SSEN SPITTAL TO LOCH BUIDHE TO BEAULY PROJECT

Electric and Magnetic Fields in Overhead Line Duck-Under Scenarios

6096/134/R/HN/04

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SSEN SPITTAL LOCH BUIDHE BEAULY PROJECT

Electric and Magnetic Fields in Overhead line Duck-Under Scenarios

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Executive Summary

Scottish and Southern Electricity Networks/ SSEN Transmission plc ("SSEN") is proposing to construct and operate approximately 96 kilometres (km) of new double circuit 400 kilovolts (kV) overhead transmission line (OHL) between the proposed Banniskirk and Carnaig 400 kV Substations and 77 km of new double circuit 400 kV OHL between the proposed Carnaig and Fanellan 400 kV Substations.

In July 2022, National Grid ESO (as of 1 October 2024 now known as the National Energy System Operator (NESO)) published the Pathway to 2030 Holistic Network Design (Pathway to 2023 HND), setting out the electricity transmission network infrastructure required to enable the forecasted growth in renewable electricity across Great Britain, in light of the UK and Scottish Government's 2030 offshore wind allocations of 50 gigawatt (GW) and 11 GW (through the Crown Estate and ScotWind leasing rounds) which are the main driver for these upgrades.

The proposed 400 kV overhead line (OHL) will consist of steel lattice towers using a new tower series known as the ASTI SSE400 or AS4 for short. These towers are expected to average 57 m in height across the routes. The conductor system is proposed to be 3 x 700 mm^2 AAAC Araucaria with 500 mm bundle spacing. The circuit is designed to function up to 90°C while maintaining a minimum ground clearance of 9 m under normal conditions. Although it is capable of operating at to 90°C, it is not currently intended to be used at this maximum rating.

This report details the EMF assessment in OHL duck-under scenarios (see Section 4). In the context of OHL, a duck-under describes a configuration where one transmission line passes beneath another, typically to prevent routing conflicts or ensure adequate clearances in constrained spaces. The primary objective of this report is to provide an EMF assessment for the general public exposure at a height of 1 m above ground at the crossing of the proposed Spittal to Loch Buidhe to Beauly and other SSEN overhead lines. This report details the input data, EMF limits, and EMF calculations conducted using the CDEGS software package, alongside a risk assessment based on industry guideline.

Main Results

Arcadis carried out an EMF assessment of the proposed 400 kV OHL duck under scenario with existing SSEN 400 kV, 275 kV and 132 kV using CDEGS (HIFREQ). All six scenarios are listed below. The calculation profile was placed at the OHL duck-under 1 m above ground. The power flow on both circuits was considered in same direction. The study acknowledges the limitation in accurately modelling insulator end fittings and conductor assembly hardware in HIFREQ; however, this does not impact EMF calculation at ground level itself.

i) Section A – Crofts of Benachielt – 132 kV Duck Under
ii) Section B - Strath Carnaig – 132 kV Diamond Duck Under
iii) Section C - West of Loch Buidhe 275 kV – Diamond Duck Under
iv) Section C – Near Invershin – 132 kV Duck Under
v) Section E – North-West of Fairburn – 132 kV Diamond Duck Under
vi) Section E – West of Fanellan/Aigas Gorge – 132 kV Duck Under

To ensure public exposure remains within safe limits, set exposure thresholds at 9 kV/m for electric fields and 360 µT for magnetic fields were used.

The calculation considers all duck-under configuration for the 275 kV and 132 kV OHLs, maintaining a statutory clearances (6.7 m for 132 kV, 7.0 m for 275 kV). At the crossing location, the ground clearance of the oversailing ASTI 400 kV overhead lines was modelled using a conservative approach, bounded between a minimum clearance of 9 meters and the conductor sag profile derived from PLS-CADD simulations, as detailed in Appendix A.

The EMF was assessed using CDEGS (HIFREQ), with all calculated values for the Craigiebuckler - Tarland 132 kV OHL duck-under scenario remaining within the safe threshold. The corresponding graphs are shown in Appendix B.

Recommendations

It is advisable for SSEN to review all input data and assumptions outlined in the report during the detailed design stage to ensure compliance with public EMF exposure limits.

1. Introduction

Scottish and Southern Electricity Networks/ SSEN Transmission plc ("SSEN") is proposing to build a number of projects including new high-voltage electricity 400 kV transmission lines, 400 kV Substations and HVDC (high voltage direct current) link to deliver the UK Government's 50 GW offshore wind by 2030 target. This has been set out as part of the Pathway to 2030 Holistic Network Design. Figure 1 illustrates the SSEN Pathway to 2030 projects.

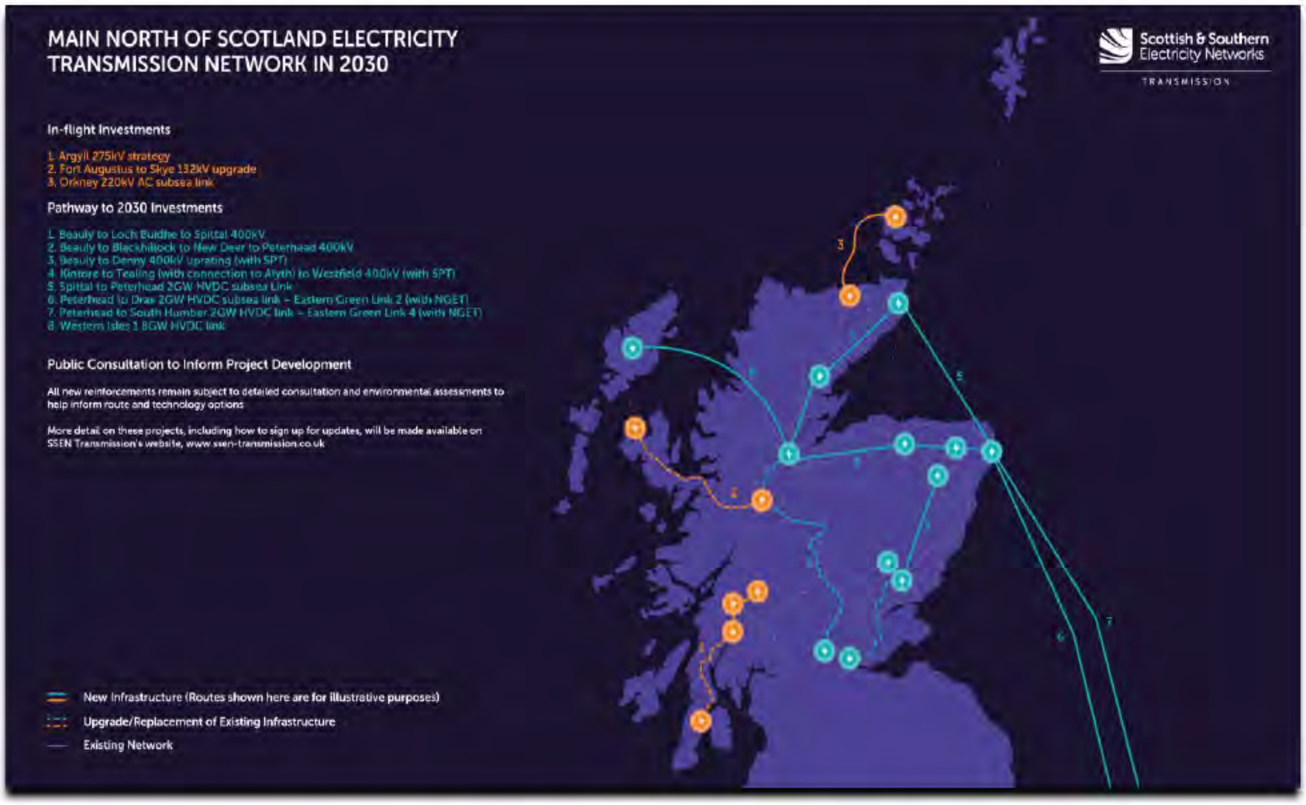


Figure 1. SSEN Pathway to 2030 Transmission Network

The Spittal to Loch Buidhe to Beauly 400 kV overhead line (OHL) will consist of steel lattice towers using a new tower series known as the ASTI SSE400 or AS4 for short. These towers are expected to average 57 m in height across the routes. The conductor system is proposed to be 3x700 mm^2 AAAC Araucaria with 500 mm bundle spacing. The circuit is designed to function up to 90°C while maintaining a minimum ground clearance of 9 m under normal conditions. Although it is capable of operating at 90°C, it is not currently intended to be used at this maximum rating.

Arcadis Consulting (UK) Ltd ("Arcadis") has been commissioned by SSEN to conduct an electric and magnetic fields (EMFs) assessment for the ASTI 400 kV OHL tower. Arcadis completed a report summarising the EMF calculations for AS4 tower [1].

This report details the EMF assessment in OHL duck-under scenarios (see Section 4). In the context of OHL, a duck-under describes a configuration where one transmission line passes beneath another, typically to prevent routing conflicts or ensure adequate clearances in constrained spaces. The primary objective of this report is to provide an EMF assessment for the general public exposure at a height of 1 m above ground at the crossing of the Spittal to Loch Buidhe to Beauly and other SSEN existing overhead lines. This report details the input data, EMF limits, and EMF calculations conducted using the CDEGS software package, alongside a risk assessment based on industry guideline. Sections 2 of the report remain unchanged from previous Arcadis report 6096/134/R/HN/01B [1].

[1] Arcadis Report 6096/134/R/HN/01B- SSE ASTI Project - 400 kV Overhead Line Tower Electric and Magnetic Fields, 18th February 2025

2. Electric & Magnetic Field (EMF) Risks

The electromagnetic field (EMF) from power lines consist of electric field and magnetic field. The electric fields are produced by voltage. Electric fields are measured in volts per metre (v/m). Magnetic fields are produced by current, which is the flow of electricity. Generally, the higher the current, the higher the magnetic field. Magnetic fields are measured in microtesla (μT).

Alternating magnetic fields induces electric fields which will produce currents in a conductive medium. The human body is conductive and hence alternative magnetic fields will induce very weak voltages and currents in the human body. If these voltages and currents are high enough, it is possible to result in physiological effects on excitable tissues of the body, mainly nerve and muscle cells. Similar, direct exposure of alternating electric fields can induce very weak voltages and currents in the human body. Again, if these voltages and currents are high enough, it is possible to result in physiological effects on excitable tissues of the body, mainly nerve and muscle cells.

An active implantable medical device (AIMD) is any medical device which is intended to be totally or partially introduced, surgically or medically, into the human body, and which is intended to remain after the procedure. The commonest are pacemakers and defibrillators (together described as "implanted heart devices"). The electronic medical implants use electrical component in their construction. Under certain circumstances some implants may be susceptible to interference from electromagnetic field. This situation could lead to improper function of medical implants e.g., a heart pacemaker disturbance can pose a health & safety threat. It should be noted that the Medicines and Healthcare products Regulatory Agency (MHRA) are aware of no instance of a patient having their implanted heart device interfered with by a high-voltage power line [2].

The two internationally recognised exposure guidelines are established by the Institute of Electrical and Electronics Engineers (IEEE) [3] and International Commission on Non-Ionising Radiation Protection (ICNIRP) and [4].

2.1 How EMF Strengths Decrease with Distance

EMF decreases with distance from the source. Generally, at a distance from the source d, the fields will decrease as follows [5]:

- Single-phase current – 1/d,
- Single circuit or double circuit un-transposed – $1/d^2$, and
- Double circuit transposed (assuming symmetrical geometry) or coil – $1/d^3$.

Figure 2 shows this rate of decrease from different sources. In practice, factors such as unequal currents, zero sequence currents, tapered towers, geometrical deviations on the structure, and very close proximity to sources will result in rates of decrease which are less than the above. Furthermore, magnetic field profiles are typically shown horizontally along the ground (at one metre above ground), perpendicular to the conductor and typically at midspan where the conductors are closest to the ground.

[2] https://www.emfs.info/

[3] IEEE (2019) Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz. IEEE Std C95.1, New York

[4] International Commission on Non-ionizing Radiation Protection (2010): Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz). Health Phys 99 (6), pp.818- 836. Erratum in Health Phys 100 (1), p.112 (2011). https://www.icnirp.org/cms/upload/publications/ICNIRPLFgdl.pdf and International Commission on Non-ionizing Radiation Protection (1998): Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic Fields and Electromagnetic Fields (up to 300 GHz). Health Phys 74 (4), pp.494-522. https://www.icnirp.org/cms/upload/publications/ICNIRPemfgdl.pdf

[5] CIGRE TB 806, Responsible management of electric and magnetic fields (EMF) – 2020.

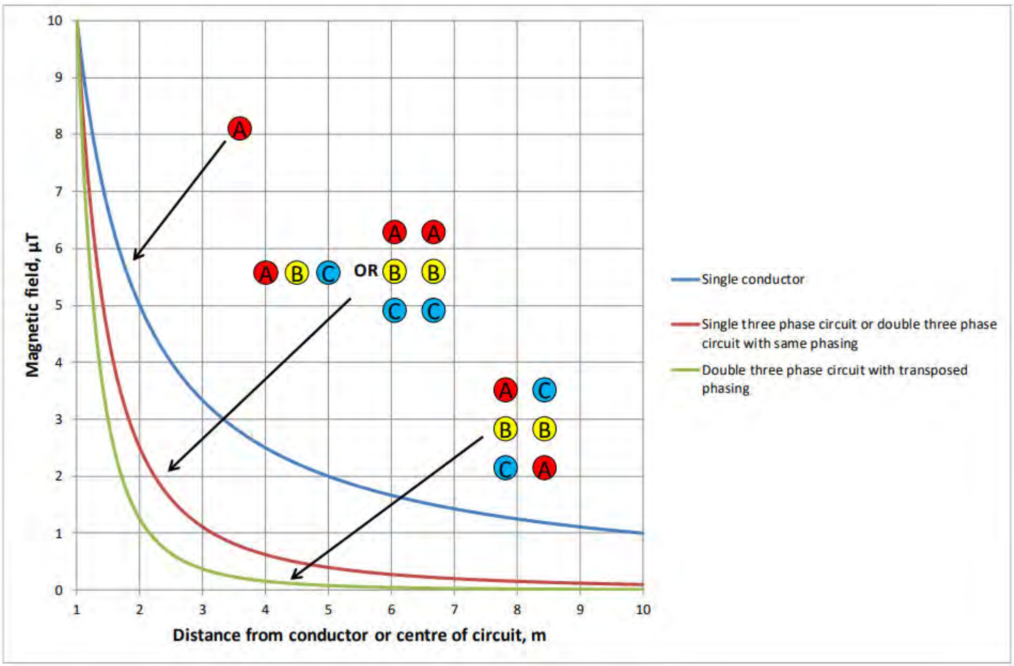


Figure 2: General Rate of Decrease of Magnetic Fields from Different Sources

2.2 EMF Limits

The EMF limits within the regulations [6], the EMF limits within the regulations are the exposure limits values (ELVs), and there are two levels: the Sensory ELVs and Health ELVs. The Sensory ELVs can be exceeded if are range of conditions are met, but the health ELVs must not be exceeded. For occupational exposure the first level of exposure limits for the unperturbed fields are the Sensory Action Levels which are.

