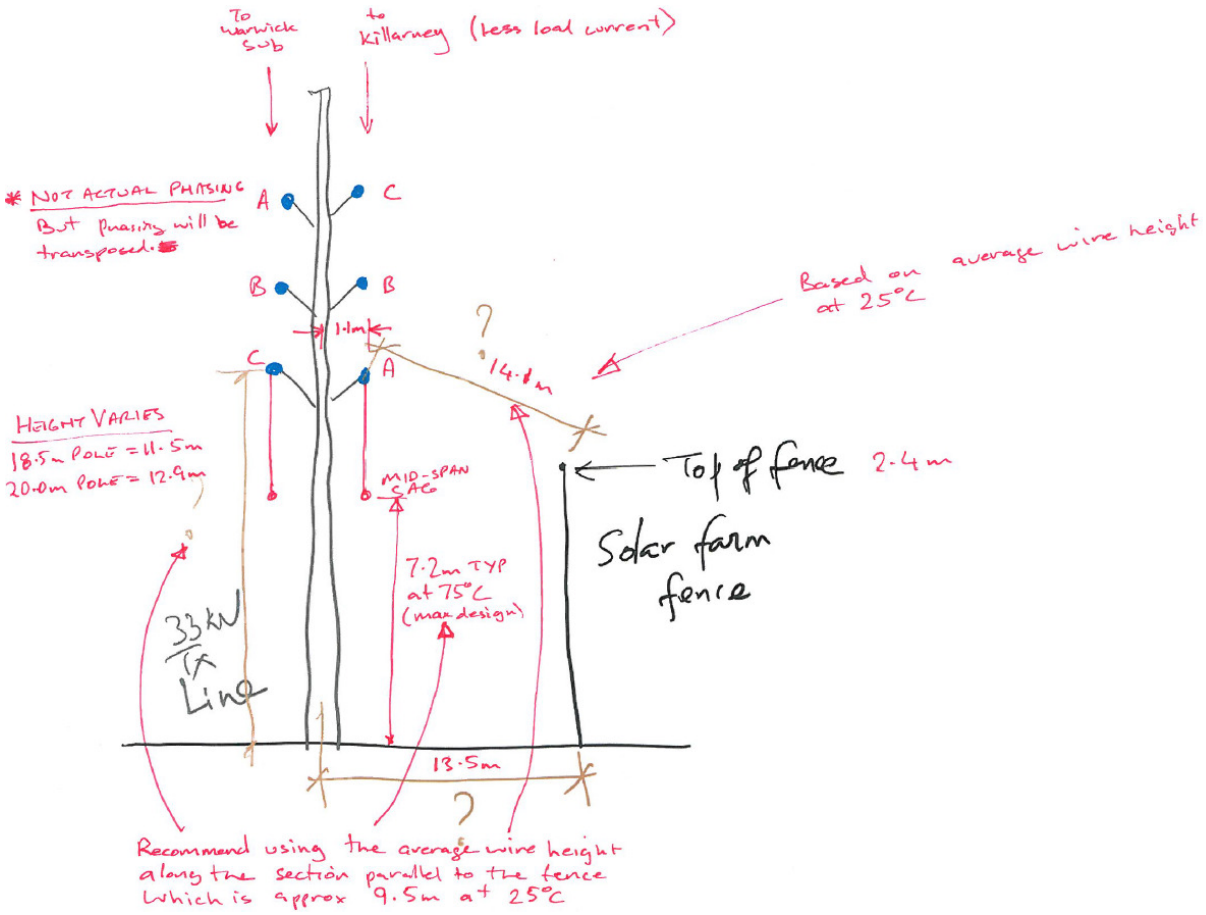


Figure 5: Geometry of the line used in modelling

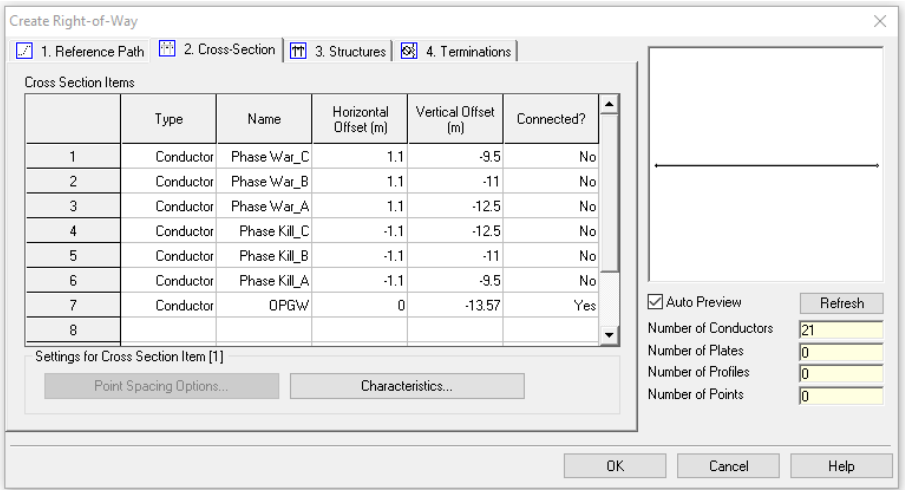


Figure 6: Geometry of the line used in modelling (CDEGS)