- Magnetic field: 1 mT or 1000 µT (18 mT for exposure only to limbs)
- Electric field: 10 kV/m

The regulations allow for the sensory effects ELVs to be exceeded under the following conditions: i) They are only exceeded temporarily. ii) Hazardous spark discharges and contact currents in excess of 1 mA are prevented through the provision of information and training and the use of suitable technical and personal protection measures. iii) Adequate information is provided to the employee on the possibility of sensory effects related to time varying magnetic fields, including retinal phosphenes. iv) Where any of those sensory effects are reported to the employer, the risk assessment is updated where necessary. Providing the above conditions are complied with, the Regulations allow exposure up to a High Action Levels (which ensure the health ELV are not exceed), which are:

- Magnetic field: 6 mT or 6000 µT (18 mT for exposure only to limbs)
- Electric field: 20 kV/m

To ensure public exposure remains within safe limits, general public exposures in the UK should adhere to the ICNIRP 1998 guidelines, as outlined in the voluntary Code of Practice [7]. In practical terms, this mean:

- An electric field of 9 kV/m.
- A magnetic field of 360 µT.

[6] The Control of Electromagnetic Fields at Work Regulations 2016, see https://www.legislation.gov.uk/uksi/2016/588/contents

[7] Power Lines: Demonstrating compliance with EMF public exposure guidelines – A voluntary Code of Practice, published by DECC in February 2011.

3. Computation Software

The EMF was calculated using **HIFREQ (Electromagnetic Fields Analysis) module of the SES CDEGS software suite.** HIFREQ is an optimal computation tool for tackling complex electromagnetic problems involving any system of conductors, which can be comprised of various materials and assembled in various configurations, and which may include metallic plates, coaxial or multi-core cables, GIS/GIL, transformers, and assorted lumped components (e.g. resistors, inductors, and capacitors, etc.). HIFREQ is the only computation module that can provide accurate solutions to transient and steady state problems in the frequency range of zero to hundreds of megahertz, for the analysis of buried and aboveground conductors. It computes electric and magnetic fields in the air and soil, as well as conductor and soil potentials, and the current distribution in the soil and in the conductors.

More information on HIFREQ module https://sestech.com/en/Product/Module/HIFREQ

Limitations: This study acknowledges the limitation in accurately modelling insulator end fittings and conductor assembly hardware in CDEGS. Accurate modelling can be attained by applying 3D electric field design and analysis software featuring Boundary Element Method (BEM) technology.

Electric fields near the surface of a conductor are very sensitive to the shape of the conductor. HIFREQ can be used to compute electric fields by modelling the OHL tower and phase conductors, however, the conductors are represented as wire filaments and the exact shape of a conductor (for example the steel members of a tower), and insulators cannot be modelled. It is important to note that electric fields computed with HIFREQ at points located far away (i.e., several conductor radii away) from the conductors should nonetheless be accurate.

4. OHL Duck-Under Scenarios

The proposed Spittal to Loch Buidhe to Beauly OHL involves the construction of approximately 96 km of new double circuit 400 kilovolts (kV) OHL between the proposed Banniskirk and Carnaig 400 kV Substations and 77 km of new double circuit 400 kV OHL between the proposed Carnaig and Fanellan 400 kV Substations.

Special arrangements are required to facilitate the crossing of the Proposed Development with existing 132 kV or 275 kV OHLs. As part of the Proposed Development, six special arrangements are proposed. The location of these and each of the proposed arrangements that are part of the EMF assessment are shown in the figures below.

The circuit data for the proposed 400 kV OHL and crossing arrangement is shown in Section 5 and 6.

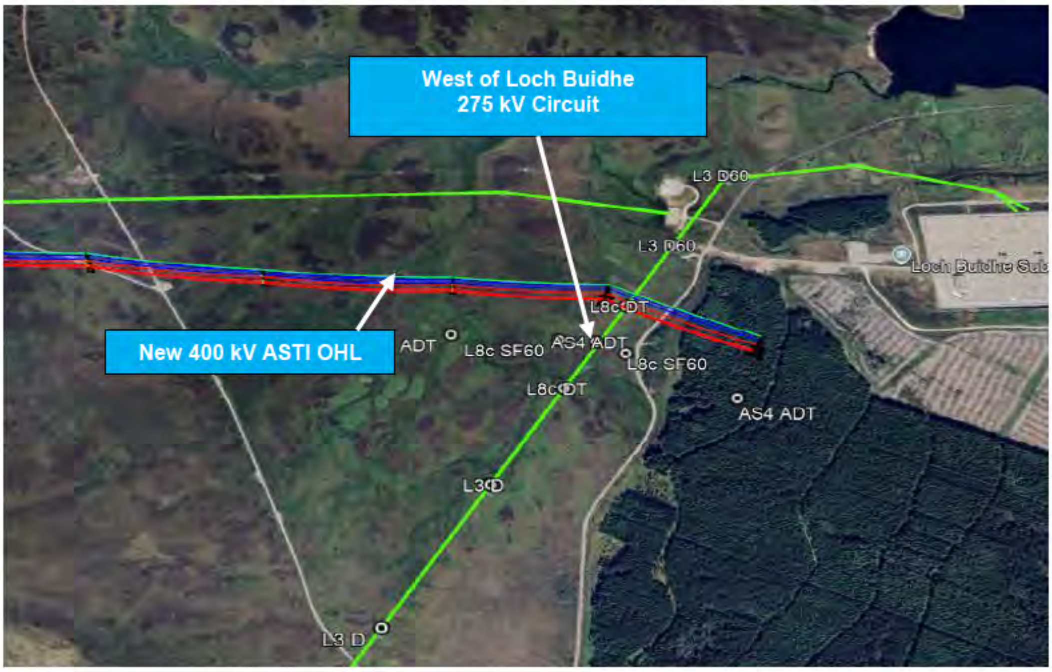


Figure 3: West of Loch Buidhe – 275 kV Diamond Duck Under

Figure 4: Near Invershin – 132 kV Duck Under

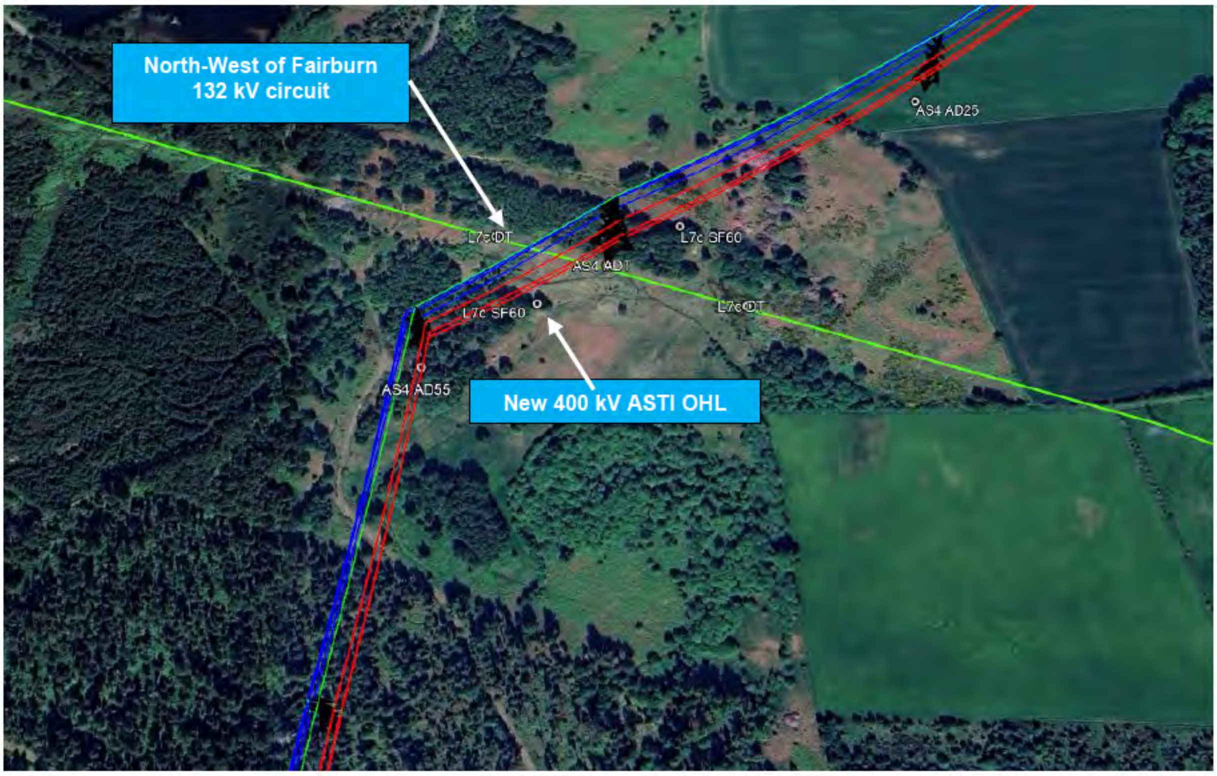


Figure 5: North-West of Fairburn – 132 kV Diamond Duck Under

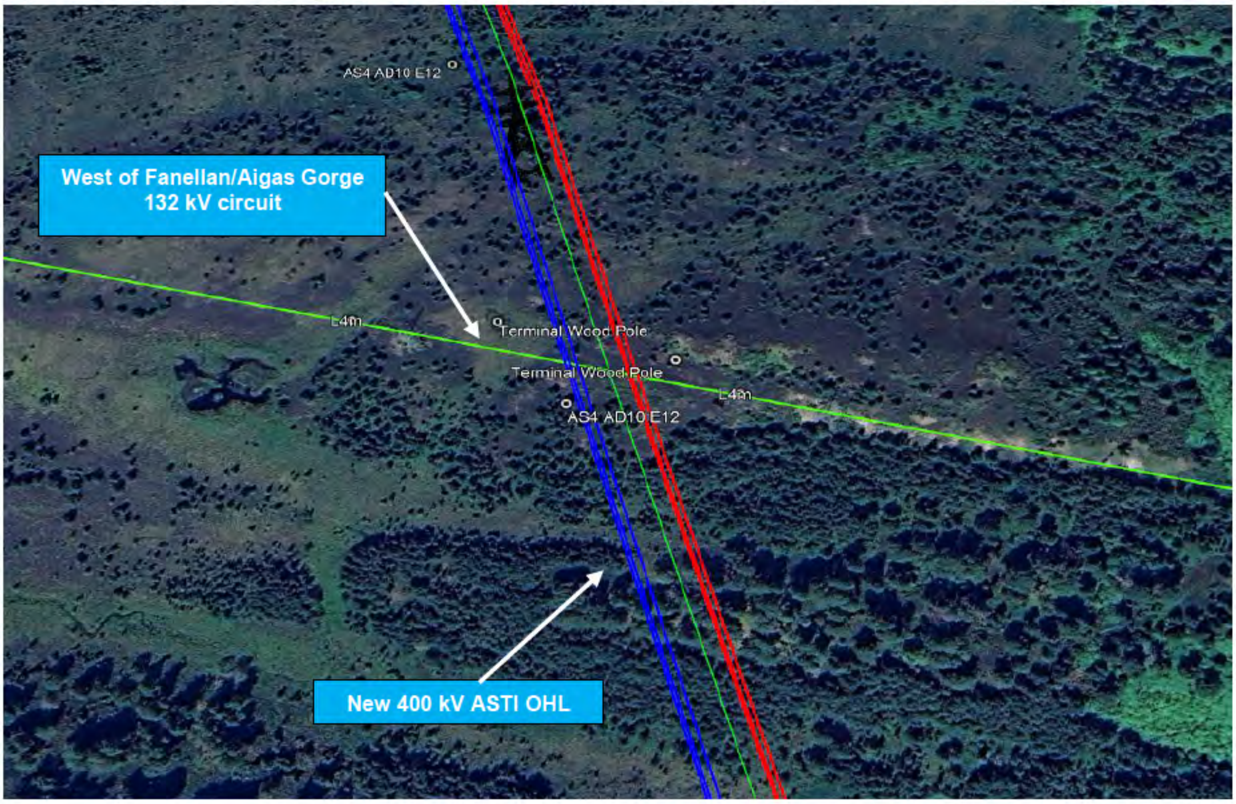


Figure 6: West of Fanellan/Aigas Gorge – 132 kV Duck Under

Figure 7: Crofts of Benachielt – 132 kV Duck Under

Figure 8: Strath Carnaig – 132 kV Diamond Duck Under

5. Data for CDEGS Model

This section details the input data for the proposed Spittal to Loch Buidhe to Beauly 400 kV circuits that was used to develop a computer model to calculate EMF as requested by SSEN.

5.1 Soil Resistivity

The soil resistivity along the OHL route was considered 500 Ωm. The magnitude was chosen based on the Arcadis engineering experience within SSEN network area. The above soil model will be used in all future subsequent analysis to represent the soil conditions.

5.2 Conductor Data

The Spittal to Loch Buidhe to Beauly 400 kV OHL route will consist of steel lattice towers using a new tower series known as the ASTI SSE400 or AS4 for short. A 400 kV tower drawing is detailed within the Appendix A of this report. For each crossing the tower type, span length and sag was designed in a PLSCAD model and information shared by SSEN [8]. The conductor system is proposed to be 3 x 700 mm^2 AAAC Araucaria with 500 mm bundle spacing. The phase and earth wire data sheets are attached in Appendix A.

At OHL duck-under scenarios, the existing OHL phase and earth wire data was based on the information attached in Appendix A of this report.

5.3 OHL Voltage Levels and Load Current

The steady state coupling in this report considers the proposed Spittal to Loch Buidhe to Beauly 400 kV OHLs operating at maximum pre fault continuous winter rating of 5000 A and maximum 400 kV voltage.

At OHL duck-under scenarios, the duck under OHL rating was based on the information attached in Appendix A of this report. At the crossing location, the ground clearance of the oversailing ASTI 400 kV overhead lines was modelled using a conservative approach, bounded between a minimum clearance of 9 meters and the conductor sag profile derived from PLS-CADD simulations, as detailed in Appendix A. The sag of duck under OHL was modelled such that these phase approaching statutory clearance 6.7 m for 132 kV, 7.0 m for 275 kV as given in the Electricity Safety, Quality and Continuity Regulations 2002 (see https://www.legislation.gov.uk/uksi/2002/2665/contents).

The report does not consider fault conditions. As per CIGRE guidelines, in extreme cases, lightning and electrical faults can create very brief, large, fault currents in equipment and conductors/cables, and consequently elevated magnetic fields in the vicinity. Fault current events are of very short duration (typically a few cycles), rare (typically a few times per year or less) and have a low probability of coincidence with someone being in very close proximity at the time. This is a somewhat similar scenario to lightning strikes. ICNIRP 2010 does not provide specific guidance on fault currents. IEEE [3] states that the averaging time for assessing exposures is 200 ms or ten cycles. Faults currents that exceed ten cycles are typically on low-voltage distribution systems or remote from the protection. In these cases, the current is typically lower. In any case where such faults occur the electricity system is designed to immediately isolate the fault and thereby eliminate any exposure. Therefore, electrical networks are compliant with the general principle that when a danger is identified it is eliminated as soon as possible, and all reasonable attempts are made to avoid its occurrence.

[8] Email from SSEN, "RE: Special Arrangement Models - SF60s for EMFs" 20th February 2025.

5.4 OHL Phasing

Similar to the phase and earth wire, the phase arrangement of the OHL on a double circuit tower can impact EMF. SSEN have provided data on the proposed phasing for both the existing and proposed OHL which is shown within Appendix A. The Spittal to Loch Buidhe to Beauly OHL will have optimal phasing with a "centre points symmetrical" phase arrangement, similar to that illustrated in Figure 9. The existing OHL phasing has been modelled as per the information provided in Appendix A.

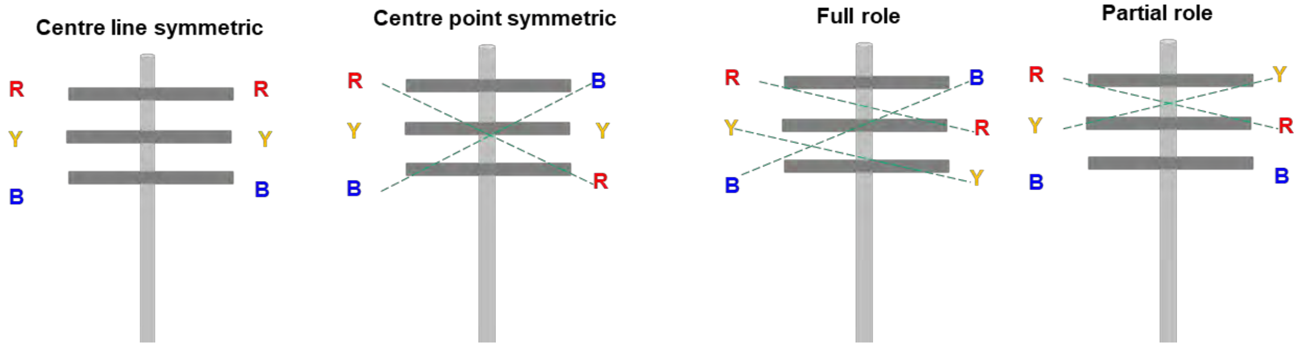


Figure 9: Possible Phase Arrangements -Double Circuit OHL

6. EMF Calculations

This section details the calculations and interpretations of EMF using HIFREQ along the CDEGS model at the proposed crossing. The OHL tower, phase, and earth wires were modelled using the data, in Section 4. Two spans were modelled, and calculation profile were placed at OHL duck-under 1 m above ground. The power flow on both circuit was considered in same direction. As stated before, this study acknowledges the limitation in accurately modelling insulator end fittings and conductor assembly hardware in HIFREQ. The insulators were omitted, and conductors were modelled at respective locations at the tower crossarm, it should be noted however that as the conductor is sagged to achieve 9m clearance to ground the insulator length has negligible impact.

West of Loch Buidhe 275 kV circuit – Diamond Duck Under: According to the CDEGS model, the maximum electric and magnetic field values are presented below, with the corresponding CDEGS plot provided in Appendix B.

- An electric field 6.42 kV < safe threshold of 9 kV/m
- A magnetic field 65.71 μT < safe threshold 360 μT

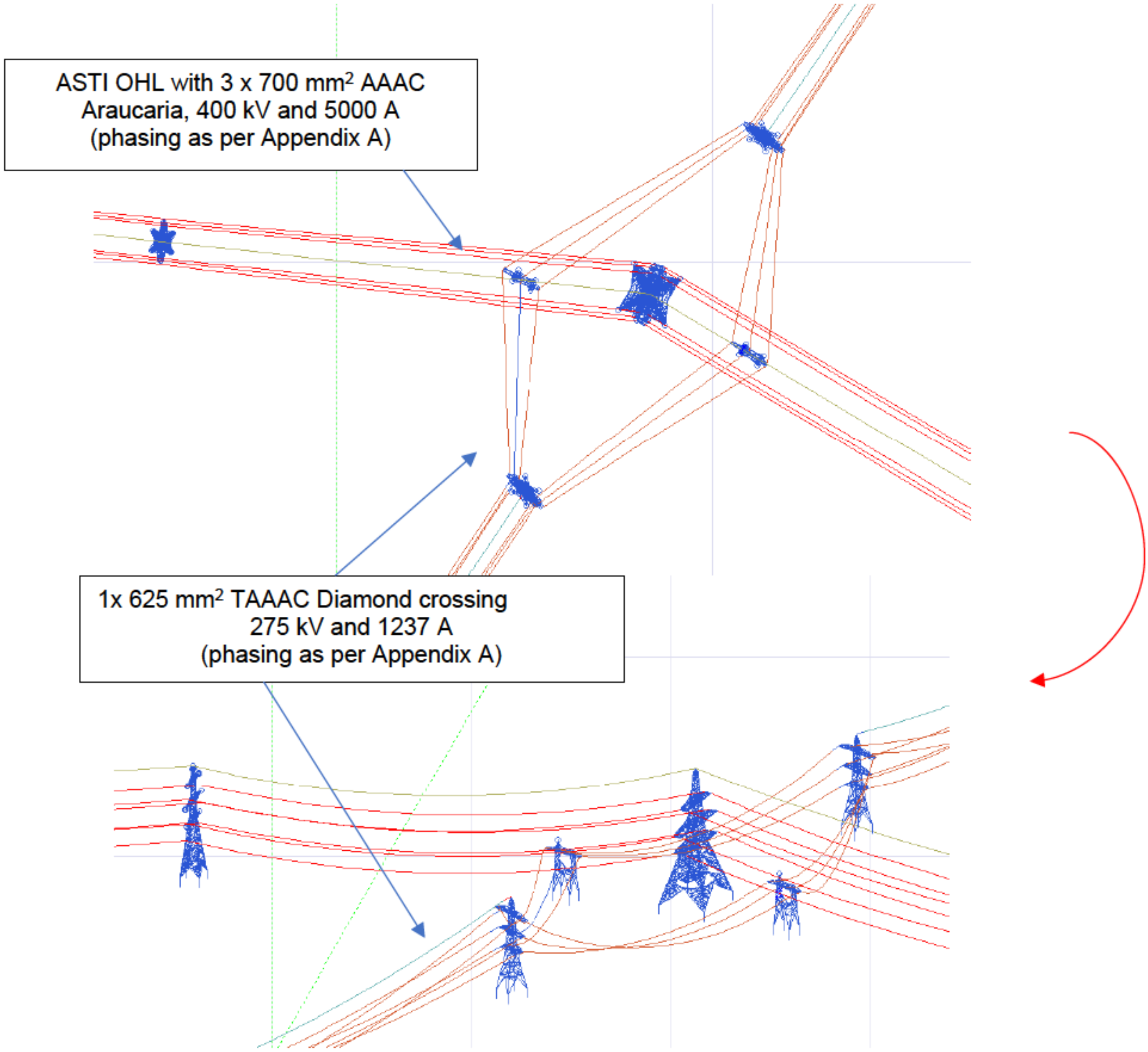


Figure 10: West of Loch Buidhe 275 kV circuit – Diamond Duck Under

Near Invershin 132 kV circuit – Duck Under: According to the CDEGS model, the maximum electric and magnetic field values are presented below, with the corresponding CDEGS plot provided in Appendix B.

- An electric field 6.04 kV < safe threshold of 9 kV/m
- A magnetic field 68.63 μT < safe threshold 360 μT

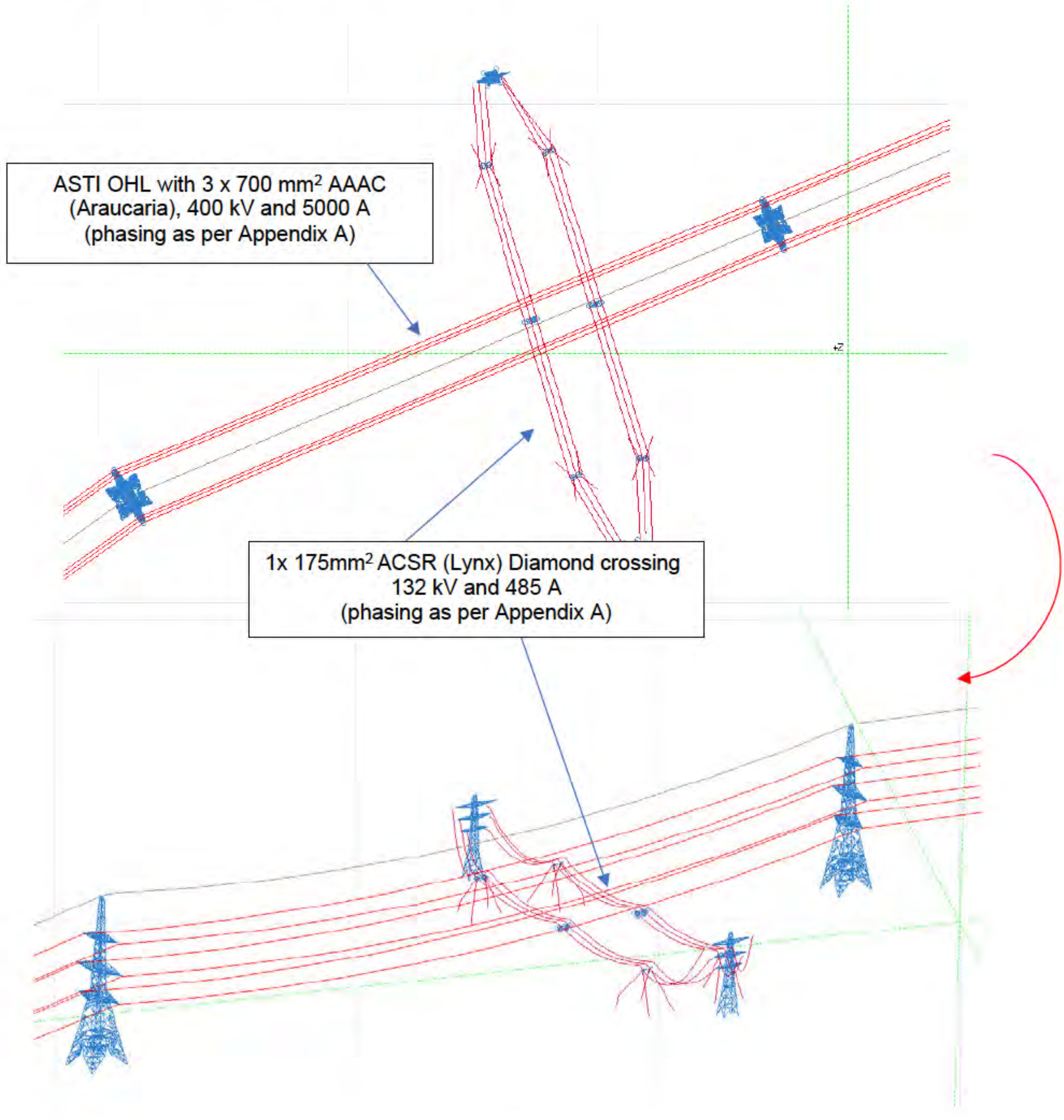


Figure 11: Near Invershin 132 kV circuit – Duck Under

North-West of Fairburn 132 kV circuit – Diamond Duck Under: According to the CDEGS model, the maximum electric and magnetic field values are presented below, with the corresponding CDEGS plot provided in Appendix B.