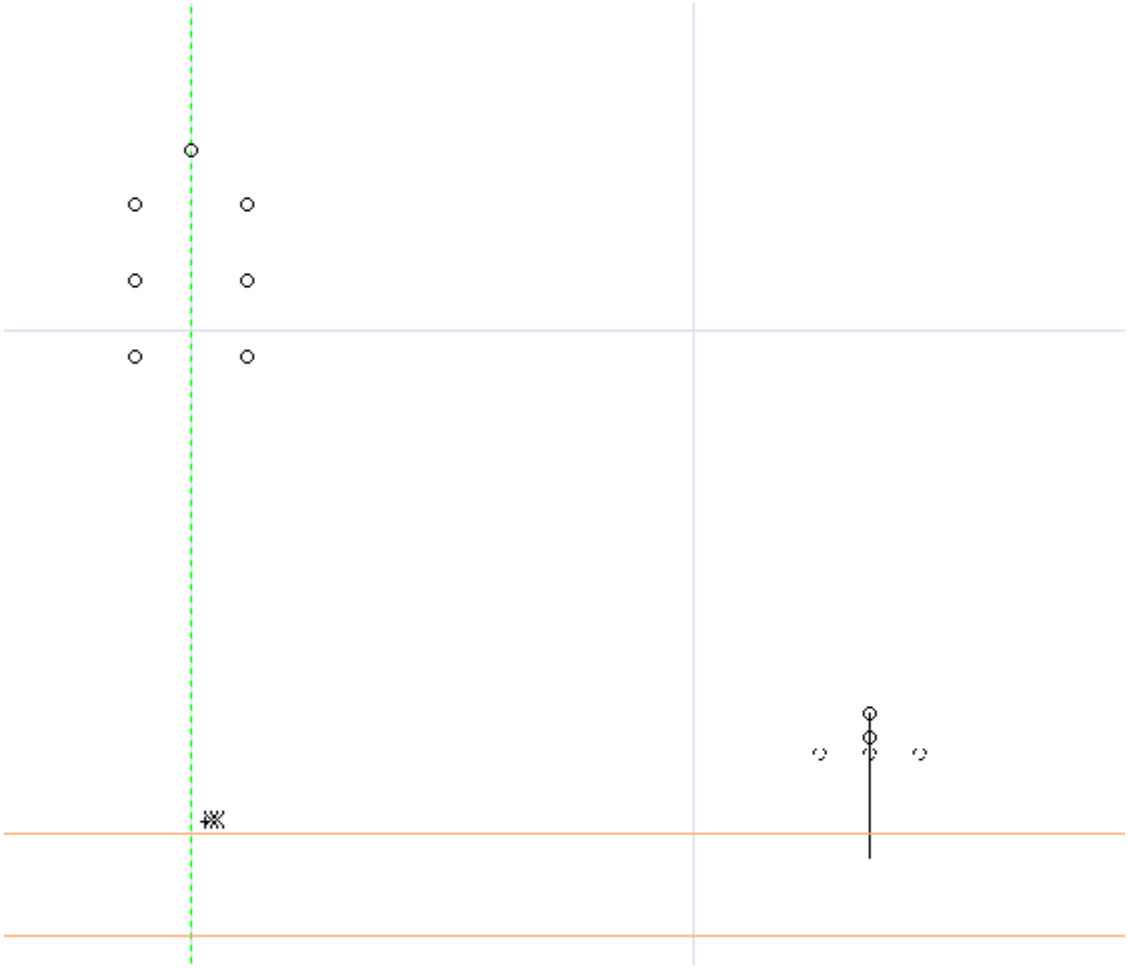


Figure 7: OHL Plan View (CDEGS) – step and touch