- An electric field 6.871 kV < safe threshold of 9 kV/m
- A magnetic field 74.94 μT < safe threshold 360 μT

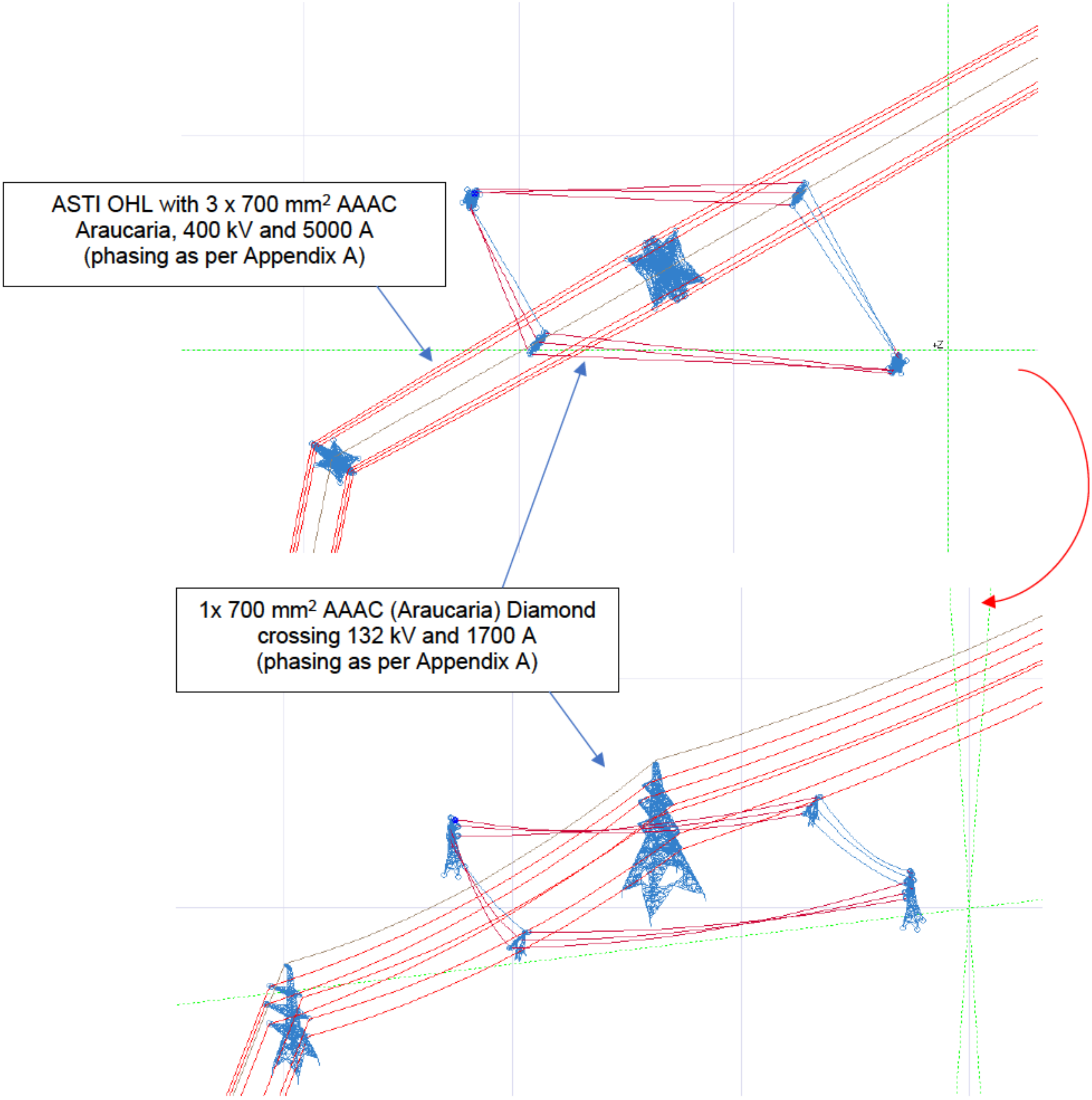


Figure 12: North-West of Fairburn 132 kV circuit – Diamond Duck Under

West of Fanellan/Aigas Gorge 132 kV circuit – Duck Under: According to the CDEGS model, the maximum electric and magnetic field values are presented below, with the corresponding CDEGS plot provided in Appendix B.

- An electric field 4.59 kV < safe threshold of 9 kV/m
- A magnetic field 55.91 μT < safe threshold 360 μT

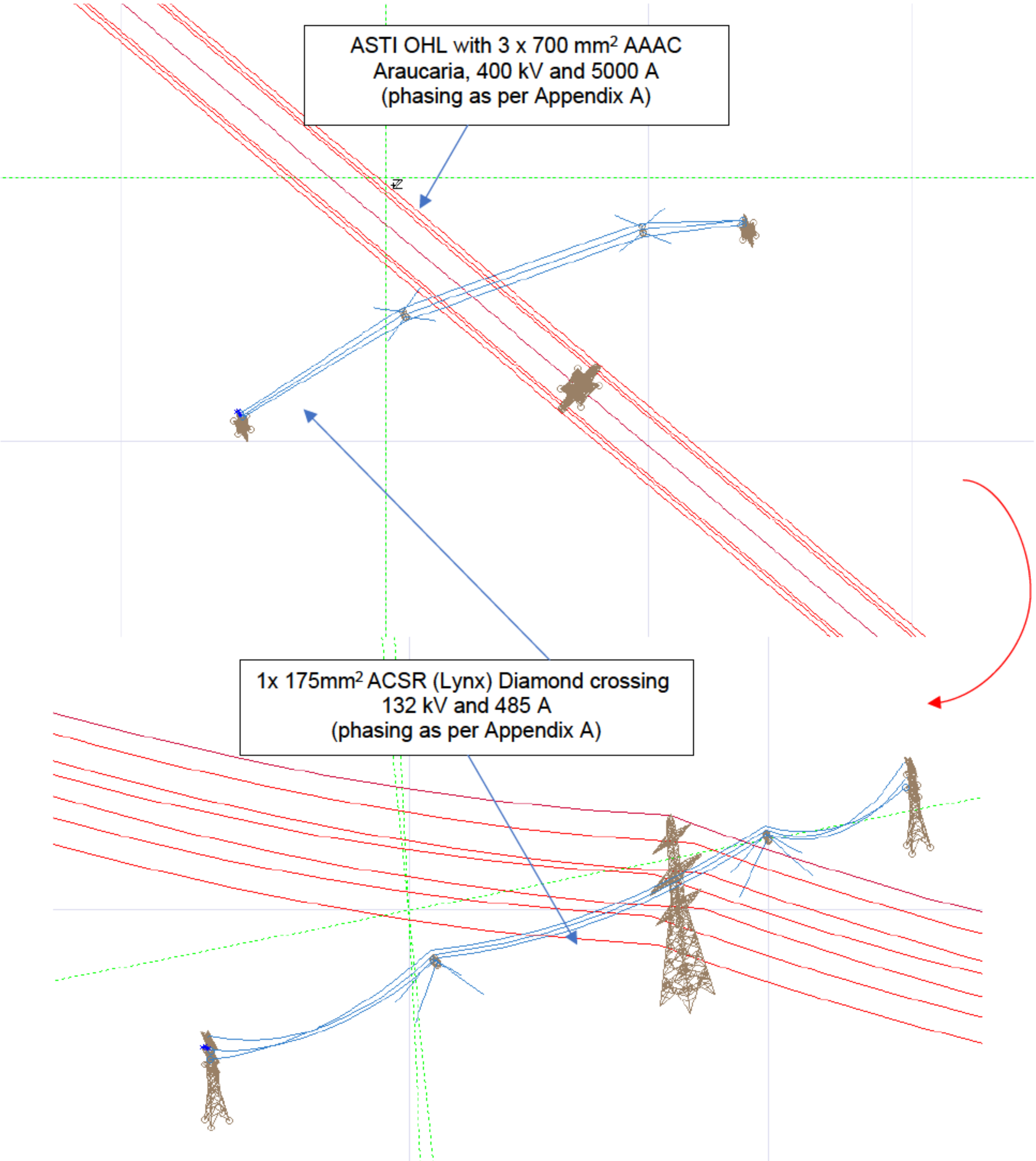


Figure 13: West of Fanellan/Aigas Gorge 132 kV circuit – Duck Under

Crofts of Benachielt 132 kV circuit – Duck Under: According to the CDEGS model, the maximum electric and magnetic field values are presented below, with the corresponding CDEGS plot provided in Appendix B.

- An electric field 6.83 kV < safe threshold of 9 kV/m
- A magnetic field 78.28 μT < safe threshold 360 μT

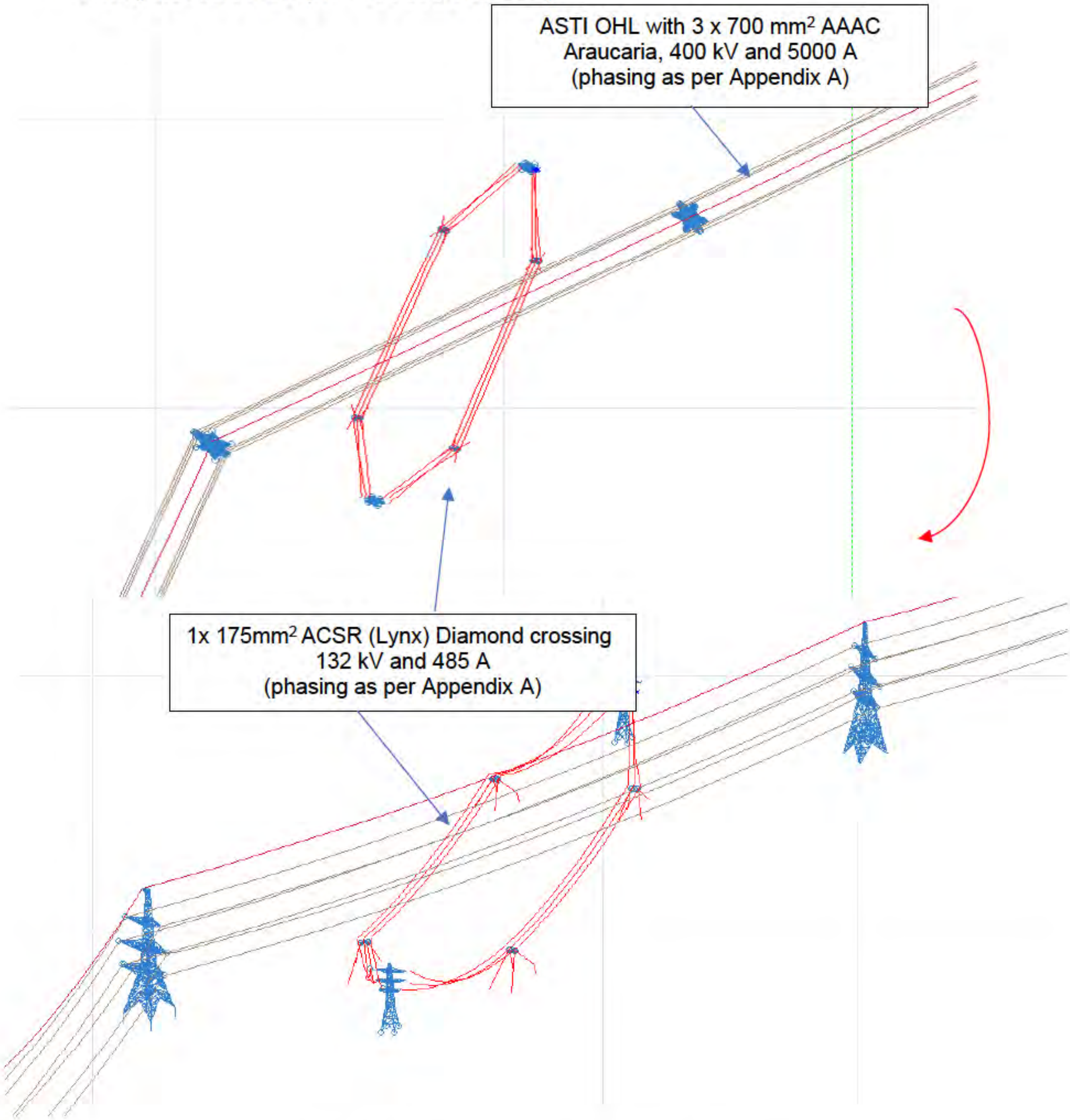


Figure 14: Crofts of Benachielt 132 kV circuit – Duck Under

Strath Carnaig 132 kV circuit - Diamond Duck Under: According to the CDEGS model, the maximum electric and magnetic field values are presented below, with the corresponding CDEGS plot provided in Appendix B.

- An electric field 4.67 kV < safe threshold of 9 kV/m
- A magnetic field 55.77 µT < safe threshold 360 µT

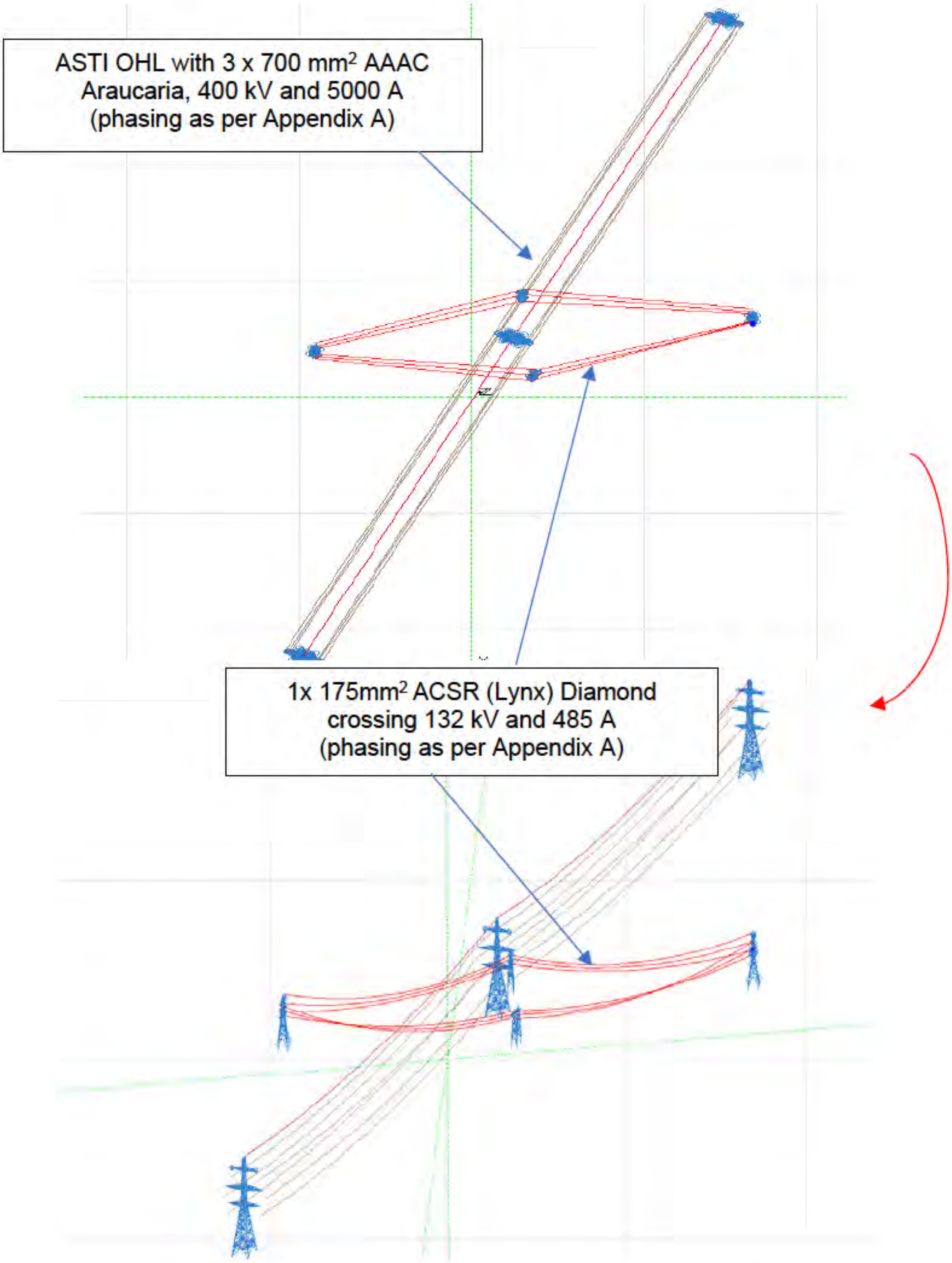


Figure 15: Strath Carnaig 132 kV circuit - Diamond Duck Under

7. Conclusions

a) Arcadis carried out an EMF assessment of the proposed Spittal to Loch Buidhe to Beauly 400 kV OHL duck under scenario with existing SSEN 400 kV, 275 kV and 132 kV using CDEGS (HIFREQ). The calculation profile was placed at OHL duck-under 1 m above ground. The power flow on both circuits was considered in same direction. The study acknowledges the limitation in accurately modelling insulator end fittings and conductor assembly hardware in HIFREQ however this does not impact EMF calculation at ground level itself.

b) To ensure public exposure remains within safe limits, set exposure thresholds at 9 kV/m for electric fields and 360 µT for magnetic fields were used.

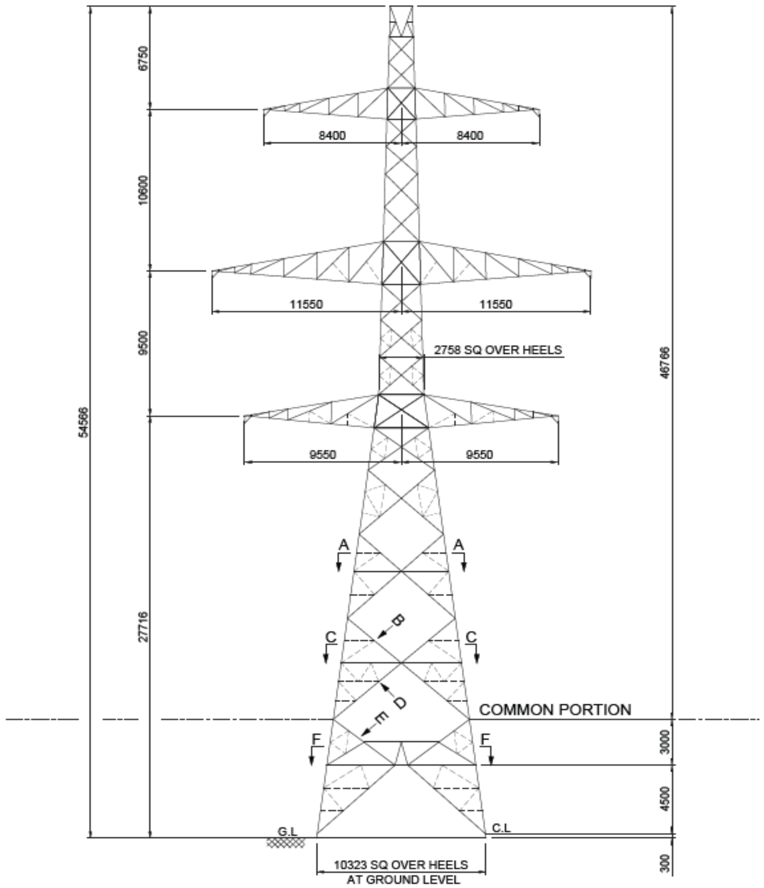
c) The EMF was assessed using CDEGS (HIFREQ), with all calculated values for various duck-under scenarios remaining within the safe threshold. The corresponding graphs are shown in Appendix B.

8. Recommendations

a) It is advisable for SSEN to review all input data and assumptions outlined in the report during the detailed design stage to ensure compliance with public EMF exposure limits.

Appendix A

ASTI 400 kV OHL Tower (Information Only)



TRANSVERSE FACE
±0.0M TOWER.
(STD.HT)

ASTI 400 kV OHL Phase and Earth Wire

data sheet

LF AAAC Araucaria EHC

LAMIFIL

Version 1, 23-02-2008

Conductor	AAAC 820mm²
Code name	LF AAAC Araucaria EHC

Mechanical specifications	Metric (SI)					Imperial				
Nominal aluminium equivalent area	mm²	761				in²	1,179			
Nominal cross sectional area of aluminium alloy	mm²	821,1				in²	1,273			
Number, diameter and type of central wire	#, mm	1	4,14	R	Alloy	#, in	1	0,163	R	Alloy
Number, (eq.) diameter and type of wire in layer	#, mm	6	4,14	R	Alloy	#, in	6	0,163	R	Alloy
Number, (eq.) diameter and type of wire in layer	#, mm	12	4,14	R	Alloy	#, in	12	0,163	R	Alloy
Number, (eq.) diameter and type of wire in layer	#, mm	18	4,14	R	Alloy	#, in	18	0,163	R	Alloy
Number, (eq.) diameter and type of wire in layer	#, mm	24	4,14	R	Alloy	#, in	24	0,163	R	Alloy
Diameter tolerance of aluminium wires (Al or Alloy)	mm	± 0,03				in	± 0,001			
Lay ratio of inner layer(s)		10-16					10-16			
Lay ratio of outer layer		10-14					10-14			
Overall diameter	mm	37,26				in	1,467			
Rated tensile strength of conductor (RTS)	kN	242,2				klbf	54,5			
Nominal mass per unit length - total	kg/km	2350,5				lb/kft	1579,5			
Nominal mass per unit length - total bare	kg/km	2271,5				lb/kft	1526,4			
Nominal mass per unit length - grease	kg/km	79,0				lb/kft	53,1			
Coefficient of linear expansion below thermal kneepoint	/ K	0,00002300				/ °F	0,00001278			
Modulus of elasticity below thermal kneepoint	GPa	56,6				Msi	8,20			
Geometric mean radius	mm	14,5				ft	0,0476			

Electrical specifications	Metric (SI)		Imperial	
Nominal DC resistance at 20 °C (tolerance ± 2%)	Ohm/km	0,0381	Ohm/mile	0,0612
Temperature coefficient		0,00403		0,00403
Frequency	Hz	50	Hz	60
Nominal AC resistance at 20 °C (tolerance ± 2%)	Ohm/km	0,0401	Ohm/mile	0,0659
Nominal AC resistance at 25 °C (tolerance ± 2%)	Ohm/km	0,0408	Ohm/mile	0,0671
Nominal AC resistance at 50 °C (tolerance ± 2%)	Ohm/km	0,0445	Ohm/mile	0,0729
Nominal AC resistance at 75 °C (tolerance ± 2%)	Ohm/km	0,0482	Ohm/mile	0,0787
Nominal AC resistance at 100 °C (tolerance ± 2%)	Ohm/km	0,0519	Ohm/mile	0,0846
Maximum allowable continuous operating temperature (surface)	°C	90	°F	194
Inductive reactance: Xa (conductor part)	Ohm/km	0,1914	Ohm/mile	0,3696
Shunt capacitive reactance: X'a (conductor part)	MOhmkm	0,1204	MOhmmile	0,1003

Individual wires	Metric (SI)			Imperial		
Maximum resistivity of aluminium alloy at 20 °C, minimum IACS	nOhmm, %	30,50	57%	nOhmft, %	100,07	57%
Minimum tensile strength, aluminium alloy wire	MPa	295		psi	42786	
Minimum elongation for aluminium alloy wire.	%	3,5		%	3,5	

Standard applied for conductor manufacturer: TS 3.4.2 - Issue 5 - juni 2004

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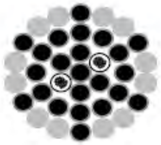
AFL

08.04.2024, Ja
TK 14988-10 Rev. 00

ASLH-V(2S)bbb 96 SMF (AL3/A20SA 109/209)

Optical Ground Wire (OPGW)

according to IEC 60794-4-10



- Stranding direction of outer layer: right hand (Z-stranding)
- Greasing acc. to EN 50182 A.2 / Grease acc. to EN 50326, type A
- Entire conductor greased except outer layer
- Wires acc. to EN 50183 / EN 61232
- Maximum fibre capacity per steel tube: 48 x 250µm Ø / 66 x 200µm Ø
- Fibres coloured acc. to colour code 048 F TIA-598-D
- Fibres acc. to G.652.D
- Tube marking: #1: none #2: ▌▌2 2▌▌

Configuration

Center		1 A20SA - Wire	3,50 mm
Layer 1		4 A20SA - Wires	3,40 mm
	+	2 Stainless Steel Tubes with 48 SMF	3,00 / 3,40 mm
Layer 2			
		12 A20SA - Wires	3,40 mm
Layer 3		12 AL3 - Wires	3,40 mm
		6 A20SA - Wires	3,40 mm

Mechanical Data

Cable Diameter	23,9 mm
Cable Weight	1798 kg/km
Supporting Cross Section	318,3 mm²
Rated Tensile Strength (RTS)	278,6 kN
Modulus of Elasticity	126,1 kN/mm²
Thermal Elongation Coefficient	14,5 10^{-6}/K
Permissible Maximum Working Stress (50% RTS)	437,7 N/mm² (139,3kN)
Recommended Everyday Stress (20% RTS)	175,1 N/mm² (55,7kN)
Ultimate Exceptional Stress (80% RTS)	700,3 N/mm² (222,9kN)

Electrical Data

DC Resistance (20°C)		0,176 Ω/km
Conductivity		30,8% IACS
Short Time Current	(1,0s; 20-200°C)	25,8 kA
Short Time Current	(0,5s; 20-200°C)	36,5 kA
Short Time Current Capacity I²t	(20-200°C)	665,4 kA²s

Application

Maximum Permissible Installation Force			83,6 kN
Minimum Bending Radius		static	299 mm
		dynamic	359 mm
Normal Delivery Length			3000 m
Temperature Range	Installation		-10 to +50°C
	Transportation and Operation		-40 to +85°C

All Sizes and Values are Nominal Values. The latest edition of referenced documents applies. opgw_pro8.xlsm, Ver. 23.02

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Duck-under Parameters and Phasing

LT132

Special Arrangement 1

Conductor type:

- Existing conductor: 1x625mm² EHC TAAAC
- New conductor: Same as old

Circuit rating:

- Voltage: 132kV
- For 625mm² TAAAC @ 70°C: [ratings are the same for both FYL1 & FYL2
  Winter Pre Fault = 1237A

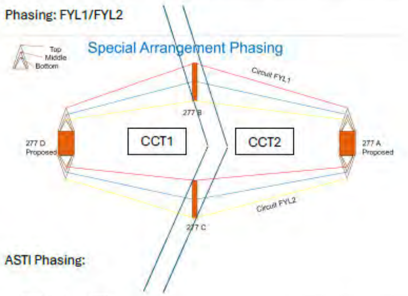
Circuit Thermal Overload Ratings for 275 kV, 1 x 625 mm² TAAAC
Resistivity 30.5 nΩ.m

O/H Circuit ID – FYL1

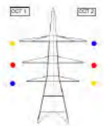
Rated Temperature: 70°C

ALL RATINGS ARE PER CIRCUIT	Winter Amps	Winter MVA	Spring / Autumn Amps	Spring / Autumn MVA	Summer Amps	Summer MVA
Pre-Fault Continuous	1237	589	1172	559	1057	503
Post-Fault Continuous	1473	702	1396	665	1258	599

Phasing: FYL1/FYL2



ASTI Phasing:



Min Clearance AS4 to ground 1-2 – 15.7m
Min clearance AS4 to ground 2-3 – 21.8m

Special Arrangement 2

Conductor type:

- Existing conductor: 1x Lynx
- New conductor: Same as old

Circuit rating:

- Voltage: 132kV
- For Lynx @ 50°C: Winter Pre Fault = 485A

Circuit Thermal Overload Ratings for 132kV, 1 x 175 mm² Lynx ACSR

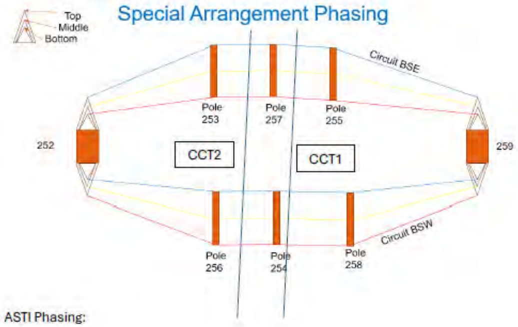
O/H Circuit ID – BSW (Beauly-Shin (excluding Alness T))

Rated Temperature: 50°C

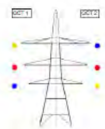
By winter 2015 will be partially cabled. Same for BSE.