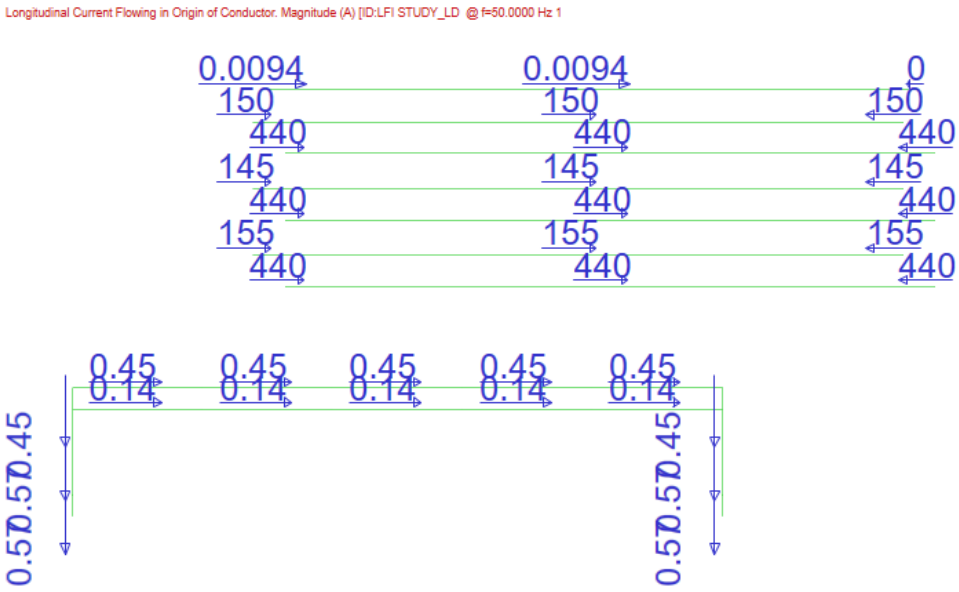


Figure 8: Longitudinal Current Flowing in Origin of Conductor (Maximum Load Condition)