ALL RATINGS ARE PER CIRCUIT	Winter Amps	Winter MVA	Spring / Autumn Amps	Spring / Autumn MVA	Summer Amps	Summer MVA
Pre-Fault Continuous	485	111	450	103	390	89
Post-Fault Continuous	580	132	540	123	465	106

Phasing: BSE/BSW



ASTI Phasing:



Clearance AS4 to ground 22-23 – 20.2m

Special Arrangement 3

Conductor type:

- Existing conductor: 1x Araucaria
- New conductor: Same as old

Circuit rating:

- Voltage: 132kV
- For Araucaria @ 90°C: Winter Pre Fault = 1700A

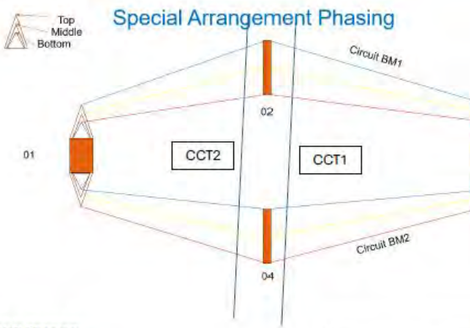
Circuit Thermal Overload Ratings for 132kV 1x700mm2 Araucaria AAAC

O/H Circuit ID – BM1 (Beauly-Orrin-Luichart-Corriemoillie)

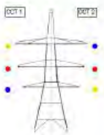
Rated Temperature: 90°C

ALL RATINGS ARE PER CIRCUIT	Winter Amps	Winter MVA	Spring / Autumn Amps	Spring / Autumn MVA	Summer Amps	Summer MVA
Pre-Fault Continuous	1700	390	1630	375	1520	350
Post-Fault Continuous	2030	465	1950	445	1810	415

Phasing: BM1/BM2



ASTI Phasing:



Clearance to ground 181 182 – 14.2m

Clearance to ground 182 183 – 18.8m.

Special Arrangement 4

Conductor type:

- Existing conductor: 1x Lynx
- New conductor: Same as old

Circuit rating:

- Voltage: 132kV
- For Lynx @ 50°C: Winter Pre Fault = 485A

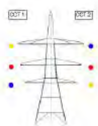
Circuit Thermal Overload Ratings for 132kV, 1 x 175 mm² ACSR with Restricted Continuous Ratings

O/H Circuit ID – BDN (Beauly-Culligran-Deanie)

ALL RATINGS ARE PER CIRCUIT	Winter Amps	Winter MVA	Spring / Autumn Amps	Spring / Autumn MVA	Summer Amps	Summer MVA
Pre-Fault Continuous	485	111	450	103	390	89
Post-Fault Continuous	550	126	510	117	440	101

Phasing: BDN

ASTI Phasing:



Clearance to 227 to 228 ground is 24.8m

LT428 – SLU4

Special Arrangement 1

Conductor type:

- Existing conductor: 1x Lynx
- New conductor: 1x Lynx

Circuit rating:

- Voltage: 132kV
- For Lynx @ 50°C: Winter Pre Fault = 485A

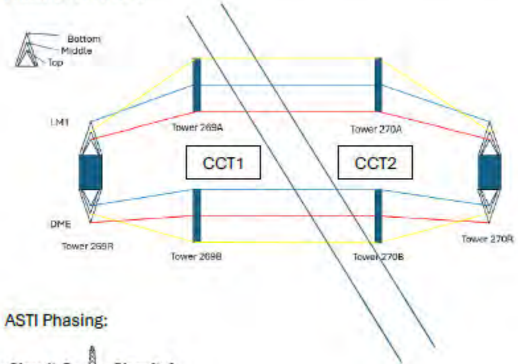
Circuit Thermal Overload Ratings for 132kV, 1 x 175 mm² ACSR with Restricted Continous Ratings

O/H Circuit ID – LM1

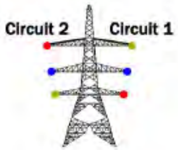
Rated Temperature: 50˚C

ALL RATINGS ARE PER CIRCUIT	Winter Amps	Winter MVA	Spring / Autumn Amps	Spring / Autumn MVA	Summer Amps	Summer MVA
Pre-Fault Continuous	485	111	450	103	390	89
Post-Fault Continuous	550	126	510	117	440	101

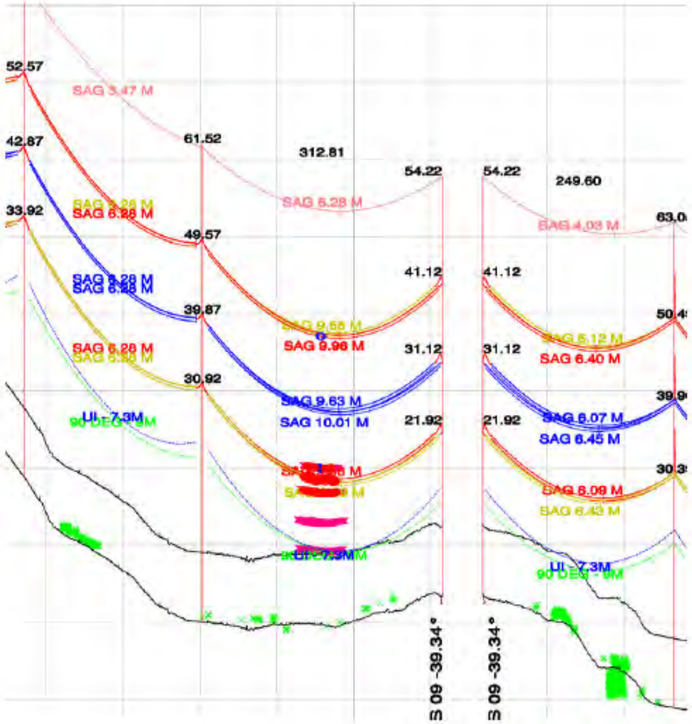
Phasing: LM1/DME



ASTI Phasing:



Oversailing circuit profile:



Min clearance to ground during oversailing span:

For 132kV LM1/DME crossing, minimum ground clearance for 400kV OHL between t#63 and 64 is 16.8m.

Special Arrangement 2

Conductor type:

- Existing conductor: 1x Lynx
- New conductor: 1x Lynx

Circuit rating:

- Voltage: 132kV
- For Lynx @ 50°C: Winter Pre Fault = 485A

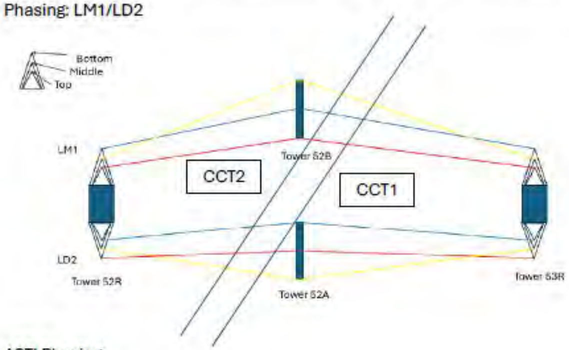
Circuit Thermal Overload Ratings for 132kV, 1 x 175 mm² ACSR with Restricted Continous Ratings

O/H Circuit ID – LM1

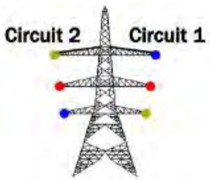
Rated Temperature: 50°C

ALL RATINGS ARE PER CIRCUIT	Winter Amps	Winter MVA	Spring / Autumn Amps	Spring / Autumn MVA	Summer Amps	Summer MVA
Pre-Fault Continuous	485	111	450	103	390	89
Post-Fault Continuous	550	126	510	117	440	101

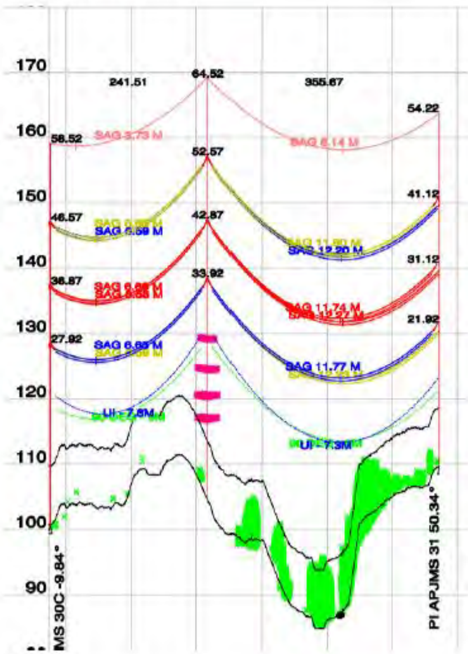
Phasing: LM1/LD2



ASTI Phasing:



Oversailing circuit profile:



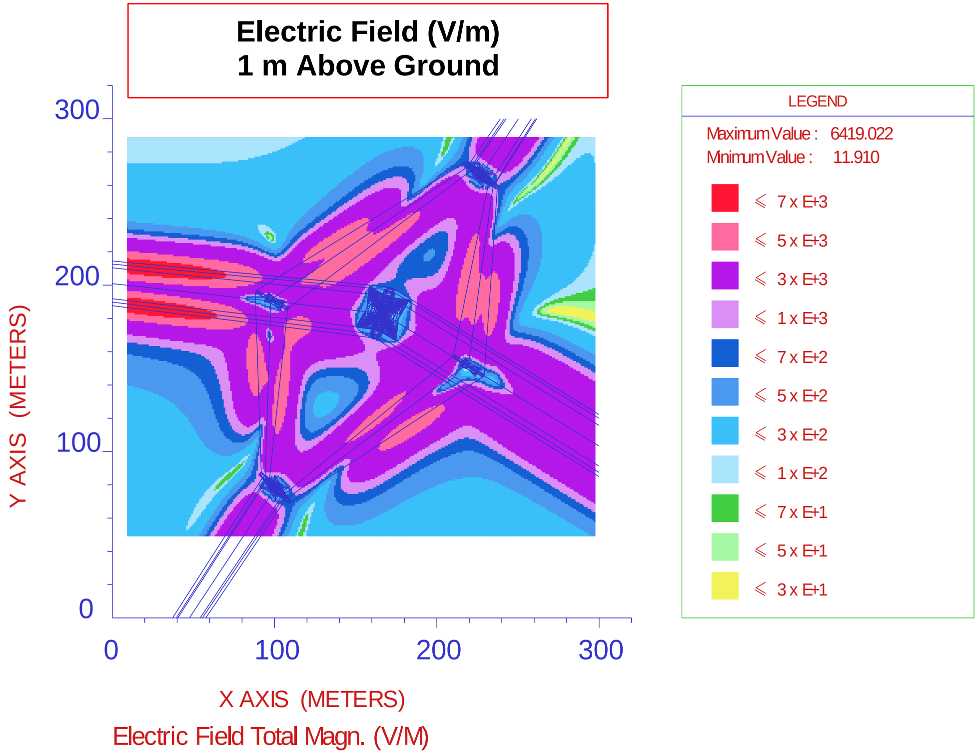
Min clearance to ground in span either side:

For 132kV LM1/LD2 crossing, minimum ground clearance for 400kV OHL between t# 274 & 275 is 17.4m and between t#275 & 276 is 18.9m.

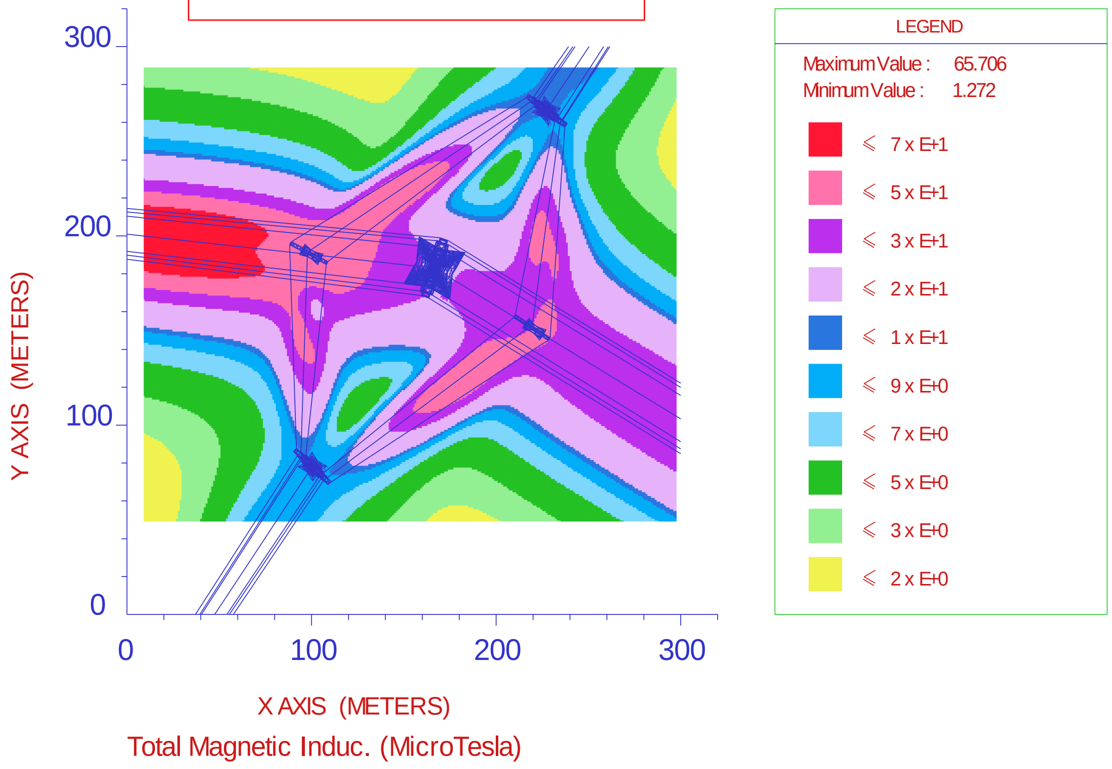
Appendix B

CDEGS (HIFREQ) Results

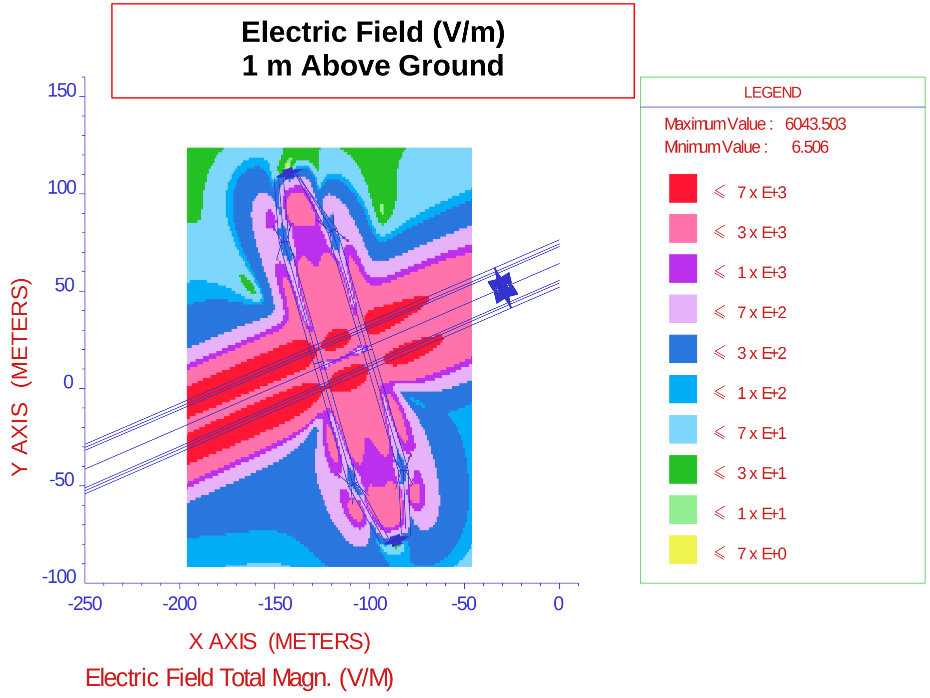
i) West of Loch Buidhe 275 kV – Diamond Duck Under



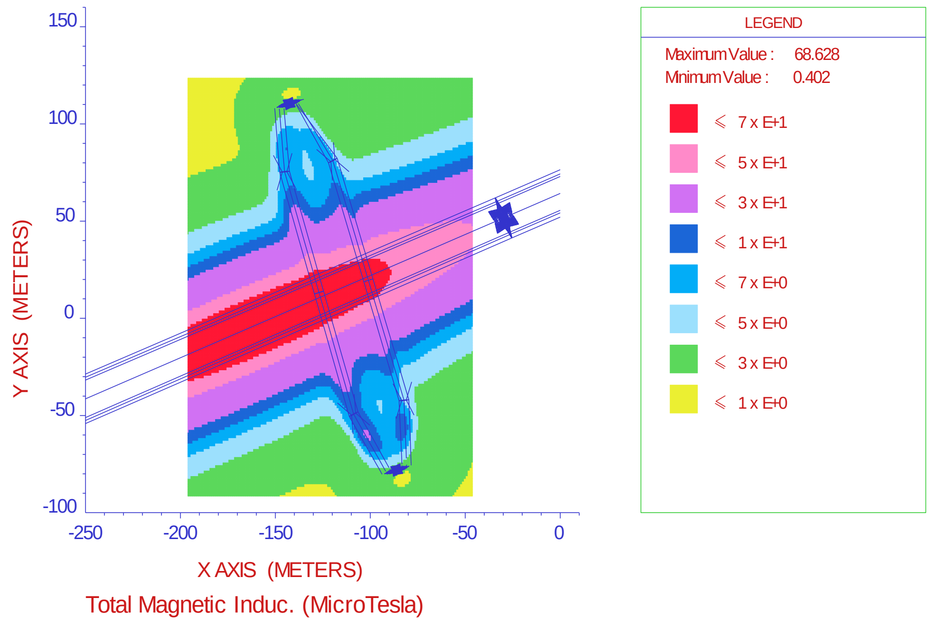
Magnetic Field (μT)
1 m Above Ground



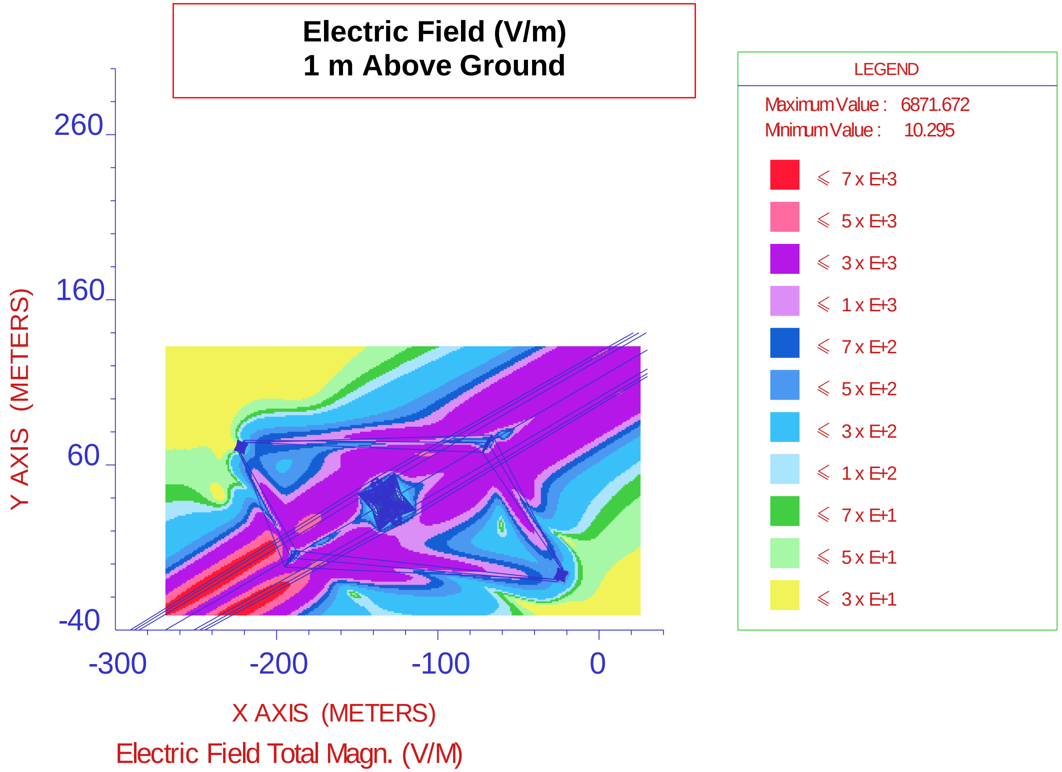
ii) Near Invershin – 132 kV Duck Under

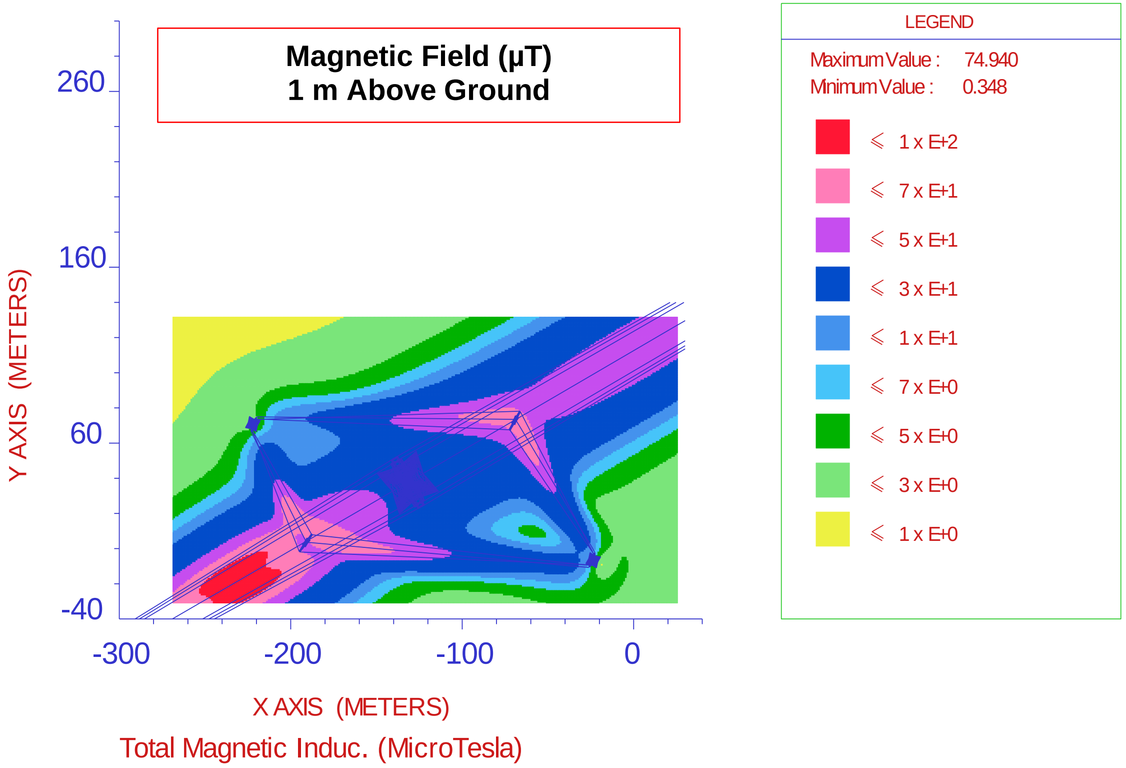


Magnetic Field (μT)
1 m Above Ground

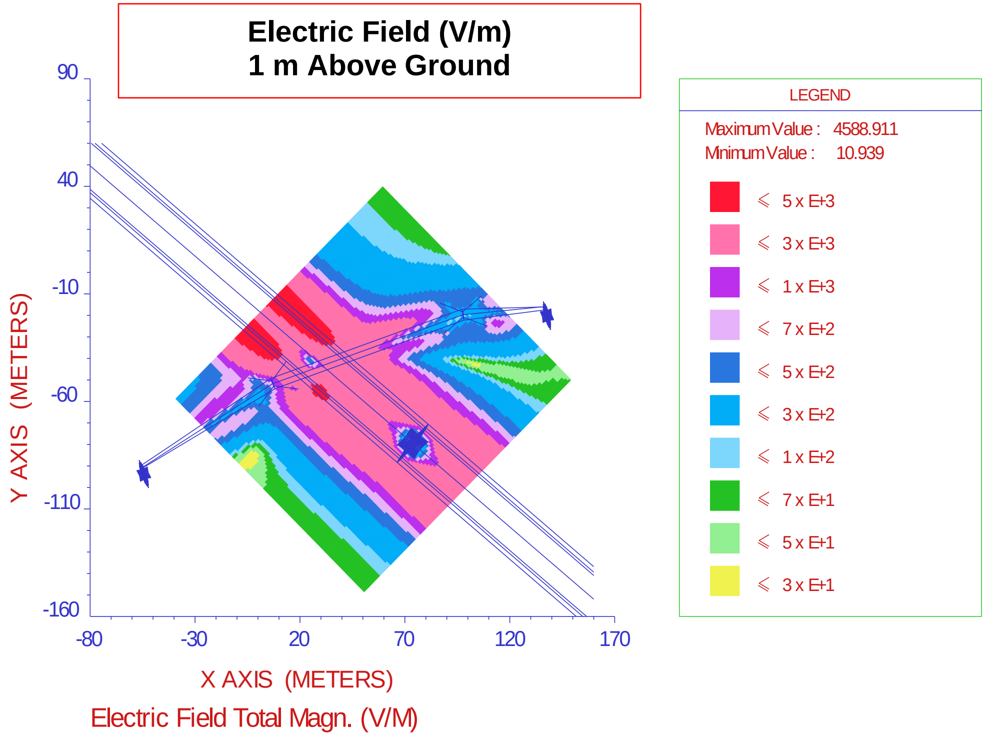


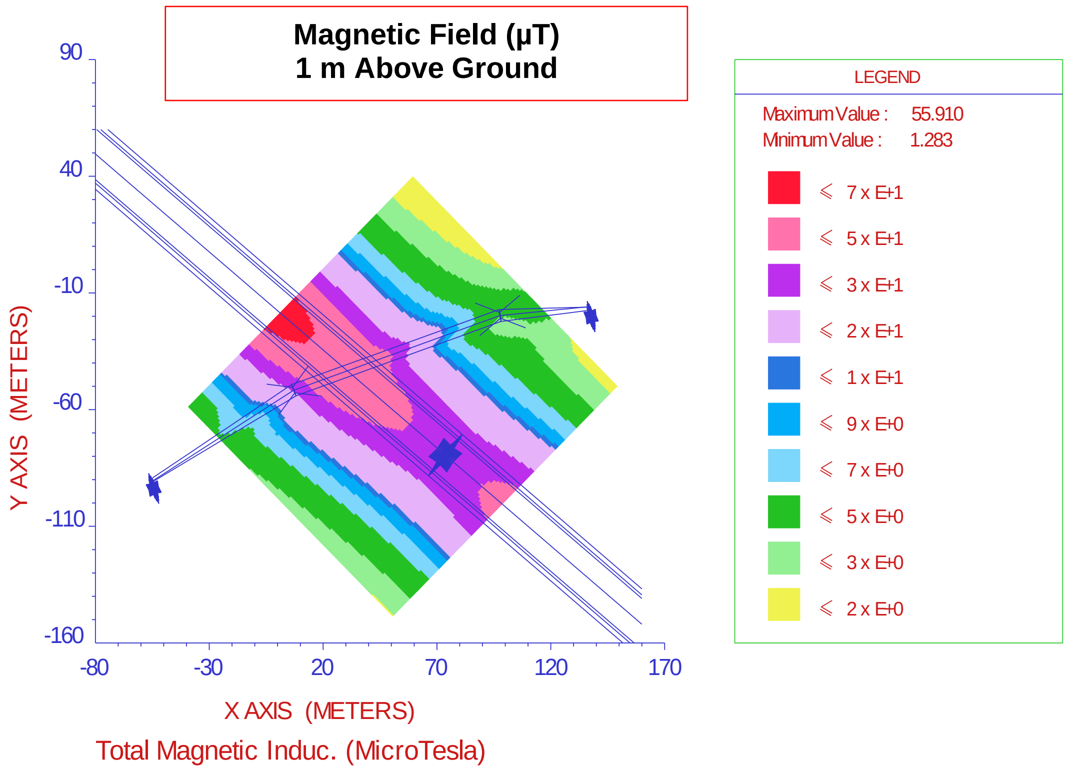
iii) North-West of Fairburn – 132 kV Diamond Duck Under