6.1.1 Oxygen Line parameters – AAAC 1120 19/4/75

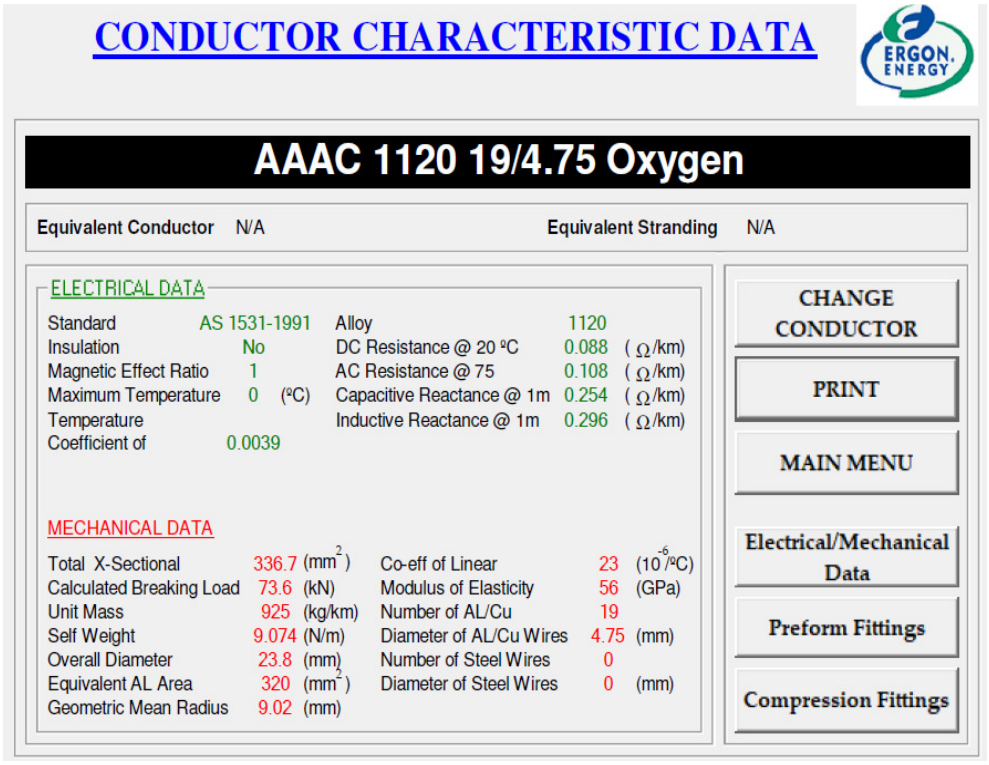


Figure 9: Oxygen Line parameters – AAAC 1120 19/4/75

6.1.2 Ground Wire SC/AC 7/3.25

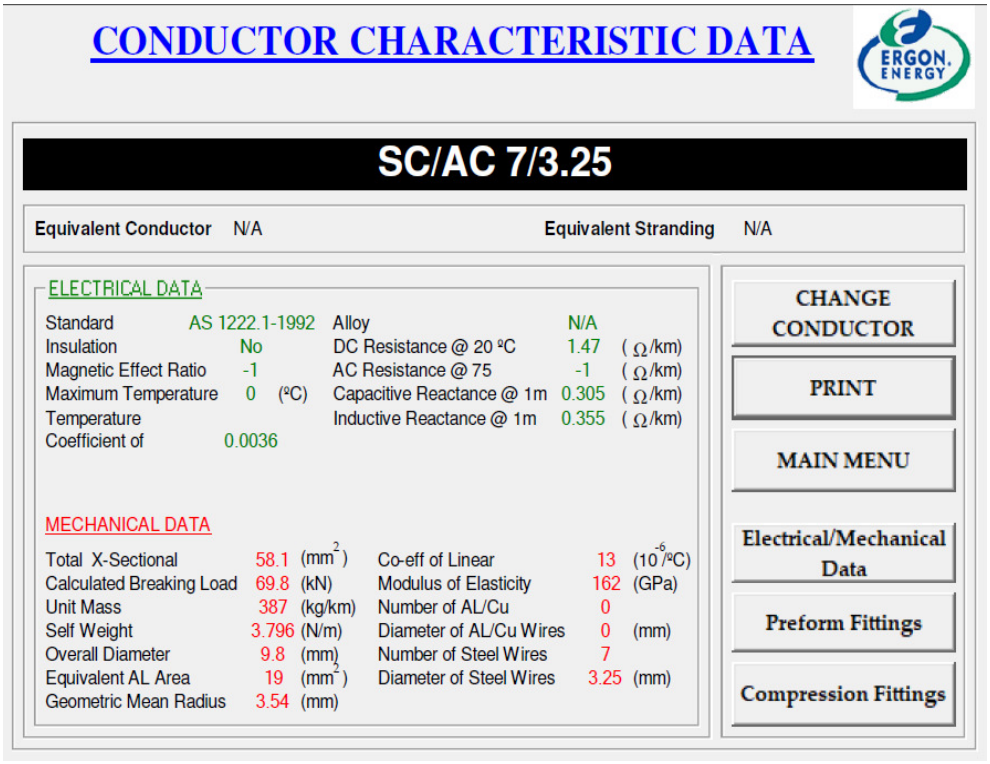


Figure 10: Ground Wire SC/AC 7/3.25

Note – Actual conductor is not available in CDGES library, 9.5mm OD equivalent conductor was used