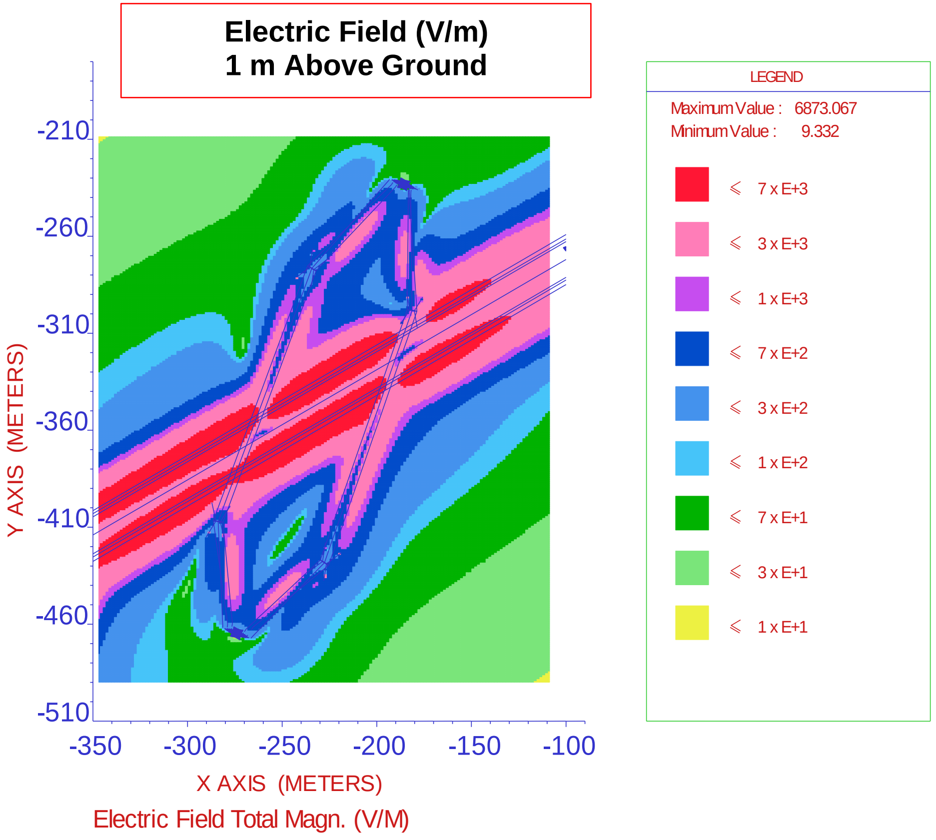

Magnetic Field (μT)
1 m Above Ground
260
160
60
-40
-300
-200
-100
0
Y AXIS (METERS)
X AXIS (METERS)
Total Magnetic Induc. (MicroTesla)
LEGEND
Maximum Value : 74.940
Minimum Value : 0.348
⩽ 1 x E+2
⩽ 7 x E+1
⩽ 5 x E+1
⩽ 3 x E+1
⩽ 1 x E+1
⩽ 7 x E+0
⩽ 5 x E+0
⩽ 3 x E+0
⩽ 1 x E+0

iv) West of Fanellan/Aigas Gorge – 132 kV Duck Under

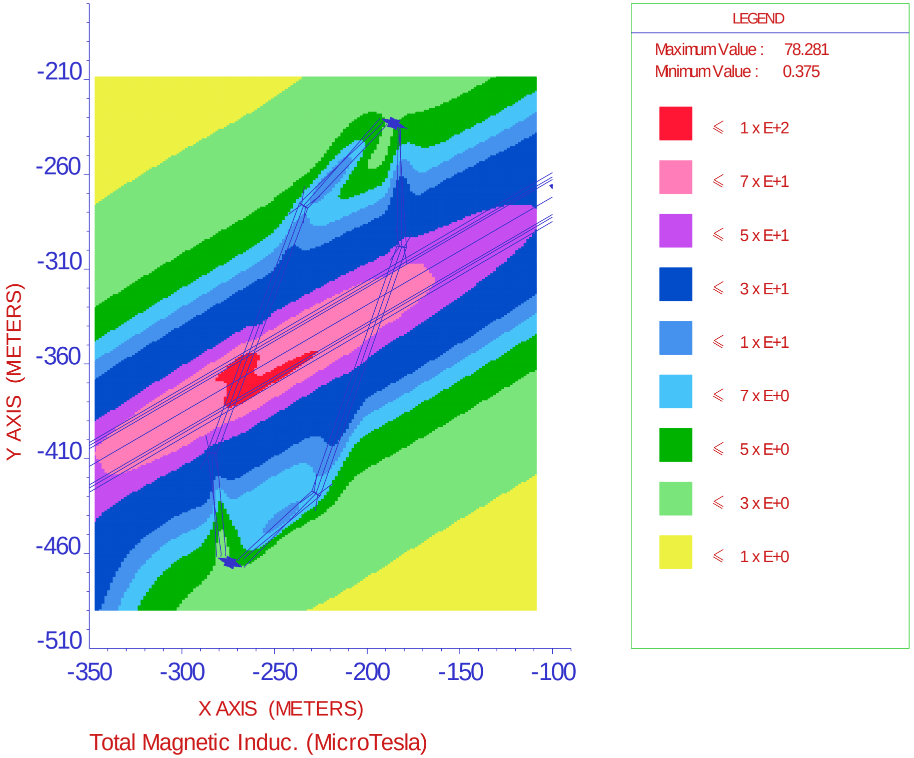



Magnetic Field (μT)
1 m Above Ground
90
40
-10
-60
-110
-160
Y AXIS (METERS)
-80
-30
20
70
120
170
X AXIS (METERS)
Total Magnetic Induc. (MicroTesla)
LEGEND
Maximum Value : 55.910
Minimum Value : 1.283
⩽ 7 x E+1
⩽ 5 x E+1
⩽ 3 x E+1
⩽ 2 x E+1
⩽ 1 x E+1
⩽ 9 x E+0
⩽ 7 x E+0
⩽ 5 x E+0
⩽ 3 x E+0
⩽ 2 x E+0

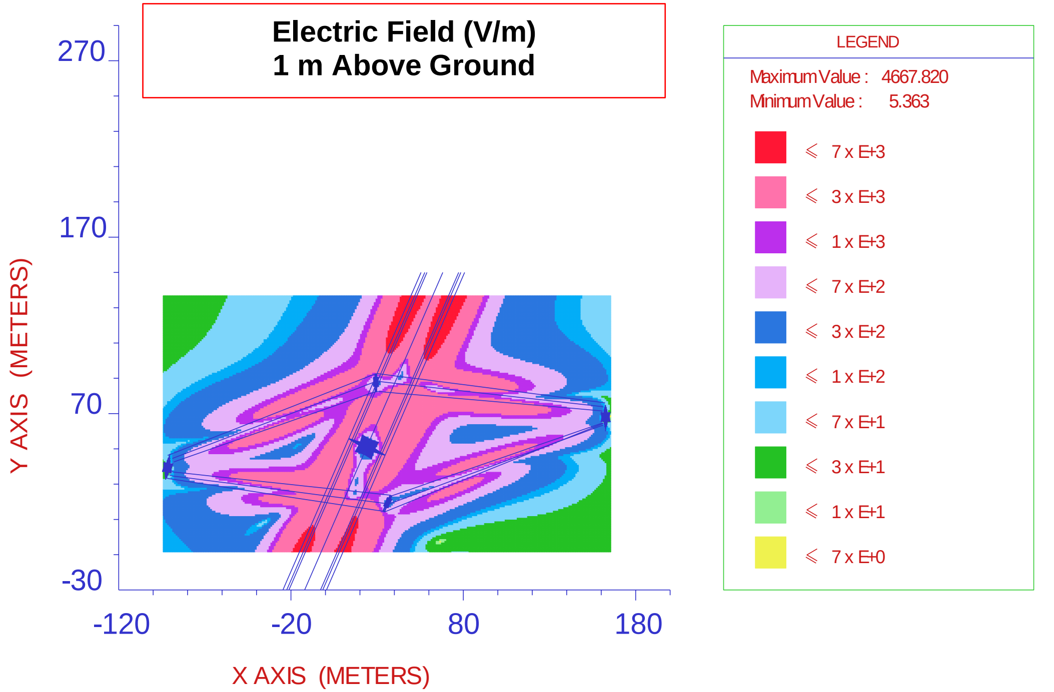
v) Crofts of Benachielt – 132 kV Duck Under



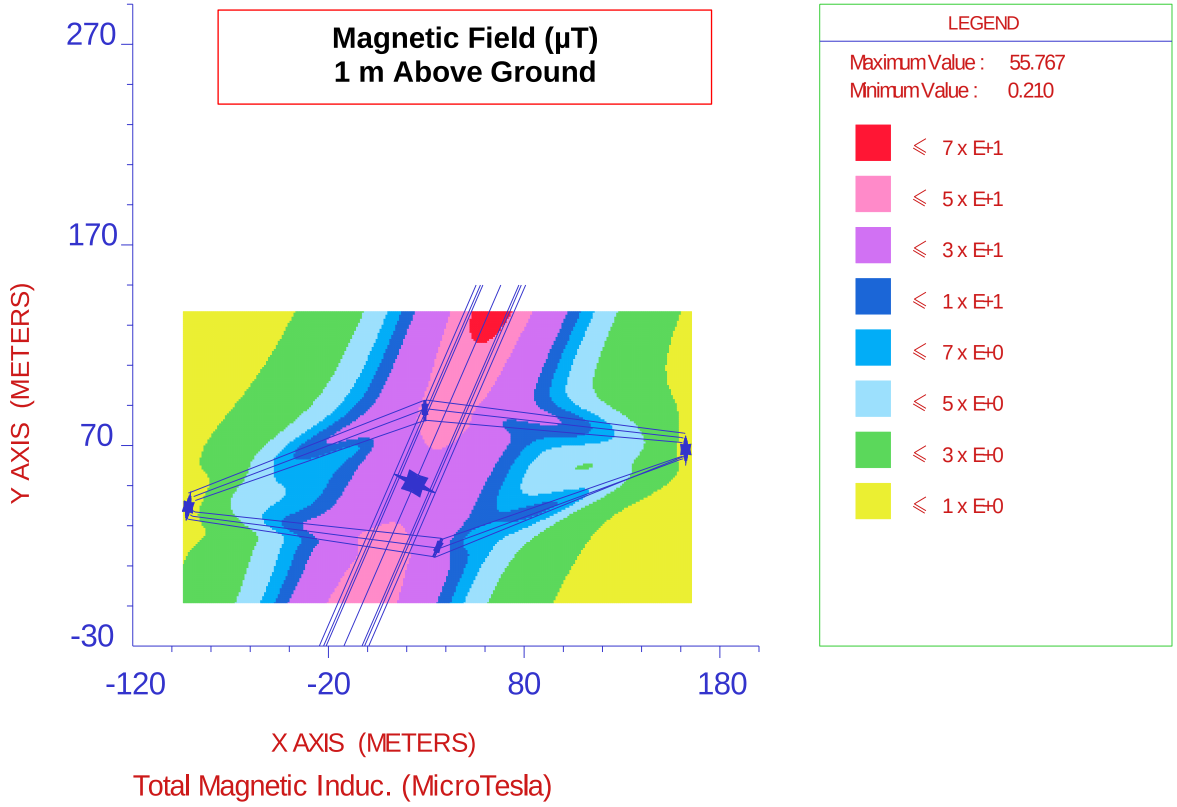
Magnetic Field (µT)
1 m Above Ground



vi) Strath Carnaig – 13 2kV Diamond Duck Under



Electric Field Total Magn. (V/M)


Magnetic Field (µT)
1 m Above Ground
270
170
70
-30
-120
-20
80
180
Y AXIS (METERS)
X AXIS (METERS)
Total Magnetic Induc. (MicroTesla)
LEGEND
Maximum Value : 55.767
Minimum Value : 0.210
⩽ 7 x E+1
⩽ 5 x E+1
⩽ 3 x E+1
⩽ 1 x E+1
⩽ 7 x E+0
⩽ 5 x E+0
⩽ 3 x E+0
⩽ 1 x E+0

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